PennState Extension

The 2023-2024

AGRONOMY GUIDE

About the Guide

The *Penn State Agronomy Guide* is designed for easy reading and quick reference.

In Part I: Crop and Soil Management, the sections on specific crops include information about:

- Varieties
- Nutritional Requirements
- Establishment
- Harvesting
- Special Considerations

In Part II: Pest Management, the sections on pest control for specific crops include information on:

- Weeds
- Insects
- Diseases

The College of Agricultural Sciences strongly recommends that you have a soil test made to determine your lime and fertilizer needs before using the suggestions presented throughout this book. Success is directly related to correct analysis of your soils.

This guide is not a substitute for the product label. Please consult a current product label for detailed usage information.

The *Penn State Agronomy Guide* was prepared by extension and resident staff members in the Departments of Agricultural and Biological Engineering; Agricultural Economics, Sociology, and Education; Ecosystem Science and Management; Entomology; Plant Pathology and Environmental Microbiology; and Plant Science; representatives of the U.S. Pasture Laboratory; county agricultural extension educators; representatives of the fertilizer, lime, pesticide, and seed industries; and representatives of state agricultural and environmental government agencies.

Project Coordinators

Part I: Crop and Soil Management
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Part II: Pest Management
Charles White and Dwight Lingenfelter

Photo credit: Brian Yarvin/Adobe Stock

Precautions on Pesticide Use

- *Use of restricted pesticides requires certification.*
- Use pesticides only when necessary.
- Use pesticides only at the recommended dosages and timing to keep residues on crops and animals within the limits set by law.
- Avoid spray or dust drift to other crops and bee yards.
- Cover food and water containers in livestock areas.
- Read the label and follow safety precautions listed.
- Maintain a pesticide use record and inventory. Wear protective masks and clothing if so directed on label.
- Avoid inhaling pesticides.
- Never eat or smoke while spraying or dusting.
- Avoid spilling spray materials on skin and clothing. If spilled, wash off immediately with soap and water.
- Wash hands and face and change to clean clothing after spraying or dusting. Wash spray clothing after each day's use.
- Store pesticides in original containers and out of reach of children, pets, and livestock, and away from food and feed; keep in a locked storeroom or cabinet marked "Pesticides—Keep Out!"
- Dispose of empty containers so that they are no longer a hazard to people, especially children, and animals.
- Do not contaminate streams, ponds, and water sources or endanger wildlife.
- If poisoning symptoms develop from pesticides, medicines, or any other poison source, show your physician a label of the material involved. He or she can phone one of the Poison Control Centers for complete treatment information.
- *Before using any pesticide, read the directions.*
- **The National Poison Center Hotline number is 1-800-222-1222.**

Part I, Section 1

Soil Management

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The Climate of Pennsylvania

Pennsylvania's climate is highly affected by movements of cold air masses descending from the north and subtropical air masses moving up from the south. Each spring the battle is on, with frigid air causing temperatures to descend below freezing alternating with periods when the mercury may rise above 80°F. Without large mountain ranges or water bodies surrounding the state, these air movements have fair play in the Commonwealth. Hurricanes that develop east of the Caribbean, sweep across the Gulf of Mexico, and subsequently move northeast are another large-scale process that influences our climate. These air movements usually occur in the summer or early fall, pick up moisture above the oceans, and can dump large quantities of rain on parts of the state.

While the movements of cold and warm air fronts determine temperature and precipitation from fall to spring, a different process governs normal precipitation patterns in the summer when convectional storms are common. Solar radiation warms the surface of the earth, causing air to rise. The relative humidity of the air increases as it cools, until moisture condenses and precipitation starts. This causes pockets of intense precipitation accompanied by thunderstorms in the summer. These events are highly localized, causing great variation in precipitation from one site to the next.

The influence of the Great Lakes is also worth mentioning. Distinct zones are highly affected by air movements coming across Lake Erie. These air currents pick up moisture over the lake, causing bands of high snowfall in the winter. The lake also moderates the temperature near its shore.

Temperature is also affected by elevation, which varies from 10 to 3,123 feet in Pennsylvania (the highest point is Mount Davis in Somerset County). Mountain ranges such as the Alleghenies cause orographic effects, with higher precipitation on the windward side and lower precipitation on the leeward side (e.g., in Bedford, Franklin, Huntingdon Counties). Overall, average precipitation in Pennsylvania varies from 32 to 49 inches per year (Figure 1.1-1). Average annual temperatures vary from 43 to 56°F, with higher temperatures in the southeast and coldest temperatures in the northcentral parts of the state and at high altitudes. The frost-free period varies considerably, causing large variations in length of growing seasons. The latest hard frost in spring ranges from the end of March around Philadelphia and in pockets in Luzerne County to the beginning of June in sections of the Allegheny Plateau (Figure 1.1-2). The first hard frost begins typically around November in the southeast but around September 1 at high elevations and northern parts of the state (Figure 1.1-3). The mean frost-free period is only 100 days at high elevations in the Allegheny Mountains and the Allegheny Plateau and almost 200 days in the southeast. Because of climatic differences across the state, the mean annual growing degree days (base 50°F) accumulated vary from approximately 1,800

Figure 1.1-1. Average annual precipitation in Pennsylvania, 1981–2010.

Figure 1.1-2. Mean departure of 28°F during spring in Pennsylvania.

Figure 1.1-3. Mean onset of 28°F during fall in Pennsylvania.

to 3,600. The consequences of the differences in climatic conditions for the types of crops grown across the state are profound, and cropping systems vary considerably.

Moisture stress is one of the major causes of year-to-year yield variation in Pennsylvania. The differences in temperature and precipitation affect the water balance, which can be represented as P = E + T + R + D, where P = precipitation (snow and rain), E = evaporation (moisture lost from soil and plant surfaces), T = transpiration (moisture lost through leaves after uptake through roots), R = runoff, and D = deep drainage below the root zone. Simulation models can help estimate the moisture balance over the year. Figure 1.1-4 shows how evaporation + transpiration (ET) and precipitation vary in three contrasting locations in Pennsylvania. The figure shows averages based on 1961–1990 climate data employing the Newhall Simulation Model to calculate ET. Precipitation in Meadville, northwestern Pennsylvania, averages 44 inches, and annual potential ET is 24 inches, resulting in an annual moisture surplus of 21 inches. Moisture surplus is almost year-round, with a deficit of 0.3 inch in June/July. The last frost in this area is mid-May, while the first hard frost in the fall occurs in early October. The growing season for summer crops is therefore approximately 4.5 months. Precipitation in Lewistown (central Pennsylvania) is 38 inches and potential ET is 27 inches, with an annual moisture surplus of 11 inches. Moisture deficit from June to August is 3.7 inches. The last frost is in mid-April, and the first hard frost normally hits Lewistown in mid-October, giving it a growing season of about 6 months. In Lancaster (southeast Pennsylvania), precipitation averages 41 inches and ET 27 inches, resulting in a moisture surplus of 14 inches. Moisture deficit from June to August is 3.8 inches. The last frost date in Lancaster is in mid-April and the first hard frost is in late October, giving it a growing season of almost 6.5 months. Moisture deficits will clearly be a greater threat to crop production in the southeast than in the northwest, whereas the opposite can be expected of moisture surplus in the spring. The moisture challenges in a particular location largely depend on the soil type, including such factors as moisture storage capacity, depth to impervious layer, depth to water table, and percolation, and are moderated by management practices.

The Soils of Pennsylvania

Twelve broad soil regions can be distinguished in Pennsylvania (Figure 1.1-5). They are described in the following sections. The primary determinant that explains differences between soils in Pennsylvania is the parent material from which the soils developed; the effects of past glaciation are also important. Sedimentary rock is the origin of most soils in Pennsylvania, with some exceptions. Sandstone, shale, and limestone are the primary parent materials from which soils developed in the Commonwealth.

Figure 1.1-4. Average moisture balance for Meadville, Lewistown, and Lancaster.

PRCP = monthly precipitation; PET = monthly potential evapotranspiration

Source: W. J. Waltman, E. J. Ciolkosz, M. J. Mausbach, M. D. Svoboda, D. A. Miller, and P. J. Kolb. *Soil Climate Regimes of Pennsylvania* (University Park: Penn State Agricultural Experiment Station, 1997).

Figure 1.1-5. Soil regions of Pennsylvania.

1. Eastern Lake Shore

The soils on the shores of Lake Erie developed in beach sand and lacustrine silts and clays. The soils developed in the beach sands are mostly sandy and gravelly and have rapid internal drainage, although some have a shallow water table where the silts and clays underlie the beach deposits. The landscape is mostly level, and erosion potential is therefore low. The lacustrine soils generally contain few rock fragments and have moderate available water-holding capacity in the root zone. The climate is moderated by the proximity of Lake Erie.

2. Glaciated Region of the Appalachian Plateau

The soils in northwest Pennsylvania are derived from glacial till. Glacial till is material deposited by glaciers, some of which was once under huge masses of ice. Water percolates very slowly through this till. Many soils in this region also have a fragipan—a dense subsoil that cannot easily be penetrated by roots and allows very slow water and air movement. The poor drainage of many soils in this region is characterized by gleying (gray color from reduced iron) and mottling (spots of gray color) caused by a perched seasonal high water table and impeded percolation. The landscape is mostly level or undulating, and erosion potential is low to moderate. Rock fragments can be present if the till is near the soil surface. The available water-holding capacity of the root zone of these soils is primarily determined by the depth to the impermeable layer. If the soil is shallow, crop roots will have a small volume of soil to explore for water. The result is that crops may suffer from drought stress in the summer on soils that are saturated in the spring. Although the growing season is short, the soils in this area can be highly productive if properly drained.

3. Allegheny High Plateau

Soils in the Allegheny High Plateau of northcentral Pennsylvania developed primarily in sandstone. The dominant texture of these soils is sandy loam. They are mostly well drained. If slopes are steep, erosion potential is substantial. Rock fragment content can be high. The available water-holding capacity of the root zone of these soils is often low due to their coarse texture and the presence of rock fragments. The growing season in this region is short (fewer than 100 days) because of the high elevation. Due to their low agricultural productivity, most soils of the Allegheny Plateau are under forest vegetation, but there are some notable exceptions, such as areas used for potato and pasture production.

4. Glaciated Low Plateau

The soils in northeastern Pennsylvania are derived from glacial till like those in the northwestern part of the state. However, the till in the northeast is typically more discontinuous and the drainage problems more spotty than in the northwest. Some of these soils have a fragipan at shallow depths and are therefore somewhat poorly to poorly drained. The surface texture of these soils is predominantly silt loam. The landscape is undulating and the erosion potential is low to moderate. Rock fragments are common in the soils of this area. Some of the soils have very low available water-holding capacity in the root zone due to their limited rooting depth. The growing season is short due to the elevation and northern latitude.

5. Pittsburgh Plateau

The Pittsburgh Plateau in central and southwest Pennsylvania is dominated by soils developed in acid clay shales and interbedded shales and sandstones. These soils contain more clay and silt than those derived from sandstone. The surface texture of these soils is predominantly silt loam. The soils are usually well drained. The landscape of this region has rather steep slopes, and erosion is a major concern. Many of these soils also contain substantial amounts of rock fragments. Many soils in this region have a moderate available water-holding capacity in the root zone due to their limited depth. However, in the southwest region of this area, soils tend to be deeper and have a moderately available high water-holding capacity in the root zone. The growing season is rather short in most of the area, except in the southwest, which is also the most productive agricultural area within this region.

6. Allegheny Mountain

The Allegheny Mountain section is dominated by soils developed in sandstone. The texture is mostly sandy loam to loamy sand. Drainage is good. The landscape is often steeply sloping, and erosion potential is high. Rock fragments are common, resulting in low available water-holding capacity in the root zone. The high elevation of the Allegheny Mountain section gives this region a short growing season (fewer than 100 days). Much of this area is under forest vegetation, although there are some important agricultural areas.

7. Ridge and Valley Province

The ridges and valleys in the central/eastern part of Pennsylvania are a distinct landscape characterized by sandstone ridges, shale footslopes, and shale and limestone valleys. Sandy loam soils similar to those on the Allegheny High Plateau and Allegheny Mountain sections are found on the forested ridgetops. Colluvial soils that are a mixture of sandstone and shale are found on the slopes. In the valleys, limestone-derived soils predominate, although some soils are derived from shale. The limestone-derived soils are among the most productive in Pennsylvania. They are usually deep, well drained, and have a high available water-holding capacity in the root zone and few rock fragments. The shale-derived soils are less productive because of their acidic nature, steep slopes, and generally low available water-holding capacity in the root zone. The soils in the valleys are on level or undulating land, and erosion potential is low to moderate. The valley soils are used intensively for agriculture.

8. Blue Ridge

The Blue Ridge province covers eastern Franklin, southern Cumberland, and western Adams Counties. The soils in this area are derived primarily from igneous and metamorphic rocks. Igneous rocks are of volcanic origin. Metamorphic rocks have been altered under great pressure below the surface of the earth. The soils in these areas are generally well drained. Their surface texture is silt loam. They often contain significant amounts of rock fragments. Steep slopes are common, giving many soils in this area high erosion potential. The available water-holding capacity in the root zone of the soils is commonly moderate. The high elevation results in a short growing season. Much of this area is under forest.

9. Triassic Lowlands

The soils in the Triassic Lowland section of the Piedmont developed in reddish sandstone, shale, and siltstone. The soils are generally silt loams, well drained, and located on sloping land. The erosion potential of these soils is moderate to high. The Abbottstown-Doylestown-Reading association in Bucks and Montgomery Counties is an exception to this rule; those soils are poorly drained and located on level land. The soils in the Triassic Lowland section can contain substantial amounts of rock fragments. The available water-holding capacity in the root zone is moderate. The region has a long growing season.

10. Conestoga Valley

Limestone-derived soils predominate in the Conestoga Valley section. These soils are comparable to the limestone soils in the valleys of the Ridge and Valley province. They have a silt loam surface texture and clayey subsoils. They are well drained. The landscape is level to undulating, and erosion potential is low. Rock fragments are scarce, and the available water-holding capacity in the root zone is high. The growing season is long. These are productive soils that are used intensively for agriculture.

11. Piedmont Upland

Soils in the Piedmont Upland section are predominantly derived from metamorphic rock. These soils have a silt loam texture and are well drained. The landscape has rather steep slopes, and erosion potential is moderately high. Rock fragments are scarce on these soils. Their available water-holding capacity in the root zone is moderate to high. The growing season is long. These soils are used intensively for agriculture and can be very productive if they are deep.

12. Coastal Plain

The soils of the Coastal Plains section developed in coastal sands. These soils usually have a sandy surface texture and are well drained. Because the topography is level, erosion potential is typically low. The soils contain few rock fragments but have moderate available water-holding capacity in the root zone due to the coarse soil texture. This region has the longest and warmest growing season in Pennsylvania. Most of the area is occupied by the city of Philadelphia and its suburbs.

Table 1.1-1 lists major soils of Pennsylvania, along with some of their properties and expected yield potentials.

Soil Health

Soil health (also called "soil quality") is defined as "the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health, and promote plant and animal health." Soil properties that determine soil health include soil physical, chemical, and biological properties. This section focuses on the physical and biological aspects of soil health; chemical aspects are discussed in the soil fertility section (Part I, Section 2). Some soil properties are a given and cannot be readily changed by management. This information can be gleaned from the county soil survey, your local USDA Natural Resources Conservation Service (NRCS) office, or on the web at https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

The concept of soil health focuses on properties that are readily affected by management. The best soil quality is usually found in soils under permanent vegetation such as trees or sod. However, intensively managed soils can be very low or very high in quality depending on how they are managed. Soils with poor health often have inferior tilth, lower organic matter content, few living organisms, and show signs of soil erosion, crusting, and soil compaction. Eventually, poor soil health results in problems with crop establishment, root growth, and crop yields. Increasing amounts of fertilizers, pesticides, and tillage are needed to maintain yields on poor-quality soil. That is why it is so important to maintain high soil quality.

Table 1.1-1. Selected properties and typical capabilities of major Pennsylvania soils.

Soil Series	Depth Class[1]	Drain Class[2]	Leaching Potential[3]	Crop Prod. Group	Corn Grain (bu/A)	Corn Silage (tons/A)	Alfalfa (tons/A)	Clover (tons/A)	Wheat (bu/A)	Oats (bu/A)	Barley (bu/A)	Sorghum/ Sudan Silage (tons/A)	Soybeans (bu/A)
Abbottstown	D[4]	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Albrights	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Allegheny	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Allenwood	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Alton	D	WD[6]	3	3	160	21	5	4.5	60	80	75	4	40
Alvira	D[4]	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Andover	D[4]	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Armagh	D	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Atkins	D	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Barbour	D	WD	2[7]	1	200	30	7	5.5	70	100	100	5	60
Basher	D	MWD	2[7]	2	160	21	6	5	70	100	100	4	50
Bath	D[4]	WD	1[7]	2	160	21	6	5	70	100	100	4	50
Bedington	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Berks	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Birdsall	D	PD	1[7]	5	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Birdsboro	D	MWD	2[7]	1	200	30	7	5.5	70	100	100	5	60
Blairton	MD	MWD	1[7]	4	130	15	5	3.5	50[8]	80	50[8]	3	40
Bowmansville	D	SWPD	2[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Braceville	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Brecknock	D	WD	2	2	160	21	6	5	70	100	100	4	50
Brinkerton	D	PD	2	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Brooke	MD	WD	1	2	160	21	6	5	70	100	100	4	50
Buchanan	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Bucks	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Calvin	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Cambridge	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Canfield	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Cavode	D	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Chenango	D	WD[6]	3	2	160	21	6	5	70	100	100	4	50
Chester	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Chippewa	D[4]	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Clarksburg	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Clymer	D	WD	2	2	160	21	6	5	70	100	100	4	50
Comly	D	SWPD	1[7]	3	160	21	5[8]	4.5	60	80	75	4	40
Conestoga	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Conotton	D	WD	2	2	160	21	6	5	70	100	100	4	50

Table 1.1-1. Selected properties and typical capabilities of major Pennsylvania soils (continued).

Soil Series	Depth Class[1]	Drain Class[2]	Leaching Potential[3]	Crop Prod. Group	Corn Grain (bu/A)	Corn Silage (tons/A)	Alfalfa (tons/A)	Clover (tons/A)	Wheat (bu/A)	Oats (bu/A)	Barley (bu/A)	Sorghum/ Sudan Silage (tons/A)	Soybeans (bu/A)
Cookport	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Croton	D[4]	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Culleoka	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
DeKalb	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Dormont	D	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Duffield	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Duncannon	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Edgemont	D	WD	2	2	160	21	6	5	70	100	100	4	50
Edom	D	WD	1	2	160	21	6	5	70	100	100	4	50
Elliber	D	WD[6]	3	2	160	21	6	5	70	100	100	4	50
Erie	D[5]	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Ernest	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Fredon	D	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Frenchtown	D[4]	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Gilpin	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Glenelg	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Glenville	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Guernsey	D	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Hagerstown	D	WD	1	1	200	30	7	5.5	70	100	100	5	60
Hanover	D[4]	WD	1[7]	2	160	21	6	5	70	100	100	4	50
Hartleton	D	WD	2	3	160	21	5	4.5	60	80	75	4	40
Hazleton	D	WD	2	2	160	21	6	5	70	100	100	4	50
Highfield	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Holly	D	PD	2[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Hublersburg	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Huntington	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Klinesville	S	WD	2	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Kreamer	D	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Lackawanna	D[4]	WD	1[7]	2	160	21	6	5	70	100	100	4	50
Laidig	D[4]	WD	1[7]	2	160	21	6	5	70	100	100	4	50
Langford	D[4]	WD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Lansdale	D	WD	2	2	160	21	6	5	70	100	100	4	50
Leck Kill	D	WD	2	2	160	21	6	5	70	100	100	4	50
Lehigh	D	MWD	1[7]	4	130	15	5	3.5	50[8]	80	50[8]	3	40
Letort	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Lewisberry	D	WD	2	2	160	21	6	5	70	100	100	4	50

Table 1.1-1. Selected properties and typical capabilities of major Pennsylvania soils (continued).

Soil Series	Depth Class[1]	Drain Class[2]	Leaching Potential[3]	Crop Prod. Group	Corn Grain (bu/A)	Corn Silage (tons/A)	Alfalfa (tons/A)	Clover (tons/A)	Wheat (bu/A)	Oats (bu/A)	Barley (bu/A)	Sorghum/ Sudan Silage (tons/A)	Soybeans (bu/A)
Lordstown	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Manor	D	WD	2	2	160	21	6	5	70	100	100	4	50
Mardin	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Meckesville	D[4]	WD	1[7]	2	160	21	6	5	70	100	100	4	50
Melvin	D	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Mertz	D	WD	1	2	160	21	6	5	70	100	100	4	50
Monongahela	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Morris	D[5]	SWPD	2	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Morrison	D	WD	2	2	160	21	6	5	70	100	100	4	50
Murrill	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Neshaminy	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Opequon	S	WD	2	4	130	15	5[8]	3.5	50	80	50	3	40
Oquaga	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Penn	MD	WD	2	3	160	21	5	4.5	60	80	75	4	40
Philo	D	MWD	2[7]	2	160	21	6	5	70	100	100	4	50
Platea	D[4]	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Pope	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Rainsboro	D	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Ravenna	D[4]	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Rayne	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Readington	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Reaville	D	SWPD	1[7]	4	130	15	5[8]	3.5	5[08]	80	50[8]	3	40
Red Hook	D	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Sheffield	D[4]	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Shelmadine	D[4]	PD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Swartswood	D[4]	MWD	1[7]	2	160	21	6	5	70	100	100	4	50
Tunkhannock	D	WD[6]	3	2	160	21	6	5	70	100	100	4	50
Tyler	D	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Upshur	D	WD	1	2	160	21	6	5	70	100	100	4	50
Venango	D[4]	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Volusia	D	SWPD	1[7]	4	130	15	5[8]	3.5	50[8]	80	50[8]	3	40
Washington	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Watson	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Weikert	S	WD[6]	2	4	130	15	5[8]	3.5	50	80	50	3	40
Wellsboro	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Westmoreland	D	WD	2	2	160	21	6	5	70	100	100	4	50

Table 1.1-1. Selected properties and typical capabilities of major Pennsylvania soils (continued).

Soil Series	Depth Class[1]	Drain Class[2]	Leaching Potential[3]	Crop Prod. Group	Corn Grain (bu/A)	Corn Silage (tons/A)	Alfalfa (tons/A)	Clover (tons/A)	Wheat (bu/A)	Oats (bu/A)	Barley (bu/A)	Sorghum/ Sudan Silage (tons/A)	Soybeans (bu/A)
Wharton	D	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Wheeling	D	WD	2	1	200	30	7	5.5	70	100	100	5	60
Wurtsboro	D[4]	MWD	1[7]	3	160	21	5	4.5	60	80	75	4	40
Wyoming	D	WD[6]	3	3	160	21	5	4.5	60	80	75	4	40

Moisture contents: corn grain = 15.5%; corn silage = 65%; alfalfa and clover = dry matter; wheat, oats, and barley = 12%; sorghum/sudan silage = 65%; and soybeans = 13%
Ratings provide relative information for comparing soils and should not be used quantitatively.

[1] D = deep (more than 40 inches); MD = moderately deep (20 to 40 inches); S = shallow (less than 20 inches).
[2] WD = well drained; MWD = moderately well drained; SWPD = somewhat poorly drained; PD = poorly drained.
[3] Relative rating of leaching potential. The higher the number, the greater the relative leaching potential.
[4] Fragipan is present starting at 16 to 40 inches below the surface.
[5] Fragipan is present starting at 10 to 16 inches below the surface of the soil.
[6] Soils are well drained to excessively well drained.
[7] Soils have a seasonal high water table that is less than 6 feet from the surface. Leaching potential may be a consideration of water resource use and water table following pesticide application.
[8] Crop is not well suited for this soil.

Key soil physical and biological properties:

- Soil texture
- Soil depth
- Soil organic matter content
- Cation exchange capacity
- Bulk density
- Porosity
- Plastic/liquid limit
- Soil structure and tilth
- Aggregate stability
- Hydraulic conductivity (permeability)
- Infiltration rate
- Earthworms
- Water content
- Water-holding capacity

Soil texture is a classification of the primary particle size distribution of soil. It has a profound effect on other soil health indicators such as porosity, water infiltration and percolation, moisture-holding capacity, and sensitivity to compaction. The textural class is a measure of the proportions of sand (2 to 0.05 millimeters in diameter), silt (0.05 to 0.002 millimeter), and clay (smaller than 0.002 millimeter) (Figure 1.1-6). Only particles smaller than 2 millimeters (0.79 inch) are considered when classifying soil texture, so gravel and rocks are not included in soil texture classifications. Soil texture is determined in the laboratory after completely dispersing soil aggregates with a deflocculant. With experience, it is also possible to determine soil texture by the "feel method." Soil textural class mentioned with a soil series name (e.g., Hagerstown silt loam) refers to the soil texture of the surface soil. Loam is a term used for a soil with equal proportions of clay, silt, and sand. Soil with a high clay content holds the most water, while a sandy soil holds little water because it has lower total porosity, with silty/loamy soils being intermediate. A large proportion of the water in clay soil is held in submicroscopic pores so tightly that it cannot be extracted by roots. Therefore, the plant available water content of a loam soil is higher than that of a clay soil, while a sandy soil has the lowest plant available water content. Water movement in clay soils is much slower than in sandy soils due to the small pore size in clay soils. Loamy soils have intermediate permeability. Clay particles are typically plate-shaped and have negative charge and therefore determine the cation exchange capacity of a soil together with its humus content. Silt and sand particles are typically not plate-shaped but round with jagged edges and do not contribute to cation exchange capacity. Clay, therefore, increases inherent fertility of soil. However, because of their fine size and plate-shape, clay soils compact more easily than soils with high silt or sand content.

Soil depth is the depth of soil to bedrock or to an impermeable layer. Soil depth determines how deep roots, water, and air can penetrate into a soil, which in turn influences how much water can infiltrate and be held by the soil and how much soil the plant roots can occupy.

Figure 1.1-6. The textural triangle quickly helps to determine the textural classification of a soil from the percentages of sand, silt, and clay it contains.

Soil organic matter consists of living and partially to fully decomposed organic materials. Soil organic matter is typically 1 to 5 percent of the total dry weight of topsoil, with lower amounts in the subsoil. Different types of organic matter play unique roles in soil. Highly decomposed organic matter (also called humified organic matter) typically makes up 95 percent of the total soil organic matter and contributes to the cation exchange capacity, water-holding capacity, and stability of small aggregates. Other, less highly decomposed types of organic matter, such as polysaccharides, are produced by bacteria and determine the stability of larger aggregates. Living organic matter, such as fungal hairs and plant roots, is also important for the stability of large aggregates. Soil organic matter contains large amounts of nutrients such as nitrogen, phosphorus, and micronutrients and increases soil fertility.

Cation exchange capacity (CEC) is determined by the soil's clay and humus content. These particles carry a negative charge that enables a soil to hold positively charged molecules (cations). Potassium, calcium, and magnesium are nutrient cations that dissolve in water and would wash out of the soil if they were not held by the CEC. The CEC of your soil is reported on soil test reports.

Bulk density is a measure of the mass of particles that are packed into a volume (e.g., a cubic foot) of soil. If bulk density goes up, porosity goes down. It is favorable to have a low bulk density so that water and air can move through the soil. Optimal bulk density depends on soil texture. Ideal and

Table 1.1-2. Ideal soil bulk densities and root-growth-limiting bulk densities for soils of different textures.

Soil Texture	Ideal Bulk Densities (g/cm^3)	Bulk Densities That May Affect Root Growth (g/cm^3)	Bulk Densities That May Restrict Root Growth (g/cm^3)
Sand, loamy sand	<1.60	1.70	>1.80
Sandy loam, loam, sandy clay loam, clay loam, silt, silt loam, silty clay loam	<1.40	1.60	>1.75
Sandy clay, silty clay, clay	<1.10	1.50	>1.60

Source: Generalized from USDA-NRCS soil quality test kit guide.

problem bulk densities of different soils are given in Table 1.1-2.

Plastic limit and **liquid limit** are two measures used to characterize the ease with which a soil can be worked or compacted. The plastic limit is the moisture content at which it is possible to make a wire of approximately one-quarter inch in diameter by rolling the soil between your hands. The liquid limit is the moisture content at which soil starts to flow and act like a liquid. Soil is most compactable between the plastic limit and liquid limit and most susceptible to rutting above the liquid limit. A simple method to determine soil readiness for tillage and traffic is the "ball test." Take a handful of soil and squeeze it into a ball. If the soil molds together, it is in the plastic state and too wet for planting, tillage, or field traffic.

Soil structure and **soil tilth** are very important but still elusive concepts. Soil tilth refers to the state of aggregation of a soil. Aggregates are conglomerates of clay, silt, and sand particles that are held together by biological, physical, and chemical forces. A common method of determining aggregate stability is to place aggregates on a sieve and move the sieve up and down in a water bath. If a lot of soil passes through the sieve, the aggregate stability is low; if most of the soil remains on top of the sieve, the aggregate stability is high. Soils with stable aggregation tend to have better soil tilth, greater water infiltration, and better aeration for root growth.

Hydraulic conductivity (permeability) and **infiltration rate** are two closely related properties. Hydraulic conductivity is the rate of water movement in the soil, whereas infiltration is the rate at which water enters into the soil from the surface. Hydraulic conductivity and infiltration are determined by soil texture, changes in soil texture between the surface and subsurface, impermeable layers, depth to bedrock, soil aggregation and porosity, pore size distribution, and pore continuity.

Earthworms generally increase microbial activity, increase the availability of nutrients, and enhance soil physical properties. They also accelerate the decomposition of crop residue by incorporating litter into the soil and activating mineralization and humification processes. Earthworms improve aggregation and porosity, suppress certain pests or disease organisms, and enhance beneficial microorganisms. There are various types of earthworms; some live in the surface of the soil and make horizontal burrows that they fill with their excretions, while others live in vertical burrows that stay open and can be more than 3 feet deep. Nightcrawlers are among the important earthworm species in agricultural soils. They make permanent, vertical burrows that provide channels for infiltration. They need surface residue, which they gather and pull toward their burrows while they deposit their excretions at the soil surface at the mouths of the burrows. A good method for monitoring earthworm populations is to excavate 1 cubic foot (1 foot × 1 foot × 1 foot) of soil and count the earthworms in and beneath it. A good time to do this is after a rainstorm or early in the morning in the spring or fall when the soil is moist. Earthworms tend to hide deeper when the soil is dry and show reduced activity in summer or winter. Earthworms that reside below the foot-deep hole will come to the surface if you pour some mustard powder dissolved in water in the hole. Ten earthworms per square foot of soil surface is generally considered a good population in agricultural systems.

Measuring soil health with scientific methods takes major investments. For more information, see the "Pennsylvania Soil Quality Assessment Scorecard," available from your Penn State Extension county office or online at extension.psu.edu.

Improving Soil Health

Soil Organic Matter

Soil organic matter content is considered one of the most important indicators of soil health. From an agronomic and environmental point of view, organic matter gives the largest benefits if it is found close to the soil surface. Near-surface organic matter improves soil aggregation, which increases infiltration, improves resistance to erosion, improves workability, and leads to improved seed-to-soil contact when planting. The surface soil also becomes more resistant to compaction and will facilitate root development. Organic matter also contains large quantities of nutrients, a small portion of which is released when it decomposes. To maintain or increase near-surface organic matter content, one needs to maximize additions of organic materials and minimize

Table 1.1-3. Typical crop residue production of different crops in rotation.

Crop	Yield (bu/A)	Bushel Weight (lb/bu)	Yield (lb/A)	Moisture Content (ratio)	Dry Matter (ratio)	Grain Dry Matter Yield (lb/A)	Residue-to-Grain ratio	Residue Dry Matter Yield (lb DM/A)	Tons Per Acre
Barley	70	48	3,360	0.120	0.880	2,957	1.5	4,435	2.2
Corn	130	56	7,280	0.155	0.845	6,152	1.0	6,152	3.1
Oats	60	32	1,920	0.120	0.880	1,690	1.0	1,690	0.8
Rye	50	56	2,800	0.120	0.880	2,464	1.5	3,696	1.8
Sorghum	90	56	5,040	0.135	0.865	4,360	1.5	6,539	3.3
Soybeans	40	60	2,400	0.130	0.870	2,088	1.0	2,088	1.0
Wheat	55	60	3,300	0.120	0.880	2,904	1.5	4,356	2.2

To calculate crop residue yield, multiply crop grain yield (bu/A) by bushel weight (lb/bu) and dry matter content (ratio) and residue-to-grain ratio.

outputs, or losses. Inputs can be increased by growing crops that produce large amounts of residue and fine roots (such as corn, small grains, and grasses), leaving crop residue in the field, growing cover crops during otherwise bare fallow periods, and adding compost and manure (especially bedded manure).

How much organic material should be returned to the soil to maintain organic matter contents? This question has been receiving increased attention because of the interest in harvesting crop residue to produce biofuels. One study suggested that, in a no-till system, 4,500 pounds of crop residue per acre need to be returned per year to maintain surface organic matter content under conditions pertaining to the Corn Belt. Meeting this goal will be very challenging because most annual crops don't produce that much crop residue, even without residue removal (Table 1.1-3).

Other sources of organic inputs are manure, compost, and cover crops. Liquid manure does not directly contribute to organic matter if it does not contain any solids. Highly decomposed packed manure or compost contributes much to organic matter content since it is already partly humified. Organic matter losses include removal of crop residue (such as hay, straw, or silage harvest) and burning.

Soil tillage reduces surface organic matter content, so eliminating tillage will help improve soil health. The type of tillage also matters. The moldboard plow tends to cause the largest losses of surface organic matter, while the chisel plow and disk harrow cause smaller surface organic matter losses. Recent research suggests that tillage primarily redistributes organic matter to deeper soil layers. With moldboard plowing, soil organic matter content is uniform throughout the plow layer. On the other hand, in long-term no-tillage or sod, soil organic matter content will be high at the soil surface and decrease rapidly below 2 or 3 inches. Chisel plows and disks typically lead to soil organic matter distribution that is intermediate between moldboard and no-tillage.

Overfertilizing with nitrogen fertilizer may also reduce organic matter content by stimulating decomposition.

Aggregate Stability or Soil Tilth

Besides organic matter, crop rotations and crop mixtures can help improve the aggregation of soils. When designing crop rotations, take the following factors into account: (1) crops with extensive fine root systems, such as grasses and cereals, stimulate aggregate stability; (2) perennial crops in the rotation have a favorable effect on aggregation that lasts many years; and (3) actively growing root systems improve soil aggregation. Crops with easily decomposed residue (carbon-to-nitrogen ratio below 25) stimulate aggregate stability in the short term because bacteria that feast on the residue produce polysaccharides and other easily degradable organic substances that act as glue holding aggregates together. Crop residue with a higher carbon-to-nitrogen ratio takes longer to decompose and stimulates aggregate stability and soil health in the long run. Amendments that stimulate biological activity, such as manure or sewage sludge, will also help improve aggregate stability.

Soil Profile Modification

The soil profile is modified by tillage (Figure 1.1-7). Tillage mixes soil and crop residues in the surface, pulverizes aggregates, increases soil sealing and crusting at the very surface of the soil, compacts soil just below the tillage tool, and leads to a decline in certain earthworm species, especially nightcrawlers, that make deep burrows into the subsoil. On the other hand, in long-term no-till, the soil profile is characterized by mulch cover that protects the soil from the elements and provides a food source and habitat for soil organisms, high organic matter content near the surface that decreases rather abruptly with depth, macropores (many created by nightcrawlers) that lead from the surface 3 to 4 feet into the

Figure 1.1-7. No-till soil profile changes compared to changes in a tilled soil profile.

soil, and a firm soil that has intact aggregates. The changed soil profile in long-term no-till leads to higher infiltration and reduced evaporation and makes the soil more trafficable. It should be noted that the soil profile modification needs time to develop but can be changed rapidly by one tillage pass, hence the importance of long-term no-tillage.

Soil Erosion

Soil erosion is the most important soil degradation problem in Pennsylvania. It contributes to the loss of soil quality and pollution of surface waters. Soil erosion above a certain level will reduce soil productivity over the long haul. Soil erosion exposes subsoil, which often has poor qualities for crop establishment and growth. It can also lead to stand loss by sediment deposition.

Three types of soil erosion are classified: water erosion, wind erosion, and tillage erosion. Water and tillage erosion are the more important types of erosion in Pennsylvania and will be discussed here. A survey by NRCS revealed that 60 percent of the cropland in Pennsylvania is "highly erodible land" (HEL). In 2003, 40 percent of the HEL cropland eroded at greater than tolerable levels. Eleven percent of non-HEL cropland eroded above the tolerable level. In summary, more than one-quarter of cropland in Pennsylvania was losing soil at a rate that affects soil productivity in the long run, which shows how urgent this problem is.

Water Erosion

The four types of water erosion are:

1. Sheet erosion—the movement of soil by rain splash and its transport by thin surface flow.
2. Rill erosion—erosion by concentrated flow in small rivulets.
3. Gully erosion—erosion by runoff scouring large channels (deeper than 1 foot).

4. Streambank erosion—erosion by rivers or streams cutting into their banks.

The term "interrill-erosion" is technically more accurate but not commonly used, so we use the traditional term "sheet erosion" here.

The National Resources Conservation Service (NRCS) assists farmers with conservation planning. The NRCS uses the Revised Universal Soil Loss Equation (RUSLE) to calculate average annual soil loss to sheet and rill erosion (A) as a function of five factors, R × K × LS × C × P, where:

A = annual soil loss (tons per acre per year)
R = erosivity of rainfall (function of total rainfall and rainfall intensity)
K = erodibility of the soil (function of soil texture, soil organic matter, and soil structure)
LS = slope length/steepness
C = cropping and management factors (e.g., crops grown, canopy cover, residue cover, surface roughness)
P = erosion control practices (contour tillage and planting, strip-cropping, terracing, subsurface drainage)

The impact of raindrops on the soil surface is the beginning—and most important part—of the erosion process. The erosivity of rainfall depends on the size and velocity of raindrops and the amount of precipitation. Gentle, drizzly rain is not very erosive, whereas fierce thunderstorms and hurricanes are very erosive. High-intensity storms produce larger drops that fall faster than those of low-intensity storms and therefore have greater potential to destroy aggregates and dislodge particles from the soil matrix. Although the same total amount of rain may fall, a short, high-intensity rainfall event causes much more erosion than a long, low-intensity storm. Total average precipitation does not vary much across Pennsylvania, but the intensity of rainfall does. Thunderstorms and hurricanes with accompanying high-intensity rainfall tend to hit the southeastern part of the Commonwealth more frequently, leading to a higher erosion threat in the southern rather than northern parts of Pennsylvania. Most erosive precipitation events usually occur in the late summer and early fall. Soils that are bare during this period are under extreme risk of soil erosion. Bare soil, especially if planted with wide-spaced crops such as corn, is also extremely vulnerable to erosion before canopy closure in the spring.

Soil erodibility is influenced by many factors, some of which vary during the year and/or with soil management.

- Erodibility of a soil increases with a decrease in aggregate stability. Clay and organic matter help improve aggregate stability and reduce erodibility.
- Living or dead roots increase aggregate stability and decrease erodibility.
- Erodibility decreases with an increase of large sand grains and rock fragments since these large particles are not easily moved with water.

Soil conservation personnel use standard erodibility values published for each soil series in their county based on typical soil texture, structure, and organic matter contents.

Since soils are continuously formed from parent material, it is commonly accepted that a low level of erosion will not compromise soil productivity. NRCS personnel use tolerable soil loss (T) levels, which vary per soil type, to indicate the maximum rate of soil erosion that can be allowed while still permitting crop productivity to be sustained indefinitely. Tolerable soil loss levels are a function of root development, gully prevention, on-field sediment problems, seeding losses, reduction of soil organic matter, and loss of plant nutrients, and vary from 3 to 5 tons per acre per year for most soils in Pennsylvania. Deep soils with subsoil characteristics favorable for plant growth have greater T levels than soils with shallow root zones or high percentages of shale at the surface because the shallow soils and soils with high contents of rock fragments lose their productivity more quickly than deep soils without rock fragments. Research suggests that values of T are set too high and that soil erosion should not exceed 1 T per acre per year for soil management to be truly sustainable.

The RUSLE used by conservation planners predicts the effects of management practices on sheet and rill erosion. Cropping and management practices used to control sheet and rill erosion include previous management and cropping, protection by the vegetative canopy of the soil surface, and surface cover and roughness. Generally, the following important crop management practices will help decrease these types of water erosion:

- Maintain crop residue cover above 30 percent until crop canopy closure.
- Alternate summer crops with winter crops and perennial crops.
- Use cover crops during periods when the soil may have insufficient residue.

Additional protection from water erosion is provided by contour farming and contour strip-cropping. Contour farming implies that crops are planted nearly on the contour. The benefit of this practice is greatest on moderate slopes (2 to 6 percent) when crops are planted in tilled soil where ridge height is 2 to 3 inches. However, even in no-till, contour farming can reduce erosion if residue cover is marginal and ridge height is 2 inches or more.

Contour strip-cropping involves alternating strips of perennial grass or close-growing crops with strips with low residue cover. The strips should be laid out close to the contour, which is not always possible in rolling landscapes. Strip width is usually between 75 and 120 feet. Soil that erodes

Figure 1.1-8. Three causes of erosion resulting from tilling soils on slopes.

Source: Fred Magdoff and Harold van Es, *Building Soils for Better Crops*, 2nd ed. (Beltsville, Md.: Sustainable Agriculture Network, 2000), 47. Used with permission from the Sustainable Agricultural Research and Education (SARE) outreach office, www.sare.org.

from the bare or low-residue strips is deposited in strips with high residue or dense vegetation since runoff velocity is decreased. This practice is most useful if the soil is tilled or left bare during part of the year in no-till. If high-residue cover (greater than 30 percent at all times) is maintained in no-till systems, contour farming and contour strip-cropping are usually not necessary to control erosion. However, the problem is that there are periods in the crop rotation when the soil has little residue, even in no-till systems.

As slope length and steepness increase, runoff and soil loss also increase. However, changing the slope steepness is relatively uncommon in Pennsylvania. The slope length, on the other hand, can be changed by installing terraces and diversions to divert runoff.

Terraces are cross-slope channels that are built to allow crops to be grown on them and control erosion. Storage terraces hold water until it can be absorbed by the soil or released to stable outlet channels or through underground outlets. Storage terraces are usually designed to drain completely in 48 hours to avoid waterlogging within the terrace. Gradient terraces are channels designed to be almost perpendicular to the natural field slope that collect runoff water and carry it to a stable outlet like a waterway.

Diversions are similar to terraces but wider, higher, and usually permanently vegetated with grass. They are used on steeper slopes where a terrace would be too expensive or difficult to build, maintain, or farm. They can also be used to protect barnyards or farmsteads from runoff.

Other erosion-control practices help maintain water quality but are not immediately relevant to maintaining soil productivity on working cropland. The following practices are helpful in reducing sediment and nutrient load in surface waters even though they do not directly improve soil quality:

- Contour buffer strips—narrow, permanently vegetated strips located between wider crop strips on sloping land.
- Field borders—bands or strips of permanent vegetation at the edge of a field.
- Filter strips—strips or areas of permanent vegetation used to remove sediment, organic materials, nutrients, pesticides, and other contaminants from runoff.
- Riparian forest buffers—areas of trees and/or shrubs along streams, lakes, ponds, or wetlands.
- Vegetative barriers—narrow permanent strips of stiff-stemmed, tall, dense perennial vegetation established in parallel rows perpendicular to the dominant field slope.
- Grassed waterways—natural or constructed swales where water usually concentrates as it runs off a field.
- Streambank protection—structures such as fences and stable crossings to keep livestock out of the stream and provide streambank stabilization with rocks, grass, trees, shrubs, riprap, or gabions.

Ephemeral Gully Erosion

Ephemeral gully erosion is not estimated in RUSLE simulations and is not part of the calculation of A (annual soil loss), but its magnitude can be many times greater than sheet and rill erosion. It is also a form of erosion that farmers need to address to be in compliance with their conservation plan. Ephemeral gullies are between 4” and 18” deep, can be erased with tillage, form in the same landscape position, and can become classic gullies if left unattended. Gully erosion can sometimes be addressed by improving soil health so that water infiltration increases to the point that runoff is negligible. If runoff still occurs and the ephemeral gully forms again, other practices may be needed. The most common conservation practice to address ephemeral gully erosion in fields is probably a grassed waterway to stabilize the area of concentrated flow. Other practices include methods to shorten the slope such as strip cropping, terraces or diversions. Further, contour planting and contour buffer strips are ways to improve infiltration in-field to combat ephemeral gully erosion as well.

Tillage Erosion

Tillage erosion is a form of erosion that is receiving increased attention. Tillage erosion moves soil from the top of the field downward, exposing subsoil at the crest while burying soil at the bottom. After many years of tillage, topsoil accumulates at the bottom of the slope. If tillage erosion continues, exposed and eroded subsoil from up slope will eventually cover this topsoil at the bottom of the slope. With tillage erosion, no soil has to leave the field, but the effects on productivity and

Figure 1.1-9. Topsoil compaction is caused by contact pressure, whereas lower subsoil compaction is caused by axle load.

increased yield variability can be very significant. Exposed subsoil has unfavorable properties for crop growth—50 percent yield reduction is not uncommon on clay knobs—but it still takes the same amount of inputs such as seed, fertilizer, and herbicides. Because crop growth is poor, the soil is not protected from water erosion and weeds have a greater chance to become a problem in these areas. Tillage erosion delivers soil from upper slope positions to the lower parts of the slope where water erosion tends to be more important, so tillage erosion tends to reinforce water erosion (Figure 1.1-8).

Unfortunately, many practices that have been promoted to control water erosion do nothing to control tillage erosion. For example, it has been suggested that chisel plows cause as much tillage erosion as moldboard plows. Field cultivators can also move substantial amounts of soil. Leaving crop residue at the surface does not control tillage erosion. Narrow contour strips, often promoted on steep slopes to control water erosion, favor tillage erosion because topsoil is slowly plowed away at the top of each strip, exposing subsoil and causing soil to accumulate at the bottom of each strip. The narrower the strips, the more subsoil can be exposed.

The best way to control tillage erosion is to eliminate tillage. With the use of continuous no-till systems, tillage erosion can be completely eliminated. If tillage is still part of the crop production system, all unnecessary tillage trips should be eliminated, speed reduced (especially downhill), and tillage tools set to the shallowest depth possible. Downhill plowing should be avoided. Plowing on the contour causes less tillage erosion, whereas plowing uphill causes the least but doesn't totally eliminate tillage erosion like no-till does. It is beneficial to turn soil uphill with contour tillage, but this is practically impossible if slopes exceed 17 percent. Running the tillage tool at a constant depth and speed is recommended to limit tillage erosion—don't reduce tillage depth or slow down on clay knobs or rock outcroppings. This often means additional horsepower will be required to pull the tillage tool, which can result in damage to tillage equipment. The final method to "solve" tillage erosion is to transport topsoil from depositional areas to hill crests to remediate clay knobs and rock outcroppings.

Soil Compaction

Soil compaction is the reduction of soil volume due to external factors. The risk of soil compaction is greater today than in the past due to an increase in the size of farm equipment.

Soil compaction reduces soil productivity. Research in tilled soils showed average first-year yield losses due to severe compaction of approximately 15 percent. Yield loss in the first year after compaction was mostly due to residual effects of surface compaction. In this summary of many studies in different countries, yield losses decreased to approximately 3 percent 10 years after the compaction event (in the absence of recompaction). The final yield loss was assumed to be a result of subsoil compaction and considered a permanent yield reduction.

Besides reducing yields, soil compaction also reduces soil health and environmental quality.

- Compacted soil is dense and has low porosity. Compaction preferentially compresses large pores, which are very important for water and air movement in soil. Infiltration is then reduced and erosion is increased.
- Compaction causes an increase in the soil's penetration resistance. There is little root penetration in soil above 300 psi (pounds per square inch), except if there are cracks and macropores in the soil that can be followed by plant roots.
- More energy is expended when tilling compacted soil.
- Compacted soil is a harsher environment for soil organisms, especially earthworms, to live in.
- Compaction affects nutrient uptake. Denitrification rates can increase in compacted soil due to limited aeration. Manure ammonia volatilization losses have been found to increase when liquid manure is surface applied to compacted soils because of reduced infiltration. Phosphorus and potassium uptake can be reduced if root growth is inhibited.

Compaction is caused by wheel or foot traffic on the soil and soil tillage. Soil is most compactable at a moisture content approximating field capacity (when the free water has drained

from the soil). Soil that is saturated is difficult to compact since the pores are filled with water. However, rutting and slipping caused by traffic over saturated soil will destroy soil structure. When thinking about the effects of and management options to avoid soil compaction, it is important to understand the underlying causes. An important distinction needs to be made between what causes surface compaction versus what causes subsoil compaction (Figure 1.1-9).

Surface compaction is caused by contact pressure (expressed in psi). A pickup truck tire can cause as much surface compaction as a manure spreader at the same contact pressure. Contact pressure is approximately similar to tire pressure in flexible tires. On the other hand, subsoil compaction is caused by axle load (expressed in tons). The higher the axle (or wheel) load, the deeper the stress will be transmitted into the soil.

Plow pans are caused just below the tillage tool if that layer of the soil has a moisture content conducive to compaction at the time of tillage. The moldboard plow is renowned for causing plow pans, but the disk plow or harrow and chisel plow have also been found to cause plow pans.

Not all compaction is caused by humans. Some glaciated soils have been compacted by glaciers in the past and are still compacted at depth. Other soils have fragipans, which are naturally compacted subsoils high in silt content. Some sandy coastal plain soils have such poor structure in the subsoil that root growth is negatively affected.

An understanding of the causes of soil compaction makes it possible to develop management strategies that either avoid or correct its effects. Compaction avoidance is much preferred over compaction alleviation after a problem has been caused because correction strategies can be costly and will likely not solve the problem entirely.

The aim of compaction management should be to avoid subsoil compaction altogether and to limit surface compaction as much as possible. Soil compaction is not likely to cause much damage if traffic is limited to dry soil conditions (i.e., drier than the plastic limit; see above). However, if soil is moist, the following points are important.

- To avoid subsoil compaction, reduce axle load to at least below 10 tons by:
  - Reducing load
  - Increasing number of axles
- To avoid surface compaction, reduce contact pressure by:
  - Setting tire pressures at the minimum allowable
  - Using flotation tires
  - Using tracks or duals to replace singles
  - Using radial-ply instead of bias-ply tires
  - Installing larger diameter tires to increase length of footprint
  - Properly ballasting tractor for each field operation

Reduce the number of passes over the field and limit the area of the field that is impacted by traffic by increasing swath width of spreading and spraying equipment and reducing width of tracks.

- To avoid plow pans:
  - Do not drive a tractor wheel in the furrow.
  - Use no-tillage.
  - Use a chisel instead of a moldboard plow.
  - Use a field cultivator instead of a disk harrow.

A producer can make the soil more resistant to compaction by increasing its organic matter content, building a soil ecosystem that has a permanent macropore system, and maintaining a living root system in the soil year-round. Cover crops help soil resist compaction with their root systems.

Correcting soil compaction may be necessary if options to avoid compaction have not been successful. Tillage is an option for reducing compaction, but tillage costs money and has negative effects on soil quality and erosion. Subsoiling is one form of tillage that can alleviate deep-seated compaction.

Answer the following questions to help determine which tillage method should be used to correct compaction:

1. Is tillage needed to correct soil compaction?
2. Which tillage tool is suited to address the problem?
3. What are the best settings to correct soil compaction?

Whether tillage is needed or not depends on soil type and severity of compaction. Some coastal plain soils (found in the southeastern United States) are known to respond to annual subsoiling with a yield boost. While Penn State research showed an 11 percent increase in corn yield due to subsoiling with a shallow fragipan, most other soils did not respond with yield increase.

The degree of soil compaction can be diagnosed with a penetrometer and supplemented by visual observations of soil structure and root and plant growth. In stony or shaly soils, the penetrometer cannot be used, so only visual observations are possible. The severity of compaction also needs to be assessed visually (e.g., do you see ruts?) and by analyzing field traffic history.

- If field traffic has been limited to dry soil conditions, tillage is probably not needed to alleviate compaction.
- If field traffic has occurred while an area was at field capacity, the area of the field impacted needs to be assessed.
- Ruts need to be leveled. If ruts are uniformly distributed and cover much of the field, fieldwide tillage may be needed to enable crop production. However, if ruts are limited to certain areas of the field, targeted repair may suffice.
- If less than 50 percent of the field was impacted by tires or tracks and there are no deep ruts, it probably does not

pay to do tillage. However, if more than 50 percent of the field was impacted, it may be beneficial to do tillage to alleviate compaction.
- If large stones are present, it may not be beneficial to do tillage because equipment may break and many stones may have to be removed after the tillage operation.
- It may be possible to limit tillage to high-traffic areas such as field borders.

If the diagnosis has determined that tillage is justified, it becomes necessary to select the best tillage tool to ameliorate compaction. Leaving > 30 percent residue cover after planting is recommended to reduce erosion and increase soil quality, so the tillage tool selected should not reduce residue cover below this level.

The moldboard plow is not recommended for ameliorating soil compaction because it buries most residue and can actually lead to the formation of a plow pan. Chisel plows are better suited than moldboard plows for alleviating compaction if they can penetrate the compacted soil, but the tension springs on the chisel plows are often not heavy enough for them to penetrate the compacted layer. In this situation, subsoilers are often used. Disk harrows and field cultivators can help level rutted-up fields.

Traditional subsoiler shanks are heavy, wide, and have curved shanks and large points. These subsoilers were designed to cause maximum fracturing and disturbance of the soil. At the same time, however, they bury most residue and leave a rough surface that necessitates secondary tillage. Clearly, residue conservation and reduction of secondary tillage were not considerations at the time these subsoilers were designed. Modern subsoilers are designed differently. They usually have narrow shanks, coulters to cut through residue in front of the shank, and some type of attachment to leave the soil in a condition that is ready to be planted. These subsoilers leave most residues at the soil surface and do not create much surface disturbance. They vary in subsoil fracturing according to their design. Set the tillage tool 1 to 2 inches below a compacted layer, if present.

Cover crops are increasingly used to correct compaction. These cover crops are planted in the fall and grow when soil moisture contents are high and soil is easy to penetrate. Taprooted cover crops have been found to be most effective for creating new pore spaces in compacted soil. Other cover crops have a massive, fine root system that intermeshes with soil particles, stabilizing aggregation and creating many small channels. Roots of summer crops can take advantage of the channels created by cover crop roots at a time when soil moisture content is typically lower than in the winter. More research is needed to further substantiate the benefits of cover crops for alleviating soil compaction and to enable recommendations for cover crop selection and management for this purpose.

Tillage Management

In recent years there has been an increasing realization of the negative aspects of soil tillage, which explains the increased adoption of no-tillage. Soil tillage:

- Takes time
- Costs money (fuel, equipment, maintenance)
- Increases erosion
- Reduces near-surface organic matter content
- Destroys soil tilth
- Promotes soil crusting
- Increases runoff
- Increases evaporation losses
- Reduces biological activity (e.g., earthworms)
- Brings rocks to surface

A systems approach to no-till needs to take into account that:

- Diversity in crop rotations and cover crops is central to the no-till systems approach. This approach maximizes nutrient use efficiency and enables excellent weed and pest control without excessive pesticide use.
- Sufficient mulch cover is essential for no-till success, including uniform distribution of crop residue after harvest. Almost all environmental benefits of no-tillage, such as erosion, runoff reduction, and water conservation, are due to the mulch cover.
- Soil improvement with no-till takes years. Continuous no-till is, therefore, recommended because rotating between tillage and no-till destroys the soil-building benefits of no-till.

Research and experience have shown that, on most Pennsylvania soils, no-till yields are similar to or better than yields obtained with tillage. One disadvantage of no-till is that manure is surface-applied, leading to greater odor nuisance and/or ammonia volatilization. However, novel shallow-disk manure injectors consistent with no-till are now available that can eliminate these problems by injecting manure into the soil.

Tillage Tools

A repertoire of primary and secondary tillage tools is available for farmers who still rely on tillage for crop management. Among the most important primary tillage tools are the moldboard plow, the chisel plow, and the disk plow.

The **moldboard plow** is excellent for weed control and preparing a level seedbed after alfalfa or grass sod or heavy cover crops. The moldboard plow can also be counted on to completely bury surface-applied manure, eliminating ammonia losses and odor problems. Different types of moldboard plows are available, such as wheel mounted pull hitch and

three-point hitch, one-way and two-way (reversible) plows, and one-bottom and multiple-bottom plows. Some moldboard plows come with trip mechanisms to reduce damage in rocky soil. Moldboard plows can be run at different depths and may be used to completely or incompletely turn the plow furrow. Disadvantages of the moldboard plow include that it leaves no crop residue cover and therefore exposes the soil to water erosion. Tillage erosion is also significant with the moldboard plow, which is typically set to deeper depths than the other tillage tools. The moldboard plow can also cause the creation of a tillage pan just below the depth of plowing, especially if one tractor wheel or draw horse runs in the open furrow. The moldboard leaves a "dead furrow," which sometimes creates an opportunity for gully erosion and inaccurate crop establishment. Moldboard plowing demands a skilled operator and consumes more fuel than plowing with a chisel or disk.

The **chisel plow** is a popular tillage tool in Pennsylvania that is easy to operate and helps loosen the soil to enable conventional planting equipment to operate. It is not effective for weed control, nor is it recommended for terminating or preparing a seedbed after alfalfa, grass sod, or heavy cover crops. Chisel plows mix soil and surface residue or manure, which will reduce ammonia losses and odor problems. However, while the chisel plow does not invert the soil much, tillage pans can still be a problem. Chisel plows may be of the wheel mounted, pull hitch or three point, hitch mounted type and may come with curved shanks on which the springs determine how well the chisels penetrate the soil, especially if the soil is compacted. A variety of points can be mounted on the chisel shanks. These points may be wide or narrow and twisted or straight. The wider and more twisted the point, the more soil disturbance will be achieved by the chisel plow, and the more residue cover will be reduced. It is important to use sharp points that penetrate the soil effectively; otherwise, the chisel points will merely scratch the surface of the soil. Chisel plowing does not require much skill and consumes less fuel than moldboard plowing. Dead furrows are not a problem with chisel plows. Although the chisel plow is considered a conservation tool, it is not common to achieve 30 percent residue cover after secondary tillage and planting operations are completed, except after a high-yielding corn grain harvest. Chisel plows are often combined with secondary tillage tools on the same frame, enabling farmers to prepare the soil for planting in a one-pass operation.

The **disk plow** is another conservation tillage tool. It is not as common as the chisel plow in Pennsylvania. It is easy to operate and helps loosen and break up the soil. Disk plows come in many different types, such as wheel mounted pull hitch or three-point hitch, and one-way and two-way types. Secondary tillage is mostly required after disk plowing to allow for successful seedbed preparation. Mixing action may be sufficient to largely eliminate ammonia losses and odor after manure application, depending on the depth of tillage and coverage of the manure. The disk plow is not recommended for terminating alfalfa or grass sod or managing heavy cover crops. The disk plow typically does not enter soil as deep as the chisel plow because it does not pull itself in as well. Sufficient weight on the disk plow is needed to guarantee soil penetration. The disk plow can create plow pans, just like the moldboard plow. Its effect on crop residue cover depends on disk type and depth of operation. Disk plowing does take less power and fuel than moldboard plowing.

Besides these traditional tools, new tillage tools have been developed, including vertical tillage machines. These tools are a combination of shallow primary tillage and secondary tillage. Narrowly spaced coulters or disks are run up front, followed by secondary tillage tools, such as rolling or tine harrows and rolling baskets. The tools are designed to mix residue with soil to speed up decomposition of high-yielding corn and alleviate surface crusting or compaction and yet leave sufficient residue for erosion control. If used in low-residue situations (such as after soybeans), they leave the soil nearly bare, which is not consistent with soil conservation goals. Further, they do not help control weeds and will have a marginal effect on ammonia volatilization if used to incorporate manure. The tools differ in their aggressiveness and soil inversion. They tend to be very heavy and cause soil compaction below their depth of operation.

After primary tillage, secondary tillage is needed to prepare a proper seedbed. Tools for this purpose include the disk harrow, field cultivator, spring-tooth harrow, wire-tooth harrow, spike-tooth harrows, packer rollers, and rolling baskets. Sometimes, these tools are integrated with the primary tillage tool, enabling one-pass operation. Secondary tillage is used to level soil, bust clods, and create a seedbed that is fine and firm enough to guarantee seed-to-soil contact. With improvements in planting equipment, it becomes less necessary to do secondary tillage after primary tillage. However, it is still uncommon for farmers to plant immediately after chisel plowing without any secondary tillage. Disk harrows tend to bury more residue than field cultivators, which are preferred for conservation tillage because they bring crop residue to the surface and don't create tillage pans like those formed by a disk harrow. Spike-tooth harrows are more rigid and tend to break up clods better than spring-tooth harrows, which are more rigid than wire-tooth harrows. Rolling baskets can also be used to break up clods while smoothing and slightly packing soil. Packer rollers primarily pack soil to eliminate air pockets that could compromise seed-to-soil contact. Crop residue can sometimes create a problem with secondary tillage if there is not good residue flow through the tillage machine.

With the realization that full-width inversion tillage has many disadvantages for soil quality and is expensive, companies are continuously developing new tillage tools for specific

Table 1.1-4. Land-use statistics.

Land	Acres in 2012	Percent of Total in 2012	Acres in 2017	Percent of Total in 2017	Percent Increase/ Decrease
Cropland where no-till was used	1,379,252	59	1,611,121	67	+17
Cropland where reduced till was used	504,502	21	487,115	20	-3
Cropland where intensive till was used	470,436	20	298,405	12	-37
Total	*2,354,190*		*2,396,641*		+2
Cropland where cover crop was used (excluding CRP)	446,295	19	595,309	25	+33
Land drained by tile	297,320	13	309,758	13	+4

Source: USDA Agricultural Census, 2017.

purposes. These tools generally perform limited soil inversion but may fracture the soil or open it up so that infiltration or aeration is improved. For example, straight, narrow-shanked subsoilers have been developed that disturb very little above but fracture soil below the surface to alleviate soil compaction. Attachments have been developed to create zones in which a crop like corn can be planted. The soil temperature warms up faster in the spring in these zones, allowing more rapid germination and early growth of corn. These tools are designed to be used in a one-pass operation. Because of the multiple benefits of no-till systems, however, tillage should be limited as much as possible.

Tillage Classification

Various types of tillage classification are available, of which two are discussed here:

1. Classification Based on Time during Cropping Cycle

   - Primary tillage: deep-tillage operation (more than 6 inches) that loosens and fractures soil to kill weeds, reduce soil strength, and mix residue, lime, fertilizers, and manure into soil.
   - Secondary tillage: shallow tillage operation (less than 6 inches) to kill weeds, cut and cover residues, incorporate herbicides, and prepare a pulverized seedbed.
   - Tertiary tillage: in-crop tillage used to control weeds or inject fertilizers and manure.

2. Classification Based on Residue Cover

Tillage that leaves more than 30 percent residue cover on the soil surface after planting is considered conservation tillage, while tillage that leaves less than 30 percent residue cover after planting is not (https://www.ctic.org/). Six classes are distinguished within this classification:

a. Intensive Till or Conventional Till (less than 15 percent residue cover after planting)
   Involves full-width tillage and, typically, one or more tillage passes and/or moldboard plowing.
b. Reduced-Till (15 to 30 percent residue cover after planting)
   Somewhat similar to mulch-till in involving full-width tillage, this class uses the same implements and one to three tillage trips.
c. Mulch-Till (more than 30 percent residue cover after planting)
   This full-width (100 percent of soil surface disturbed) tillage system usually involves one to three tillage passes and the use of implements such as chisel plows, disks, field cultivators, and combination tools.
d. Ridge Till (more than 30 percent residue cover after planting)
   Involves building 4- to 6-inch-high ridges during row cultivation and scraping 1 to 2 inches off of the ridges during planting.
e. Strip-till (more than 30 percent residue cover after planting)
   Usually involves the use of a mole knife to till a zone approximately 10 inches wide and 4 to 5 inches high in the fall with the concurrent application of a combination of nutrients. The following spring, planting occurs in the tilled strip.
f. No-Till (more than 30 percent residue cover after planting)
   This concept has evolved as the technology has changed. With no-till, producers disturb only the minimum amount of soil needed to ensure a good stand and yield.

Status of Soil Tillage in Pennsylvania

The most recent tillage statistics for Pennsylvania are reported in the Agricultural Census of 2017, published by USDA (Table 1.1-4). It shows that no-tillage is now the predominant

tillage system: 67 percent of planted acres are managed with no-till practices, followed by reduced tillage (21 percent) and intensive tillage (12 percent). Between 2012 and 2017, no-till grew by 17 percent, while reduced tillage decreased by 3 percent and intensive tillage decreased by 37 percent.

Agricultural Drainage

Some soils in Pennsylvania are poorly or somewhat poorly drained and can benefit from artificial drainage. Drainage can markedly improve productivity on this land, reducing nitrogen losses by denitrification, enhancing uptake of nutrients, and improving field access and timely operations. However, like any human activity, drainage also has its drawbacks. Wetlands usually occupy these lands in a natural condition. More than half of the wetlands in the United States have been lost to drainage practices, causing loss of wildlife habitat and adverse effects on water quality. Compared with uncleared land under natural conditions, improved drainage and agricultural production usually increase peak runoff rates, sediment losses, and pollutant loads in surface water. Therefore, before starting to install drainage, producers should check with their local Conservation District or NRCS office to determine whether there are wetland restrictions that could void the producer's eligibility for government payments. On the other hand, improved drainage can reduce runoff, peak outflow rates, and sediment losses compared with undrained agricultural land. Therefore, drainage can improve the productivity and environmental function of working farmland.

Several factors determine the need for artificial drainage, including slow soil permeability, flat or depressional topography, restrictive layers at shallow depth, and periods of excessive precipitation. Soil factors that cause a soil to experience drainage problems include texture (high clay content causes slow permeability), structure (a massive soil structure without macropores causes poor percolation), compaction of surface or subsurface soil by farm equipment, and sealing of the soil surface and depositional crusts in low-lying areas. Evidently, artificial drainage cannot resolve all these problems and has to be combined with other soil management practices to improve infiltration and percolation.

Two forms of artificial drainage can be distinguished: surface and subsurface drainage. Surface drainage removes standing water from the soil surface. It affects the water table by removing water before it enters the soil profile. Surface drainage usually involves land leveling and smoothing, installing surface inlets, and constructing shallow ditches and grassed waterways that lead water to streams and rivers without causing erosion. Surface ditches are used on about 123,000 acres in Pennsylvania (5 percent of total planted acres). Subsurface drainage is designed to lower the water table by installing plastic or clay tile below the soil surface to drain water to an outlet that leads water safely to surface water bodies. Tile-drained acres total 310,000 acres in Pennsylvania (13 percent of cropland; see Table 1.1-4). Controlled drainage involves installation of a water control structure in the drainage pipe to allow for regulation of the water table. This may help to reduce nitrate leaching by allowing saturated conditions in the winter and help to recharge the water table during summer. Subirrigation uses drainage pipes to irrigate crops during the summer. Created wetlands can be integrated with drainage systems. Runoff and drainage run into the wetland. The water level in the wetland is maintained to no deeper than 2 feet. The wetland helps to remove sediment and nutrients from the water. The water can subsequently be pumped to a reservoir that can be used to provide a source of irrigation during the dry summer months.

Crop productivity increased markedly in long-term studies on very poorly drained Toledo silty clay and Hoytville silty clay soils in northern Ohio. In a 20-year study on the Toledo soil, corn yields increased by about 40 bushels per acre, soybean yields 40 bushels per acre, and oat yields 40 bushels per acre. On the Hoytville soil, corn yields increased 20 to 30 bushels per acre and soybean yields 7 to 14 bushels per acre. Subirrigation increased corn yields by 12 percent and soybean yields 21 percent over subsurface drainage on a Hoytville silty clay loam in Ohio. The benefits of drainage systems, therefore, depend on soil type. Studies of drainage on water in the northcentral United States have shown the following impacts on water quality on cropland:

1. Up to 63 percent of precipitation can leave a field through a subsurface drainage system.
2. Reduction of overland flow ranges from 29 to 65 percent.
3. Reduction in peak runoff is from 15 to 30 percent.
4. Total water discharge is not affected, merely the partitioning between runoff and drainage.
5. Water erosion is reduced by 16 to 65 percent.
6. Phosphorus losses are reduced by up to 45 percent.
7. Nitrogen losses by denitrification are reduced.
8. Nitrate-nitrogen losses increase.

Artificial drainage is now typically installed by professionals with laser leveling devices. Consulting a company with a good track record and experience with laying out a drainage pattern will help avoid undue disappointments.

Part I, Section 2

Soil Fertility Management

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The goal of soil fertility management is to create soil chemical conditions that encourage plant growth and supply required nutrients in the amounts and at the times they are most needed. Liming materials and plant nutrients may be added to the soil in many forms and in a way that maximizes the economic benefits of nutrients while minimizing negative environmental impacts. The ways in which crops respond to these applications are often different because some soils have inherent physical limitations to plant growth. Soil testing is the best guide to soil fertility. Plant tissue analysis may also be helpful when used in conjunction with soil testing. Some highlights of soil fertility management are presented in the following sections.

Plant Nutrients

The plant nutrients taken up by crops during the growing season may come from many sources, including soil reserves, added fertilizer or manure, and decomposing crop residues. Nutrients such as nitrogen, phosphorus, and potassium are required in large quantities, while others are required in very small quantities. Nutrients such as sulfur, calcium, and magnesium are required in intermediate quantities. Soil supplies of nutrients required in small quantities (micronutrients) need not be large, but the nutrients must be available to the plant.

All the nutrients listed in Table 1.2-1 are essential for plant growth. The roles and deficiency symptoms of the primary nutrients are discussed below. The symptoms are rarely clear cut, so it is important to use both soil and plant analyses when trying to diagnose a suspected nutritional problem.

Nitrogen (N) is a critical component of proteins, which control the metabolic processes required for plant growth. It is also an integral part of the chlorophyll molecule and thus plays a key role in photosynthesis. An adequate supply of nitrogen promotes vigorous vegetative growth and gives plant tissue a dark green color. Nitrogen deficiency is characterized by reduced plant growth and a pale green or yellow color. In corn, this yellowing generally begins at the tip of the

Table 1.2-1. Essential plant nutrients.

Primary Nutrients	**Micronutrients**
Nitrogen (N)	Iron (Fe)
Phosphorus (P)	Manganese (Mn)
Potassium (K)	Boron (B)
	Chlorine (Cl)
Secondary Nutrients	Zinc (Zn)
Sulfur (S)	Copper (Cu)
Magnesium (Mg)	Molybdenum (Mo)
Calcium (Ca)	Nickel (Ni)

leaf and goes down the middle of the leaf. If the deficiency is severe, the affected area eventually turns brown and dies. Since nitrogen is mobile in the plant, older leaves show the first symptoms of deficiency. Nitrogen behavior is extremely dynamic in the soil and very dependent on the weather. Most soil nitrogen is in the organic matter and must be mineralized into soluble forms by microbes before it can be taken up by plants. Because of this dynamic behavior, soil testing for mineral forms of nitrogen ahead of the growing season in humid areas like Pennsylvania is not reliable. Testing can be used to adjust nitrogen management during the season (see the nitrogen recommendations section later in this chapter and in the corn chapter). Also, because of its behavior, nitrogen is very susceptible to losses to both the atmosphere and water and can be an environmental pollutant.

Phosphorus (P) is a critical component of nucleic acids, so it plays a vital role in plant reproduction, of which grain production is an important result. Phosphorus is often found in large quantities in seeds and fruit. Phosphorus is essential for the biological energy transfer processes that are vital to life. Adequate phosphorus is characterized by improved crop quality, greater straw strength, increased root growth, and earlier crop maturity. Phosphorus deficiency is indicated by reduced plant growth, delayed maturity, and small fruit set. These symptoms may be accompanied by a purple coloring, particularly in young plants. Like nitrogen, phosphorus is mobile in the plant; therefore, deficiency symptoms show up first in older leaves. Most soil phosphorus occurs in relatively insoluble minerals and organic matter in the soil. The availability of these forms is very sensitive to soil pH. Phosphorus strongly adsorbs soil minerals and is relatively immobile in the soil. In no-till systems, where the surface soil is not mixed with tillage and fertilizers are often applied to the soil surface, phosphorus can become stratified, with very high concentrations in the first few inches of soil depth and declining concentrations with increasing depth. Phosphorus availability can be estimated reliably with soil tests. Although phosphorus is tightly bound to soil, it can be lost to the environment. The primary loss pathways are through erosion of soil particles and organic matter containing phosphorus, and soluble phosphorus in runoff from soils with very high P levels at the surface, which can occur over time in no-till systems or when manure or fertilizer is applied to the soil surface without incorporation. Phosphorus lost to surface water can be an environmental pollutant.

Potassium (K) is not an integral part of any major plant component, but it does play a key role in a vast array of physiological processes vital for plant growth, from protein synthesis to maintenance of plant water balance. Potassium deficiency is characterized by reduced plant growth and a yellowing and/or burning of leaf edges. Since potassium is mobile in the plant, the symptoms appear on the older leaves first. Another indication of potassium deficiency is reduced straw or stalk strength, which results in lodging problems, reduced disease resistance, and reduced winter hardiness of perennial or winter annual crops. Excess potassium in the soil can lead to excess potassium in plants and in some cases can result in animal nutrition/health problems. Potassium in the soil is mainly in the form of insoluble minerals and as the K+ cation on the soil cation exchange capacity (CEC). Soil tests can estimate available potassium by measuring the K+ cation on the soil CEC.

The secondary nutrients calcium, magnesium, and sulfur play a variety of roles in plants.

Calcium (Ca) is an integral part of plant cell walls. Calcium deficiency is rare among agronomic crops under Pennsylvania conditions. When a soil is limed to maintain an optimum pH level, calcium is usually adequate for agronomic crops. Calcium is mainly found in soil minerals and as the Ca^{2+} cation on the soil CEC. Soil tests can estimate available calcium by measuring the Ca^{2+} cation on the soil CEC.

Magnesium (Mg) is a key component of chlorophyll that plays a critical role in photosynthesis. Magnesium deficiency is characterized by white stripes between the leaf veins. Magnesium is best supplied by a limestone that contains this nutrient. Magnesium is mainly found in soil minerals and as the Mg^{2+} cation on the soil CEC. Soil tests can estimate available magnesium by measuring the Mg^{2+} cation on the soil CEC.

Sulfur (S) is a common component of proteins and vitamins. Sulfur-deficient plants have a general yellowing and are very spindly. Symptoms of sulfur deficiency are similar to those of mild nitrogen deficiency, except that they appear sooner in new growth than in old growth since sulfur is not as mobile as nitrogen in the plant. Under Pennsylvania conditions, sulfur deficiency has not been common in the past because rainfall has historically supplied significant amounts of sulfur, and sulfur is recycled efficiently through the manure applications that much of the cropland in the state receives. However, as efforts continue to reduce acid rain, sulfur deficiencies are becoming more common. Similar to nitrogen, most of the sulfur in the soil is found in the organic matter. The plant-available ionic form of sulfur, sulfate (SO_4^{2-}), easily leaches out of surface soils, but substantial quantities can accumulate in clay-rich subsoil layers that are still within reach of deep-rooted crops. Consequently, routine soil fertility testing for sulfur is only moderately reliable in humid environments like Pennsylvania's. Plant analysis can be used as a complementary tool for monitoring sulfur nutrition in the crop.

Micronutrients are key players in many of the processes that are important for plant growth. Few micronutrient problems exist in Pennsylvania because (1) the heavier loamy texture of our soils helps to maintain adequate levels of micronutrients (sandy-textured soils, by contrast, often show micronutrient deficiencies), (2) the slightly acidic nature of our soils helps to maintain micronutrient solubility, and

Figure 1.2-1. Relative mobility of essential plant nutrients in the soil.

(3) Pennsylvania agriculture is largely animal based, so much of our cropland gets periodic applications of manure, a good source of most micronutrients.

Of the micronutrients, **boron (B)** and **zinc (Zn)** are the two that are occasionally deficient in the state. Boron deficiency is most likely in alfalfa and can be overcome by periodically applying boron when topdressing alfalfa. Zinc deficiency is sometimes observed on corn, particularly when phosphorus levels become excessive from overapplication of phosphorus fertilizer. Symptoms on corn appear as a rough striping on either side of the midrib of the leaf. Zinc deficiency can be corrected with a periodic broadcast application of zinc. Routine application of zinc is not recommended.

The lack of general response to micronutrients has made it difficult to calibrate a micronutrient soil test for use in Pennsylvania. In addition, it is not possible to rely on calibrations developed for other soil, climatic, and cultural systems. The best tool for evaluating a plant's micronutrient status is plant tissue analysis.

Additional Considerations

Some nutrients, such as nitrogen and phosphorus, are present in the soil in large amounts but, under most conditions, are made available to plants very slowly. Others, such as potassium, are both present in the soil in large amounts and readily available.

Nutrients also behave differently in the soil. One important behavioral characteristic of a nutrient in soil is its relative mobility (Figure 1.2-1). In general, as nutrient mobility increases, fertilizer placement becomes less critical, but the potential for nutrient loss becomes greater. Thus, nitrogen placement relative to the plant is not very critical for uptake, but the potential for loss of nitrogen once it has been applied to the soil is generally very high and little available nitrogen will accumulate in the soil.

Conversely, as nutrient mobility decreases, fertilizer placement becomes more critical, but the potential for nutrient loss declines. At this extreme, phosphorus placement near the plant is very critical for uptake since phosphorus does not move more than ¼ inch to get to a root. The loss of phosphorus from soils usually requires erosion of the soil itself; therefore, phosphorus accumulates in the soil.

Recent evidence indicates that, despite its low solubility, significant amounts of soluble phosphorus can be lost in runoff from fields when the soil becomes saturated with very high or excessive soil test phosphorus levels, or when phosphorus fertility sources are applied to the soil surface without incorporation. Therefore, from an environmental perspective, it is best to manage phosphorus to avoid excessive soil test phosphorus levels and to incorporate phosphorus fertility sources beneath the soil surface. The behavior of most micronutrients is similar to that of phosphorus. The other nutrients fall between these two extremes in mobility behavior.

Economics of Nutrient Application

Ideally, soil should be managed to maintain an adequate supply of nutrients to meet crop needs. The highest total profit per acre and the lowest cost per unit of crop produced result in recommended application rates as maximum plant yields are approached. However, if resources are limited, low to medium application rates provide the higher plant response and often the higher economic return per dollar invested. As application rates increase, the plant response per unit of nutrient applied decreases, as does the economic return per unit applied, and at some point other factors may become limiting—adding plant nutrients in amounts beyond those required for maximum plant growth in a given situation will produce no plant growth response or positive economic return. Nutrient recommendations provided here for agronomic crops in Pennsylvania are based on research to estimate the amount of a nutrient needed to ensure economically optimum crop production. As the economic conditions change (e.g., nutrient or crop prices change), the recommended amount of nutrients may also change.

Soil Testing

Soil testing is an excellent method for estimating the fertility status of a soil, and it provides valuable information for developing a sound fertility management program. Because the fertility status of a soil cannot be determined visually, a good soil test is essential.

An example Penn State soil test report is shown in Figure 1.2-2. The website for the Penn State Agricultural Analytical Services Laboratory is https://agsci.psu.edu/aasl. The Penn State report is divided into three parts: (1) Soil Nutrient Levels, (2) Recommendations, and (3) Additional Results.

Sample Information

The top of the report provides information on both the laboratory identification of the sample (DATE, LAB #, and SERIAL #) and your identification of the sample (COUNTY,

Figure 1.2-2. Sample agronomic soil test report.

PennState Extension

Agricultural Analytical Services Laboratory
The Pennsylvania State University
111 Ag Analytical Svcs Lab
University Park, PA 16802
(814) 863-0841 aaslab@psu.edu www.aasl.psu.edu

SOIL TEST REPORT FOR:	ADDITIONAL COPY TO:
JOHN JONES JONES FAMILY FARM HARMONY LANE GREENVILLE PA 22222	SAM COOK TOP GROW ENTERPRISES 111 ALFALFA RD. SMITHVILLE PA 11111

DATE	LAB #	SERIAL #	COUNTY	ACRES	ASCS ID	FIELD ID	SOIL
06/11/2020	S01-19627	55	Centre	7.5		Back 40	Hagerstown

SOIL NUTRIENT LEVELS			Below Optimum	Optimum	Above Optimum
[1]Soil pH	5.4				
[2]Phosphorus (P)	40	ppm			
[2]Potassium (K)	175	ppm			
[2]Magnesium (Mg)	50	ppm			

RECOMMENDATIONS: *(See back messages for important information)*

Limestone*: 4000 lb/A for a target pH of 7.0. **Magnesium (Mg):** 20 lb/A

Calcium Carbonate equivalent

Plant Nutrients: ***(If manure will be applied, adjust these recommendations accordingly. See back of report.)***

Year	Crop	Expected Yield	Nitrogen (lb N/A)	Phosphate (lb P_2O_5/A)	Potash (lb K_2O/A)	
1	Established Alfalfa	6 T/A	0	50	60	*See ST2 for other crop recommendations*

Apply fertilizer after first cutting or, for large recommendations, split after first cutting and in the fall.
Apply 2 lbs boron per acre with the fertilizer.

2	Corn for Silage	27 T/A	200	50	40	*See ST2 for other crop recommendations*

A N credit for the previous Established Alfalfa crop should be subtracted from the base N recommendation listed above. Credits based on percent stand of the legume crop are as follows: less than 25 % stand -40 lb/A, 25-50 % stand - 80lb/A, greater than 50 %stand - 120lb/A
Use a starter fertilizer. (See Back)

3	Corn for Grain	190 Bu/A	190	40	0	*See ST2 for other crop recommendations*

Use a starter fertilizer. (See Back)

ADDITIONAL RESULTS:						Optional Tests:			[2]Trace Elements		
[2]Calcium (ppm)	[3]Acidity (meq/100 g)	[4]CEC (meq/100 g)	% Saturation of the CEC K	Mg	Ca	Organic Matter %	Nitrate-N ppm	Salts mmhos/cm	*See back for comments* Zinc ppm	Copper ppm	Sulfur ppm
1021	3.9	9.9	4.5	4.2	51.7				4.2	1.7	14.0

Test Methods: [1]1:1 soil:water pH, [2]Mehlich 3 (ICP), [3]Mehlich Buffer pH, [4]Summation of Cations

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Figure 1.2-3. Soil test information sheet.

PennState Extension

Agricultural Analytical Services Laboratory
The Pennsylvania State University
111 Ag Analytical Srvcs Lab
University Park, PA 16802

Phone: 814-863-0841
Fax: 814-863-4540
Web: www.aasl.psu.edu

SOIL TEST INFORMATION FORM FOR AGRONOMIC CROPS

Grower Name (Please Print):			Send copy to:
Business Name:		ASCS Farm ID:	Business Name:
Street or R.D. No.:			Street or R.D. No.:
City, State, and Zip:		County	City, State, Zip:
Telephone No.:	Fax No.:	E-mail:	

☐ ***Email report only***: Check this box and record your email address if you would prefer to have your report sent to you by email rather than surface mail.
Note: Please submit payment of $9 per sample (check payable to Penn State University) if NOT submitting samples in pre-paid kits.

Sample/Field Info For plow depth,use code 7, 9, or 12 7 = < 9 " 9 = 9-11" 12 = > 12"			**Last Year's Crop** If legume, complete this column.	**Recommendations** will be made for 3 crop years. For each sample, complete crop and yield goal information for years 1, 2, and 3. See back of form for crop codes and yield ranges.			**Additional Analyses** See back of form for additional analyses not listed below. Enclose payment for additional tests with checks made payable to **Penn State.**
			Last yr's crop	**Crop-Year 1**	**Crop-Year 2**	**Crop-Year 3**	
Field ID (10 digits or less)	Plow Depth (7,9, or 12)	# Acres	Last yr's crop code if legume	Crop Code 1	Crop Code 2	Crop Code 3	__ Organic Matter ($5.00)
Sample bag serial #	Soil Type			Yield goal Crop 1	Yield goal Crop 2	Yield goal Crop 3	__ Soluble Salts ($5.00)
							__ Nitrate Nitrogen ($5.00)
							__ DEP Permit 271 ($235.00)
							__ _____
							__ _____
Field ID (10 digits or less)	Plow Depth (7,9, or 12)	# Acres	Last yr's crop code if legume	Crop Code 1	Crop Code 2	Crop Code 3	__ Organic Matter ($5.00)
Sample bag serial #	Soil Type			Yield goal Crop 1	Yield goal Crop 2	Yield goal Crop 3	__ Soluble Salts ($5.00)
							__ Nitrate Nitrogen ($5.00)
							__ DEP Permit 271 ($235.00)
							__ _____
							__ _____
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							__ _____
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Sample bag serial #	Soil Type			Yield goal Crop 1	Yield goal Crop 2	Yield goal Crop 3	__ Soluble Salts ($5.00)
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							__ _____
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Sample bag serial #	Soil Type			Yield goal Crop 1	Yield goal Crop 2	Yield goal Crop 3	__ Soluble Salts ($5.00)
							__ Nitrate Nitrogen ($5.00)
							__ DEP Permit 271 ($235.00)
							__ _____
							__ _____

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ACRES, FIELD ID, and SOIL). Check identification information to be sure that it is correct. Consistency in identifying fields (FIELD ID) simplifies comparison of soil tests on the same fields over time to determine and react to any trends. Laboratory identification is also important if you have a concern about the results or a question about the report. Should laboratory personnel need to retrieve your soil sample or report to check a problem or answer a question, they will need to know the LAB # of the report. Soil samples are not retained indefinitely—prompt action is important if you think there is a problem with your results. If you suspect a problem with your soil analysis, contact the Agricultural Analytical Services Laboratory at 814-863-0841 or aaslab@psu.edu.

Sampling

A soil test is no better than the care given to taking samples. Follow the guidelines below for taking soil samples. Not following these instructions or the instructions from your soil testing lab can invalidate your soil test results and interpretations. It is very important to completely and accurately fill out the soil sample submission form because this information (e.g., crop, expected yield, plow depth) is used to adjust lime and nutrient recommendations for your specific conditions (Figure 1.2-3). Mailing kits for submitting samples to the Agricultural Analytical Services Laboratory are available from all Penn State Extension offices.

1. Do not wait until the last minute. The best time to sample is generally in the late summer or fall.
2. Use a soil probe to collect cores from at least 15 to 20 spots randomly over the field to obtain a representative sample. One sample should not represent more than 10 to 20 acres.
3. Sample between rows. Avoid old fencerows, dead furrows, and other spots that are not representative of the whole field.
4. Take separate samples from problem areas if they can be treated separately.
5. In cultivated fields, sample to plow depth.
6. Take two samples from no-till fields: one to a 6-inch depth for lime and fertilizer recommendations, and one to a 2-inch depth to monitor surface acidity. pH in the 2-inch depth sample can be sent to the lab separately or checked with a field pH test kit.
7. Sample permanent pastures to a 3- to 4-inch depth.
8. Collect the samples in a clean container.
9. Thoroughly mix the core samplings, allow to air-dry, and remove roots and stones.
10. Fill the soil test mailing container.
11. Complete the information sheet, providing all of the information requested. Be sure to include the soil name. Remember, the recommendations can be only as good as the information supplied.

Sampling No-Till Fields

If the area has been in no-till corn management or long-term perennial grass for two years or longer, it is advisable to use a reliable field kit to measure the pH of the surface soil. Surface applications of nitrogen fertilizers and manure may acidify this layer rapidly, creating an "acid roof," which can decrease herbicide effectiveness and reduce nutrient availability. Collect several cores less than 2 inches deep from the no-till area and mix thoroughly in a clean bucket. Remove a sample for pH measurement. Simple colorimetric field pH test kits are normally the most satisfactory for field use. If the pH of the surface soil is less than 6.2, take a standard soil sample for laboratory analysis. Apply the recommended lime as early as possible before corn plantings.

If this standard sample does not indicate a need for limestone and the surface pH is below 6.2, apply 2,000 pounds of calcium carbonate equivalent per acre. This amount should be adequate to neutralize the acidity created by the surface-applied nitrogen fertilizer.

Analysis

The soil testing procedures currently used by the Penn State Soil Testing program are listed below and on the soil test report.

- Soil pH: Water, 1:1
- Acidity: Mehlich Buffer
- Phosphorus, potassium, magnesium, calcium, sulfur, zinc, and copper: Mehlich 3

This information is useful if you compare analytical results from different labs. Direct comparisons can be made only between labs using exactly the same procedures. Many different methods are in use around the country. Which test will be used in a given area is based on research to determine how well the test works under local soil, crop, and climatic conditions. Be careful in selecting a soil testing lab, especially one in a different region. It is very important to send samples to a lab that uses soil tests that are appropriate for Pennsylvania conditions. A lab in a different part of the country may provide excellent quality results, but if the tests are not appropriate for our conditions, these tests may not result in correct interpretations and recommendations. The tests used by Penn State's Agricultural Analytical Services Lab have been determined through extensive research to work best for Pennsylvania conditions. Note that some state regulations, such as the Pennsylvania Nutrient Management Law, require soil tests to follow the recommended procedures in the list above. While most soil testing laboratories doing business in Pennsylvania use the recommended test methods listed above, it is important to determine if the lab you use is following these recommended procedures for your soil test results to be valid.

Soil nutrient levels on the Penn State soil test report are given as parts per million (ppm) elemental phosphorus, potassium, and magnesium. However, while other labs doing soil testing in Pennsylvania may use the recommended methods above, they may report the results in different units. Below are simple mathematical conversions that can be used to change soil test results from labs using the recommended procedures but reporting results in units different from those used on the Penn State soil test report. (Important note: This only applies to the soil test level. The recommendations are always given as pounds of P_2O_5 [phosphate] and K_2O [potash] per acre, so no conversions are necessary for the recommendations.)

lb P_2O_5 per acre ÷ 4.6 = ppm P
ppm P_2O_5 ÷ 2.3 = ppm P
lb P per acre ÷ 2 = ppm P
lb K_2O per acre ÷ 2.4 = ppm K
ppm K_2O ÷ 1.2 = ppm K
lb K per acre ÷ 2 = ppm K
lb MgO per acre ÷ 3.2 = ppm Mg
ppm MgO ÷ 1.6 = ppm Mg
lb Mg per acre ÷ 2 = ppm Mg

For example, if a soil test reports the Mehlich 3 phosphorus level as 140 pounds of P_2O_5 per acre, you would need to divide by 4.6 to convert this to 30 ppm phosphorus. If the results were reported as 60 pounds of phosphorus per acre, you would simply divide by 2 to convert this to 30 ppm phosphorus. Finally, if the result were reported as 70 ppm P_2O_5, you would divide by 2.3 to convert this to 30 ppm phosphorus. Note that in this example, 140 pounds of P_2O_5 per acre, 60 pounds of phosphorus per acre, and 70 ppm P_2O_5 are all the same as 30 ppm phosphorus, just reported in different units. This conversion is important if you want to compare results from different labs because they must all be in the same units. Also, if you want to look up a Penn State recommendation using a result from another lab, the results must be in ppm phosphorus, potassium, and magnesium.

Interpreting the Results

The results of the laboratory analysis are meaningless by themselves; they must be interpreted by relating lab values to known crop responses under local conditions. The relationship between the soil test level and crop yield can be represented as a response curve (Figure 1.2-4). As soil test levels increase from very low levels, the yield will increase until it reaches a "yield plateau," the point above which yield no longer increases as the soil test level increases. The optimum soil test level lies just above that point. Eventually, if soil test levels continue to increase, yield reduction may occur in some instances. Once the response curve has been determined by field research in the area where the soil test will be used, the

Figure 1.2-4. Yield response curve illustrating the soil test interpretation levels.

interpretation levels for the soil test (i.e., below optimum, optimum, above optimum) can be established as shown in this figure. Unfortunately, there is no standard terminology for these soil testing categories. Be sure to determine the exact meaning of the interpretation terms used on your soil test. The interpretation, based on crop response research, is given as a bar chart on the Penn State soil test report that indicates whether the level for each nutrient is below optimum, optimum, or above optimum for the crop to be grown (see Figure 1.2-2). The definition for each category on the Penn State soil test report is given below. The terms used in the Penn State soil test report are given first in bold and alternative terms sometimes used by other labs are given in parentheses for each category.

Below optimum (very low, low, medium) soil test level indicates that the nutrient is probably deficient and the deficiency will likely limit crop growth. There is a high probability of a profitable return from correcting a low level. The recommendation for a below-optimum-testing soil is designed to gradually build up the nutrient level to optimum and maintain it at that level.

Optimum (medium, high, sufficient, adequate) soil test level indicates that the nutrient is probably adequate and will likely not limit crop growth in a typical growing season. There is a low probability of a profitable return from adding nutrients to increase the soil test level above optimum. The recommendation for an optimum-testing soil is designed to offset a portion of crop removal in order to maintain the nutrient in the optimum range. If you are soil testing on an annual basis, no maintenance nutrient applications are needed when the soil tests in the optimum range. Optimum soil test ranges for pH, phosphorus, potassium, and magnesium used for agronomic crops in Pennsylvania are given in Table 1.2-2.

Above optimum (high, very high, excessive) soil test level indicates that the nutrient is more than adequate and will not limit crop growth. There is a very low probability of a profitable return from applying a nutrient to a soil testing above optimum. Consequently, no nutrient applications are recommended on these soils. Too much of a plant nutrient

Table 1.2-2. Optimum levels used to interpret the Mehlich 3 soil test for agronomic crops in Pennsylvania.

Soil Test	Optimum Range	Comments
pH	6.0–7.0	A pH of 6.0–6.5 is considered adequate for most agronomic crops; however, 6.5–7.0 is recommended for alfalfa and barley
Phosphorus (P)	30–50 ppm	All agronomic crops
Potassium (K)	100–150 ppm	Grain crops
	100–200 ppm	Forage crops
Magnesium (Mg)	120–180 ppm	Grass forage crops
	60–120 ppm	Other agronomic crops

may cause a nutrient imbalance in the soil and, as a result, in the plant. Additional broadcast applications of fertilizers, manure, or other nutrient sources to soils that are very high not only result in unsatisfactory economic returns but can also adversely affect plant growth, animal health, and environmental quality.

Recommendations

The recommendations on the Penn State soil test report are made for a three-year sequence of crops. These recommendations are made based on the soil test results and the information you provided on the submission form, such as crop to be grown, expected yield, crop rotation, and plow depth. Fertilizer recommendations given on the soil test report are derived from the *Soil Fertility Testing Recommendation Handbooks* found on the Penn State Agricultural Analytical Services Laboratory website at https://agsci.psu.edu/aasl/soil-testing/fertility/handbooks/agronomic. The tables on this website can be used to change your Penn State soil test recommendation to a different crop or expected yield. They can also be used to determine a Penn State recommendation based on soil test results from another lab. If you use these tables to determine a recommendation based on results from another lab, be sure that the recommended soil testing methods listed earlier are used and the units for the soil test results are ppm elemental phosphorus, potassium, and magnesium.

Limestone Recommendation

Liming an acidic soil is the first step toward creating favorable soil conditions for productive plant growth. Crops vary in their ability to tolerate an acidic (low pH) soil, but a soil pH of 5.5 or lower will often result in significant yield loss for most crops. In addition, evidence has shown that soil acidity may influence other crop management problems such as herbicide activity. The general goal of liming agricultural soils continues to be a soil pH of 6.0 to 7.0.

Raising soil pH requires a quantity of agricultural liming material that is determined by the amount of acidity in the soil and the quality of the liming material. Soil acidity is measured by soil testing and is reported as "Acidity" in the "Additional Results" section of the soil test report (see Figure 1.2-2). The quality of agricultural liming material is determined by its purity and particle size distribution. In Pennsylvania, agricultural liming materials must, by law, meet minimum quality standards.

Limestone is applied to neutralize the acidity in the soil and thus raise the soil pH to the optimum range for crop growth. The limestone recommendation is based on the amount of exchangeable acidity measured in the soil and the optimum soil pH level for the crop. The recommended limestone application is a one-time application to cover the three years on the test. The pH requirements vary from crop to crop. For most agronomic crops, the optimum pH is 6.5. For alfalfa and barley, the pH goal is 7.0. Since only one limestone recommendation is made for three years, the recommendation on the report will adjust the pH for the most sensitive crop to be grown during the three years. The actual pH goal used to make the limestone recommendation is indicated next to the recommendation on the report.

Lime requirement, expressed as pounds of calcium carbonate equivalent (CCE) per acre, can be estimated using the following formulas. The exchangeable acidity is given at the bottom of the Penn State soil test report (see Figure 1.2-2). Some soil testing labs report exchangeable acidity as "Exchangeable H+."

For a desired pH of 7.0, the lime requirement in lb CCE/A can be estimated as follows:

Lime requirement = exchangeable acidity × 1,000

For a desired pH of 6.5, the lime requirement in lb CCE/A is estimated as follows:

If the exchangeable acidity is greater than 4.0, then lime requirement = exchangeable acidity × 840

or

If the exchangeable acidity is less than 4.0 and the soil pH still is still less than 6.5, then lime requirement = 2,000 lb/A

Otherwise, no lime is recommended.

The recommendation is based on liming an acre furrow slice approximately 7 inches deep. If the limestone will be mixed with a larger volume of soil (i.e., if the plow depth is more than 9 inches), the recommendation is adjusted as follows:

- Less than 9 inches and reduced or no tillage: no limestone adjustment
- 9 to 11 inches: basic limestone requirement × 1.5
- More than 12 inches: basic limestone requirement × 1.8

Additional Considerations for Prioritizing Soil Acidity Management

Although the best practice is to apply the recommended amount of a liming material, a partial application should be considered rather than no application at all. Below are some important considerations for prioritizing the application of agricultural lime.

- Always maintain soil pH above 5.5. This pH is critical for root growth in most agronomic crops. With limited money to spend on lime, try to apply at least some limestone to any field with a pH near or below 5.5. To estimate a limestone recommendation (lbs CCE/A) for a target pH of 5.5, multiply the "Exchangeable Acidity" on your soil test by 400.
- Prioritize fields that will be planted to alfalfa for limestone application. The rhizobia that fix nitrogen in the nodules on alfalfa roots are less productive at low soil pH. This can result in nitrogen deficiency in alfalfa. Since an alfalfa seeding is a long-term investment, this is an especially critical time in the crop rotation to correct the soil pH to at least 6.5 to 7.0.
- Correct the pH in fields transitioning to no-till management when lime can still be incorporated through the whole plow layer. After transitioning to no-till soil management, it will not be possible to mix lime into the soil to correct the acidity below the first few inches of soil. Furthermore, lime application rates calculated to correct the acidity of a topsoil layer that is below optimum in pH may result in over-liming of the first few inches of soil when the lime is not mixed with the whole plow layer.
- Maintain optimal pH in long-term no-till fields and long-term perennial forage fields. Because there is no mixing by tillage, regular liming is essential to maintain soil pH in these fields. If the pH in a no-till or long-term perennial field is allowed to get too low, it can take a long time to correct this condition without going back to tillage. Follow the recommended soil sampling practices for no-till fields described above to detect the development of an acid roof, and apply lime accordingly. With regular recommended liming (i.e., about every three to four years), pH can be maintained in these fields with no special management required.
- For better nutrient use efficiency and herbicide activity, try to maintain the pH at least above 6.0 if possible. Even if you cannot afford the full recommended rate of lime, the next priority would be to get as many fields as possible above 6.0. To estimate a limestone recommendation (lbs CCE/A) for a target pH of 6.0, multiply the "Exchangeable Acidity" on your soil test by 600.
- Ideally, apply the amount of limestone recommended on the soil test for the crops to be grown.

When less than the full limestone requirement is applied in a tillage system, make the application after primary tillage and incorporate it by secondary tillage, thus mixing the limestone 4 inches into the surface. This ensures a better environment for germinating seeds and young seedlings, as well as more effective herbicide action in the surface soil layer.

Because there is generally little advantage to applying more than 8,000 pounds of calcium carbonate equivalent per acre in any one application, when high rates of limestone are recommended (4 tons or more per acre), the applications should be split. For recommendations between 4 and 9 tons per acre, apply the limestone in two applications; for recommendations greater than 9 tons per acre, apply the limestone in three applications. Separate the applications by six months or at least by tillage operations. In a tillage-based management system, plowing down part of the limestone and then applying the balance and incorporating with secondary tillage is an excellent way to correct the pH in the whole plow layer.

As soil acidity increases (i.e., soil pH becomes lower), the need to apply a liming material to any crop and the expected economic returns become greater. If soil acidity is limiting crop production, other production inputs such as fertilizer, seed, pesticides, machinery costs, and labor will not realize the kind of return that would be possible on a well-limed soil.

See "Agronomy Facts 3: Soil Acidity and Liming" for details on limestone recommendations, liming material quality, and liming practices.

Magnesium (Mg) Recommendation

If the soil magnesium level is below the optimum level for crop production, magnesium will be recommended to raise the level to optimum. Agricultural limestone is generally the most economical and convenient source of magnesium for agronomic crops. In addition to the actual amount of magnesium recommended (pounds of magnesium per acre), the magnesium recommendation is also given as the minimum percentage of magnesium in the recommended amount of limestone required to meet the magnesium needs. Magnesium requirements vary from crop to crop. However, because the magnesium recommendation is linked to the limestone

recommendation, only one magnesium recommendation is made. This recommendation is based on the needs of the most sensitive crop to be grown during the three years.

Low magnesium levels in soil may result in low magnesium levels in forage crops, especially if a significant amount of nitrogen and/or potassium fertilizer is applied or soil test potassium levels are above optimum. This can result in potentially fatal grass tetany in grazing animals. Use caution if grazing in this situation. To protect against this potential problem, magnesium fertilizer recommendations for forage crops are increased when soil test potassium levels are above optimum. In these cases, it is especially important to apply the recommended magnesium; however, be aware that if the potassium is very high and the magnesium is low, it may not be possible to correct this soil imbalance immediately. Therefore, it is

Figure 1.2-5. Nitrogen management process.

Table 1.2-3. Nitrogen recommendations for agronomic crops.

Crop	Recommendation (pounds of nitrogen per unit of expected yield)	Comments
Corn grain (bu/A)	1	For better nitrogen efficiency, delay application of the nitrogen until the corn is between 10 and 20 inches tall. If the field has a history of manure and/or legumes, delay all of the nitrogen. If there is no history of manure and/or legumes, split the nitrogen, applying one-third near to planting and delaying the balance. Adjust this recommendation for any previous legume in the rotation (see Table 1.2-4) and for residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12). The PSNT or chlorophyll meter test can be used to refine nitrogen recommendations for corn, especially where manure is a major nutrient source.
Corn silage (ton/A)	7	For better nitrogen efficiency, delay application of the nitrogen until the corn is between 10 and 20 inches tall. If the field has a history of manure and/or legumes, delay all of the nitrogen. If there is no history of manure and/or legumes, split the nitrogen, applying one-third near to planting and delaying the balance. Adjust this recommendation for any previous legume in the rotation (see Table 1.2-4) and for residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12). The PSNT or chlorophyll meter test can be used to refine nitrogen recommendations for corn, especially where manure is a major nutrient source.
Grain sorghum (bu/A)	0.75	Adjust this recommendation for any previous legume in the rotation (see Table 1.2-4) and for residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12).
Forage sorghum (ton/A)	7	Adjust this recommendation for any previous legume in the rotation (see Table 1.2-4) and for residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12).
Oats (bu/A)	0.8	Apply the nitrogen with any other fertilizer before planting. Adjust this recommendation for any residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12).
Wheat/rye (bu/A)	1	If plants did not tiller well, apply nitrogen by mid-March; otherwise, apply at any time up to growth stage 5. Adjust this recommendation for any residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12).
Barley (bu/A)	0.8	If plants did not tiller well, apply nitrogen by mid-March; otherwise, apply at any time up to growth stage 5. Adjust this recommendation for any residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12).
Small grain silage (ton/A)	15	Apply at greenup in the spring.
Grass hay (ton/A dry hay equivalent)	50	Split the nitrogen recommendation and apply it based on the expected yield for each cutting. For grass-legume mixtures, if the legume is more than 50% of the stand, the field should be managed as a legume; thus, no nitrogen is recommended. Adjust this recommendation for any residual nitrogen from previous manure applications (see Tables 1.2-11 and 1.2-12).

These are base recommendations and should be adjusted for previous crop, previous manure history, and planned manure applications (see "Manure Nutrient Management" section).

critical that your feed rations are properly balanced based on the actual forage mineral content.

Nitrogen (N) Recommendation

No soil analysis is used to make the nitrogen recommendations on the report.

The most important concept for managing nitrogen recommendations is that soil nitrogen management is an adaptive process; there is no simple answer regarding how much nitrogen a crop needs. It means managing a variety of potential nitrogen sources, including soil nitrogen and applied nitrogen sources, over time within a complex and dynamic nitrogen cycle to meet not only the overall crop need but also the peak demand for nitrogen by the crop. Figure 1.2-5 illustrates the process for managing nitrogen, which starts with a recommendation, but the ultimate outcome is the result of an ongoing, repeated process of management decisions, observation, testing, analyzing, and adjustments based on an understanding of the nitrogen cycle, which must be a continuous activity of the manager.

Recommendations are based on estimates of crop requirements for nitrogen as determined by extensive crop response research under Pennsylvania conditions. Most recommendations are based on the information you provided about the crop to be grown and the expected yield. The recommendations are given as pounds of nitrogen required per acre for each crop. A summary of the nitrogen recommendations for agronomic crops is given in Table 1.2-3. These recommendations should be considered only as a starting point for nitrogen management.

Adjustments should be made to the basic recommendations for the nitrogen contributions from legumes and manure. Legumes are able to fix the nitrogen they need from the atmosphere and thus do not require additional nitrogen. Also, growing a legume in a rotation preceding a nitrogen-requiring summer annual crop may result in a high level of residual nitrogen in the soil that can be utilized by the following crop. The nitrogen recommendations must be adjusted to take this residual nitrogen into account. Recommended credits for this residual nitrogen are provided with the nitrogen recommendation on the soil test report. These credits also are summarized in Table 1.2-4. Adjust the basic nitrogen recommendation accordingly. Nitrogen contributions from legumes to winter crops such as wheat or barley are much smaller and less predictable due to the necessity for microbes to mineralize the nitrogen in the legume residue, which typically results in a very small amount of nitrogen available from the legume at the time of major nitrogen uptake by winter crops. The most common scenario might be wheat or barley following soybeans where the credit would be very small and is usually not counted.

Although the nitrogen recommendation for a legume is zero, and no yield response will result if nitrogen is applied, legumes will use some applied nitrogen, such as that from manure applications. However, nitrogen applied to legumes can increase weed and grass competition and thus shorten the life of a forage legume stand. Approximate amounts of nitrogen that will be removed by legumes are given in Table 1.2-5. More information on manure application on legumes is provided under "Manure Nutrient Management" in this section of the *Penn State Agronomy Guide*.

Nitrogen supplied by manure should also be considered in determining the nitrogen management for a crop. Residual nitrogen from past manure applications may reduce the amount of nitrogen required for the current crop. The nitrogen in manure applied for the current crop must also be accounted for. Manure nitrogen availability varies depending on how it is handled and applied. Manure analysis is available

Table 1.2-4. Residual nitrogen contributions from legumes to summer annual crops.

		High-Productivity Fields (Soil Productivity Group 1)	Moderate-Productivity Fields (Soil Productivity Groups 2 and 3)	Low-Productivity Fields (Soil Productivity Groups 4 and 5)
Previous Crop	**Percent Stand**	**Nitrogen Credit (lb/A)**		
First year after alfalfa	>50	120	110	80
	25–49	80	70	60
	<25	40	40	40
First year after clover or trefoil	>50	90	80	60
	25–49	60	60	50
	<25	40	40	40
First year after soybeans harvested for grain		1 lb nitrogen/bu soybeans		

When a previous legume crop is checked on the Penn State soil test information sheet, the residual nitrogen for the year following the legume is calculated and given on the report. This credit should be deducted from the nitrogen recommendation given on the soil test report. See Table 1.1-1 in the basic soils section for information on soil productivity groups.

Table 1.2-5. Nitrogen removal by legumes.

Legume Crop	Pounds of Nitrogen Removed Per Unit of Yield
Alfalfa (ton/A)	50
Clover (ton/A)	40
Trefoil (ton/A)	50
Soybeans (bu/A)	3.2

No nitrogen application recommended. Although legumes will use nitrogen from manure and other sources, applying nitrogen may increase competition from weeds and grasses. If you apply manure, limit it to an application rate that balances the crop's phosphorus requirement.

from the Penn State Agricultural Analytical Services Lab. More detailed information on manure management is provided under "Manure Nutrient Management" in this section of the *Penn State Agronomy Guide*.

Nitrogen testing is not possible as part of a routine soil testing program because nitrogen is very dynamic in the soil-plant system. Consequently, the available nitrogen changes throughout the season. For nitrogen testing to be valid, it must be conducted very near to the time when the crop has the most demand for nitrogen and thus used to make adjustments to nitrogen management during the season. A soil nitrogen test, the "presidedress soil nitrate test (PSNT)," has been developed for corn. This test is an in-season, presidedress analysis for nitrate nitrogen in the surface foot of soil. The test is very good for determining if the soil contains adequate nitrogen to produce the current corn crop, and it can give some guidance for adjusting sidedress nitrogen recommendations. This test is especially useful where manure is expected to contribute significantly to the nitrogen needs of the crop. This test is available only for corn (see "Agronomy Facts 17: Presidedress Soil Nitrate Test for Corn" for details).

Another test using a chlorophyll meter to estimate the nitrogen status of the corn based on the color of the corn leaves has been developed. This is also a presidedress test that is to be run at the critical time just before the major nitrogen demand by the crop. However, with this test, the greenness of the corn leaves is measured with a handheld meter. Thus, no samples need to be collected and analyzed, and the results are available immediately. The recommended use and accuracy of this test is similar to the PSNT (see "Agronomy Facts 53: The Early Season Chlorophyll Meter Test for Corn" for more details). With both of these tests, the procedures must be followed exactly for the results to be valid. One of the important requirements to be aware of for the chlorophyll meter test is that no more than 10 lbs/ac of nitrogen fertilizer should be applied to the crop prior to sidedressing; otherwise, the fertilizer nitrogen can skew the greenness of the corn leaves and render the chlorophyll meter results inaccurate.

More recently, nitrogen models have been adapted for use in making nitrogen management decisions. These models

Figure 1.2-6. Nitrogen uptake by corn and seasonal weather patterns that must be considered when designing a nitrogen application strategy.

use high-resolution weather data for the season along with field, crop, and management information input by the farmer to model the behavior of nitrogen in the soil up to the point in the season when a decision must be made. Typically, these models are run at the same time that a PSNT or chlorophyll meter test would be run, just before the period of major nitrogen uptake but still in time to apply sidedress nitrogen if needed. These models estimate nitrogen availability from soil organic matter, crop residues, and manure, as well as nitrogen losses throughout the season. This information, along with modeled crop uptake, can provide useful information for adjusting sidedress nitrogen recommendations. The recommendations from nitrogen computer models are only as good as the information that is put into the model by the user, however. Details such as soil depth, crop planting date and maturity, the presence of a cover crop, and previous manure and fertilizer applications affect the results of the model and should be entered as accurately and comprehensively as possible.

Along with understanding the nitrogen cycle, it is also necessary to understand that a nitrogen recommendation must consider not only the total amount of nitrogen recommended for the crop but also the uptake dynamics of the crops being grown. Figure 1.2-6 shows the nitrogen uptake curve for corn as an example. The objective of managing nitrogen for this corn crop is not just to supply adequate nitrogen but, more important, in the right amounts and at the right time to meet the uptake demand of the crop and avoid conditions when there is potential for high loss. In the case of corn, the amount and rate of uptake are low early in the season, but about six weeks after planting there is a dramatic growth period and the nitrogen uptake requirement of the crop becomes very high. This demand may be as much as 10 pounds of nitrogen per acre per day. If a large amount of nitrogen is applied long before planting, when there is little crop demand but temperatures are high enough for microbial activity to mineralize nitrogen into available forms, and high

Table 1.2-6. Typical crop nutrient removal for phosphorus and potassium.

Crop (units)	Per Unit of Yield		Typical Yield Per Acre	Removal for Given Yield	
	P_2O_5	K_2O		P_2O_5	K_2O
Corn (bushels)	0.4	0.3	150	60	45
Corn silage (tons)[1]	4.0	8.0	25	100	200
Grain sorghum (bushels)	0.6	0.8	125	75	100
Forage sorghum (tons)[1]	3.0	10.0	15	45	150
Sorghum/sudangrass[1]	7.0	7.0	15	105	105
Alfalfa (tons)[2,3]	15.0	50.0	5	75	250
Red clover (tons)[2,3]	15.0	40.0	3.5	52	140
Trefoil (tons)[2,3]	15.0	40.0	3.5	52	140
Cool-season grass (tons)[2,3]	15.0	50.0	4	60	200
Bluegrass (tons)[2,3]	10.0	30.0	2.5	25	75
Wheat/rye (bushels)[4]	1.0	1.8	60	60	108
Oats (bushels)[4]	0.9	1.5	80	72	120
Barley (bushels)[4]	0.6	1.5	75	45	112
Soybeans (bushels)	1.0	1.4	50	50	70
Small grain silage (tons)[1]	7.0	26.0	6	42	156

[1] 65 percent moisture.
[2] For legume-grass mixtures, use the predominant species in the mixture.
[3] Dry hay equivalent, 10 percent moisture.
[4] Includes straw.

rainfall increases the potential for nitrogen loss, the efficiency of use of this nitrogen by the crop will be very low. The strategy needs to manage nitrogen so that the availability peaks when the crop demand is highest. Thus, applying manure or compost near to planting time will provide a small but significant amount of available nitrogen from the mineral nitrogen in the manure to meet the early crop needs. This should reduce the risk of the early spring high nitrogen loss potential when there is low crop demand. Then, if good soil quality for optimum conditions in the soil is in sync with more ideal weather conditions to promote microbial activity, the organic nitrogen will mineralize to supply the high nitrogen demand of the crop during the rapid growth phase. If nitrogen must be applied well before the season—for example, in fall or early spring manure applications—cover crops are vital for capturing the nitrogen and protecting it against loss. Then when the cover crops are killed at planting time, the decomposition of the residue will release the N closer to the time of crop need.

The source of nitrogen and the method of application will also influence the nitrogen use efficiency of the crop. Nitrogen sources are discussed later in this chapter.

Finally, experience and observation are critical to successful nitrogen management. Keeping records of nitrogen management activities and weather and observing the results are important parts of this process. A useful tool to assist with assessing the performance of your nitrogen management program is the late season cornstalk nitrate test. For this test, samples are collected from the lower stalk of corn plants near maturity and analyzed for their nitrate level. This analysis provides a very good assessment of whether the corn crop was deficient in nitrogen, had adequate nitrogen, or had an excess of nitrogen. This, along with management records for the growing season, can be very helpful in assessing the success of the management and/or suggesting improvement for future years (see "Agronomy Facts 70: Late Season Cornstalk Nitrate Test" for more details).

Nitrogen management may sound simple, but it is incredibly complex due to unknowns related to the weather, the quality of the soil, the characteristics of the nitrogen source, and so forth. The key is the adaptive nitrogen management process. Use all information available to make decisions. Carefully observe the conditions in the soil, the crop, and the weather. Analyze these observations relative to the nitrogen cycle and crop uptake dynamics. Make adjustments where necessary and when possible. Sometimes adjustments in management can be made in real time; other times, these experiences must be saved for use in making adjustments in following years (see "Agronomy Facts 76: Nutrient Management to Improve Nitrogen Use Efficiency and Reduce Environmental Losses" for more details).

Phosphorus (P) and Potassium (K) Recommendations

Recommendations are given as pounds of P_2O_5 and K_2O required per acre for each crop. The phosphorous and potassium recommendations are intended to gradually build below-optimum testing soils up into the optimum range over multiple years. Once an optimum level has been achieved, the recommendation is to maintain that level by applying enough phosphorous and potassium to offset the amount that is removed by the harvested crop (Table 1.2-6). If the soil level is above optimum, no phosphorous or potassium is recommended. This approach is sometimes called the "build and maintain" philosophy of fertility management, and it provides a cost-effective way to manage soil nutrients when fertilizer prices are relatively low.

If fertilizer prices are high and are expected to decline in the future, an alternative way to manage fertilizer additions is the "sufficiency" approach. In the sufficiency approach, if the soil test is in the optimum range already, no fertilizer is recommended in order to reduce costs because the soil already contains enough nutrients to meet the needs of a crop in the coming year. This approach can save on fertilizer costs in the short term, but, eventually, crop removals will draw down nutrient levels into the below-optimum range, and fertilizers will be required to maintain crop yields. In the sufficiency approach, when soil nutrient levels are below optimum, only the minimum rate of fertilizer required to achieve the best economic return is needed—no additional fertilizer to build the soil test level into the optimum range is recommended. This approach requires a large database of crop response trials to determine what the most economical fertilizer rate is for any given crop at a particular soil test level, and this information is not readily available in Pennsylvania or nearby states. However, fertilizing at a crop removal rate of P or K when soil test levels are below optimum is an alternative way to implement sufficiency-based fertilizer recommendations. Over the long run, this approach results in similar fertilizer application rates to the build and maintain approach because, ultimately, crops will be fertilized at the crop-removal level. The best economics can be realized by implementing the build and maintain approach when fertilizer prices are stable and temporarily switching to the sufficiency approach when sharp increases in fertilizer prices are expected to be short-term.

Very high soil test levels should be avoided as much as possible. High soil nutrient levels not only represent an economic loss but may also bring about crop, animal, or environmental problems. Very high phosphorus levels in the soil may lead to crop production or feed quality problems and may result in potentially harmful phosphorus loss to the environment. Best management practices may be necessary to reduce the potential for environmental problems with phosphorus. The Pennsylvania Phosphorus Index (P Index) can be used to estimate the risk of excess phosphorus loss to the environment. If fields are very close to water (within 150 feet), have very high soil test levels (greater than 200 ppm phosphorus), and are in a special protection watershed, or if large amounts of manure phosphorus are to be applied, the P Index should be used to estimate the risk of phosphorus loss and suggest management changes to protect the environment (see "The Pennsylvania Phosphorus Index v 2.0" for more details).

Very high potassium levels in the soil can lead to nutrient imbalances in forage crops, which can cause serious health problems in animals. Use caution when grazing forage crops, especially if the soil magnesium is not also in the high range. It may not be possible to correct these soil imbalances in the short term. Feed rations must be balanced accordingly. Very high soil test levels are often a side effect of using manure to supply the nitrogen needs of crops. Usually, when manure is applied to meet the nitrogen requirements of a crop, excess phosphorus and potassium will be applied. Over time, this can lead to very high phosphorus and potassium levels in the soil. This should be monitored with regular soil testing, and appropriate management action should be taken to limit applications in excess of crop needs to minimize the potential for negative crop, animal, or environmental consequences.

Starter Fertilizer

Starter fertilizer nitrogen, phosphorus, and potassium can be important to getting a crop off to a good start, especially when planting in lower testing soils and under adverse, cold, wet conditions. However, on optimum or higher testing soils, especially as planting dates get later and soils warm up, the benefit from starter fertilizer goes down and it is not recommended. A nitrogen-only starter is often adequate, even under adverse conditions, when soil test levels are above optimum. Secondary nutrients (calcium, magnesium, and sulfur) and micronutrients are usually not necessary in starter fertilizers unless nutrient deficiencies are suspected based on plant symptoms or analysis. The correct material, rate, and placement for starter fertilizer are critical to be effective. See "Agronomy Facts 51: Starter Fertilizer" and the fertilization information under each crop section in this guide for more details.

Recommendation Messages

The messages and comments that accompany the recommendations are important parts of the report (see Figure 1.2-2). Immediately below the amounts of nutrients needed are several messages specific to the actual results and recommendations. Important general comments about the results and recommendations are found on the back of the report. These comments and the material enclosed with the report are all part of the recommendation.

Figure 1.2-7. Changes in soil test levels over time.

Additional Results

Test levels for calcium and exchangeable acidity and optional tests for organic matter, nitrate nitrogen, and soluble salts are provided in this section. Also included here are calculated values for the soil cation exchange capacity (CEC) and percent saturation of the CEC by potassium, magnesium, and calcium. These calculated values are not used in making recommendations; they are provided for reference only. Zinc, sulfur, and copper results are also included on the report. These are not used to make recommendations but rather to flag potential deficiencies of zinc and sulfur that should be confirmed with plant analysis or potential toxicity of copper on dairy farms where copper sulfate is used extensively in foot baths. Recent research on sulfur fertility in Pennsylvania suggests that when the Mehlich 3 sulfur level is below 15 ppm, there is approximately a 50 percent chance that yield will increase by adding sulfur fertilizer. When Mehlich 3 sulfur levels are above 15 ppm, sulfur is usually adequate and the chance of a yield increase from adding sulfur fertilizer is very low. Additional information about managing sulfur fertility is available in "Agronomy Facts 80: Sulfur Fertility Management for Grain and Forage Crops."

Keeping Records

Keeping good records of soil test results can be very helpful for finetuning fertility management. To make the most of the results, collect samples regularly and consistently (i.e., same time of year, same depth). Once you have obtained optimum soil test levels, the goal is to maintain those levels.

Figure 1.2-7, Part A illustrates how records of soil tests can be used to monitor soil fertility levels, finetune recommendations to maintain optimum levels, and evaluate odd values. A decrease or increase in a soil test level at a relatively constant yield might indicate underfertilization or overfertilization, respectively. Adjust soil test recommendations according to observed trends. Soil test levels will vary from one test to the next; however, if an obviously odd value is observed, the soil testing lab can recheck the results and/or test a new sample for confirmation.

In a crop rotation, the objective is the same: to maintain the soil test levels in the optimum range over time. However, this is complicated by the different crops in the rotation. On most farms with animals, manure is applied to the corn crop and not to the hay crop. This results in a buildup of nutrients during the corn part of the rotation that can be used by the hay crop later. In this type of system, the test levels fluctuate during the rotation, but the average trend over time remains in the optimum range (Figure 1.2-7, Part B). If manure is applied to all crops in the rotation, especially at nitrogen-based rates, then there will most likely be a continuous upward trend in soil test phosphorus and potassium levels over time.

Diagnosing Problems

Soil testing can be used to determine plant nutrient needs for a future crop or aid in diagnosing production problems in a growing crop. The sampling guidelines to use for diagnosis are the same as those given above, except that the area represented may be smaller. Collect a minimum of 15 cores, even from a small area. It is also important to collect separate samples from both the problem area and a nearby area of "normal" growth. Test results may be used in a comparison to help identify the problem.

For questions about interpreting the recommendations on your soil test, contact the Penn State Extension office in your county. For questions about the analysis of the samples, contact the Penn State Agricultural Analytical Services Laboratory (phone 814-863-0841).

Plant Tissue Analysis

Plant tissue analysis is a valuable tool for nutrient management. It can verify the success of a soil fertility program or uncover potential problems. Plant tissue analysis complements soil testing by providing additional information. While soil testing is used to predict the availability of soil nutrients and the need for fertilizers, plant tissue analysis measures the nutrients actually taken up by the plant. In addition, the sufficiency of nitrogen, sulfur, and micronutrients (e.g., zinc and boron) are more reliably assessed by plant tissue analysis than soil testing.

Plant tissue analysis is frequently used for problem solving to diagnose or verify suspected nutrient deficiencies where visual symptoms are observed. Plant tissue analysis can also be an economically viable tool used to finetune fertilizer applications. Samples collected for routine monitoring of nutrient status can identify hidden hunger where nutrient deficiencies are not so severe that they cause obvious visual symptoms, but levels are low enough to reduce crop performance. It should be noted that plant nutrient content represents the effects of not only soil nutrient status but also all the factors controlling plant growth. Therefore, a single year's information may not be useful for planning a soil fertility management program. As results are accumulated over a period of years, the information becomes more valuable.

Sample collection for plant tissue analysis is very important. The nutrient concentration in a plant varies with the plant's age and the part of the plant sampled. If plant analyses are to be meaningful, the appropriate plant part must be collected for the age of the plant and a number of plants must be included to obtain a representative sample to submit to the lab. Specific directions on plant sampling are usually available with each sampling kit from the laboratory. Sampling instructions and sufficiency levels for corn, alfalfa, small grains, and soybean are given in Table 1.2-7. Try to avoid sampling crops damaged by insects, disease, drought, or other adverse conditions. Environmental conditions should always be noted when collecting samples.

When plant tissue analysis is to be used to diagnose suspected crop nutritional problems, it is a good idea to collect samples from both affected plants in the problem area and reference plants in a nearby "normal" area for comparison. Paired sampling is especially useful when collecting diagnostic samples for a crop that is at a growth stage with no reference sufficiency ranges. When collecting diagnostic samples, it is critical that the same plant part be sampled at the same time from both the problem and normal areas. When the problem is encountered at a growth stage when there are no sampling guidelines, young seedlings should be sampled by collecting the entire plant 1 inch above the soil surface, while larger plants should be sampled by collecting the most recently mature or fully expanded leaf. Collecting paired soil samples from good and bad areas can also be helpful. Gather as much information as possible, including growing conditions, crop development stage, location of symptoms on the plant (old versus new growth), landscape position of normal and problem areas, and so forth. This information

Table 1.2-7. Plant part to be sampled, growth stage, and sufficiency levels for plant tissue analysis.

Crop	Corn	Corn	Alfalfa	Small Grains	Soybean
Plant part	Whole plant	Ear leaf	Leaves, top 33% of plant	Uppermost leaves	Uppermost full leaves
Growth stage	~12 inches tall	Silking	Bud to 10% bloom	Before heading	Prior to or early flowering
Element			*Sufficiency Range (percent)**		
Nitrogen	3.50–5.00	2.75–3.50	3.75–5.50	2.50–3.50	4.25–5.50
Phosphorus	0.30–0.50	0.25–0.50	0.25–0.70	0.20–0.40	0.25–0.50
Potassium	2.50–4.00	1.70–2.50	2.00–3.50	1.50–3.00	1.70–2.50
Calcium	0.30–0.70	0.20–1.00	1.75–3.00	0.20–1.00	0.35–2.00
Magnesium	0.15–0.45	0.20–0.60	0.30–1.00	0.15–0.60	0.25–1.00
Sulfur	0.21–0.76	0.20–0.50	0.25–0.50	0.15–0.50	0.20–0.40
Element			*Sufficiency Range (ppm)**		
Manganese	20–300	20–150	30–100	25–150	21–150
Iron	50–250	20–250	30–250	20–250	50–350
Boron	5–25	4–25	30–250	6–25	20–50
Copper	5–20	6–20	10–30	6–25	10–30
Zinc	20–60	20–70	20–70	20–70	20–50

At least 10 subsamples of the indicated plant part(s) should be taken at the indicated growth stage to make a complete sample for submission to the lab.
*Sufficiency range is valid only for the crop, plant part, and sampling time indicated.

may provide important clues to help identify the cause of the symptoms. Digital pictures of the whole field, the problem area in the field, a whole plant, and a closeup of the leaf symptoms can be very helpful when you need to ask for assistance in diagnosing a problem.

Keep in mind that not all nutrient deficiencies in plants are the result of nutrient deficiencies in the soil. Soil testing and plant analysis can confirm each other, but they can also indicate when the cause of the problem is something other than a nutrient deficiency in the soil. If the soil test level is optimum, but the plants are deficient, some other factor is limiting the plants' ability to take up available nutrients. Factors to consider include possible interactions with other cultural practices such as tillage or pesticide use, pest injury such as rootworm feeding, differences in varieties or hybrids, or soil physical conditions such as compaction.

Soil and plant sampling and mailing kits are available from your county Penn State Extension office.

Plant Nutrient Recommendations Based on Crop Removal

Soil testing remains the best guide for predicting a crop's nutrient requirements. Occasionally, however, soil tests are not available. In such cases, fertilizing based on crop removal levels of phosphorus and potassium may be considered. If the unknown soil test levels are below optimum, fertilizing based on crop removal levels should help alleviate yield losses, but it will not build soil test levels into the optimum range. If the unknown soil test levels are above optimum, then purchasing and applying additional fertilizer is not economical, underscoring the importance of soil testing for economical production. To determine crop removal levels of phosphorus and potassium, multiply the expected crop yield by the P_2O_5 and K_2O removal rates in Table 1.2-6.

Lime and Fertilizer Sources

Liming Materials

Limestone quality can vary significantly. The purity and the fineness of the limestone must be considered in choosing a liming material to meet a liming recommendation.

Purity

The limestone recommendation on most soil test reports, including the Penn State soil test report, is based on the use of a liming material that is equivalent in neutralizing power to pure calcium carbonate—that is, a material with a calcium carbonate equivalent (CCE) of 100 percent. This does not mean that you must use a liming material that is 100 percent CCE.

Figure 1.2-8. Effect of aglime fineness on speed of reaction.

However, you must adjust the recommended amount of any liming material not equivalent to pure calcium carbonate limestone in neutralizing power (higher or lower than 100 percent CCE) so that you apply the correct amount of liming material to neutralize the acidity in your soil. All agricultural liming materials sold in Pennsylvania must, by law, be labeled with their calcium carbonate equivalent. Using the CCE of your liming material, you can calculate the actual amount required to neutralize the acidity in your soil (as shown below).

Actual liming material required = (soil test limestone recommendation ÷ % CCE of liming material) × 100
Example:
Soil test recommendation for limestone: apply 4,000 lb CCE/A
Liming material label: CCE = 80%
Actual liming material required: (4,000 ÷ 80) × 100 = 5,000 lb liming material/A

Fineness

A liming material must be finely ground to be effective. This is important because (1) limestone's solubility increases as it is ground finer and (2) limestone affects only a very small volume of soil around each particle. Therefore, more finely ground limestone has more particles and, if there is adequate mixing, neutralizes more of the soil with which it comes into close contact. The effect of limestone fineness on changing soil pH is illustrated in Figure 1.2-8. The mesh number indicates the number of wires per inch on a sieve. Thus, larger numbers represent finer material.

In each case in Figure 1.2-8, sufficient aglime was applied to neutralize soil acidity to raise the pH to 7.0. Note that material larger than 20 mesh was of little value for increasing soil pH and that only 100-mesh material came close to achieving a pH of 7.0 in a short time. Therefore, it would seem desirable to use only limestone that is 100 mesh

or smaller. However, this decision must be balanced against the high cost of grinding limestone to finer than 100 mesh. A compromise must be reached so that the material is fine enough to be effective agronomically but still economically sound.

Pennsylvania aglime regulations classify agricultural liming materials into the following three groups based on fineness:

1. Fine-sized:
   95 percent through a 20-mesh screen
   60 percent through a 60-mesh screen
   50 percent through a 100-mesh screen
2. Medium-sized:
   90 percent through a 20-mesh screen
   50 percent through a 60-mesh screen
   30 percent through a 100-mesh screen
3. Coarse-sized: all liming materials that fail to meet one of the above minimums for fineness

A material meeting the standard for a "fine-sized" liming material is considered adequate for meeting soil test recommendations in most situations. It is assumed that fine-sized materials will react rapidly enough to effect a change in soil pH in the year of application and typically will remain effective for about three years. The medium- and coarse-sized materials are slower to react; thus, they are less effective in changing soil pH during the year of application and take longer to react completely. If a coarser material is used, only the amount of limestone passing through a 20-mesh screen should be considered effective. For example, if the limestone only has 80 percent passing a 20-mesh screen, then you could assume that you only have about 1,600 pounds of effective limestone per ton. The actual fineness must be printed on the label. The calculations and table for adjusting your recommendations for the CCE of your liming material assume that the material meets the minimum fineness standards for fine-sized limestone. When selecting a liming material, there is generally little advantage to exceeding the minimum standards for fine-sized material. In emergency situations where a very rapid change in soil pH is required, paying extra for a finer material may be warranted; however, planning ahead by using a less expensive fine-sized material and giving it time to react normally will typically give better and more economical results.

Pellet and Fluid Lime

Pellet and fluid lime are forms of limestone that provide alternative application methods. Both materials are made up of very finely ground limestone. Pellet lime is manufactured by forming finely ground limestone into water-soluble pellets that can be spread like fertilizer. This allows for easier handling and more uniform spreading. After application, the pellets quickly break down and release the limestone. Fluid lime is made by suspending the finely ground limestone in a water and clay suspension. This material then can be applied with a sprayer. Fluid lime can be sprayed very uniformly. Both materials are excellent liming materials that will react very rapidly; however, the very fine nature of these materials does not increase the neutralizing value of the limestone. Thus, the same amount of calcium carbonate equivalent is required with these materials as with regular pulverized limestone. Because these materials are usually more expensive than regular pulverized limestone, people will sometimes use a lower rate, assuming the fineness will compensate. This is not true. You need the full recommended rate regardless of the fineness or physical form of the material.

For maximum effectiveness, incorporate the liming material. Note that minimum tillage mixes to only one-third of tillage depth. Since liming material incorporation is not possible in no-till situations, the soil should be limed adequately before no-till crop production begins. Also, it is very critical in long-term no-till management systems to maintain soil pH near optimum. No special management is required, and this can be accomplished with a normal liming program every three years or so. Just do not let the soil pH become too low—it can be very difficult and will take a long time to correct in a continuous no-till system. This same recommendation also applies in long-term perennial forage fields.

Calcium and Magnesium

Although limestone is applied primarily to neutralize soil acidity, it also serves as a source of essential calcium (Ca) and magnesium (Mg). When a soil test indicates the need for magnesium, limestone is the most economical way to meet that need. The magnesium content of limestone varies considerably. Unfortunately, there is no official trade classification of limestone according to magnesium content. Local classification schemes often create confusion. Therefore, to select the proper limestone material, it's best to rely on the actual magnesium analysis rather than a name (e.g., dolomitic lime, high-magnesium lime, or high-calcium lime). Penn State soil test recommendations not only indicate the amount of magnesium the crop requires but also include the minimum magnesium analysis of the limestone recommended to supply the needed magnesium.

Generally, if soils are limed to the recommended pH, there will be more than enough available calcium for agronomic crops. A typical soil in Pennsylvania that has received sufficient lime to achieve a pH between 6.0 and 6.5 will have approximately 2,500 to 3,000 pounds of exchangeable calcium per acre. This will easily meet crop-removal amounts, which are usually below 150 pounds of calcium per acre. It will also result in an adequate calcium saturation on the CEC, which is important for nutrient balance and soil structure. This is true even when a high-magnesium lime is used.

Fertilizer Materials

Nitrogen Fertilizers

Many different chemical and physical forms of nitrogen (N) fertilizers exist. Some of the more common fertilizer nitrogen sources are given in Table 1.2-8. The nitrogen in most farm-grade fertilizers is readily available. Some fertilizers, such as "turf-grade" fertilizers, release nitrogen very slowly. Plants can use nitrogen in one of two forms: ammonium nitrogen (NH_4^+) or nitrate nitrogen (NO_3^-).

Ammonium nitrogen (NH_4^+) carries a positive charge and is adsorbed onto soil particles. In this chemical form, leaching of nitrogen does not occur; however, NH_4^+ is changed to the NO_3^- form by bacteria. This process occurs rapidly (beginning within two or three days) as the soil temperature climbs above 50°F. Complete conversion from NH_4^+ to NO_3^- occurs within about a month of application.

Nitrate nitrogen (NO_3^-) carries a negative charge and is not adsorbed onto soil particles; it is free to be leached from the soil. Nitrate nitrogen can also be lost to the atmosphere through denitrification when soils become water saturated. The nitrogen fertilizers listed in Tables 1.2-8 and 1.2-9 contain nitrogen in either or both of these forms. Products called nitrification inhibitors can inhibit the conversion of nitrogen from the nonmobile ammonium form to the very mobile nitrate form. This can reduce the loss of nitrogen. This effect is greatest under the following conditions: nitrogen applied long before crop uptake; nitrogen applied to very coarse-textured soils, especially when significant rain is expected before crop uptake; and nitrogen applied to poorly drained soils, again especially when significant rain is expected before crop uptake. Generally, even though the products may work perfectly, there is less benefit from the nitrification inhibitors when used with nitrogen applied at planting or sidedressing because the improved timing of these applications is already helping to avoid significant losses of the nitrate form of nitrogen.

A long-term effect of all ammonium-based nitrogen fertilizers is to lower soil pH. Anhydrous ammonia, urea, diammonium phosphate, and nitrogen solutions, when first applied, temporarily increase soil pH in the zone of application. Ammonia is released and can "burn" germinating seeds or seedling roots in the area of fertilizer placement. In the eventual conversion of NH_4^+ to NO_3^-, however, acidity is generated. The residual acidity from common nitrogen sources is given in Table 1.2-8. As a rule of thumb, 5½ pounds of limestone are required for each pound of nitrogen applied as ammonium sulfate, and about 2 pounds of limestone are required for each pound of nitrogen applied as anhydrous ammonia, urea, ammonium nitrate, or nitrogen solution. The effect of manure nitrogen on soil pH is variable. The ammonium nitrogen in all manure can lower soil pH. However, some manures, particularly poultry layer manure, may contain significant calcium carbonate, which can actually increase pH over time.

Acidity is a particular problem under no-till and minimum-till conditions because the nitrogen is concentrated on the soil surface. An "acid roof" can form; the pH in the upper 1 to 2 inches may be a half to one pH unit lower than at deeper depths. This greatly decreases the efficiency of triazine herbicides and can negatively impact root growth. Therefore, the upper 2 inches of soil should be tested for pH regularly. For details on taking this sample, see the discussion on sampling no-till fields earlier in this chapter. If the normal soil sample does not indicate a need for limestone, check the surface pH. If the surface pH is below 6.2, apply 2,000 pounds of calcium carbonate equivalent per acre. This should be sufficient to take care of the acidity caused by nitrogen fertilizer.

The nitrogen in urea is completely water soluble. Upon application, urea nitrogen changes rapidly to NH_4^-N. Urea nitrogen is therefore readily available to plants on application to the soil. Urea presents another problem: when it is surface-applied, significant quantities of nitrogen may be lost through volatilization as ammonia. These losses happen very rapidly—most occur within the first day or two following application, and they can account for over one-third of the urea nitrogen being lost within a week after application. Losses are accelerated by warm, moist soils, high pH, and crop residues on the soil surface. Losses are higher on low CEC or sandy soils than on soils with a high CEC, heavy clay content, or high organic matter content. Thus, urea or nitrogen solutions (which are approximately 50 percent urea) should be incorporated into the soil by mechanical mixing or water movement. Light tillage or ½ inch of rain is usually adequate. Nonurea nitrogen sources, such as ammonium nitrate and ammonium sulfate, are not subject to volatilization under Pennsylvania conditions.

Research has also shown that volatilization losses from nitrogen solution can be reduced significantly by dribbling the solution in a band on the surface rather than spraying it over the entire soil surface. This can be accomplished by using drop tubes on a conventional sprayer. Urease inhibitors can also be used to effectively reduce volatilization from surface application. These are only effective on urea-containing fertilizers and will only provide a benefit if the fertilizer is not incorporated immediately by tillage or rainfall.

Urea and urea-blended fertilizers are not recommended as starter fertilizers because of possible ammonia toxicity to germinating seeds, which results in reduced plant stand.

When the different nitrogen fertilizer materials are applied properly, they give the same results per unit of nitrogen applied. For equivalent conversions of the different materials, see Table 1.2-9.

Table 1.2-8. Descriptions of fertilizer materials.

Fertilizer	Total Nitrogen (%)	Available Phosphoric Acid (%)	Soluble Potash (%)	Equivalent Acidity (lb CCE/lb N)*	Salt Index**	Comments
Anhydrous ammonia, NH_3	82	0	0	1.8	47	A high-pressure liquid that turns into a gas when released. Must be injected 6–8 inches deep on friable, moist soil. Nitrogen loss by volatilization can occur if not properly injected or soil is too wet or too dry at application.
Urea, NH_2-CO-NH_2	46	0	0	1.8	75	A dry material in granular or prilled form, urea nitrogen rapidly hydrolyzes to NH_4^+. Can be used for direct application, in mixed fertilizers, and in liquid nitrogen. Nitrogen at application is present as urea nitrogen. Within one day after application, about 66% of urea nitrogen is hydrolyzed to ammonia nitrogen. When not incorporated, significant nitrogen loss by volatilization can occur until approximately 0.5 inch of rain has fallen. Not recommended for starter use. Broadcast (incorporated) or sidedress.
Ammonium nitrate, NH_4NO_3	33–34	0	0	1.8	105	A dry material in granular or prilled form in which half of the nitrogen is as nitrate and half as ammonium. Used for direct application and in the production of nitrogen solutions (see below). Broadcast or sidedress. Can be left on surface or incorporated into soil. Ammonium nitrate is a good fertilizer, but it can be very difficult to get since it is also used as an explosive.
Nitrogen solutions (UAN), Urea+NH_4NO_3+Water	28–32 (mostly 30 in PA)	0	0	1.8	74	A mixture of ammonium nitrate, urea, and water. Urea supplies about half the nitrogen that may be subject to volatilization loss (see comments above for urea); the other half is supplied by ammonium nitrate (see comments above for ammonium nitrate). Once applied, nitrogen solution behaves exactly like dry urea and ammonium nitrate. To minimize nitrogen loss, incorporate into soil as soon as possible after application. Sometimes ammonium thiosulfate solution (12-0-0-26S) is mixed with UAN solution to create a blend with an analysis of 28-0-0-5S. Use caution when spraying nitrogen solutions to avoid leaf burn. To minimize injury, do not spray on vegetation. For postemergence application, use a directed spray or dribble between the rows.
Ammonium sulfate, $(NH_4)_2SO_4$	21	0	0	5.4	69	A dry crystalline material in which the nitrogen is all in the ammonium form. Produced by two methods, by-product and synthetic. Used for direct application and blended complete fertilizers. Broadcast or sidedress. Can be left on surface or incorporated into soil. Contains 24% sulfur. Good starter nitrogen source.
Diammonium phosphate (DAP), $(NH_4)_2HPO_4$	18	46	0	3.6	34	A dry granular or crystalline material. Common analysis is 18-46-0. Used for direct application and in blended fertilizers. Starter fertilizers containing DAP should be used with caution; be sure to band at least 2 inches to the side and 2 inches below seed.
Monoammonium phosphate (MAP), $NH_4H_2PO_4$	11	52	0	5.4	30	A dry granular material. Common analysis 11-52-0. Used for direct application and in blended fertilizers. Makes an excellent starter fertilizer, either alone or with a small amount of potash.

Table 1.2-8. Descriptions of fertilizer materials (continued).

Fertilizer	Total Nitrogen (%)	Available Phosphoric Acid (%)	Soluble Potash (%)	Equivalent Acidity (lb CCE/lb N)*	Salt Index**	Comments
Ammonium polyphosphate (APP)	10	34	0	5.4	—	A liquid solution (10-34-0). The agronomic effectiveness of APP is similar to that of MAP. Sequesters some micronutrients and impurities in fluid fertilizers, keeping them in solution.
Triple superphosphate, $Ca(H_2PO_4)_2$	0	46	0	0	10	Dry granular material. Used for direct application and in blended fertilizers.
Muriate of potash, KCl	0	0	60–62	0	116	Dry crystalline material. Used for direct application and in blended fertilizers.
Potassium sulfate, K_2SO_4	0	0	50	0	46	Dry crystalline material. Specialty fertilizer used for direct application and in blended fertilizers.
Potassium nitrate, KNO_3	13	0	45	-0.26	74	Dry crystalline material. Specialty fertilizer used for direct application and in blended fertilizers.
Potassium hydroxide, KOH	0	0	70	-0.89	—	Crystalline material usually used in liquid fertilizers. Basic nature of this material allows production of neutral liquid fertilizers. Primarily used in liquid starter fertilizers.
Sulfate of potash magnesia, Sul-Po-Mag or K-Mag	0	0	22	—	—	Crystalline material made from langbeinite. Contains 22% sulfur and 11% magnesium.

*Pounds of calcium carbonate equivalent (CCE) per pound of nitrogen in the fertilizer material. Positive numbers indicate that the material increases soil acidity (i.e., lowers soil pH). Negative numbers indicate that the material reduces acidity (i.e., raises soil pH). These values account for the plant taking up the nitrate generated from nitrification and exchanging a neutralizing hydroxyl or bicarbonate ion, which slightly lowers the acidifying potential of the fertilizer and the associated lime requirement.
**Salt index of equal weights of the fertilizer material compared to sodium nitrate, which equals 100; useful for comparing the salt effect of different fertilizer materials.

Phosphorus Fertilizers

Plants absorb most of their phosphorus from the soil solution as orthophosphate ($H_2PO_4^-$), regardless of the original source of phosphorus. Although orthophosphate's negative charge prevents it from being attracted by the soil's CEC, it does react strongly in the soil, primarily with the large amount of iron and aluminum occurring naturally in the soil, to form products that are very insoluble and thus unavailable to plants. A major factor controlling these reactions is the soil pH. At low or high pH, the solubility of phosphorus (and thus its availability) is very low. The maximum availability occurs in the 6.0 to 7.0 pH range. This is another important reason to lime regularly.

The solubility of phosphorus in fertilizer varies. The legal definition of available phosphorus in fertilizer is the sum of the phosphorus that is soluble in water plus that which is soluble in a citrate solution. Regardless of the actual chemical form of the phosphorus, the analyses of phosphorus fertilizers are given as percent phosphate (P_2O_5). The water solubility of this phosphorus can vary from 0 to 100 percent. Generally, the higher the water solubility, the more effective the phosphorus source. This is especially important for short-season, fast-growing crops, crops with restricted root systems, starter fertilizers, and areas where less-than-optimum rates of phosphorus are applied to soils testing low in phosphorus.

The most common phosphate fertilizers are triple superphosphate (0-46-0), monoammonium phosphate (11-52-0), diammonium phosphate (18-46-0), and ammonium polyphosphate (10-34-0) liquid (see Table 1.2-8). All these materials are highly water soluble. The ammonium phosphates are also excellent nitrogen sources. Monoammonium phosphate and ammonium polyphosphate, either alone or with some added potassium, make excellent starter fertilizers because of their high phosphorus-to-nitrogen ratios, high water solubility, and low free ammonia. Diammonium phosphate (DAP) is not recommended as a starter material because it produces free ammonia, which can harm the seed. However, many starter fertilizers contain DAP; thus, when that is the case, it is critical that the starter is accurately placed a safe distance from the seed (about 2 inches) and that high rates are avoided. Because phosphorus is relatively immobile, placement where plant roots will have easy access to the fertilizer is especially important for phosphorus fertilizers. For more details, see the discussion on starter fertilizer in Part I, Section 4: Corn of this guide.

Potassium Fertilizers

Potassium occurs in the soil in three forms: as exchangeable (available) potassium (K^+) adsorbed onto the soil CEC, fixed by certain minerals from which it is released very slowly to

Table 1.2-9. Nitrogen conversion—approximate pounds of materials required per acre to supply rates of nitrogen recommended per acre.

Nitrogen Recommendation	Material to Supply Rate of Nitrogen Per Acre (lb/A)		
	Ammonium Sulfate (21% N)	Liquid Nitrogen (UAN) (30% N)	Urea (46% N)
30	143	100	65
40	190	133	87
50	238	167	109
60	286	200	130
70	333	233	152
80	381	267	174
90	429	300	196
100	476	333	217
110	524	367	239
120	571	400	261
130	619	433	283
140	667	467	304
160	762	533	348
180	857	600	391
200	952	667	435
220	1048	733	478
Actual nitrogen (lb/T)	420	600	920

To compare nitrogen costs for these materials, convert the prices to a per-unit-of-actual-nitrogen basis by dividing the price per ton of fertilizer by the pounds of actual nitrogen in a ton of each material. This figure is given at the bottom of the table.
Example: Compare urea at $500/T with ammonium sulfate at $300/T
Urea: $500/920 lb N = $0.54/lb N
Ammonium sulfate: $300/420 lb N = $0.71/lb N
In this example, urea is the best buy. Other factors such as suitability of the material, convenience, method of application, and other fertilizer properties should also be considered.
Example: Calculation of lb N/T UAN, 30% liquid nitrogen (30-0-0)
Actual N lb/T = 2,000 × N analysis (as a decimal)
Actual N lb/T = 2,000 × 0.30 = 600 lb N/T of UAN
Also note that the analysis of fertilizer is always on a weight basis. Therefore, when applying a liquid fertilizer like UAN in gallons per acre, this must be converted to a weight to determine the amount of actual nitrogen applied.
Example: Actual nitrogen applied in an application of 20 gallons UAN per acre
UAN weighs 10.85 lb/gal; therefore, 20 gal/A = 217 lb UAN/A
Since UAN is 30% nitrogen by weight, the actual nitrogen applied would be 217 lb UAN/A × 0.30 = 65 lb N/A

available form, and in unavailable mineral forms (most of the potassium in soils). Plants take up potassium as the K^+ ion.

The most common source of potassium fertilizer is muriate of potash (0-0-60), which chemically is potassium chloride (KCl) (see Table 1.2-8). Potassium chloride is highly water soluble. At excessive rates, muriate of potash can cause salt damage to plants. Potassium is between nitrogen and phosphorus in mobility. It is not lost as readily as nitrogen, but it will move into the soil to the roots more quickly than phosphorus. Potassium fertilizers are most effective if applied ahead of planting or as a topdressing on perennial forage crops. Because of the salt concern, the amount of potassium that can be safely applied in a starter band is limited. The rule of thumb for salt injury is that no more than 70 pounds per acre of N + K_2O should be applied in a band within 2 inches of the seed or no more than 10 pounds per acre of N + K_2O should be applied directly with the seed. If a potassium deficiency is observed after planting, a topdressing of potassium fertilizer can somewhat overcome the deficiency. Even if the impact on the current crop is limited, potassium will need to be applied at some point if there is a deficiency, so it is best to go ahead and topdress some potassium fertilizer to reap what immediate benefit you can and get a head start on building the potassium in the soil back up into the optimum range. One additional consideration is that compaction can often result in potassium deficiency, even in a soil testing optimum or higher. A soil test should be taken to make sure the problem is low soil potassium before topdressing in these situations.

Other potassium materials used in specialty fertilizers are also listed in Table 1.2-8.

Blended Fertilizers

Blended fertilizers are made by physically mixing fertilizer materials to give a desired grade. The individual particles remain separate in the mixture, and segregation may occur. This problem can be reduced by using materials with the same particle size. The quality of the blended fertilizer, particularly the segregation of the individual fertilizer materials, should be an important factor in choosing a fertilizer. Poor-quality blends may contain the guaranteed nutrients, but these nutrients will not be supplied uniformly to the crop if there is segregation. If properly made so as to reduce segregation during transportation and application, blends are generally equal to granulated complete fertilizers in agronomic effectiveness. Blends have the added advantage of allowing for a very wide range of fertilizer grades, making it possible to match a fertilizer exactly to a soil test recommendation.

When using a blend as a starter fertilizer, try to avoid urea and diammonium phosphate as ingredients. Both materials produce free ammonia, which can hurt seed germination and seedling growth.

Fluid Fertilizers

Fluid fertilizers are becoming more and more common. Recent fertilizer statistics for Pennsylvania indicate that nitrogen solution (UAN) is the most common source of nitrogen used in the state. Multinutrient fluid fertilizers are also becoming more popular. Fluid fertilizers may be categorized into two groups: clear solutions and suspensions.

In clear solutions, which are the most common fluid fertilizers used in Pennsylvania, nutrients are dissolved completely in water. The major advantage is in handling. The disadvantages are the generally higher price and lower possible analysis compared to dry fertilizers, especially when the material contains potassium.

Suspension fertilizers, which are much less common, are fluids in which the components' solubility has been exceeded and very fine undissolved particles are kept from settling out by the inclusion of clay. Again, the major advantage of these materials is in handling. Suspensions can also be formulated at much higher analyses than clear solutions. Analyses similar to those for dry materials are possible. The major disadvantage of suspensions is that they require constant agitation, even in storage. Furthermore, suspension fertilizer cannot be used as a carrier for certain other chemicals.

The bottom line when comparing fluid fertilizers with dry fertilizers on the basis of amount of plant food is that they are equal in agronomic effectiveness when each is used properly.

Remember when making calculations of fluid fertilizers that the analysis is given as a weight percentage, not on a volume or "per-gallon" basis. Most fluids weigh between 10 and 12 pounds per gallon. The following is an example to illustrate the calculations.

One gallon of the 10-34-0 liquid weighing 11.68 pounds per gallon contains:

11.68 lb fertilizer/gallon × 0.10 N = 1.17 lb N/gallon
11.68 lb fertilizer/gallon × 0.34 P_2O_5 = 3.97 lb P_2O_5/gallon

If 5 gallons per acre of this fertilizer are used as a corn starter fertilizer, this would apply to the following nutrients:

5 gallons/A × 1.17 lb N/gallon = 5.85 lb N/A
5 gallons/A 3.97 lb P_2O_5 per gallon = 19.85 lb P_2O_5/A

For comparing fluids with dry fertilizers, divide 2,000 by the weight per gallon to get the number of gallons per ton. In the above example, the calculation is:

2,000 ÷ 11.68 = 171 gallons per ton

Manure Nutrient Management

The Pennsylvania Nutrient Management website (https://extension.psu.edu/programs/nutrient-management) is the one-stop place for nutrient and manure management information in Pennsylvania. All fact sheets and other materials referenced in this section are available on this website.

Approximately three-fourths of the nutrients harvested in crops grown on a farm—and in the purchased feed and supplements fed to the livestock—may be recycled back to crop fields in manure. Thus, manure nutrient management always has been and continues to be an important economic consideration on farms with livestock or poultry.

However, there is growing concern about the effect of nutrient management on environmental quality. A nutrient management law requiring some farms with high animal concentrations to have a formally approved nutrient management plan has been in place in Pennsylvania for a number of years and was revised in 2006. (See "Agronomy Facts 40: Pennsylvania's Nutrient Management Act: Summary of the 2006 Regulations" for more details.) This law affects farms that have more than two animal equivalent units (AEUs) per acre. One AEU equals 1,000 pounds of live weight of any animal on the farm for a year. (See "Agronomy Facts 54: Pennsylvania's Nutrient Management Act: Who Is Affected?" for more details.) Also, the Clean Streams Law in Pennsylvania, in effect since the early 1970s, requires all farms with manure to have a manure management plan based on the Pennsylvania Department of Environmental Protection (PA DEP) *Manure Management Manual*. Related information, including a workbook to help you prepare a plan for your farm, can be found at https://extension.psu.edu/programs/nutrient

-management. Finally, very large farms are regulated under the Federal Clean Water Act as Concentrated Animal Feeding Operations (CAFOs). This program is administered by PA DEP; see https://www.dep.pa.gov/Business/Water/CleanWater/AgriculturalOperations/CAFOs/Pages/default.aspx. Environmental concerns therefore add to the importance of proper manure nutrient management on all farms in Pennsylvania.

Nutrient management is not the same for all farms. It is important to recognize the differences among farms and realize how they affect the choice of appropriate management strategies. As an aid for determining the appropriate nutrient management options, farms can be classified into the following three management categories.

Category 1: less than 1.25 AEUs per acre available for manure application, or less than 50 percent of the feed coming from off the farm. Available manure on these farms is generally not adequate to meet total crop nitrogen needs. Thus, additional nutrients in the form of purchased fertilizer or other sources are required for achieving optimum crop yields. Usually, because of the nutrient deficit, these farms are not as likely to cause environmental problems unless there is gross mismanagement.

Nutrient management plans for this type of farm emphasize practices designed to make the most of nutrient efficiency and achieve the maximum crop response from manure nutrients. A well-planned nutrient management program emphasizing economic and agronomic efficiency should reduce the need for purchased inputs and thus improve farm profitability.

Category 2: 1.25 to 2.25 AEUs per acre available for manure application, or 50 to 80 percent of the feed coming from off the farm. Available manure on these farms can meet a significant part, if not all, of the nitrogen requirements for crop production. Because these farms are often at the upper limit of being able to safely handle all the nutrients produced, nutrient management changes on these farms may offer potential environmental benefits. Practices to maximize the safe use of manure and balance nutrient inputs with removals from farm fields over time are emphasized, rather than nutrient use efficiency.

The economic return from improved nutrient management on this category of farm is likely to be minimal. That is, a large cost probably will not be associated with implementing improved nutrient management practices; but unlike the first category of farm, little profit incentive exists, either. The incentive for change on this category of farm is environmental protection.

Category 3: more than 2.25 AEUs per acre available for manure application, or more than 80 percent of the feed coming from off the farm. Manure on these farms generally exceeds nitrogen requirements for crop production. It is unlikely that all of the manure can be used safely on these farms. Only part of the nutrient management program is field based. A significant component involves off-farm cooperation for acceptable off-farm uses for the excess manure. An economic cost is likely to be associated with implementing an environmentally sensitive nutrient management plan for this category of farm. Nutrient management programming most likely will result in environmental benefits as excesses on the farm are reduced. This is the group of farms primarily targeted in the Pennsylvania Nutrient Management Law.

This simplified classification scheme is intended to demonstrate the implications of differing situations for nutrient management approaches. Individual farms in each category will not necessarily fit all the characteristics described for the category (see "Agronomy Facts 38B: A Nutrient Management Approach for Pennsylvania: Plant Nutrient Stocks and Flows"). When a question exists about the classification, it should be resolved based on more comprehensive, specific information. The animal unit criteria in the categories above are for nitrogen-based planning. These criteria should be cut in half for phosphorus-based planning purposes.

The Cornell University Nutrient Management Spear Program has developed software that farmers can use to get a more detailed analysis of the nutrient balance on the farm and identify areas of concern and opportunities for more efficient nutrient use that, if addressed, could increase profitability and reduce environmental impact. This software is available at http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html.

Phosphorus versus Nitrogen Manure Management

In most cases, including in Pennsylvania, nutrient management plans are based first on balancing nitrogen. This comes from our scientific understanding of nitrogen behavior and greater concerns in general with the environmental fate of nitrogen, the potential negative human health effects of nitrates in water, and the economics of nitrogen fertilization. However, phosphorus has also received significant attention because of the potential for accelerated eutrophication in water bodies receiving excess phosphorus. Phosphorus is an essential nutrient for crops. A critical component of crop production is managing phosphorus for optimum economic benefit. However, if phosphorus is allowed to move off the land and get into water, it can be a pollution problem. Unlike nitrogen, excess phosphorus is not toxic, but can result in eutrophication of water bodies. Eutrophication is the increased growth of undesirable algae and other aquatic plants, which limits the use water for drinking, fisheries, recreation, and industrial uses. Historically, wastewater treatment plants were a major source of phosphorus in water. However, as the amount of phosphorus getting into water from this source has been reduced, agricultural sources of phosphorus have gotten more attention. Manure in particular

has been identified as a source of phosphorus to the environment. Agriculture has evolved toward greater and greater specialization. Consequently, animal feed is often produced in a different location from where the animals are fed. Feed containing phosphorus is transported to the animals. However, the manure containing much of the phosphorus that was in the feed is spread locally and not recycled back to where the crops were produced. This has resulted in phosphorus accumulating in excess amounts in some areas of high animal concentration.

At the same time, we have long recognized that one of the consequences of basing nutrient management plans on nitrogen is that, in most cases, excess phosphorus will be applied to the soil because the nutrient content of manure does not match the nutrient requirement of most crops. On the other hand, if the phosphorus requirement of the crops is balanced with the phosphorus in manure, two to four times as many acres are required to utilize the manure and nitrogen fertilizer will be required to meet the needs of the crop. This is not an ideal situation, but we know from our understanding of phosphorus behavior that there are things that we can do to minimize the environmental impact of this excess phosphorus in many cases. Consequently, we have consistently emphasized managing manure for both nitrogen and phosphorus in a way that minimizes the environmental impact but maximizes the agronomic and economic impacts of these nutrients in manure. This is the reason for including practices such as soil and water conservation, balancing manure applications over crop rotations, using cover crops, etc., in nutrient management plans.

Research has shown that a majority of the phosphorus from agricultural fields lost to water comes from a limited area on most farms and a few storm events. For nutrient loss to occur, there must be a source of phosphorus and a mechanism for transporting it to the water. A key concept of effectively managing nutrient pollution is to focus on where these two factors overlap (e.g., a high source coupled with high transport). Tools have been developed to help identify these critical source areas and suggest manure management strategies to address them. See the Penn State Extension publications "Managing Phosphorus for Agriculture and the Environment" and "The Pennsylvania Phosphorus Index v 2.0" for more details.

Agriculture is rapidly changing, and farm classifications may change with time. Therefore, farmers should periodically evaluate their farm's nutrient management status to adjust their strategy as appropriate. More detailed evaluation of fields and practices will be necessary to identify specific management options or best management practices (BMPs) for each individual situation. Since manure is an important component of nutrient management on crop and livestock farms, the following sections discuss some of the specific properties and management of manure where field application is an appropriate strategy for the farm.

Manure Production

A direct measure of manure production from storage volume or by counting loads spread is the most accurate way to estimate manure production. However, if a direct measurement of actual manure production is not possible, the daily production figures in Table 1.2-10 can be used to estimate manure production for the farm. Remember to account for animal growth when calculating manure production. For example, if you are raising hogs from weaned pigs to market weight, you would need to use an average weight of the growing animals, not the market weight, to estimate manure production. If you don't know the average weight of your animals, see "Agronomy Facts 54: Pennsylvania's Nutrient Management Act: Who Is Affected?" for typical average animal weights. You also need to account for changing populations of animals on the farm during the year. Examples might include buying feeders and selling steers at different times of the year or the downtime between broiler flocks. Finally, you must account for any additions to the manure, such as bedding, wash water, and rainwater. Some of the manure production figures in Table 1.2-10 include these additions. Check the "Comments" column in Table 1.2-10 for details. See the example below for estimating manure production using Table 1.2-10 and "Agronomy Facts 54."

Example manure production calculation:

> Six flocks of 20,000 broilers per year on the farm for 7 weeks per flock
> Manure production for broilers is 28 lb manure/animal unit (AU)/day (from Table 1.2-10)
> Average large broiler weight is 3.55 lb/broiler (from "Agronomy Facts 54")

Use the following formula:

> (animal number × weight per animal ÷1,000) × manure produced per AU per day × days manure is produced
> (20,000 broilers × 3.55 lb/broiler ÷ 1,000) × 28 lb manure/AU/day × (6 flocks × 7 weeks per flock × 7 days per week) ÷ 2,000 lb/ton = 292 tons of manure produced per year

Since the production figure in Table 1.2-10 includes litter, in this case the litter added to the manure does not need to be added to the manure production amount. Dividing this total production figure by the acreage that received manure is also a crude check of the per-acre application rate of manure and the nutrients it contains.

Table 1.2-10. Typical Pennsylvania average daily production and total nutrient content of manure.

Animal Type	Daily Production	Manure Percent Dry Matter	Analysis Units	Ammonium Nitrogen (NH_4^+)	Organic Nitrogen	P_2O_5	K_2O	Comments
Dairy Cattle								
Lactating cow, liquid	13 gal/AU/day	<10	lb/1,000 gal	14	14	13	25	Production does not include dilution; analysis includes dilution to approximately 7.5% solids
Dry cow, liquid	6 gal/AU/day	<10	lb/1,000gal	14	14	13	25	
Lactating cow, solid	111 lb/AU/day	12	lb/ton	2	8	4	8	No bedding included in production or analysis figures; use these analyses for estimating nutrients deposited on pastures by dairy cows, dairy dry cattle, and dairy young cattle
Dry cow, solid	51 lb/AU/day		lb/ton	0	9	3	7	
Heifer	60 lb/AU/day		lb/ton	2	8	3	7	
Calf	80 lb/AU/day		lb/ton	2	8	3	4	
Veal	7 gal/AU/day	2	lb/1,000 gal	14	5	13	25	Production does not include dilution; analysis includes dilution
Beef								
Cow, solid	90 lb/AU/day	12	lb/ton	1	10	7	10	No bedding or dilution included in production or analysis figures; use these analyses for estimating nutrients deposited on pastures by a beef cow and calf, beef calves, and steers
Cow, liquid	11 gal/AU/day		lb/1,000 gal	10	22	16	27	
Calf	106 lb/AU/day	12	lb/ton	2	9	7	10	
Finishing cattle, solid	49 lb/AU/day	8	lb/ton	1	13	5	8	
Finishing cattle, liquid	6 gal/AU/day		lb/1,000 gal	19	43	19	39	
Swine								
Farrow to wean (includes sows), liquid	11 gal/AU/day	2.5	lb/1,000 gal	12	6	18	11	Production includes a typical amount of in-barn-diluted water but not rainfall for an outdoor storage, except for farrow to wean, which also includes rainfall; analysis includes dilution to approximately the percent dry matter indicated
Nursery, liquid	14 gal/AU/day	1.5	lb/1,000 gal	12	7	8	14	
Wean to finish, liquid	5.5 gal/AU/day	4	lb/1,000 gal	24	13	23	21	
Grow-finish, liquid	7 gal/AU/day	4	lb/1,000 gal	20	11	24	22	
Farrow to wean (includes sows), solid	47 lb/AU/day		lb/ton	12	7	13	15	No bedding included in production or analysis figures; use these analyses for estimating nutrients deposited on pastures by swine
Nursery, solid	75 lb/AU/day		lb/ton	13	7	7	13	
Wean to finish, solid	49 lb/AU/day		lb/ton	15	8	8	11	
Grow-finish, solid	49 lb/AU/day		lb/ton	15	8	8	11	
Sheep/Goats	40 lb/AU/day	25	lb/ton	1	22	8	20	No bedding included in production or analysis figures; use these analyses for estimating nutrients deposited on pastures by sheep and goats
Horse	55 lb/AU/day	20	lb/ton	1	11	5	9	No bedding included in production or analysis figures; use these analyses for estimating nutrients deposited on pastures by horses
Poultry								
Layer (364 days)*	26.5 lb/AU/d	65**	lb/ton	12	49	58*	33*	
Layer breeders (364 days)	24 lb/AU/d	66	lb/ton	10	41	70	45	
Pullet (118 days)*	30 lb/AU/d	63**	lb/ton	7	64	58	39*	

Table 1.2-10. Typical Pennsylvania average daily production and total content of manure (continued).

Animal Type	Daily Production	Manure Percent Dry Matter	Analysis Units	Ammonium Nitrogen (NH_4^+)	Organic Nitrogen	P_2O_5	K_2O	Comments
Broiler (38–46 days)*	28 lb/AU/d	67	lb/ton	9	49	43	47*	Production and analysis figures include litter
Broiler breeders (364 days)	20 lb/AU/d	48	lb/ton	5	28	47	30	
Turkey tom (93–148 days)*	13 lb/AU/d	61	lb/ton	11	42	52	46	
Turkey hen (130–133 days)*	13 lb/AU/d	57	lb/ton	10	41	57	50	
Duck (dry)	110 lb/AU/day	27	lb/ton	4	17	26	15	No bedding included in production or analysis figures
Duck (wet)	13 gal/AU/day	5	lb/1,000 gal	21	12	23	16	Production does not include dilution; analysis includes dilution to approximately 5% solids

When possible, have manure analyzed. Actual values may vary over 100 percent from averages in the table.
*Typical production days.
**Significant differences exist between management styles.

Manure Nutrient Content

Manure is a good source of all crop nutrients, including the major and micronutrients, but nitrogen is generally the manure nutrient with the greatest value and often the highest potential for pollution. Therefore, manure is best used for crops that have large nitrogen requirements.

Average amounts of nitrogen, P_2O_5, and K_2O in manure for various animal types are shown in Table 1.2-10. Although these values are good average figures, they are inadequate if you wish to accurately account for manure nutrients on your farm. Analyzing a sample of well-mixed manure is essential for good manure nutrient management. Figure 1.2-9 shows the nutrient analysis results section from a Penn State manure analysis report, which is typical of manure analysis reports from labs analyzing manure in Pennsylvania. The minimum recommended analyses are percent moisture or percent solids, total nitrogen, ammonium nitrogen, total P_2O_5, and total K_2O. Most labs will also offer a more detailed analysis for secondary and micronutrients, pH, calcium carbonate equivalent, C:N ratio, water-extractable phosphorus, and so on. These tests can be requested to provide information for specific needs. Pay close attention to the units on manure analysis reports. On the Penn State manure analysis report, the results are given in two different units: pounds of nutrient per ton of manure, and pounds of nutrient per 1,000 gallons of manure as sampled. This is the same analysis reported in different units to make it convenient for a farmer to do rate calculations in either tons per acre or gallons per acre. Not all labs use these same units. For example, some labs report liquid manure analysis as pounds of nutrient per 100 gallons of manure. Also, while most labs report the analysis on an "as sampled" basis, some labs will in addition report the results on a dry matter basis.

Figure 1.2-9. Nutrient analysis results section of the Penn State manure analysis report.

MANURE ANALYSIS REPORT

Results on as sampled (wet weight) basis

Analyte	lb/ton	lb/1000 gal
Solids: 14.6 %		
Total Nitrogen (N)	10.33	43.07
Ammonium N (NH_4-N)	3.53	14.74
Calculated Organic N	6.79	28.33
Total Phosphate (P_2O_5)	4.09	17.07
Total Potash (K_2O)	8.99	37.50

For best results when submitting a manure sample for analysis, take a sample from the manure in the tank or spreader box being delivered to the field for application. Such samples will be most representative because the liquid manure pit is likely to have been agitated in order to load the tank and semi-solid manure scraped from the barn is moderately mixed while being loaded into a spreader.

Collect several samples of semi-solid manure from the spreader, mix well, and fill a laboratory container three-quarters full. With daily-haul manure-handling systems, periodically repeat this sampling procedure throughout the year. If liquid manure has been agitated well, one sample is sufficient

to adequately determine the nutrient status of the manure in the pit. Take a sample from the tank and fill the laboratory container three-quarters full. Caution: Do not completely fill the container; leave space for gas expansion.

In many manure storage systems, there is considerable variation in the manure nutrient content, even within the storage unit. For example, in a liquid manure storage, if some settling occurs, the phosphorus content may be higher in the bottom of the storage than in the top. Also, because the ammonium nitrogen can vary with depth in the storage, the manure nitrogen available to the crop will change as the storage is emptied, unless there is adequate agitation. In these situations, no manure in the storage actually matches the average results from the analysis of a single composite sample. To overcome this problem, it is recommended that a detailed analysis of the manure be performed at least once after the manure storage is constructed to determine the amount and nature of the variation. The process involves sampling the manure periodically as the storage is emptied for field application. Samples may be taken every so many loads or whenever a significant change in manure consistency occurs. After this intensive sampling and analysis, the farmer will have a basis for making manure rate changes or supplemental fertilizer changes to compensate for the variation. If the management of the storage is constant or thorough agitation is accomplished, this intensive sampling may not be necessary every year. Previous results can be used to make adjustments in following years.

Sample mailers and information forms are available through the Agricultural Analytical Services Laboratory (814-863-0841, aaslab@psu.edu, https://agsci.psu.edu/aasl) or from Penn State Extension county offices. For more details on sampling manure, see "Agronomy Facts 69: Manure Sampling for Nutrient Management Planning."

On farms with a deficiency of nutrients, using manure can greatly reduce fertilizer needs and expense. On farms with an excess of manure, however, these nutrients can represent an environmental hazard if they are not used properly.

Manure Nutrient Availability

Table 1.2-10 (or better yet, your manure analysis) will tell you the total amounts of the major nutrients on either a per-gallon or a per-ton basis. The phosphorus and potassium in the manure can be substituted directly pound for pound for fertilizer phosphorus and potassium to meet the nutrient recommendations on the soil test. With the ammonium and organic nitrogen, however, the total amount is not the amount available to the crop in the application year. The proportion of the manure nitrogen available to the crop equivalent to fertilizer nitrogen in the year of application depends on the manure type and how the application is managed.

Surface-applied manure has the potential to lose large amounts of ammonium nitrogen through volatilization if it is not incorporated mechanically or by rain soon after application. The organic nitrogen component of the manure needs to be mineralized by soil microbes before it is available to the crop, which takes time and is dependent on soil temperature and moisture conditions that affect microbial activity. Not all of the organic nitrogen that is applied in a given year will mineralize and become available in the first year, and the remaining organic nitrogen will persist in the soil and continue to mineralize for up to 5 additional years. The amount of nitrogen available from previous manure applications is estimated in Table 1.2-11 based on the historical frequency of manure application. The fraction of the ammonium nitrogen available to the crop (the fertilizer equivalence), in relation to when and how the manure is applied, is given in Table 1.2-12. The availability of organic nitrogen in the year it is applied and the 5 subsequent years is also given in Table 1.2-12. To determine manure nitrogen fertilizer equivalence (pound of fertilizer equivalent nitrogen per pound of total manure nitrogen), you need to answer a few questions:

1. When will the manure be applied?
2. What is the target crop and season for manure nutrient utilization?
3. How will the manure be applied?
4. What type of manure is being applied?

Note that even under the best of conditions, only about one-half to three-quarters of the nitrogen in the manure is equivalent to fertilizer for the crop in the year it is spread. The remaining nitrogen, which is derived from the organic nitrogen fraction of the manure, will become available slowly over a period of years. The availability of this residual nitrogen can be estimated from the manure history of a field. Adjustments for residual manure nitrogen based on a simplified method of accounting for the relative manure application frequency over the past 5 years are given in Table 1.2-11. A more detailed method of accounting for residual manure nitrogen involves calculating the actual organic N application rates in the manure in each of the previous 5 years and multiplying that organic N rate by an availability factor found in Table 1.2-12. The example given later in this section illustrates how to use these factors in application rate calculations.

The phosphorus in manure is available only slowly to a crop; however, manure phosphorus is not fixed readily into unavailable forms in soil like highly soluble phosphorus fertilizers are. The net result is that the phosphorus in manure is very similar to the phosphorus in fertilizer for building soil phosphorus levels and supplying crop needs. Thus, in most cases, manure phosphorus can be substituted for the phosphorus in fertilizer on a one-to-one basis.

There is one exception to this rule: manure phosphorus should not be substituted for starter fertilizer phosphorus.

Table 1.2-11. Residual nitrogen available from past manure applications based on historical frequency of application.

Historical Frequency of Manure Application on the Field	Pounds Nitrogen Available to a Summer Crop (Corn, Grass Hay, Oats, etc.)	Pounds Nitrogen Available to a Winter Crop (Wheat, Barley, Rye, etc.)	Pounds Nitrogen Available to the Winter Crop in a Double-Crop System	Pounds Nitrogen Available to the Summer Crop in a Double-Crop System
Rarely received manure in the past (fewer than two out of five years); note: if a field only received manure once out of five years, but this application was made the previous year, use the frequent credit for the following year	0	0	0	0
Frequently received manure (two or three out of five years)	20	7	7	13
Continuously received manure (four or five out of five years)	35	11	11	24

To use this table, determine the frequency of manure application and move to the right in the row to determine the amount of residual nitrogen that is available from past manure applications. Deduct this amount of residual nitrogen from the basic nitrogen recommendation before determining any additional fertilizer or manure application rates.

Even if manure phosphorus is applied in amounts adequate to meet a crop's needs, there still may be some benefit to using a starter fertilizer, especially if soil test levels were marginal or low. Manure phosphorus will accumulate in the soil. Therefore, phosphorus in manure applied in excess of one crop's needs can be used by a later crop in the rotation.

The potassium in manure occurs mostly in a soluble form similar to the potassium in fertilizer. Thus, the potassium in manure can be substituted one to one for fertilizer potassium. This high solubility of manure potassium can result in excessive levels of soluble salts if large applications of manure are made, particularly on lighter-textured (sandy) soils. This is a problem especially when poultry manure is applied at high rates immediately before the crop is planted. Like phosphorus, potassium accumulates in soil, which allows it to be built up in one part of the rotation so that it may be used later in another.

When there are already more than enough nutrients in the soil, the nutrients in manure have no immediate value if the crop does not need them. As with fertilizer, you get the greatest return from manure by applying it to crops that require nitrogen and are grown in fields testing the lowest in phosphorus and potassium. Your first step in developing a manure management plan should be to prioritize farm fields on this basis, with an additional consideration of each field's relative environmental sensitivity. Then allocate the manure to high-priority fields at a rate that meets crop nutrient requirements but is no greater than that which meets the need for manure's most vulnerable nutrient, nitrogen. If potential exists for phosphorus transport to water, the manure application rate should be limited to phosphorus crop removal. In this case, significant supplemental fertilizer nitrogen will usually be needed to meet the crop nitrogen requirement, and there is an economic incentive to apply the manure in ways that maximize the nitrogen availability by reducing volatilization and leaching losses. Luckily, methods of manure application that improve nitrogen availability, such as immediate incorporation with low-disturbance mechanical injection and spring application instead of fall application, often reduce the risk of P losses as well. The P Index is a field assessment tool that can be used to determine the risk of phosphorus loss to water based on manure and fertilizer application methods and guide appropriate management to minimize this risk (see "The Pennsylvania Phosphorus Index v 2.0" for more details). For details on managing nitrogen to improve efficiency and reduce losses, see "Agronomy Facts 76: Nutrient Management to Improve Nitrogen Use Efficiency and Reduce Environmental Losses."

Available nitrogen is less likely to be present the following year if is not removed by the crop. As mentioned above, phosphorus and potassium applied in excess of crop uptake will build soil levels and in general be available to succeeding crops. In fact, with advance planning, excess manure phosphorus and potassium applied during the corn years of a rotation will supply the high phosphorus and potassium requirements of a following hay crop. A good approach is to balance the nitrogen in the manure with the needs of the current crop, and the phosphorus and potassium in the manure with the needs of the crop rotation (see Figure 1.2-7, Part B).

Applying manure to legumes is generally not recommended. If properly inoculated, legumes do not need supplemental nitrogen for best growth. Thus, unlike a nonlegume for which potential returns from the nitrogen in the manure are great, such as with corn, there will be no economic return from the nitrogen in manure applied to a legume. However, legumes will take up nitrogen applied in manure even though they don't need it; thus, legumes may serve as a place to dispose of excess nitrogen. The uptake of nitrogen by legumes is indicated in Table 1.2-5.

Several other considerations exist when applying manure to legumes. If manure is applied to a legume to use excess nitrogen on the farm, phosphorus likely will be applied in excess of crop needs because of the relative proportions of nitrogen and phosphorus in manure; thus, the goal of

Table 1.2-12. Factors for calculating manure nitrogen availability based on time of application, incorporation, field history, and manure analysis with ammonium and organic nitrogen fractions.

Ammonium Nitrogen Analysis			
Spring/summer: for spring utilization by small grains, grazed pastures, and grass hay and summer utilization by corn, other summer annuals, grazed pastures, and grass hay			
Days to incorporation[1]	Poultry[2]	Other[2]	Compost
Immediately	0.90	0.80	0.80
1	0.80	0.60	0.60
2–4	0.60	0.40	0.40
5–7	0.40	0.20	0.20
>7	0.20	0.10	0.10
Grazing	0.15	0.20	n/a
Early fall: for fall and spring use by grass hay, grazed pastures, small grains, small grain silage[3]			
Days to incorporation	Poultry	Other	Compost
0–2	0.80	0.60	0.40
3–7	0.50	0.30	0.20
>7	0.20	0.10	0
Grazing	0.15	0.20	n/a
Early fall: for following summer utilization by a summer crop following a nonharvested cover crop used as a green manure			
Days to incorporation	Poultry	Other	Compost
0–2	0.45	0.35	0.35
3–7	0.20	0.15	0.15
>7	0	0	0
Early fall: for following summer utilization by a summer crop following a harvested winter crop or no winter crop			
No ammonium credit			
Late fall/winter: for following summer utilization by a summer crop following a harvested winter crop or no winter crop[4]			
No ammonium credit			
Late fall/winter: for spring use by grass hay, grazed pastures, or small grains, or summer use by corn or summer annuals with green manure cover crop			
	Poultry	Other	Compost
Mechanical application- All situations	0.60	0.50	0.50
Grazing	0.15	0.20	n/a

1 Mechanical incorporation or incorporation by 0.5 inch of rain.
2 Increase these factors by 0.2 after one day for very liquid manures (under 5 percent solids) to account for soaking in on application. For spring use by grass hay or small grains or summer use by corn or summer annuals with green manure cover crop.
3 Early fall is still warm enough for plant growth and microbial activity to continue (soil temperature is above 50°F at 2 inches).
4 Late fall and winter are so cold that there is no plant growth or microbial activity (soil temperature is below 50°F at 2 inches).

Organic Nitrogen Analysis (total nitrogen – ammonium nitrogen)				
Organic nitrogen decomposed during year applied				
	Poultry	Swine	Other	Compost
Summer crop	0.50	0.50	0.35	0.10
Winter crop	0.30	0.30	0.25	0.10
Grazed pastures anytime	0.15	0.20	0.20	n/a

Table 1.2-12. Factors for calculating manure nitrogen availability based on time of application, incorporation, field history, and manure analysis with ammonium and organic nitrogen fractions (continued).

Additional organic nitrogen available to the summer crop in a double-crop system from manure applied in the fall for the winter crop (above)				
	Poultry	Swine	Other	Compost
Summer crop	0.25	0.25	0.20	0.10
Organic nitrogen decomposed from past applications				
Manure applied	Manure	Compost		
One year ago	0.12	0.05		
Two years ago	0.05	0.02		
Three years ago	0.02	0.01		
Four years ago	0.02	0.01		
Five years ago	0.01	0.01		

The manure nitrogen availability factor is the fertilizer equivalence of the manure nitrogen or the pound of fertilizer nitrogen equivalent per pound of ammonium or organic manure nitrogen. For example, if the ammonium nitrogen availability factor equals 0.80, effectively there is the equivalent of 0.80 pound of fertilizer nitrogen for every pound of ammonium nitrogen in the manure. Likewise, if the organic nitrogen availability factor equals 0.35, effectively there is the equivalent of 0.35 pound of fertilizer nitrogen for every pound of organic nitrogen in the manure.

balancing the phosphorus throughout the crop rotation as discussed earlier cannot be met.

Applying manure to legume stands can encourage competition from weeds and grasses. Manure may also introduce additional weed seed to the fields. Both effects will result in lower-quality forage and reduced stand life for the legume. However, manure can be used effectively on an old legume stand that is soon to be rotated, not only to increase productivity for one more year, but also to build up soil nutrient levels to prepare for the following crop.

Sample Manure Calculations

These are just examples of the calculations used to determine a balanced manure rate and supplemental nutrient needs for your crop. Because of the natural variations in soils and manures, and the assumptions required in making the following calculations, the rates you calculate—as in the following examples—should be considered guidelines for determining the actual rates. Actual rates should be close to or less than the maximum rates you calculate for your situation.

To assist in developing a nutrient management plan for the farm, spreadsheets and workbooks for doing manure calculations are available on the Pennsylvania Nutrient Management website at https://extension.psu.edu/programs/nutrient-management under the "Planning Tools" and "Manure Management Manual" tabs. If a rate significantly less than the maximum is applied, it will need to be supplemented with one or more fertilizer nutrients. The supplemental fertilization rate is determined by subtracting the available nutrients applied with manure from the nitrogen, phosphorus, and potash recommended on the soil test. When applying an excess of phosphorus or potassium, check whether it will be used by other crops in the rotation. If not, a lower rate is more appropriate. If you select a lower rate, supplement it with nitrogen fertilizer and possibly phosphate and/or potash fertilizer, depending on the rate used.

Spreader Calibration

Finally, the plan for using the manure must be implemented. This means the manure must be spread uniformly at the planned rate. Two methods for spreader calibration are explained below. Method 1 is best for solid or semisolid manure. Method 2 is best for liquid spreaders. More details on calibrating manure spreaders can be found in "Agronomy Facts 68: Manure Spreader Calibration."

Method 1—Best for Solid Manure

Equipment required: a plastic sheet (6 feet × 6 feet or 10 feet × 10 feet), a scale (milk or bathroom scale), and a bucket

1. Weigh the sheet with the bucket on the scale.
2. Lay the sheet in the field where manure will be spread. Place the sheet at a distance from yourself great enough to put the spreader in gear and bring the tractor up to speed. Most spreaders apply less at the beginning and end of the load.
3. Drive the tractor and spreader over the sheet.
4. Fold the sheet so that no manure is spilled. Put the sheet in the bucket and weigh both on the scale.
5. Subtract the weight of the empty bucket and sheet in Step 1 from the weight of the sheet and bucket filled with manure. This number is the weight of the manure collected on the sheet.
6. Repeat the procedure and determine an average for the weights.

Sample Manure Calculations

This example illustrates calculating the maximum rate of manure required to meet the nitrogen needs of a crop and the net recommendation for the field based on analysis for dry matter, total nitrogen, NH_4-N, calculated organic N, total P_2O_5, and K_2O.

Situation

- Recommendations from the soil test report for 150 bu/A corn crop were 160-50-40 lb of nitrogen, P_2O_5 and K_2O, respectively.
- Poultry manure has an analysis of 50 lb total nitrogen, 10 lb ammonium nitrogen (NH4-N), 40 lb calculated organic nitrogen, 40 lb P_2O_5, 30 lb K_2O /ton, and 40 percent moisture.
- Manure is to be incorporated three days after application.
- Manure with the same analysis has been applied to this field at the rate of 4 ton/A each of the last three years.
- The starter fertilizer program is 5 gal/A of 10-34-0 (10-34-0 weighs 11.68 lb/gal).

Net Crop Nutrient Requirement

First, all sources of nutrients must be accounted for before a manure rate is calculated. Start with the soil test recommendations and then deduct any other sources of nutrients applied or already available in the field.

Net nutrients required = soil test recommendation – residual nitrogen from past manure – residual nitrogen from a previous legume crop in the rotation – starter nutrients

Residual Nitrogen from Past Manure Applications (Table 1.2-11 method)

Table 1.2-11 provides estimates of the residual nitrogen availability from previous manure applications based on the relative frequency of application during the previous 5 years. In this example, manure was applied in three of the previous 5 years, so the frequency category is "Frequently." The columns in the table designate the growth season of the target crop and whether it is a double crop scenario. In this example, the crop is corn, a summer crop. The residual nitrogen credit from past manure applications is, therefore, 20 lbs nitrogen/A.

Residual Nitrogen from Past Manure Applications (Table 1.2-12 method)

Residual nitrogen from past manure applications is estimated as follows: for each year in the last five when manure was applied, multiply the rate applied × organic nitrogen analysis × the appropriate factor from the section of Table 1.2-12 labeled "Organic nitrogen decomposed from past applications." If the organic nitrogen is not given on the manure analysis report, it can be calculated by subtracting the ammonium nitrogen from the total nitrogen on the report.

In this example the manure has 50 lb total nitrogen/ton and 10 lb of NH_4^-N/ton, meaning that the calculated organic nitrogen content is 40 lbs/ton.

Organic Nitrogen = Total Nitrogen – Ammonium N = 50 lb/ton – 10 lb/ton = 40 lb/ton Organic Nitrogen

Residual nitrogen from one year ago: 4 tons/A × 40 lb organic nitrogen/ton × 0.12 = 19.2 lb nitrogen/A
Residual nitrogen from two years ago: 4 tons/A × 40 lb organic nitrogen /ton × 0.05 = 8 lb nitrogen /A
Residual nitrogen from three years ago: 4 tons/A × 40 lb organic nitrogen /ton × 0.02 = 3.2 lb nitrogen /A
Total residual nitrogen from past applications: 30.4 lb nitrogen /A, which can be rounded to 30 lb nitrogen/A

Residual Nitrogen from a Previous Legume Crop in the Rotation (see Table 1.2-4)

None in this example.

Starter Fertilizer Nutrients That Will Be Applied Regardless of the Planned Manure Application
5 gal/A of a 10-34-0 starter fertilizer will be used on this field. First, since this is a liquid fertilizer the gal/A must be converted to lb/A. To do this, multiply the number of gal/A × the weight/gal.
5 gal/A × 11.86 lb/gal = 59.3 lb/A

Sample Manure Calculations, continued

Then the nitrogen, P_2O_5, and K_2O applied in this fertilizer are calculated as follows:

59.3 lb fertilizer/A × 10% nitrogen = 6 lb nitrogen/A

59.3 lb fertilizer/A × 34% P_2O_5 = 20 lb P_2O_5/A

There is no K_2O in this fertilizer.

The table below summarizes the previous calculations and illustrates how to subtract available nutrients from the soil test recommendation to determine the net requirement. For the rest of this example, we will use the residual manure nitrogen determined by the method using Table 1.2-11.

Net Nutrients Required	Nitrogen (lb/A)	P_2O_5 (lb/A)	K_2O (lb/A)
Soil test recommendation	160	50	40
–Residual manure nitrogen	20	—	—
–Residual legume nitrogen	0	—	—
–Starter nutrients	6	20	0
Net requirement (lb/A)	134	30	40

Nitrogen-Balanced Manure Application Rate

The nitrogen-balanced manure application rate is determined by dividing the available nitrogen in the manure into the net crop nitrogen requirement calculated above. The available nitrogen is the sum of the nitrogen available from both the ammonium and organic nitrogen.

Available NH_4^-N in the Manure = NH_4^-N × NH_4^-N Availability Factor (Table 1.2-12)

NH_4^-N availability factor = 0.6 from Table 1.2-12 (based on the time of application [spring], crop [corn], time until incorporation [three days], and manure type [poultry]):

NH_4^-N × NH_4^-N availability factor = 10 × 0.60 = 6 lb N/ton

Available Organic Nitrogen in the Manure = Organic Nitrogen × Organic Nitrogen Availability Factor (Table 1.2-12)

In this example, the manure has 50 lb total nitrogen/ton and 10 lb NH_4^-N/ton

Organic nitrogen = total nitrogen – ammonium nitrogen = 50 lb/ton – 10 lb/ton = 40 lb/ton organic nitrogen

Organic nitrogen availability factor = 0.50 from Table 1.2-12 (poultry manure in this example):

Organic nitrogen × organic nitrogen availability factor = 40 × 0.50 = 20 lb N/ton

Total Available Nitrogen in the Manure = Available NH4-N + Available Organic Nitrogen

Total available nitrogen = 6 lb NH4-N /ton + 20 lb organic nitrogen/ton = 26 lb available nitrogen/ton

Maximum rate per acre to meet nitrogen need = net nitrogen requirement ÷ available manure nitrogen

Rate per acre to meet nitrogen need = 134 lb nitrogen/A ÷ 26 lb nitrogen/ton = 5.15 ton/A

Any rate less than or equal to this rate is acceptable.

Nutrients Applied at the Planned Rate

Based on this calculation, which determined that up to 4.47 tons/A could be applied, the farmer decided to apply 4 tons/A. At this application rate the following amounts of nutrients would be applied:

Nitrogen: 4 tons/A × 26 lb available nitrogen/ton = 104 lb available nitrogen/A

Phosphorus: 4 tons/A × 40 lb P_2O_5/ton = 160 lb P_2O_5/A

Potassium: 4 tons/A × 30 lb K_2O/ton = 120 lb K_2O/A

Final Nutrient Balance on the Field after Manure Application

The nutrient balance is simply the difference between the net crop nutrient requirement and the nutrients applied at the planned rate.

Sample Manure Calculations, continued

Nutrient	Nitrogen (lb/A)	P_2O_5 (lb/A)	K_2O (lb/A)
Net crop nutrient requirement	134	30	40
Nutrients applied at planned rate	104	160	120
Balance after manure application	30 short	130 excess	80 excess

Supplemental Fertilizer Needs

In this example, the nitrogen applied at the farmer's planned rate almost meets the needs of the crop. It may be impractical to apply low rates of nitrogen fertilizer, such as the additional 30 lb nitrogen/A required here, and the yield and economic losses from slight underfertilization such as this are unlikely to outweigh the costs of a separate application of fertilizer for such a small quantity. Therefore, use your best judgement in determining when and how to meet the additional nutrient requirements indicated by the nutrient balance after manure application.

7. Taking into account the size of your sheet, use the average weight and Table 1.2-13 to determine the tons of manure applied per acre.
8. If you are using a different-sized sheet or the amount of manure collected is not listed in the table, use the following formula to calculate tons per acre: (lb manure × 21.8) ÷ sheet size (sq ft) = tons manure/A

Method 2—Best for Liquid Manure

Equipment required: yardstick or tape measure and a string or rope

1. Determine the manure spreader capacity from the manufacturer or by using Table 1.2-14.
2. Tie a string around the tractor tire at the top of the tire. Mark the ground directly below the string where the tire rests on the ground. Pull the tractor forward until the string is again at the top of the tire. Mark the ground again, as before, and measure the distance between the two marks on the ground. This is the distance the tractor moves with one revolution of the tire.
3. Spread the load of manure, counting the number of times the rope comes to the top of the tire. Multiply the number of revolutions the tire made to spread the load by the number of feet the tractor moved in one revolution (Step 2). This is the distance traveled to spread the load.
4. Measure the width that the spreader is covering with manure.
5. Multiply the distance traveled (Step 3) by the width that the spreader is covering with manure (Step 4) and divide by 43,560 (the number of square feet in an acre). This is the number of acres covered by one load.
6. Divide gallons or tons of manure applied (the spreader capacity from Step 1) by the number of acres covered (Step 5). The result is the tons or gallons applied per acre.

Calibrating your manure spreader is a good starting point for developing a manure management plan. Use the procedures outlined above to determine the practical spreading rate(s) for your equipment, then choose the calibrated rate that is close to but lower than your calculated rate. If you have not done this ahead of time and have a plan with rates already determined that you want to apply, you may have to make adjustments in either tractor speed or spreader settings to get the desired rate. After making any change, recalibrate the spreader. It may take several tries to get the proper adjustments for the desired rate.

The fertilizer recommendations on Penn State soil test reports do not take into consideration any manure you are applying. You should subtract the amount of fertilizer equivalent nutrients applied in the manure from the recommendation amounts (see sample calculations). For soil samples taken after manure has been applied, the manure phosphorus and potassium amounts are measured as part of the soil nutrient levels and therefore should not be subtracted from the recommendations.

Continued excessive application of manure and/or fertilizer nutrients can create crop, environmental, and economic problems. Environmental problems result from nutrients leaching into groundwater or manure nutrients running off into surface water. Not only are these nutrients lost to crop use, but their value as fertilizer replacement is also lost. In addition, excessive nutrients in the soil may contribute to excessive vegetative growth, lodging, high nonprotein nitrogen levels in crops under stress, delayed maturity or poor storage quality of vegetables, and lower uptake of magnesium and/or zinc.

To conserve manure nutrients and reduce the pollution potential of manure, follow these basic recommendations:

1. Analyze the manure for nutrient content.
2. Determine an appropriate rate based on the availability of the manure nutrients to best match, but not exceed, crop nutrient requirements.

3. Spread the manure uniformly and at a known rate. See "Agronomy Facts 68: Manure Spreader Calibration."
4. Avoid winter spreading as much as possible. Do not spread manure on frozen slopes. Do not spread on slopes greater than 15 percent. Spread far enough (at least 100 feet) from streams, lakes, ponds, sinkholes, and wells so that runoff does not wash manure into them. Never spread on bare soil in the winter. When possible, use cover crops to hold the nutrients against loss.
5. To take better advantage of its nutrients, apply manure just before the growing season, preferably to nitrogen-requiring crops.
6. If possible, inject or incorporate manure soon after application to conserve as much nitrogen as possible and reduce exposure of the manure to surface runoff.

Because of its nutrient content, manure has a dollar value and can be thought of as a commodity. Farmers with manure in excess of needs should consider some type of arrangement with farmers who could use more nutrients, rather than using continued heavy applications. Regardless of the formality of the arrangement, a manure analysis is an absolute first step. Because high water content dilutes the manure—reducing its per-ton value and increasing the transportation required—diverting some of the water that normally would be added is one way to increase manure's value.

Soil testing is extremely important in manure management. Soil tests provide information that can be used to decide where manure can do the most good in supplying nutrients required by the crop. The lower the soil test level, the higher the probability of a response to adding the nutrient.

Soil tests also help monitor the effect of manure application on soil phosphorus and potassium levels. Consistent use of this tool can be effective in detecting nutrient imbalances or excesses so that corrective action may be taken.

Cropland benefits little from extremely heavy manure application rates. As is the case with other plant nutrient sources, excess phosphorus and potassium accumulations in the soil may occur when manure is applied at excessive rates. Nitrogen also may leach from the plant root zone and adversely affect the environment. In addition, the associated organic matter, which is beneficial at low rates, may become undesirable at excessive levels. Heavy surface applications of manure with no incorporation may inhibit herbicide activity, provide a favorable area for insect pest development, or create an odor problem.

As more farmers store their manure and spread it in the spring all at once, compaction is becoming a more serious consideration in manure management. Compaction is hard to avoid entirely since there is usually little time in the spring when soil conditions are perfect for hauling manure without creating compaction and many other jobs have to be done at this time. Compaction can be reduced by using wide flotation tires on heavy manure-spreading equipment, which might otherwise seriously damage the soil and significantly reduce yield.

Probably the most important factor to be considered in reducing compaction is soil moisture—compaction is much more severe on wet soils than on dry soils. Yield decreases

Table 1.2-13. Manure spreader rate calibration.

Manure on Sheet (pounds)	Manure (tons per acre)	
	Sheet Size: 6 feet × 6 feet	Sheet Size: 10 feet ×10 feet
2	1.2	0.4
4	2.4	0.9
6	3.6	1.3
8	4.8	1.7
10	6.1	2.2
12	7.3	2.6
14	8.5	3.1
16	9.7	3.5
18	10.9	3.9
20	12.1	4.4
22	13.3	4.8
24	14.5	5.2
26	15.7	5.7
28	17.0	6.1
30	18.2	6.5
32	19.4	7.0
34	20.6	7.4
36	21.8	7.8
38	23.0	8.3
40	24.2	8.7
42	25.4	9.2
44	26.6	9.6
46	27.9	10.0
48	29.1	10.5
50	30.3	10.9
52	31.5	11.3
54	32.7	11.8
56	33.9	12.2
58	35.1	12.6
60	36.3	13.1
62	37.5	13.5
64	38.8	14.0
66	40.0	14.4

Table 1.2-14. Determining manure spreader capacity.

Spreader capacity, weight basis: tons per load = volume × density ÷ 2,000	
Density varies from 55 to 62 pounds per cubic feet depending on manure moisture—dry manure is 55 and liquid manure is 62; liquid manure weighs 8.3 pounds per gallon.	
Spreader capacity, volume basis: volume in gallons = volume in cubic feet × 7.48 gallons per cubic feet	
Calculate the volumes in cubic feet as follows (see diagrams at right).	
Solid or semisolid manure	
A. Box-shaped spreader* (level load): volume = length (l) × width (w) × depth (d)	
B. Box-shaped spreader* (piled load): volume = length (l) × width (w) × [depth (d) + stacking height (h) × 0.8]	
C. Flail-type barrel spreader (level load): volume = length (l) × depth (d) × depth (d) × 1.6	
D. Flail-type barrel spreader (piled load): volume = length (l) × depth (d) × 1.6 × [depth (d) + stacking height (h)]	
Liquid manure	
Box-shaped spreader: same as box-shaped spreader* (level load)	
Flail-type barrel spreader: same as flail-type spreader (level load)	
E. Tank spreader (round): volume = length (l) × tank diameter (d) × tank diameter (d) × 0.8	
F. Tank spreader (noncircular): volume = length (l) × width (w) × depth (d) × 0.8	

*For a box-shaped spreader with sloping sides, use an average width.

Commonly Required Conversions for Manure Spreader Volumes

To convert from	To	Multiply by
bushels	cubic feet	1.24
gallons	cubic feet	0.134
gallons	pounds	8.3 (liquid)
gallons	tons	0.0041 (liquid)
tons	gallons	240 (liquid)
cubic feet	gallons	7.48
cubic feet	tons	0.031 (liquid) or 0.0275 (solid)
cubic feet	pounds	62 (liquid) or 55 (solid)

Table 1.2-15. Nonconventional soil additives.

Product Group	Method of Application	Reported Action
Growth stimulants or regulators	Seed, soil, or plant	Promote growth, improve nutrient water uptake, or solubilize soil nutrients
Biological additives	Soil	Enhance soil microbial activity
Low-rate nutrient additions	Seed or plant	More efficient nutrient use
Organic amendments	Soil	Provide nutrients; improve soil "tilth"
Mineral amendments	Soil	Substitute for lime or fertilizers
Soil conditioners	Soil	Improve soil drainage, soil physical properties, or nutrient release

due to compaction are usually related to restrictions in the plant's root system that prevent the plant from getting the nutrients and water it needs.

Nonconventional Soil Additives

Current nonconventional soil additives cannot substitute for proven practices and products used in a good soil management program. General groups of these products are described in Table 1.2-15.

Before purchasing or using a nonconventional soil additive, investigate the claims made about the product and the manufacturer. All these products must be registered for sale in Pennsylvania through the Pennsylvania Department of Agriculture Bureau of Plant Industry in Harrisburg, Pennsylvania. Check with your county extension office or the Bureau of Plant Industry to be sure the product has been registered. Be wary of products that are sold through high-pressure sales techniques relying heavily on testimonial support or that have "secret" ingredients or no details describing the methods of product performance.

If you decide to use one of these products, in addition to the area treated with the product, be sure to include several check strips with no treatment and several with your normal production practices so that you can compare plant growth and yield.

Part I, Section 3

Storing Seed and Grain

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Maintaining Seed Viability and Vigor

At times, it is necessary to store seed for periods of several months to a year or even more. Unfortunately, exposing seed to temperatures of 90°F or higher or to a relative humidity of 60 percent or greater can lead to a rapid decline in seed germinability and vigor. As a rule of thumb, stored seed best maintains viability and vigor when the combination of air temperature in degrees Fahrenheit and percent relative humidity of the air is 100 or lower. Thus, a seed storage relative humidity of 30 percent or less at a temperature of 70°F or lower would maintain viability and vigor in the seed of most plant types. Conversely, as is often the case where seed is stored, air temperatures during part of the year may be 80 to 90°F or higher, and the relative humidity of the air may be 70 percent or greater. Such conditions can lead to lower germinability and vigor in only a few months.

Seeds exposed to air gain or lose water according to the relative humidity of the surrounding air. At 50 percent atmospheric relative humidity, the equilibrium moisture content of wheat and rye seeds is about 12 percent; of barley, about 11 percent; and of oats, about 10.5 percent. Seeds of small grains—and, in fact, seeds of most kinds of plants—store reasonably well if the moisture content in the seed is 10 to 12 percent. Seeds with a high fat or oil content, such as soybean, store better at 9 to 10 percent moisture or lower. Oat seeds should be dried to 10 percent or less moisture content.

At 60 percent or greater atmospheric relative humidity, seeds of many plant kinds rapidly gain water. Thus, the equilibrium moisture content of small grain seed exposed to 70 percent relative humidity is nearly 15 percent. This is too high for safe seed storage. At 90 percent atmospheric relative humidity, the seed moisture content of several small grain crops swells to 20 to 23 percent. Viability and vigor are lost rapidly under these conditions (Table 1.3-1).

Although it usually is not practical to control the temperature and relative humidity of the space where carryover seed is stored, you should pick a place where the temperatures are below 86°F most of the time and seed is not exposed to humid conditions.

Be sure the seed is dry when stored. Seed is often farm grown for oats, wheat, barley, rye, soybeans, red clover, and timothy. Such seed may be harvested at moisture contents of 16 to 18 percent or higher. This seed should be dried carefully to 10 to 12 percent seed moisture content soon after harvesting. Do not dry such seed at temperatures over 90 to 95°F, and do not maintain elevated temperatures any longer than is required to dry the seed.

Seed of corn, sorghum, alfalfa, and most grasses is often not grown in Pennsylvania. To maintain viability and vigor in purchased carryover seed of such plant kinds, reseal the containers to reduce air exchange, and store where temperatures are moderate and atmospheric relative humidity is as low as possible.

Table 1.3-1. Effects of moisture content in seeds.

Seed Moisture	Condition
4–8%	Little or no insect activity (too dry for most insects)
10–12%	Satisfactory to store most seeds in open storage and in cloth bags or moisture-resistant containers
14–16%	Molds (fungi) may grow on and in seeds in open storage and on seeds in cloth bags or sealed containers; harmful to seeds of many plant kinds
18–20%	Seed may heat because of seed respiration and microbial activity; seed declines rapidly in viability and vigor
24–60%	Seeds may rot
46–60%	Germination begins

At times, farm-grown red clover or timothy seed is bagged and laid in a bin on top of freshly harvested oats. Moisture moves upward as the oats dry and may condense on the surface of or in the bags of timothy or red clover. This can lead to a rapid decline in germination and vigor.

Remember that heat and humidity are enemies of seed viability and vigor. If insects are a problem in stored seed, see the following.

Controlling Pests in Stored Grains

Managing grain in storage to prevent insect damage is just as important, or more so, than managing the crop while it is growing in the field. When insect infestations develop, they can reduce grain weight by up to 10 percent. A farmer with a grain bin containing 30,000 bushels of corn valued at $3.00 per bushel would lose $9,000 if an insect infestation developed and consumed 10 percent of the grain mass. This loss does not include dockage or the cost of eliminating the insects from the grain.

To prevent losses from insect feeding, growers should implement a sound integrated pest management (IPM) program in their grain bins. An integrated pest management program involves (1) sanitation of grain bins and harvest equipment, (2) proper adjustments to harvest equipment, (3) grain cleaning, (4) uniform distribution of the grain during uploading into the bin, (5) moisture management, (6) temperature management, (7) periodic grain monitoring, (8) residual insecticide treatment for long-term storage, and, as a last resort, (9) fumigation. If the first eight tactics are used effectively, fumigation should be needed only rarely.

Preparing the grain bin to receive grain is one of the most important steps in an IPM program. Before placing new

grain in a bin, remove all old grain, which may be a source of insect populations that can rapidly infest the new grain. Once you have removed the old grain, clean the bin, sweep or wash off the walls and floor, and be sure to remove grain from any ledges above the door and between the ceiling and walls. Use a shop vacuum to remove debris from under metal flashing at the floor/wall interface and other tight areas that cannot be reached with a broom or hose. It is a good idea to remove the false floor and grain auger once every five years or so and clean out any grain residue and dirt.

Remember that the insects that infest grain can be very small, ranging in size from 1/16 to about ½ inch in length. Large numbers of these insects can be harbored in very small amounts of debris. If half of an initial population of 1,000 insects is female, and each female produces 200 offspring, then the population can produce approximately 10 million insects in two generations. At a grain temperature of 90°F, many species produce one generation per month. If a grain handler detects live insects in your grain, you may be docked or sent home with the grain to eliminate the infestation. Investing time and money in a clean bin is a good start to preventing insect injury to stored grain.

After cleaning the interior of the grain bin, remove old grain that has collected around the bin's exterior. Bury or discard this grain to eliminate any inhabiting insects. Also remove or mow any weeds that have grown up around the outside of the bin. Because many grain-infesting insects are seed feeders, they can develop on the seed of these weeds and then move into the grain. Weedy areas can also harbor rodents that can enter grain storage structures, especially wooden ones. After cleaning, inspect all areas of the bin for leaks or small gaps where insects could enter. Repair any cracks and continue to monitor the facility for damage.

Once you have prepared the grain bin, make sure that your harvest equipment is cleaned and properly adjusted. A corn picker or grain combine that was used last year and then parked in the equipment shed without cleaning can harbor insect infestations at the lower ends of augers or on screens inside the combine. Remove plant residue from all augers and other areas within the combine before using the equipment to harvest grain. It also is important that a combine be adjusted properly to prevent shattering of grain. Small pieces of grain or cracked grain make it easy for grain-infesting insects to become established and develop; most insect species have a difficult time feeding on whole kernels of grain.

Grain harvested with a clean and properly adjusted combine should also be run through a grain cleaner to further remove fine materials on which insects can feed. Grain with many broken kernels can also be run through a cleaner, but this will lead to additional weight loss. Clean, whole grain helps with insect management, but it also contributes to proper aeration of the grain mass during drying and storage. If fine materials are absent, air drawn into the grain from outside the bin will move more uniformly through the mass. A grain distributor is extremely helpful in preventing aggregations of fine material by spreading it uniformly across the grain mass. When a distributor is not used, the fine material will concentrate in a column at the center of the grain mass. Because this column is more dense, air will move around it through the grain mass and allow moisture to build up in the center of the bin. Moisture buildup is the first step toward deteriorating grain quality.

Lowering the grain temperature and levels of moisture will help inhibit fungi, bacteria, and insect feeding and reproduction. Thus, harvesting and storing grains during cool, dry periods will help prevent pest infestation. Reduce the grain moisture to 13 percent or lower while loading or after the grain has been loaded into the bin. Level the grain surface and remove any peaks. As with a fine material buildup, the peak in the grain does not dry properly because air moves through the grain mass below it. Once you have loaded the clean, dry grain into the bin and leveled off the top, the next step is to cool the grain after outside temperatures fall below 40°F in late fall. Lower the grain mass temperature by running the fan during periods when the temperature is below 40°F. If possible, do not run the fan if the outside air is moist; wait until the air is dry. The amount of time necessary to cool the entire grain mass varies depending on the fan capacity, the initial bin temperature, and the height of the bin. Do not cool the grain below 32°F. An airflow rate of 1/10 cubic foot of air per minute per bushel is usually ample to cool dry grain.

After the grain has been prepared properly for storage, its quality still can decline if not properly monitored. During the winter, check grain for moisture and temperature buildup once every two months. During the summer, check grain once a month. Changes in grain moisture content and temperature are the first signs that grain quality is declining. Moisture infiltration can occur in a bin when outside temperatures are greater or lower than the grain mass temperature. When the outside temperature is cooler than the grain temperature, air in the grain mass drops along the bin walls and then rises in the center of the warmer grain mass. As the air rises, it picks up moisture and drops it in the center at the top of the grain. When the outside temperature is warmer than the grain mass, the air circulates in the opposite direction and deposits moisture along the bin wall at the top of the grain mass.

As the moisture level increases, fungi and bacteria begin to grow as they feed on the grain. Through respiration, these organisms give off heat. This cycle then continues to drive up the grain temperature, which in turn increases the moisture levels. Once the temperature rises above 40 to 50°F, insects can begin to develop and reproduce. The higher the temperature, the faster the insects complete each generation and increase in numbers. This cycle will continue until the grain is dried and the temperature is brought back down using the fan.

Once grain crusting occurs, drying efficiency is reduced because the air will not move through this dense area in the grain mass. It may be necessary to break up the crusted area. Prevent this cycle from getting out of control by monitoring the grain periodically and using the fan as your primary management tool.

If you will be storing the grain for only six to nine months, these measures should be sufficient to prevent insect infestations. If you will be storing the grain for more than nine months, however, you may need a residual insecticide treatment (Table 1.3-2). Cooled grain will maintain temperatures below 60°F well into the summer, but by late summer temperatures may rise to levels at which active insect populations will colonize the grain and build up population levels. The longer grain is stored, the greater the chances are that insect infestations will develop. When possible, do not store grain for more than one year. The best residual insecticide treatments provide only 18 months of protection.

Be sure to keep grain storage facilities animal proof. Rodents, birds, cats, and other animals can quickly contaminate clean grain.

Preventing Infestations

Good sanitation and local environment maintenance are generally sufficient to prevent major pest outbreaks. However, if pests have previously been a problem or grain will be stored for an extended period, other options are available to avoid future problems. There are four main modes of pesticide application for stored grain: empty bin sprays, grain protectants, topdressing/pest strips, and fumigation.

After bins have been cleaned, an empty-bin treatment may be applied (see Table 1.3-2 and refer to label to confirm rates). Pay special attention to cracks, crevices, and "hidden" or out-of-the-way spaces. Bins should be sprayed at least two to three weeks before filling with grain; allow 24 hours for sprays to dry.

Grain protectants are insecticides added to grain as the bin is being filled. These products kill insect pests as they crawl or feed on treated grain. Grain protectant treatments are recommended for grain in extended storage, storage in flat structures, or under conditions favorable to pest development. Protectants may take the form of liquids or dusts; they are generally applied during auguring or loading. Chemical formulations should not be applied before high-temperature drying. If using these products, keep bin temperature and humidity levels low. Heat and moisture shorten the residual life and efficacy of most chemical grain protectants.

Moth pests often enter storage areas from the top surface, so some grain protectants may be applied as a surface treatment. *Bacillus thuringiensis* (Bt) is a highly selective biological insecticide that provides protection against moth larvae (caterpillars). This may be applied to the surface, or another treatment may be used (see Table 1.3-2). Topdressing treatments should be mixed into the top 4 inches of the grain. If the surface is already infested with moth larvae (webbing is present), remove the webbing and rake the surface treatment to a depth of 5 inches. Resin strips (dichlorvos or DDVP) can also be hung in the top air space; these strips help control moths. Use one strip per 1,000 cubic feet of air space and replace it after three months. When using strips, the bin top and roof vent must be sealed temporarily (aeration will make this treatment ineffective). Before re-aerating, remember to open the roof vent.

Fungus Beetle Infestations in Stored Shelled Corn

Several species of fungus beetles, including the foreign grain beetle, can be abundant in storage bins. These insects do little damage to the grain. They simply use the grain as a home, becoming most obvious in late summer and fall. Grain contamination from these insects can result in dockage, however, when the grain is sold.

The presence of fungus beetles in grain indicates a moisture and heating problem. Under these conditions, fungi grow and the beetles feed on them. Two things can be done to keep these beetles out of storages: eliminate fines, debris, screenings, etc., from the storage during filling, and keep the storage amply ventilated.

Indian Meal Moth Infestations

Indian meal moth infestations can occur in farm storages where grain has been held over winter. Indian meal moth is not a common pest of stored grain in Pennsylvania, but it is a serious pest in those relatively few storages where infestations develop.

There are at least two approaches for attacking an infestation of Indian meal moth in stored grain: fumigate as discussed on the following pages, or use a grain surface treatment of Dipel. Dipel 2X is a formulation of toxic proteins isolated from Bacillus thuringiensis (Bt) that are toxic to lepidopteran larvae when eaten—this is the same active ingredient found in transgenic varieties of Bt corn. Mix ½ pound of Dipel 2X in 10 gallons of water for every 500 square feet of grain surface; sprinkle over grain surface and incorporate into the top 4 inches of grain. Some formulations of Bt toxins are certified for organic use.

See specific crop sections in this guide for information on other insect, mite, and disease pests of stored products.

Using Fumigants

The cheapest and safest method of controlling grain pests is prevention. Consider fumigation only as an emergency treatment. Once grain has become infested with insects, the quickest and most effective way to remedy the problem is usually with a fumigant. All fumigants, however, are hazardous and

Table 1.3-2. Products registered for insect control in grain stored on-farm.

Treatment Site	Insecticide	Amount to Use*	Comments
Residual spray on floor and sides of storage facility**	Beta-cyfluthrin (Tempo SC Ultra)	0.27–0.54 fl oz per 1 gal water	For general surface spot, mist, or crack and crevice application; use higher rate for longer residual; avoid contact with treated surfaces until dry; some reports say that this product may not protect fully against weevils
	Deltamethrin (Suspend SC)	0.25–1.25 fl oz per 1 gal water	Clean bins thoroughly before use; apply finished spray mixture to equipment, walls, and floor surfaces of grain bins at 1 gallon per 1,000 square feet prior to storing or handling grain; do not allow runoff to occur
	Malathion	Many trade names are sold; check rates	Many stored grain insect pest species are resistant to malathion
	Pyrethrins + piperonyl butoxide	Several trade names sold; check rates	Barley, corn, oats, rye, and wheat
	Spinosad (Contain)	5.9–10.5 fl oz per 1,000 bushels depending on commodity	Barley, oats, sorghum, triticale, and wheat; some formulations are approved for organic use
Grain protectants**	Pirimiphos-methyl (Actellic 5E)	9.2–12.3 oz per 5 gal water per 30 tons of grain	Labeled on corn and sorghum
	Methoprene (Diacon II)	1–14 fl oz per 5 gal water	Insect growth regulator; does not kill adults but prevents the development of larvae into adults, stopping cycling of generations
Surface treatments or topdressing after the bin is filled	Pirimiphos-methyl (Actellic 5E)	3 oz per 2 gal of water per 1,000 sq ft of surface area	Helps prevent establishment of migrating insects if grain cannot be moved
	Diatomaceous earth	Several trade names are sold (Insecto, Protect-It, etc.); check rates	Cover all interior wall surfaces of empty storage area
	Bacillus thuringiensis	Several trade names are sold (Dipel, Biobit, Javelin, etc.); check rates	For Indian meal moth and almond moth control; does not control weevils or other beetles
	Methoprene (Diacon II)	0.034 fl oz (1 mL) per 1 gal water per 1,000 sq ft of surface area; see label for further details	Insect growth regulator; does not kill adults but prevents the development of larvae into adults, stopping cycling of generations
	Pyrethrins + piperonyl butoxide	Several trade names sold; check rates	Approved for barley, corn, oats, rye, sorghum, and wheat
Bin headspace	Dichlorvos resin strips	Hang one strip per 1,000 cu ft of bin headspace	Barley, corn, rye, oats, sorghum, and wheat; protects against Indian meal moth
Fumigation	Aluminum phosphide or sulfuryl fluoride (sold under a variety of trade names, including Fumitoxin, Gastion, Gastoxin, Phostek, Phostoxin, ProFume, Vikane Fumigant)	Seek professional assistance	Restricted-use pesticide—extremely toxic and potentially explosive; strict application procedures required
	Carbon dioxide	Corn, wheat (small grains), sorghum, soybeans	Requires CO_2 generator; bin must be completely sealed; fumigation will take many days to be effective

*Be sure to read labels to confirm details, including whether materials are "restricted use."
**Storcide II, containing chlorpyrifos-methyl and deltamethrin, is also available for cleaning bins (1.8 fl oz per 1 gal water), but as of March 2022, products containing chlorpyrifos are being phased out and may no longer be allowed to be used on crops grown for, or grain stored for, food or feed. This restriction applies to any products containing chlorpyrifos that you may have had on hand prior to these label changes. Storcide II is still labeled for "non-food/non-feed uses" as defined on the label, which can include cleaning storage facilities, but check the label to be certain.

must be handled with extreme caution. Fumigants are considered restricted-use pesticides, and their container labels all carry the signal word "DANGER" and a skull-and-crossbones symbol. Only chloropicrin, aluminum phosphide, magnesium phosphide, and sulfuryl fluoride are available for use as grain fumigants. As of 1990, fumigation of grain storage facilities requires special certification. Contact your local Penn State Extension office or the Pennsylvania Department of Agriculture for details. The use of methyl bromide has been phased out; its registration ended in 2005.

Although it is legal to acquire private certification to apply fumigants on the farm, farmers should seriously consider the hazards associated with fumigation products before attempting to fumigate grain. The most commonly used grain fumigant is phosphine gas, which is produced by aluminum phosphide or magnesium phosphide coming in contact with water. These materials are sold as pellets or tablets that are placed in the grain mass. When they make contact with normal air moisture levels, they slowly begin to liberate the phosphine gas. The amount of time that an applicator has to place these tablets in the grain mass and get out before phosphine levels become toxic depends on moisture and air temperature levels. If a tablet or pellet contacts too much moisture, the reaction liberating the gas is rapid, resulting in an explosion. This explosion can harm the applicator and set the grain mass on fire.

In addition to this significant hazard, the fumigant is a very small molecule that is only slightly heavier than air. Because of these properties, the gas is hard to contain unless the grain bin is tightly sealed. Phosphine can move through plastic, concrete, wood, and any crack or seam in a metal bin. Because it is heavier than air, it will slowly displace air in low areas and become concentrated if it escapes from the bin. Therefore, any work areas, nearby homes, or livestock shelters near a bin under fumigation can build up concentrations of the gas high enough to kill livestock or humans. It is important to note that in 2010, Environmental Protection Agency (EPA) implemented new restrictions on phosphine fumigants that prohibit their use around residential areas, increasing buffer zones for treatment around nonresidential buildings that could be occupied by people or animals, and require more protective product labeling. Properly handling and using fumigants requires considerable experience. Novices can easily harm themselves, employees, family members, and livestock. For this reason, fumigation is best left in the hands of experienced professionals.

For those who choose to use fumigants, the methods of application, dosages, temperature, moisture, exposure periods, and all precautions are listed on the label. Be certain to read and understand all directions before using any fumigant. In addition, consider the following recommendations:

- Fumigants are generally not fully effective at temperatures below 60°F.
- Aluminum phosphide is less likely than other fumigants to impair seed viability.
- Aluminum phosphide and magnesium phosphide are extremely corrosive to gold and copper—electrical and computer circuitry will be damaged if it contacts the gas.
- Use of methyl bromide, once a stored-grain fumigant, is no longer legal. This chemical was phased out completely by EPA, effective January 1, 2005.

Safer Options for Insect Management

Producer and consumer safety are important considerations when making decisions about insect management. Choosing low-toxic control options will help keep you safe and increase consumer confidence in your product. Diatomaceous earth (Insecto, Protect-It, etc.) is one such product that can be used as a topdressing. This substance is milled from the silica-rich cell walls of fossilized sea algae. As insects crawl through the grain, their hard cuticle coverings are abraded by the sharp edges of the diatomaceous earth. The insects then desiccate and die. Diatomaceous earth should be used to treat the first loads in the bottom of the bin and the last loads in the top. As with any treatment, use proper protection and caution; diatomaceous earth can be irritating to workers, particularly those who breathe the dust, so use personal protection equipment as necessary. Keep in mind that diatomaceous earth can abrade equipment.

Insect growth regulators are also a relatively safe option. Compounds such as methoprene mimic naturally occurring insect hormones and prevent the development of larvae into adults. Insect growth regulators do not prevent insect larvae damage; instead, they promise to stop insect populations from cycling by preventing the development of reproductive adults. Because adults do not develop, new eggs cannot be laid and therefore future generations are prevented.

As mentioned above, Bt applied as an insecticide can provide highly selective control for moth larvae; however, if the grain being stored is "Bt corn," the grain may have some protection against larval moth damage. There is evidence that Bt corn provides a degree of protection against caterpillar pests of stored products, such as the Angoumois grain moth and Indian meal moth. On the other hand, there is little evidence to suggest that strains of Bt that are active against corn rootworm larvae, which are immature beetles, provide any control of weevils or other beetles that are pests of stored products. Keep in mind that little research has been done to test the effectiveness of Bt grain in stored conditions, so continue to sample grain for pest presence.

Carbon dioxide can also be used as a safer fumigation alternative, but the bin must be completely sealed. While the

bin is sealed and fumigated over several days, the carbon dioxide keeps the insects' respiratory openings open, causing the pests to dehydrate. Heating or cooling the bin to extreme temperatures may also kill some species. Biological control using beneficial natural enemies is another option; some companies sell species that attack maize weevil, granary weevil, confused flour beetle, lesser grain borer, sawtooth grain beetle, and Indian meal moth.

Eliminating unnecessary chemical applications improves food quality and saves money. Be sure to properly identify insect pests; many are very small and have only subtle characteristics. Some fungus-eating beetles can appear to be pests of the grain itself. However, their presence indicates a different problem: high moisture levels. To be certain of the identity of a stored-grain pest, consult a professional, including the Insect Diagnostician in the Department of Entomology at Penn State. To submit specimens, contact your county extension office, which should have the supplies to submit insects for identification.

Some insects are becoming resistant to various chemicals, most notably malathion and phosphine. A few populations of insects (Indian meal moth, red flour beetle, lesser grain borer) are resistant to malathion control, so treatment can be ineffective. Although they are labeled as grain protectants, malathion dusts are not recommended. Insect resistance is widespread and the public is concerned about malathion residues in food, so its use is discouraged. Phosphine resistance is a newer challenge that has spread across the Midwest and perhaps farther; the status of resistance to phosphine gas in Pennsylvania is unclear.

Part I, Section 4

Corn

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Corn is a high-energy feed grain with a high carbohydrate content. An average analysis of corn grain contains 69.5 percent carbohydrate (starch), 8.9 percent protein, 0.31 percent phosphorus (P), 0.41 percent potassium (K), and 4.2 percent oil. Approximately 38 percent of the corn grown in the United States is fed to livestock, 14 percent is exported, and 30 percent is made into ethanol. An equivalent of 9 percent of the corn used as ethanol reenters the feed market as distillers grains. Most of the exported corn is used for livestock feed. The remaining 10 percent of the crop is used for food, seed, or industrial purposes.

Types

Yellow and white dent, brown midrib, sweet, and pop are examples of corn types grown in Pennsylvania. Each has unique characteristics that affect its use and in some cases how it is grown. Of these, yellow dent and brown midrib are the most popular in Pennsylvania.

Yellow Dent Corn

Most of the corn crop in the United States is yellow dent. Its vitamin A content and high feed value and the availability of adapted superior hybrids account for its extensive use. Of the cereal grains, it contains the highest content of carotene (vitamin A). Dent corn originated from crosses of flint and floury corns. Dent hybrids vary in the proportion of hard and soft endosperm. The hard endosperm has a brownish-tan color and is composed of starch enveloped in a protein matrix. The softer starch appears white and has little protein. Dent hybrids with higher amounts of floury endosperm are known for high starch digestibility.

Brown Midrib Corn

Brown midrib plants are characterized by a brown pigmentation in the leaf midrib at the V4 to V6 stage and a light brown coloration of the pith after tasseling. Brown midrib hybrid contains a gene (bm3) that causes a lower lignin content in corn plant tissue. Lignin is a relatively indigestible compound that limits the digestibility of the fiber in the corn plant. The reduced lignin in brown midrib corn results in silage with fiber that is more digestible than normal corn.

Animal feeding trials have shown about 10 percent greater intake and increased milk production with brown midrib silage compared to normal silage. However, brown midrib lines have frequently been low yielding and have had poor standability if left for grain production. Although recently released brown midrib hybrids have improved these features, they are still lower than those of comparable normal hybrids. In our trials, brown midrib lines have yielded about 6 to 15 percent lower than conventional hybrids in fields where they are best adapted. When considering a brown midrib corn

planting, growers should weigh the potential for improved milk or animal gains, which can be significant, against the higher production costs and lower yields per acre. New brown midrib hybrids can contain several biotech traits that are improving the stress tolerance of these lines.

Varieties

Open Pollinated

The availability and performance of superior hybrids have essentially made the practical use of open-pollinated corns mostly obsolete. Open-pollinated corns often suffer from low yields and poor standability. Five open-pollinated varieties—Early Butter, Reids Yellow Dent, Golden Surprise, Bloody Butcher, and Lancaster Surecrop—were evaluated in Pennsylvania hybrid corn tests over several years. Of 59 county tests, the average yield for the open-pollinated varieties was 82.9 bushels per acre with 29.4 percent down stalks. The average yield of the hybrids was 132.9 bushels per acre with 7.8 percent down stalks—a 50-bushel or 60 percent yield advantage. There is some resurgence in interest in open-pollinated corn as a feedstock for the distilled spirits industry.

Hybrids

Hybrids are available for all types of corn and include double crosses, three-way crosses, single crosses, and modified crosses. These terms simply describe the number of inbred parent lines used to produce a hybrid and do not guarantee that one is superior to another. The merits of a hybrid rest with its genetic potential to produce grain and/or silage.

Many corn hybrids contain transgenic traits that render them resistant to some herbicides and some pest insect species, including some caterpillar species and rootworm larvae feeding belowground. Refer to Part II, Section 2 for pest resistance traits. Hybrid corn performance results for both grain and silage are published in the "Pennsylvania Commercial Grain and Silage Hybrid Corn Tests Report," available online at extension.psu.edu.

The performance of a particular hybrid may vary among locations and years. A key to successful corn production is to have an effective corn hybrid selection strategy. First, you should use more than one hybrid each year. Reserve part of your acreage for evaluating new hybrids, but grow the bulk of your acreage to hybrids with which you have experience and that have a known performance record on your farm.

The second implication of hybrid performance variability is that hybrids should be selected based on their performance in a number of environments. Average performance over a wide range of environments is usually the best predictor of hybrid performance on your farm next year.

Hybrids with wide ranges of adaptability have less variation and consistently rank as superior. Although specific hybrids may adapt particularly well to some environments, these environments often are difficult to identify and are usually found after growers have had several years of experience growing a specific hybrid.

Hybrid Relative Maturity

Along with yield potential, maturity is of primary importance in selecting a hybrid that will produce mature grain with a high test weight during a normal growing season for a particular area. The relative maturity (RM) of a hybrid is defined as the time from planting to physiological maturity (i.e., black layer formation). This information can be found in the seed tag or in the hybrid's description and is often given in calendar days (i.e., days to maturity) and growing degree days (GDD), also known as growing degree units (GDU).

Growing degree days are a daily accumulation of heat for crop growth. To monitor GDD accumulation throughout the season, visit one of the online GDD calculators, such as the one at http://climatesmartfarming.org/tools/csf-growing-degree-day-calculator/. Alternatively, producers can use a minimum-maximum thermometer to record daily temperatures and calculate GDD using the formula below (note that the maximum daily high is 86°F because temperatures higher than that do not increase plant growth rate, and the minimum daily low is 50°F because corn does not grow at temperatures below this limit):

$$GDD = \frac{(daily\ high + daily\ low)}{2} - 50$$

Example 1 (daily high = 84, daily low = 62):
84 + 62 = 146
146 ÷ 2 = 73
73 – 50 = 23 GDD

Example 2 (daily high = 90, daily low = 70):
86 + 70 = 156
156 ÷ 2 = 78
78 – 50 = 28 GDD

It is important to note the term "relative" in RM. The time from planting to maturity (both in days and GDD) varies depending on environmental factors; thus, RM values reported by seed companies are given in comparison with other hybrids evaluated in the same trial. For example, an 85-day hybrid, rated per the company's field trial performed in the Midwest last year, will likely not mature in 85 days if planted in the following year in Pennsylvania. One can be confident, however, that, if an 85-day and a 95-day hybrid are grown under the same conditions, the 85-day hybrid will mature earlier.

While GDD ratings may be more accurate than calendar days when comparing maturity across varying conditions,

Figure 1.4-1. Pennsylvania corn maturity zones and the approximate maximum relative maturity of adapted hybrids for full-season grain production.

Table 1.4-1. Approximate relative maturity rating and growing degree days available for Pennsylvania corn maturity zones.

Maturity Zone*	Approximate Relative Maturity Rating	Growing Degree Days	Planting Dates
1	90–95	1,600–1,824	May 15–25
	96–100	1,825–2,024	
2	101–105	2,025–2,350	May 1–15
	106–110	2,350–2,499	
3	111–115	2,500–2,724	April 25–May 7
	>115	2,725–2,949	
4	>115	2,950–3,174	April 15–May 1
	>115	3,175 or more	

*See Figure 1.4-1 map for maturity zones.

GDD ratings are still relative because maximum and minimum daily temperatures do not capture all of the environmental factors that influence plant growth. We have found that hybrids typically use about 200 fewer GDD to mature in Pennsylvania compared with some midwestern locations, so companies that use GDD ratings based on Midwest data may overestimate the GDD requirements of their hybrids in the east. Our data indicate that a 105-day hybrid matures in about 2,350 GDD when grown in Pennsylvania though some 105-day hybrids are rated at 2,600 GDD.

To estimate calendar days or GDD to maturity when introducing a new hybrid in their operation, producers can: 1) if the new hybrid is from the same seed company, compare its RM with that of the previous hybrid or 2) if the new hybrid is from a different seed company, compare the grain moisture content at harvest from multi-company performance tests, such as the Penn State variety trial reports found at extension.psu.edu (e.g., lower grain moisture is indicative of earlier maturity). Most importantly, producers must pay attention to the information reported on the seed tag or hybrid's description, as it is not guaranteed that all companies use the same definition of relative maturity. Recently, many companies also have been reporting GDDs from planting to silking, as using hybrids with different pollination periods can mitigate risks.

The Pennsylvania corn maturity zones shown in Figure 1.4-1 are based on long-term weather data, including frost-free growing days and GDD. See Table 1.4-1 for approximate RM and GDD ratings for Pennsylvania corn maturity zones.

Nutritional Requirements

Basic Fertility Management

Lime, phosphate (P_2O_5), potash (K_2O), and magnesium (Mg) requirements are best determined by soil testing. The Penn State Agricultural and Analytical Services Laboratory provides soil testing to the general public for a fee (https://agsci.psu.edu/aasl). The soil testing report gives lime, P_2O_5, K_2O, and Mg recommendations, which are based on the yield goal or crop yield potential for the soil type and the fertility level of the specific soil. The report also gives nitrogen (N) fertilizer recommendations based on the yield potential of the crop and the contribution of previous legume crops and any manure additions. On manured fields, sidedress N requirements can also be estimated using the presidedress N soil test (PSNT; see https://agsci.psu.edu/aasl/soil-testing/pre-sidedress-nitrate-test-for-corn-psnt). For a more detailed discussion of basic soil fertility management, see Part I, Section 2: Soil Fertility Management.

Adjusting Recommendations

To determine the amount of commercial fertilizer required to produce a corn crop:

1. Determine total nutrient requirements from soil test recommendations.
2. Adjust the recommendations for manure applications using Tables 1.2-10, 1.2-11, and 1.2-12. (See Table 1.4-2 for an example.)
3. If you did not check the appropriate previous legume crop on your soil test questionnaire, adjust the nitrogen recommendations using Table 1.2-6. (For an example, see Table 1.4-3.)
4. Determine the amount of N-P_2O_5-K_2O to be applied as row (starter) fertilizer and subtract this amount from the adjusted recommendation to determine broadcast or plowdown requirement. (For examples, see Tables 1.4-2 and 1.4-3.)

Lime

Meeting the soil's lime requirement is the first essential step in an efficient and successful fertility program. For fields where

Table 1.4-2. Example of adjusting plant nutrient recommendations for manure applications (corn following manure application, manure incorporated immediately).

	Plant Nutrients (lb/A)		
	N	P_2O_5	K_2O
Recommendations for 125 bushels per acre	130	100	80
Row fertilizer (200 lb 10-30-10)	20	60	20
Cattle manure (12 tons)	60	36	60
Total credits	80	96	80
Additional needed	50	4	0

corn is grown in rotation with legume crops, maintain the pH between 6.5 and 7.0. Performance efficiency of the triazine herbicides and availability of most plant nutrients are greatest within this pH range. The pH for continuous corn fields should be maintained between 6.2 and 7.0.

Apply lime whenever it is required. During the last year of corn in a rotation and before small grains or legume forage crops are planted are critical times to meet lime requirements and minimize corn herbicide residue problems on the succeeding small grains. In addition, replace atrazine and/or simazine with shorter-residue herbicides in this last year of corn.

Reduced-tillage systems can contribute to the development of an acidic soil surface, often referred to as an "acid roof," due to surface applications of nitrogen fertilizers and manure and the decay of organic materials in this layer. Therefore, the pH of the 1-to 2-inch surface of minimum and no-tillage corn fields should be measured each year. Collect several soil cores, each 1 to 2 inches deep, thoroughly mix them in a clean bucket, and remove a sample for pH measurement. A simple colorimetric kit using pH indicator solutions is satisfactory, fast, and inexpensive. These kits, available at most local extension offices and lawn and garden stores, do not determine lime requirements.

If the pH of the surface soil is less than 6.2, take a standard soil sample for laboratory analysis and lime requirements. The recommended lime should be applied as early as possible before corn planting. If the standard test does not call for any lime and the surface pH is less than 6.2, apply 2,000 pounds of limestone per acre.

Presidedress Soil Nitrogen Test

Nitrogen fertilizer recommendations can be made using the presidedress soil nitrogen test (PSNT) for corn grown on land that has had manure applications. This approach to testing soil for nitrogen involves taking soil samples just before sidedressing—after the spring wet period but before the period of major nitrogen demand by corn—and determining the nitrate nitrogen available in the soil sample. The results of the test then are used to make sidedress nitrogen recommendations.

Table 1.4-3. Example of adjusting plant nutrient recommendations for previous crop (corn following a legume).

	Plant Nutrients (lb/A)		
	N	P_2O_5	K_2O
Recommendations for 125 bushels per acre	130	100	80
Row fertilizer (200 lb 10-30-10)	20	60	20
Previous crop (alfalfa, 50 to 75 percent)	110	0	0
Total credits	130	60	20
Additional needed	0	40	60

This test is recommended primarily for use on fields with a history of manure application. This test is of limited value on most fields without organic nitrogen contributions due to the fields' generally low soil nitrate levels. Standard recommendations are preferable in these situations.

Procedure

1. Apply only a minimum of fertilizer nitrogen in the spring (starter fertilizer and/or nitrogen used as an herbicide carrier).
2. Apply manure based on the history of the field, manure analysis, manure handling, and crop requirements for nitrogen estimated from the yield goal and crop history.
3. Take soil samples when the corn is 12 inches tall or at least a week before planned sidedressing.
4. Sample the fields by taking 10 to 20 cores to a 12-inch depth, if possible. If not, sample as deep as you can. Avoid starter bands and other atypical areas. Because of sampling problems, this test cannot be used on fields that have received injected fertilizer or manure.
5. Combine and crumble the cores and dry them as quickly as possible (within one day of sampling). Spread the samples out in the sun or under a heat lamp in a well-ventilated area to dry.
6. Send the sample to a reputable soil testing lab for soil nitrate-nitrogen analysis. A reliable field test kit can also be used to determine the nitrate-nitrogen level in the sample.
7. From Table 1.4-4, determine the sidedress nitrogen recommendation. See the PSNT recommendation guidelines below for more details.

Recommendation Guidelines

These nitrogen rates should be considered guidelines for making recommendations. It is important that the actual recommendation be made in the context of the field information. Check for consistency between the test results and the field's history. Double-check inconsistencies by rerunning the sample and/or taking a new sample and having it analyzed. A

Table 1.4-4. Nitrogen recommendation worksheet to be used for making PSNT-based sidedress nitrogen recommendations in Pennsylvania.

Soil nitrate-nitrogen		ppm (1)					
If the soil nitrate level is greater than or equal to 21 ppm, the nitrogen recommendation is zero; otherwise, continue the calculations below.							
Yield factor =		×	1.1	=	_____(2)		
	Expected yield						
History factor =		+		+		=	_____ (3)
Coefficients →	Manure applied since last harvest None = 0.75 Any = 3.5		Manure applied in three years prior to the last harvest None = 0 Any = 1.75		Previous crop Corn = 0 Soybeans = 1 Forage legume = 3.5 Other = 0		
Recommendation =		– (		×		) =	
	(2) Yield factor		(3) History factor		(1) PSNT NO_3-N ppm		

If the calculated recommendation is less than 30 pounds per acre, a zero recommendation is suggested.

very low test on a field where you would expect a high level of residual nitrogen—such as on a field with a history of heavy manure applications or a recent legume in the rotation—or a very high test on a field with little or no history of manure or legumes in the rotation should warn you of a potential problem.

If a rerun of the analysis confirms that the test is very low, but the field's history indicates that a high level of residual nitrogen should be present, apply no more than 50 to 75 pounds of nitrogen per acre. On the other hand, if the test is very high, but the history indicates a low level of residual nitrogen, then the recommendation should be to apply nearly a full rate. As with any soil test recommendation, use all available information to arrive at the best final recommendation for the situation. For more information, see "Agronomy Facts 17: Presidedress Soil Nitrate Test for Corn."

Applying Fertilizers

Potash (K_2O)

Potash can be applied broadcast or with row fertilizer. Total potash plus nitrogen should not exceed 60 to 70 pounds per acre when applied 2 inches from the seed in the row fertilizer. Potash can be broadcast on the surface in no-till systems. Incorporation by plowing down and secondary tillage are the preferred methods under tilled systems.

Phosphate (P_2O_5)

Phosphate can be applied with the potash or as row fertilizer. Apply potash and phosphate anytime in the fall or spring, but avoid broadcasting on frozen ground. The efficiency of phosphate uptake is improved greatly by band applications (see "Using a Starter Fertilizer" below).

Nitrogen (N)

An effective nitrogen management strategy is one that minimizes the potential for nitrogen losses occurring from (1) volatilization of urea, (2) leaching of soil nitrate, or (3) denitrification (the conversion of nitrate to N2 gas in the soil). Volatilization can be minimized by incorporating fertilizers that contain urea or dribbling liquid nitrogen solutions (e.g., urea ammonium nitrate, UAN).

Leaching and denitrification losses can be minimized by delaying nitrogen application until corn is 10 to 16 inches tall (sidedressing). This is especially critical on soils with a high potential for leaching or denitrification. On these soils, responses to sidedressing are relatively consistent. Leaching is most serious on well-drained, sandy, and gravelly soils, but it can also occur on well-drained upland limestone and shale soils. Denitrification is most serious on soils rated as somewhat poorly drained or poorly drained, but it can also occur on any soil that is saturated with water.

All of the commercially available nitrogen sources give adequate performance, provided the properties of the material are taken into consideration at application. The following are commonly applied nitrogen sources for corn:

- Incorporate (knife in) anhydrous ammonia 6 to 8 inches deep. Soil should be moist. Sidedressing corn at 10 to 16 inches tall and at planting are the preferred times of application. Fall applications are not recommended.
- Incorporate urea within 24 to 36 hours to avoid nitrogen loss from volatilization. Mechanical incorporation by plowing down, disking in, cultivating in as a sidedress, and timing the application just before a rainfall are all effective methods. Fertilizer can also be amended with an additive that minimizes urea volatilization. One-half inch of rain is sufficient to incorporate urea fertilizers

and minimize volatilization. Broadcasting urea on corn plants causes some leaf injury, and although this is not a widespread practice, it has been used by some farmers and in research trials with satisfactory results. Fertilizer can also be amended with an additive that minimizes urea volatilization. For untreated urea fertilizer, sidedressing that is incorporated is preferred over topdressing.

- UAN solutions are approximately one-half urea. Therefore, observe the above application methods for urea, but do not apply UAN as a topdress; such application would cause severe leaf injury. Sidedressing 50 to 90 percent of nitrogen requirements using UAN and dribble tubes is preferred—it increases nitrogen efficiency over broadcast spraying solution nitrogen. This is especially important in no-till or mulch-covered fields. Incorporating or knifing in the UAN improves efficiency slightly over dribble applications. Fertilizer additives that contain a urease inhibitor can reduce urea volatilization and increase the flexibility of fertilizer application.
- Ammonium nitrate, ammonium sulfate, and the ammoniated phosphates can be surface applied without significant volatilization losses.

The efficiency of recovering applied nitrogen is improved by sidedressing. This practice applies the nitrogen nearest to the time when the corn crop's need for nitrogen is approaching its peak—during rapid vegetation growth. Sidedressing also shortens the time during which the nitrogen is subject to possible field losses from leaching or denitrification. Figure 1.4-2 illustrates how delayed nitrogen application reduces nitrogen vulnerability. Corn yields do not always respond to delayed applications, but under some conditions (e.g., during a wet year) yield differences can be sizable (Table 1.4-5). In 23 Penn State studies conducted from 1982 to 1995, the yield response to delaying at least half of the nitrogen until sidedressing averaged 5 bushels per acre.

Fifty to 90 percent of the nitrogen requirement can be applied at sidedressing. In fields that receive periodic manure applications and where legumes are grown in a relatively short rotation, applying all but the starter nitrogen as a sidedress is the best approach. In continuous corn where manure is not applied, applying more nitrogen than just the usual starter amount at planting time may be advantageous. This is usually done by using UAN as a carrier for the herbicide. Remember that spraying UAN on the soil surface can result in significant nitrogen loss. Additional nitrogen can be applied safely in the starter fertilizer, as long as the nitrogen source is not urea and the rate and analysis of the starter fertilizer are such that the total amount of nitrogen plus potash is kept below 60 to 70 pounds per acre.

As noted in the discussion of nitrogen materials, these delayed applications can be done in many ways. The best way is probably to dribble UAN solution between the rows of corn using a sprayer equipped with drop tubes. Anhydrous ammonia is also an effective sidedress material, providing that soil conditions are sufficient to entrap the gaseous ammonia in the soil. Urea can also be used as a topdressing material, but it may result in significant nitrogen loss and some leaf damage.

Figure 1.4-2. Effect of delayed nitrogen application on nitrogen vulnerability.

Table 1.4-5. Effects of method and time of nitrogen application (Penn State).

Time	Method	Bushel per Acre
At planting	Surface	135
At planting	Incorporated	141
Sidedress	Surface	148
Sidedress	Incorporated	152

Sidedressing nitrogen when corn is 10 to 20 inches tall is a practical way to significantly improve the efficiency of nitrogen fertilizer use.

Nitrogen and Soil pH

Applications of nitrogen increase soil acidity (i.e., lower the pH). As a general rule, for each pound of nitrogen applied as ammonium sulfate, 6 pounds of limestone are required; 3 pounds of limestone are required for each pound of other nitrogen sources, including manure nitrogen.

Nitrate Toxicity

Under normal growing conditions, fertilizers applied at recommended rates do not create nitrate nutritional problems in livestock. Excessive accumulation of nitrate in the corn plant may be caused by any factor that produces plant stress, such as prolonged drought and defoliation of the plant by disease, insects, or hail.

In general, the greatest risk of high nitrate levels has been in drought-stunted fields that have received excessive manure or nitrogen fertilizer. The risk of high nitrate levels is highest immediately following a drought-ending rain. Nitrates accumulate in the lower portion of the plant, so harvesting higher under these conditions can help you avoid high nitrate concentrations. Normally, the ensiling process removes about half of the nitrates present in the fresh corn silage. If you

suspect unsafe levels of nitrates in corn silage, have the silage tested at a reputable forage testing lab.

Using a Starter Fertilizer

The term starter fertilizer refers to a practice, not a material. Starter fertilizer is placed strategically near seed so that it is readily available. This practice improves early seedling growth during cool growing conditions and can help produce earlier maturing and higher-yielding crops.

Cool, wet soils (even high-fertility soils) reduce root growth and mobility of nutrients, especially phosphorus, thus limiting the availability of soil nutrients to the seedling plant with its very small root system.

Placement

To achieve the starter effect, place the planter fertilizer to give the roots ready access to it while protecting the seed from fertilizer damage. The standard placement, 2 inches beside and 2 inches below the seed, meets the above criteria for a wide range of materials and rates. For this placement, the material should contain less than 30 pounds of nitrogen as urea, and the rate should supply no more than 60 to 70 pounds of nitrogen plus potash per acre. Generally, high rates of starter fertilizer are not necessary. There is more potential for problems from too much starter fertilizer than from too little. By reducing the rate of starter fertilizer and using the proper materials, you can reduce the distance between the fertilizer and seed from the 2-inch by 2-inch placement.

With pop-up applications of the fertilizer, make sure the application rate supplies no more than 10 pounds of total nitrogen plus potash. Improper placement or excessive rates of starter fertilizer injure seedlings and reduce stands. Limited soil moisture during germination and seedling emergence increases the chance of seedling injury.

Placing starter fertilizer on the soil surface either over or beside the row will reduce its effectiveness in stimulating early season growth.

Rates

For applications 2 inches away from the row, it is possible to apply 100 to 300 pounds per acre. The data in Table 1.4-6 show the corn yield response from starter fertilizer in a three-year study on soils testing high in phosphorus. Early season growth was improved with both nitrogen and phosphorus fertilizers, but grain yields were similar. For in-row applications of liquid starter fertilizers, which are becoming much more common, rates are between 3 and 5 gallons of product per acre.

Materials

The ideal starter fertilizer depends on existing soil nutrient levels. On soils with optimum or low phosphorus and potassium levels, a good complete starter fertilizer should contain a high percentage of P_2O_5; for example, N-P_2O_5-K_2O ratios of 1-2-1, 1-3-1, 1-4-2, or 1-5-0 are common. Where phosphorus levels are high, increasing the nitrogen and decreasing the phosphorus in the starter should be considered. Often some starter response in these soils can be achieved with nitrogen alone and thus reduce the nitrogen recommendation. If nitrogen is increased in the starter or you use a nitrogen-only starter, ammonium sulfate is the preferred material. Be careful using urea in a starter because there is some risk of seedling injury, and keep 2-inch by 2-inch rates to less than 30 pounds of nitrogen as urea or move the placement more off the row to 4 inches. Monoammonium phosphate (MAP) is preferred over diammonium phosphate (DAP) as a starter fertilizer ingredient. Both dry and liquid fertilizer materials perform well.

Crop requirements for phosphate can be met by band applying all the phosphate in the starter fertilizer. Do not allow the nitrogen plus potash in this starter application to exceed 60 to 70 total pounds per acre. When planting early or on soils with marginal potash levels, a starter fertilizer containing some potash is recommended. Some research has shown benefits to adding potassium to the starter in no-till soils, even at optimum potassium levels.

Micronutrients and secondary nutrients (calcium, magnesium, and sulfur) are usually not necessary in starter fertilizers unless you have strong reason to suspect nutrient deficiencies based on plant symptoms or analysis.

Table 1.4-6. Corn yield response on high-phosphorus soils from starter fertilizer, three-year data (Penn State).

Treatment	Rate	Early Season G1rowth (percent)	Yield Response (bu/A)
Check	0	100	126
10-30-10	180 lb/A	118	129
21-0-0-24	180 lb/A	116	124

Establishment

Crop Rotation

Crop rotation is an important aspect of production that most Pennsylvania corn producers should consider. A carefully planned crop rotation that includes corn has many advantages over continuous corn. Corn yields are often increased by 5 to 7 percent following soybean and up to 10 to 15 percent following hay. These "rotational effects" are often enhanced in drought years.

Corn yields in a long-term rotation experiment are listed in Table 1.4-7. Input costs for corn in a rotation are often

Table 1.4-7. Average yields of corn as affected by crop rotation over a five-year period (1990–1995) at Rock Springs.

Crop Rotation	Corn Yield (bu/A)
Continuous corn (C)	122
C/soybean	141
C-C-C-C/four-year alfalfa	147
C-**C**-C-C/four-year alfalfa	138
C-C-**C**-C/four-year alfalfa	134
C-C-C-**C**/four-year alfalfa	131

reduced substantially because of the need for less nitrogen, corn rootworm insecticides, and sometimes herbicides. Crop rotation often facilitates no-till corn production since soybean stubble and fall-killed sod crops make excellent no-till seedbeds, and rotation reduces the inoculum for diseases such as gray leaf spot, which can be severe in continuous no-till corn. In addition, a diverse crop rotation reduces the risk of yield losses from drought since more drought-tolerant crops such as soybean or small grains are often included in the rotation. Rotations also help spread out labor requirements and encourage more timely corn planting and harvesting. Such timeliness can help increase whole-farm corn yields more than the rotation effect can alone. Corn-following-corn rotations increase risks from drought and pests but may be profitable on high-yielding soils with good management.

In Pennsylvania, crop rotations vary widely across the landscape. An example of an effective grain crop rotation is corn, soybean, small grain, and double-crop soybean. In this rotation, inputs are minimized while high yields are still produced.

Tillage Systems

A variety of tillage systems can be used to establish the corn crop successfully. Each system has advantages and disadvantages that should be considered for individual situations. Conventional tillage (plow plus disk and/or harrow), minimum tillage (chisel plow plus disk, disk plus disk), and no-till are three basic tillage systems used in Pennsylvania. See Part I, Section 1: Soil Management for more details. Increasingly, Pennsylvania farmers are using no-till methods for growing corn.

Planting Date

The ideal planting time is only a few days long. In most years, each day of delay past this period reduces yields by up to 1 bushel per acre per day (see Table 1.4-8 and Figure 1.4-1). Consequently, corn planting should begin early enough to ensure the bulk of the crop can be planted during this optimum period.

Normally, corn can be planted safely 10 to 14 days before the average date of the last killing frost. This date ranges from April 15 in long-season areas to May 15 in cooler regions of the state. Ideally, soil temperatures in the seed zone at 8:00 a.m. should be 50°F or above and the five-day extended weather forecast should indicate continued warm or warmer conditions. Planting before a forecasted cool, rainy period can result in poorer emergence due to imbibitional chilling injury (injury caused by the seeds imbibing cold water). Soil physical conditions for good seed coverage are equally important in deciding to plant.

When planting is delayed past the optimum dates or a crop needs to be replanted, it may be necessary to switch hybrid maturities. In most areas, switching to hybrid maturities that are shorter than adapted should not be considered until at least the last week of May. Very full-season hybrids should be planted by mid-May in most areas.

An important factor is to determine the approximate number of growing degree days left in the season before a killing frost in your area. If you are growing corn for grain, use only hybrids that require fewer than the number of growing degree days to mature. Hybrids may reduce their GDD requirement by 100 to 150 growing degree days in late planting situations. For silage, full-season hybrids may still be planted and can yield slightly more than shorter-season hybrids. However, if soils on these late planted fields are poorly drained, earlier hybrids are probably also justified for silage since they help avoid the risk of wet soils at harvest.

When stands are less than desired, you may consider replanting the field. Base this decision on the anticipated costs of replanting compared to the potential yield gain. In some cases, it may be advisable to leave a reduced stand and forego replanting since the yield potential of the replanted corn may not be high enough to justify the cost. Use Table 1.4-8 as a guide for estimating the yield of replanted corn. Part C of the table is most appropriate for fields where yields average more than 175 bushels per acre. Recent research in Illinois has shown that high-yielding fields are particularly responsive to early planting and higher plant populations. For many Pennsylvania fields with moderate yield potentials between 125 and 175 bushels per acre, the responses in Part C are most appropriate. Note in the table that the response to plant population is often limited when there are more than 24,000 plants per acre. Tools are also available online to assist in replant decisions.

Seed Depth

Seed must contact moist soil. Depending on conditions, 1.5 to 2.5 inches of soil coverage is desirable. Remember that corn seed responds to warm temperatures and moist soil. For optimum stands, planting depth should take this factor into

Table 1.4-8. Estimated grain yields for various planting dates and population rates.

Part A. Figures shown are most applicable to fields with less than 125 bushels per acre.

	Plants per Acre at Harvest						
	12,000	14,000	16,000	18,000	20,000	22,500	25,000
Planting Date	Optimum Yield (percent)						
April 20	72	78	83	87	90	93	95
April 25	75	81	86	90	93	96	98
May 1	77	83	88	92	95	98	100
May 6	78	83	88	92	95	98	100
May 11	77	83	88	92	95	98	99
May 16	75	81	86	90	93	96	98
May 21	73	78	83	87	91	94	95
May 26	69	75	80	84	87	90	92
May 31	64	70	75	79	82	85	87
June 5	59	64	69	73	77	80	81
June 10	52	58	63	67	70	73	75

Part B. Figures shown are most applicable to corn fields with yields between 125 and 175 bushels per acre.

	Plants per Acre at Harvest								
	10,000	12,500	15,000	17,500	20,000	22,500	25,000	27,500	30,000
Planting Date	Optimum Yield (percent)								
April 10	62	70	76	82	86	90	92	94	94
April 15	65	73	79	84	89	92	95	97	97
April 20	67	74	81	86	91	94	97	98	99
April 25	68	75	82	87	92	95	98	99	100
April 30	68	75	82	87	92	95	98	99	100
May 4	67	75	81	86	91	94	97	99	99
May 9	65	73	79	85	89	93	95	97	97
May 14	63	70	76	82	86	90	92	94	95
May 19	59	66	73	78	83	86	89	90	91
May 24	54	62	68	74	78	82	84	86	86
May 29	49	56	63	68	73	76	79	80	81
June 4	43	49	57	63	67	70	73	75	75
June 9	36	42	49	56	60	62	65	67	68

account. For example, plant 1.5 inches deep when soil is cold and/or moist; plant deeper when soil is warm and/or dry.

Plant 1.5 inches deep in heavy soils or where soil crusting is anticipated. Shallow planting (less than 1.5 inches) increases the risk of poor seed coverage, poor root development, and uneven emergence in dry springs.

Inadequate seed coverage can result in variable plant emergence and stands. Check the actual seed depth you are achieving in the field, preferably in every field, at least at the beginning of each day. No-till planting in wet soils can sometimes lead to a furrow that does not close. Spiked-tooth or similar closing wheels can help curb this problem.

Corn Planter Adjustments

Several planter considerations can help improve seed placement and seed-to-soil contact. Adjust the coulter down pressure and depth to slice cleanly through residue in no-till situations. This improves seed-to-soil contact and prevents pinning of the residue in the seed furrow. Worn double disk openers can contribute to a W-shaped seed furrow and poor

Table 1.4-8. Estimated grain yields for various planting dates and population rates (continued).

Part C. Figures shown are most applicable to corn fields with yields greater than 175 bushels per acre.

	Plants/A at Harvest						
	10,000	15,000	20,000	25,000	30,000	35,000	40,000
Planting Date	Optimum Yield (percent)						
April 1	54	68	78	88	95	99	99
April 10	57	70	81	91	97	100	100
April 20	58	71	81	91	97	100	99
April 30	58	70	80	89	95	97	96
May 9	55	68	77	86	91	93	91
May 19	50	63	72	80	85	86	84
May 29	44	56	65	73	77	78	75
June 8	35	47	56	63	67	67	64

Source: Adapted from the University of Illinois and Purdue University.

seed-to-soil contact. Inspect the openers and replace them when they are less than the manufacturer's recommended size. The tension and placement of the closing wheels should also be adjusted to ensure the furrow is being closed and firmed adequately. Row cleaners can remove residue from the row and reduce the potential of hairpinning residue in the row. Seed firmers can also help firm the seed in the furrow and improve seed-to-soil contact.

It pays to monitor the effectiveness of planter seed distribution equipment. Stands should be evaluated for doubles and skips. Generally, more than one double or skip in a 1/1,000-acre row segment should be a signal to examine planter performance. Smaller seed sizes may require some planter adjustments. Plate planters require using different plates. Air planters may require using seed disks designed for smaller seed sizes. Some air planters require reduced air pressure and an accurate seed brush setting to handle small seeds. Finger pickup mechanisms need to be checked for wear and an accurate tension setting. Be sure the seed brushes are not worn. Vacuum planters, like air planters, depend on the proper disk for relative seed size. Small disks are needed for small seeds.

Regardless of the planter you have, check the seed distribution before going to the field. Some equipment dealerships can evaluate seed-metering mechanisms in the shop. This often worthwhile investment can result in improved seed distribution in the row.

Row Width

Thirty-inch rows are most common in corn production in Pennsylvania. Thirty-inch rows average yields approximately 10 percent higher than 40-inch rows. Thirty-inch rows provide 4,356 more feet of row per acre than do 40-inch rows, and plants will be over 2 inches farther apart within the row (Table 1.4-9). Reducing the row spacing below 30 inches to 20 or 15 inches can result in higher yields as well. Penn State research has shown a 5 percent advantage for grain production and a 10 percent advantage for silage production in using 15-inch or 20-inch rows compared to 30-inch rows. This response most likely appears where N is not limiting.

Plant Populations

The optimum plant population range for corn varies depending on the yield potential of the soil, the hybrid, and the intended use of the crop. For many Pennsylvania soils, a harvest population of 28,000 to 30,000 plants per acre is necessary to achieve maximum economic grain yields. On the best soils where yields of 175 bushels per acre and higher are common, plant populations of 30,000 to 35,000 plants per acre are needed to maximize grain yields. On droughty or poorly drained soils with grain yield potentials around 100 bushels per acre, optimum plant populations are lower, in the 24,000 to 28,000 range. See Table 1.1-1 in Part I, Section 1.

Hybrids vary in their tolerance of high populations, and some may experience some lodging at the upper end of these ranges. Consequently, you should review the seed company's plant population recommendations for each hybrid and adjust accordingly. Also consider populations at the lower end of these ranges in fields where gray leaf spot is common and there is an increased risk of lodging.

For silage production, higher plant populations are warranted. In general, optimum populations appear to be about 2,000 to 4,000 plants per acre higher for silage than grain. Thus, on most soils, populations of 30,000 to 34,000 plants per acre appear to optimize both yield and forage quality. Higher plant populations can increase yields, but the energy content of the forage appears to decrease slightly. In a recent two-year test conducted at Rock Springs, increasing plant

Table 1.4-9. Corn planting and plant population guide.

Seed Drop*		Population Check				
Population Desired (plants/A)	Seeds Required per Acre Allowing for 10% Loss	Row Spacing (inches)	Kernel Spacing (inches)	Kernels per 50-Foot Row	Plant Spacing (inches)	Plants per 50-Foot Row
28,000	31,111	15	13.4	45	13.0	40
		20	10.0	60	11.2	53
		30	6.7	89	7.5	80
		32	6.3	95	7.0	86
		36	5.6	107	6.2	96
		38	5.3	113	5.9	102
30,000	33,333	15	12.6	48	14.0	43
		20	9.4	64	10.4	57
		30	6.3	96	7.0	86
		32	5.9	102	6.5	92
		36	5.2	115	5.8	103
		38	5.0	121	5.5	109
32,000	35,200	15	13.1	46	11.9	51
		20	9.8	61	8.9	67
		30	6.5	92	5.9	101
		32	6.1	98	5.6	108
		36	5.4	110	5.0	121
		38	5.2	116	4.7	128
34,000	37,400	15	12.3	49	11.2	54
		20	9.2	65	8.4	72
		30	6.1	98	5.6	107
		32	5.8	104	5.2	114
		36	5.1	117	4.7	129
		38	4.9	124	4.4	136

*Assuming a 10 percent average loss. Obtain specific hybrid plant population recommendations from your seed supplier. Check seed tags for actual percent germination.

Table 1.4-10. Length of row equal to 1/1,000 acre.

Row Width (inches)	Length (feet)
38	13.8
36	14.5
34	15.4
32	16.3
30	17.4
20	26.2
15	34.8

populations from 30,000 to 36,000 plants per acre increased yield by 0.7 ton per acre (35 percent dry matter) and decreased whole-plant digestibility by 0.7 percentage unit. The forage quality response to increased plant populations may also vary with hybrids, particularly leafy hybrids, so be sure to also review the seed company's planting recommendation for hybrids grown for silage.

An extremely useful measurement is the length of row equal to 1/1,000 acre. This row length is dependent on the row width (Table 1.4-10). Yield, population, harvest loss, and other measurements can be taken in this row length and multiplied by 1,000 to convert them to a per-acre basis. For example, if you count 24 plants in a 1/1,000-acre row length, you can estimate the population on a per-acre basis to be 24 multiplied by 1,000, or 24,000 plants per acre. For improved accuracy, use the average of several 1/1,000-acre row lengths for these estimates.

Growth and Development

An important part of tracking corn growth and development is understanding the growth stages of corn, which can also be important for timing fertilizer and herbicide applications. Documenting corn growth stages is required when applying pesticides. The most common growth staging system divides corn development into vegetative and reproductive development. The vegetative stages are based on the number of leaves with a fully developed collar, starting with the first rounded leaf. These are numerically designated as V1, V2, V3, etc., to V18. Tasseling, referred to as VT, is the last of the vegetative stages. The reproductive stages are based on the development of the kernels and ear: R1, silking; R2, the blister stage; R3, the milk stage; R4, the dough stage; R5, the dent stage; and R6, the black layer or physiological maturity.

Crop Development

Silking and pollination indicate approximately the midpoint in corn crop development. Physiological maturity usually occurs 50 to 60 days after pollination. Kernel development is usually described by the milk, dough, and dent stages of development. Crop development is regulated by growing degree units and hybrid maturity rating. For an early medium-season hybrid (105-day), the growing degree days required to reach maturity from the early dough, early dent, and full-dent (all kernels dented) stages are about 660, 440, and 275, respectively. Late plantings and/or early frost can result in corn that becomes frosted before maturity.

Weather Impacts

Various weather events, including frost, drought, hail, and wind, affect corn in Pennsylvania.

Frosted Corn

Corn is occasionally damaged or killed by frost before it reaches the desired maturity for ensiling. If the frost is early and green leaves remain on the plant, the crop will continue to accumulate dry matter and should be left in the field until it reaches the appropriate moisture content. Plants that are killed while still immature will likely contain too much moisture for immediate ensiling. These plants will dry slowly, and dry matter losses will increase as the dead plants drop their leaves in the field and sugars leach from the frosted leaves.

The best option is to leave the crop in the field to dry to an acceptable level (at least 72 percent moisture for a horizontal silo, 68 percent for an upright silo), unless it appears that dry matter losses are becoming too high or harvesting losses will increase dramatically.

Drought-Stressed Corn

Corn so drought stressed that it may not resume growth should be ensiled. Corn in this condition usually has few ears and its leaves have turned brown and are falling off. Be careful not to harvest prematurely—corn with ears and some green leaves may still have the potential to resume growth and accumulate dry matter later in the season. Corn in this stage will often be higher in moisture than it appears. If this is the case, delay harvest. The net energy content of drought-damaged corn often is 85 to 100 percent of normal, and it sometimes contains slightly more crude protein. Drought-stunted silage often contains high fiber digestibility and can be an excellent forage and sustain high milk production when it is supplemented with additional grain.

One concern with drought-stressed corn is the potential for high nitrate levels in the silage. High nitrate levels are found most frequently where excessive nitrogen rates were applied and when a drought-stressed crop was chopped within three days following a rain event. Ensiling crops that are suspected to have high nitrate levels is preferred over greenchopping because the fermentation process will decrease nitrate levels by about 50 percent. When in doubt, obtain a forage analysis with nitrate determination before feeding the questionable forage and then take appropriate precautions in feeding this silage.

Harvesting

Harvest date should be determined by crop maturity, not by the calendar. Scout fields to determine those with potential lodging or harvest loss problems such as stalk rot or deer damage. Plan to harvest these fields first.

Corn Silage

One of the most important steps in producing quality corn silage is to harvest at the proper moisture for the storage structure. Desired moisture levels for different structures are as follows: for sealed airtight silos, 60 to 65 percent; for upright silos, 63 to 68 percent; and for trench silos, 65 to 72 percent. Ideally, moisture levels in the silage should be monitored at harvesting to prevent harvesting the crop outside the desired range. If moisture testing is not feasible, then you can estimate crop moisture by the stage of crop development.

As kernels start to dent, a separation between kernel starch and milk can be seen. The firm starch is deposited in the crown (outer) area of the kernel and the milk occupies the basal area of the kernel (Figure 1.4-3). A whitish line appears, separating the two areas. As the crop matures, this kernel milk line moves down the kernel and whole-plant moisture declines. When the milk line reaches the base of the kernel, a black layer forms and the crop is physiologically mature.

Figure 1.4-3. Kernel milk line showing separation between firm starch and milky starch.

When an ear of corn is broken in half, the tip half (left) shows the smooth endosperm, while the butt end (right) shows the embryos. The arrow points to the milk line border between the milk and starch layers.

Recent research has shown the kernel milk line to be only a rough indicator of corn silage moisture levels. On average, silage moisture levels will be about 70 percent at full dent when the milk line first appears, falling to 60 percent at physiological maturity (black layer) (Table 1.4-11). However, there is often considerable variation between years; when conditions have been particularly dry or wet for several weeks prior to harvest, the moisture can be as much as 5 percentage units different from what was predicted by the milk line. When this line reaches the midpoint of the kernel (half milk line), silage yields reach a maximum and the crop moisture level should be near 65 percent. At this point, the stover part of the plant has good digestibility and the moisture is at the desired level for storage in airtight silos.

One strategy for timing corn silage harvest is to chop a sample at the full dent stage, just as the milk line appears, and determine the moisture content. Then estimate the harvest date for the field using a typical drydown rate of 0.5 to 0.75 percentage unit per day.

Harvest considerations should also focus on obtaining the correct particle size distribution and the need to process the crop. Processing silage refers to running the chopped material between two rollers that are installed in the harvester to crush the harvested material as it passes through. Kernel processing units are popular on corn silage harvesters in Pennsylvania. Kernel processing has the advantage of crushing cob slices and kernels, and it can increase the starch availability in the silage by about 10 percent. In some cases, this has resulted in increased milk production compared to unprocessed silage. A good general recommendation for the theoretical length of cut (TLC) for processed silage is ¾ inch with a 1- to 2-millimeter roller clearance.

For unprocessed silage, an average theoretical length of cut should range from ⅜ to ¾ TLC. Particle size of corn silage should be monitored during harvesting because it can change as crop moisture content varies. The Penn State Particle Size Separator can be used to estimate the particle size distributions for harvested corn silage.

Table 1.4-11. Whole plant moisture relative to stage of kernel development.

Stage	Moisture (percent)
Full dent	72–68
Half milk line	68–62
Black layer	60–50

Once harvesting has begun, fill the silo as rapidly as possible and continue until it is full. Continue to evaluate processed corn throughout the harvest season. Kernels should be broken into multiple pieces, and cobs should be broken into thumbnail-sized or smaller pieces. As the crop matures after half milk line, it may be desirable to have more kernel breakage so that much of the grain is in the bottom pan of the particle size separator.

One desirable method of packing bunker silos is the progressive wedge method, where silage is continually packed on a 30 to 40 percent grade. This minimizes the surface area that can be exposed to the air and result in dry matter and forage quality losses. If this is not possible, then silos should be packed by spreading relatively thin layers of silage (6 inches deep) and packing it well. If packed well, the silage should have a density of about 14 pounds of dry matter per cubic foot.

Ensiled High-Moisture Corn

The advantages of harvesting high-moisture corn include earlier harvesting, use of longer-season hybrids, and elimination of costs and delays associated with harvesting. Disadvantages include reduced marketing flexibility and higher storage and handling costs.

- Any good airtight storage structure can be used (oxygen-limiting silos, conventional upright silos, bags, bunkers, and trenches). An airtight seal over the top is recommended; additional reinforcement may be necessary.
- In general, ear corn must be ground before ensiling to increase compaction and to exclude air. The ideal whole-ear harvest moisture content is 32 percent; the recommended range is between 30 and 35 percent. The lowest moisture level at which to ensile ground ear corn is 28 percent; the upper moisture level is 40 percent. In bunker silos, high-moisture ear corn should be 34 to 40 percent moisture and packed thoroughly. The relationship of kernel moisture to total ear moisture is shown in Table 1.4-12. In upright silos, a distributor is recommended for preventing separation of cob and grain.

Table 1.4-12. Kernel/ear moisture relationship.

Kernel (percent)	Whole Ear (percent)
20	23
22	25
24	28
26	31
28	33
30	35
32	37
34	39

- An alternative to ground high-moisture ear corn is called snaplage. Snaplage is the whole ear (husk, cob, grain, and part of the shank) harvested with a silage harvester and snapper head between 35 and 40 percent moisture. This can result in about 10 to 15 percent more total digestible nutrients per acre compared to a grain harvest, and with improved ruminal digestibility compared to dry corn.
- Whole, shelled corn should be ground or rolled before ensiling, though satisfactory results can be achieved without grinding or rolling if the grain moisture content is ideal. The ideal kernel moisture is 28 percent; the recommended range is between 25 and 30 percent. The lowest ideal moisture level at which to ensile shelled corn is 25 percent; the upper limit is 33 percent. To prevent feeding losses of undigested whole kernels, grind or crush shelled corn as it is removed from the silo.
- High-moisture corn should be ensiled rapidly after harvesting. Loads left overnight or longer will begin to heat and spoil quickly. There is a greater potential for mold growth and a reduction in the bunk life of the material after unloading.

Ear and Dry Shelled Corn

Ear corn can be cribbed safely when the grain moisture is 21 percent or lower. However, with cold weather and narrow (4-foot), well-ventilated cribs, corn may be stored when the grain moisture is several percentage points higher. Monitoring the grain moisture of ear corn is an important management step. Storing ear corn when it is too wet can result in moldy corn and mycotoxin development.

Ear corn yields can be converted to a shelled corn basis using Table 1.4-13. For example, 4 tons (8,000 pounds) of ear corn at 21 percent grain moisture is equivalent to 8,000 divided by 77.60, or 103 bushels of shelled corn at 15.5 percent moisture.

An important part of the harvesting process is monitoring harvest losses. To estimate ear corn losses, determine the

Table 1.4-13. Weight of corn (shelled and ear) to equal 56 pounds (1 bushel) of shelled corn at 15.5 percent moisture.

Grain Moisture (percent)	Weight Shelled (pound)	Ear
11.0	53.17	66.04
11.5	53.47	66.50
12.0	53.77	66.97
12.5	54.08	67.46
13.0	54.39	67.97
13.5	54.71	68.49
14.0	55.02	69.02
14.5	55.35	69.57
15.0	55.67	70.13
15.5	56.00	70.70
16.0	56.33	71.28
16.5	56.67	71.87
17.0	57.01	72.47
17.5	57.36	73.09
18.0	57.71	73.71
18.5	58.06	74.34
19.0	58.42	74.98
19.5	58.78	75.62
20.0	59.15	76.28
20.5	59.52	76.94
21.0	59.90	77.60
21.5	60.28	78.27
22.0	60.67	78.94
22.5	61.06	79.62
23.0	61.45	80.31
23.5	61.86	80.99
24.0	62.26	81.68
24.5	62.68	82.37
25.0	63.09	83.06
25.5	63.52	83.75
26.0	63.95	84.44
26.5	64.38	85.14
27.0	64.82	85.83
27.5	65.27	86.53
28.0	65.72	87.22
28.5	66.18	87.91
29.0	66.65	88.61
29.5	67.12	89.30
30.0	67.60	90.00
30.5	68.09	90.69

Table 1.4-13. Weight of corn (shelled and ear) to equal 56 pounds (1 bushel) of shelled corn at 15.5 percent moisture (continued).

Grain Moisture (percent)	Weight Shelled (pound)	Ear
31.0	68.58	91.39
31.5	69.08	92.08
32.0	69.59	92.78
32.5	70.10	93.48
33.0	70.63	94.18

Test weight of corn determines the weight of a bushel volume (1.244 cubic feet) of grain. Test weights determined on dry corn (15.5 percent moisture) can indicate whether the grain crop reached full maturity. Low test weights indicate immaturity. If bushel test weight of mature corn is determined at harvest, when grain moistures are greater than 15.5 percent, test weights will be biased downward. In other words, as corn grain dries, test weight goes up. The adjustments in test weights do not apply if (a) grain contains more than 10 percent broken kernels, (b) grain was damaged by drought or disease, (c) grain was harvested when immature, or (d) grain was dried at air temperatures of 180°F or higher.

number of full-sized (¾-pound) ears on the ground in 1/100 acre. Each of these ears in the sample represents 1 bushel per acre. For 30-inch rows, a 1/100 acre sample is two rows wide and 87.1 feet long. For 36-inch rows, the same sample is 72.6 feet long.

To estimate shelled corn losses, determine the number of kernels in a 10-square-foot area. Every 20 kernels in this area represent 1 bushel per acre. A useful tool is a rectangular wire frame 30 inches by 48 inches (10 square feet) that can be carried in the combine and used to measure losses. Be sure to include both ear and shelled corn in your harvest loss estimate. Ear corn losses from in front of the combine (preharvest losses) should be subtracted from your total harvest loss estimate.

Consider the effects of timeliness on harvest losses. Estimates of harvest losses based on long-term average data at Purdue University indicate that losses increase by 1 to 2 percent for each week that harvest is delayed. A USDA study showed harvest losses increasing threefold from October until December (Table 1.4-14).

Monitor debris and cracked corn in the grain as harvesting progresses. Debris and cracked corn can lower grain quality and increase the potential for spoilage of stored corn.

Shrink factors and discounts used by commercial elevators buying corn vary and will always be higher than the shrink due to moisture alone, to include dry matter losses during handling of the grain. For example, the moisture shrinkage on an 850-bushel load of corn at 23 percent moisture content (MC) being dried to 15 percent is:

850 × (1 - MC initial / 1 - MC final) or
850 × (77 / 85) = 770 bushels at 15 percent MC
(850 - 770) / 850= 9.4 percent shrinkage due to moisture

Table 1.4-14. Average field losses due to delayed harvest from tests in Illinois, Indiana, Iowa, and Nebraska over several seasons.

	Loss from Harvesting (percent)		
	October	November	December
Machine loss	4.6	7.0	11.8
Total loss	5.0	8.4	18.4

Source: V. W. Davis, USDA.

Using an example commercial shrinkage rate of 1.4 percent per unit of moisture removed would result in a total shrinkage of 11.2 percent, with a resulting net weight of 754 bushels. In this case, the producer would be paid on the basis of 754 bushels.

Drying charges and final moisture contents can also vary. These should be considered in marketing corn. Estimate the net value of your corn, considering discount schedules at several elevators, before deciding where to market wet corn. It is important to realize that the advertised per-bushel price is only one factor influencing the net income from a load of corn. There are no standards regarding shrinkage rates applied to corn. Higher shrinkage discounts essentially translate into a lower per-bushel corn price.

Other potential costs that can be incurred during the marketing process include storage charges or discounts for broken corn and foreign material, foul or musty odors, and low test weight.

To find the approximate number of bushels of shelled corn grain in a bin, multiply the number of cubic feet in the bin by 0.8. To estimate the number of bushels of shelled corn in a crib of ear corn, multiply the number of cubic feet in the crib by 0.4.

Test Weight

Test weight of corn determines the weight of a bushel volume (1.244 cubic feet) of grain. Test weights determined on dry corn (15.5 percent moisture) can indicate whether the grain crop reached full maturity. Low test weights indicate immaturity. The minimum test weight for USDA No. 2 corn is 54 pounds per bushel. Test weights of wet corn are lower than those of corn that has been dried to 15.5 percent. In other words, as corn grain dries, test weight increases slightly.

For many classes of livestock, the feed value of corn with a low test weight is only slightly lower than that of corn with test weights of 54 pounds or more. A University of Minnesota study showed that corn with a test weight of 47 pounds had a TDN (total digestible nutrient) value that was 98 percent of normal (54 pounds per bushel) corn. Nevertheless, a low test weight is often a sign of immaturity, and corn with a low test weight is often docked because of higher transportation costs, lower quality for dry milling purposes, and a greater potential

for mycotoxins and storage problems. In some situations, it may be advantageous to keep low-test-weight corn separate and market or feed it to reduce dockage on the rest of the crop.

Test weight can be improved by avoiding late planting and selecting hybrids that have good test weight. Other practices that can help improve the test weight of corn include segregating low-test-weight grain in separate storage facilities, drying grain at lower temperatures, and cleaning grain going into or coming out of storage.

Part I, Section 5

Grain Sorghum

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Grain sorghum, or milo, is grown on a limited basis in Pennsylvania; however, it is widely grown and used in many of the Great Plains states. In Pennsylvania, sorghum is cultivated for use in birdseed, as a component of poultry rations, and as a grain or silage crop for swine or cattle feed.

Sorghum's main advantages are that it has more drought tolerance, suffers less damage from deer, and costs substantially less to establish than corn. Disadvantages include a lack of established markets, slightly lower yield and feed quality compared to corn, and fewer herbicides available for weed control. Sorghum yields of 80 to 100 bushels per acre are common—under good conditions, yields of more than 150 bushels per acre are possible.

Varieties

Plant certified seed of adapted hybrids. Do not use bin-run seed because it lacks hybrid vigor and is of unknown quality. In addition to yield potential, maturity is of primary importance in selecting a hybrid that produces mature, dry grain during a normal growing season for a particular area.

Sorghum hybrids are classified into maturity groupings such as medium-full, medium, medium-early, and early. For Pennsylvania, in corn maturity zones 3 and 4, medium maturity hybrids are adapted to full-season production (see Figure 1.4-1 in Part I, Section 4 of this guide). Early medium and early sorghum hybrids should be grown in corn maturity zones 2 and 1, respectively. Try not to select a hybrid that is too late, as harvesting becomes difficult if the crop gets frosted before maturity.

Determine market availability if you plan on seeding a bird-resistant hybrid. Most available hybrids are not bird resistant, but it is wise to confirm this with your seed dealer before planting.

Nutritional Requirements

Apply limestone and fertilizer the same as you would for small grains. Apply 60 to 90 pounds of nitrogen at planting or at sidedress. Make sidedress applications before the five-leaf stage. See Part I, Section 2 of this guide for more information.

Establishment

Sorghum can be planted with a drill or planter. Drilled sorghum may have a modest yield advantage of 10 percent or so in high-yield environments (more than 100 bushels per acre) or in double-crop scenarios. However, in many situations, yields are similar with wide and narrow rows. Sorghum can be established successfully using no-tillage with either a no-till grain drill or a corn planter. Planters provide improved seed depth and seed singulation, which can result in improved stands in no-till or high-residue conditions. If a grain drill is used, selected feed cups may need to be closed to achieve the low seeding rates necessary. With a corn planter, use special sorghum seed cups or plates.

Plant when soil temperature at 3-inch depth at 8:00 a.m. is warmer than 60°F, generally about one or two weeks after normal corn planting time. Planting too early can result in poor emergence and some chilling injury to the seed. Plant about 1 inch deep and strive to maintain good seed-to-soil contact. Sorghum can also be double-cropped following barley or early harvested wheat with the appropriate maturity hybrid.

Sorghum does well under a wide range of plant populations. For full-season production, a seeding rate of about 80,000 seeds per acre is near ideal. Under droughty or double-crop conditions, lower seeding rates of 50,000 to 60,000 seeds per acre can help improve yields and reduce drought stress and related delayed maturity.

Harvesting

Sorghum can be harvested at 25 to 30 percent moisture for storage as high-moisture grain; however, harvest losses due to unthreshed heads are likely to be higher. Kernels are more likely to be damaged at higher moisture contents, although this is not a concern when grain is to be fed on the farm.

Ideally, sorghum to be marketed should be harvested with a grain combine when grain moisture is 20 percent or less. In many cases, a frost is necessary to reduce grain moisture to this level. Harvest losses for sorghum are usually higher than for corn and may average 5 to 10 percent. If harvest losses are above 10 percent, check the combine adjustment. Seventeen kernels per square foot is a loss of approximately one bushel per acre. Do not delay harvest much beyond the first hard frost—the potential for deer and bird damage increases dramatically.

Plan on drying grain most years. Store grain at 13.5 percent moisture. Drying air temperatures for sorghum and corn are essentially the same, but sorghum takes longer to dry. Sorghum drying and cooling rates are about ⅔ to ¾ greater than those of corn because sorghum grain packs tighter than corn grain, resulting in less air space in the grain mass and more resistance to airflow. Do not increase the heat level to speed up drying.

Grain sorghum can also be harvested as silage. Grain sorghum makes an excellent silage, comparable in quality to corn and slightly better than forage sorghum silage. Harvest at the soft to medium dough stage. A reasonable yield goal for grain sorghum types is 10 to 15 tons per acre. Higher yields can be obtained with forage sorghums, but energy content of the silage can be lower. Sorghum heads can also be chopped and ensiled to produce a silage similar to ground ear corn in composition and value. Some producers will harvest the green crop residue after combining for grain for use as cattle feed.

Special Considerations

When feeding grain sorghum, grind to medium fineness. All grain sorghum types are about equal to corn or barley in feeding value for cattle. In grain rations for cattle, sorghum grain should make up no more than one-half the ration. For poultry rations, use no more than 10 percent of the bird-resistant (dark seed coat) types; when using them in place of yellow corn, an additional source of xanthophyll pigments must be added to maintain proper skin and egg yolk color. When using grain sorghum in poultry and swine rations, some adjustments may need to be made to balance protein, mineral, and amino acid content.

Sorghum yields better than corn in dry years and on droughty soils. In variety trials conducted at the Southeast Agricultural Research and Extension Center in Landisville, Pennsylvania, corn and sorghum yields were 150 and 135 bushels, respectively, in a good growing season and 60 and 90 bushels, respectively, in a drought year. Consider sorghum for dry soils where corn yields are, on average, 125 bushels per acre or less.

Part I, Section 6

Soybean

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Soybean acreage has increased rapidly over the last 20 years, from approximately 60,000 to more than 600,000 acres. There are several reasons for the rising interest in soybean production: (1) producers have learned they can grow the crop successfully, (2) a growing export demand has created markets with good prices, (3) effects of rotation, which improves the yield of the succeeding crop, (4) a recognition that soybean is an excellent source of farm-grown protein, and (5) the availability of glyphosate-tolerant varieties, which simplify weed control. Soybean is basically a cash crop, but the acreage being used as a farm-grown protein source is increasing yearly.

Soybean has two types of growth habit, determinant and indeterminate (Figure 1.6-1). Determinant types stop vegetative growth once reproductive development starts. Indeterminate types, on the other hand, continue vegetative growth after reproductive growth begins. Varieties grown in Pennsylvania show the indeterminate character, whereas the determinant character is common in varieties grown in the southern United States. This difference in growth habit is one of the main reasons row spacing and population recommendations differ between northern and southern growing areas.

As is true for other grain crops, soybean growth and development are influenced by temperature. However, soybean is very sensitive to photoperiod, or daylength, and does not move from vegetative to reproductive growth until a critical daylength is met. This requirement restricts a variety's adaptability to a band about 150 miles north and south of its origin. Daylength does not restrict the adaptability of varieties planted at the same latitude (east and west). Soybean varieties are placed in one of 12 maturity groups. These range from 00 in the north (Canada) to 10 in the south (Florida). Since Pennsylvania falls within the same latitudes as the major growing areas of the Midwest, our growers have access to the same varieties. These include varieties in maturity groups II, III, and early IV.

Soybean is classed as an oilseed crop, but the seed contains twice as much protein as oil (40 percent protein versus 20 percent oil).

Varieties

Selecting a variety for proper maturity, disease tolerance, standability, and yield performance is essential for successful soybean production. Maturity is identified by maturity groups, as described above. Figure 1.6-2 shows suggested maturity groups for each county in Pennsylvania. There is a trend in the seed industry to include a variety's relative maturity as the first two numbers of its name. For example, company ABC would name a late group III as ABC 3850 (relative maturity 3.8), whereas an early group III would be ABC 3125 (relative maturity 3.1).

Soybean varieties are developed mostly by private industry. Nearly all the soybean grown in Pennsylvania is transgenic. Most of these soybeans are glyphosate tolerant, although other traits, such as resistance to glufosinate, dicamba, and 2,4-D, appear to be increasing in use. For more information, see the section on soybean pest management. Non-transgenic soybean is available from most seed companies and is often targeted for production in non-GMO markets. Performance data for many of these varieties are

Figure 1.6-1. Soybean seedling.

Figure 1.6-2. Soybean maturity groups for Pennsylvania.

reported in the annual "Soybean Variety Trials Reports," available online at extension.psu.edu.

Poor-quality seed may limit yield and crop performance because of low germination, excessive foreign material, weed seed, and seed of other varieties or crops. Soybean seed is sensitive to rough handling and storage conditions. Bin-run grain should not be used for seed since most seed is now transgenic and saving the seed from these varieties is illegal. Even for conventional varieties, the practice is not likely to be profitable. Stud- ies comparing high-quality seed with bin-run seed indicate that high-quality seed has a yield advantage of approximately 3 bushels per acre. Certified seed offers the best assurance of quality. When using uncertified seed, make sure the seed has been cleaned and that germination and purity tests have been conducted.

Nutritional Requirements

Determine lime and fertilizer needs by soil test. Soybean in rotation can make use of fertilizer applied to the previous crop; however, this does not eliminate the need for a sound fertility program. Maintaining a pH between 6.0 and 6.5 is critical. Maintaining adequate soil potassium levels is also critical since potassium deficiency is common in soybean. In the absence of a soil test, refer to the most recent soil test available for the field; see information for soybean in Part I, Section 2: Soil Fertility Management. Apply fertilizer before seeding or band at least 2 inches to the side of seed at planting. Do not drill fertilizer with the seed or use "pop-up" fertilizer.

Soybean that has been properly inoculated with the nitrogen-fixing bacteria *Bradyrhizobia japonicum* rarely responds to nitrogen fertilization. If the previous year's crop was not soybean, inoculate seed with fresh, viable, nitrogen-fixing bacteria immediately before planting. Recent research results indicate a 70 percent chance for a yield increase of 2 bushels per acre when inoculating seed planted into fields growing soybean every other year. If soybean has not previously been grown in the field, consider using a triple inoculant rate or two different inoculants (for example, preinoculated seed and a peat-based inoculant) to ensure adequate nodulation. Be especially careful to handle inoculants or preinoculated seed to avoid reducing viability of the bacterial inoculum by exposing them to hot or freezing temperatures. Monitor these first-year fields for nodulation; if nodulation is less than desired (fewer than five to seven nodules on the taproot two weeks after emergence), consider applying nitrogen to these fields as soon as possible, before grain fill begins. Usually, about 75 pounds of nitrogen is adequate to maintain good yields on nonnodulated soybean fields. For more information, see "Agronomy Facts 11: Inoculation of Forage and Grain Legumes" at extension.psu.edu.

If pH is below 6.0 and will not be corrected with lime, consider applying molybdenum as a seed treatment at planting. This helps ensure proper nitrogen fixation and may slightly improve yields.

Establishment

Soybean seed requires more water for germination than seeds of many other grain crops; therefore, planting in soils with adequate soil moisture is ideal. In addition to adequate soil moisture, there should be good seed-to-soil contact to ensure adequate water movement into seeds.

Soybean can be established with any tillage-planting system (row crop or grain drill). Seed should be placed 1 to 1.25 inches deep. Planting too deep will result in poor emergence. Planters should be adjusted so that the seed depth is as uniform as possible.

In tilled systems, some soils are prone to crusting. If soil forms a crust before soybean plants emerge, break it with a rotary hoe or spike-tooth harrow. Harrow very shallowly.

Full-season soybean can be planted on 30-, 15-, or 7-inch rows, depending on available equipment. The yield difference between wide rows (30 inches) and narrow rows (7 inches) is minimal when planting in late April and early May. As the planting date is delayed past mid-May, the yield advantage for narrow rows increases. Planting soybean with a planter has several advantages in our cropping system. Planters can manage residue better than drills and help to improve emergence rates, reduce slug damage, and lower the potential for crusting in tilled soils. With improved emergence rates, seeding rates can be reduced with planters. Double-crop soybean should be planted in approximately 15-inch rows or narrower, or as narrow as your equipment allows.

Plant soybean based on seeds per acre rather than pounds of seed per acre. Seed size can vary from 1,800 to 3,000 seeds per pound, with an average of about 2,500 per pound.

The optimal final plant population for full-season plantings is 100,000 to 125,000 plants per acre. This increases to 200,000 in double-crop plantings in late June and early July. Seeding rates are a function of the potential germination and emergence rates. Estimate the seeding rate or plant populations per foot of row using the data in Table 1.6-1. An alternate method for estimating soybean population is to count the number of plants inside a hoop of varying dimensions; use the data in Table 1.6-2. The number of seeds planted per foot of row is based on 85 percent germination and an optimal population of approximately 150,000 plants per acre for full-season soybean and 200,000 plants per acre for double-cropped soybean. The seeding rates shown in Table 1.6-1 are adequate for seeding under ideal conditions with seed at 85 percent germination. First, adjust the seeding rates based

Table 1.6-1. Seeding rates and plant population estimates for soybean in full-season, full-season and low-risk, and double-crop scenarios.

	Number of Seeds Planted per Foot of Row[1]			Number of Plants per Foot of Row		
Row width (inches)	Full-season[2]	Full-season, low-risk[3]	Double-crop	Full-season	Full-season, low-risk	Double-crop
7	2.4	1.9	3.2	2.0	1.6	2.7
10	3.4	2.7	4.5	2.9	2.3	3.8
14	4.7	3.8	6.3	4.0	3.2	5.4
15	5.1	4.1	6.8	4.3	3.4	5.7
20	6.8	5.4	9.0[4]	5.7	4.6	7.7[4]
30	10.1	8.1	13.5[4]	8.6	6.9	11.5[4]

[1] Based on 85 percent germination (full-season = 176,000 seeds per acre; double-crop = 235,000 seeds per acre).
[2] Full-season = 150,000 plants per acre; double-crop = 200,000 plants per acre.
[3] Full-season, low-risk = target population of 120,000 plants per acre (see text for explanation).
[4] Double-crop soybeans should be planted in row widths of 15 inches or closer.

on germination of the seed. Then, consider increasing the seeding rate by:

- 10 percent for rough seedbeds
- 10 percent for short-season varieties
- 10 percent for cold soils

Similarly, consider decreasing the seeding rate per acre by:

- 10 percent if lodging has been a problem
- 10 percent if planting a lodging-susceptible variety

Because of improved emergence rates and higher seed costs, some soybean producers are reducing seeding rates. Lower target plant populations of 100,000 to 120,000 plants per acre at maturity may be most appropriate for full-season soybean producers who have a history of good emergence rates, low risk of slug damage, good planting equipment, quality seed, and relatively productive soils. Where poorer emergence or below-average canopy development is possible, reducing soybean seeding rates can pose some risks and result in lower yields. Under these conditions, planting rates of 140,000 seeds per acre can result in sufficient stands for high yields. In double-crop situations, some producers have also reduced seeding rates to 175,000, utilizing 15-inch planters that place seed at a more uniform depth than drills, and report very good yields. Recommended seeding rates for drilled double-crop beans remain near 200,000 or slightly greater, depending on anticipated growing conditions. Research to fine-tune these recommendations continues.

To avoid overplanting, calibrate planters carefully. One extra seed per foot of row equates to approximately 75,000 additional seeds per acre when planting in 7-inch rows.

Studies suggest that soybean plants have a tremendous ability to compensate for missing plants. They do this by developing more branches and setting more pods, overcoming any potential yield loss from missing plants. Reduced yield resulting from poor stands may still be more profitable than replanting a field, which incurs additional costs and means a lower yield potential because of the later planting date.

Table 1.6-2. Conversion factors for calculating plant populations per acre from plant counts inside a hoop.

Hoop Diameter (inches)*	Conversion Factor
28	10,187
30	8,874
32	7,799
34	6,609
36	6,162

*For other sizes, you can estimate the area of a circle in feet and then divide the number of square feet in an acre by the area of the circle to determine the conversion factor. For example, in a 24-inch (2-foot) hoop, the area would be equal to $\pi \times r2$ where $\pi = 3.14$ and $r = 1$, or 3.14×12, or 3.14 square feet. Dividing 43,560 by 3.14 results in a conversion factor of 13,872.

The optimal date for planting soybean is similar to corn. However, because delayed planting reduces corn yield much more than soybean yield and soybean is more sensitive to early season stress and frost, corn should generally be planted first. Once corn planting is finished, do not delay soybean planting. Planting in dry, tilled soils can pose some risk for uneven emergence. Waiting for a rain event in these situations can improve emergence, but it can also result in significant planting delays. Eliminating tillage can also help avoid this situation.

No-Tillage

The use of no-tillage continues to increase, as soybean is very adaptable to no-till systems. On sites with long slopes, no-till planting into corn residue is suggested for adequate erosion control in corn-soybean and corn-soybean-small grain rotations. Heavy corn residue can be problematic in achieving

good, uniform seed-to-soil contact, and lower emergence rates can occur, especially with no-till drills. Slugs can also be a significant factor under some high-residue conditions. Harvesting some of the stover or using vertical tillage to process the stover can reduce these problems. Proper planter adjustment is the key to successful establishment in conservation tillage planting systems.

Replant Decisions

Deciding to replant a soybean crop is difficult and involves many interacting factors: plant response to reduced plant populations, calendar date, variability of existing plant stand, cost/price relationships, and the potential yield of the existing stand versus the potential yield of the replant stand.

When making a replant decision, follow a set procedure that includes these factors:

1. Identify the cause of the stand reduction and whether it will be a problem when the field is replanted. Take steps to correct the problem before replanting.
2. Estimate the yield of a full stand at the original planting date.
3. Determine the population and distribution of the existing stand.
4. Estimate the yield potential of the reduced stand. Often, the stand is not uniform and the impact of patches or gaps in the rows would likely be greater than the population effect itself. Based on Midwest data, yields will not decline appreciably until stands drop below 60,000 plants per acre (Table 1.6-3). In one study, the impact of gaps lowered the yield potential of a stand with 70,000 plants per acre from 95 to 73 percent of normal (Table 1.6-4). One technique suggests estimating the number of gaps (at least one half-pace long) encountered in several row sections consisting of 20 typical paces each. Add up the number of paces in half- or full-pace gaps and estimate the percentage of the total number of paces in your sample. Then refer to Table 1.6-4 for your yield-loss estimate.
5. Estimate any additional costs associated with keeping the stand. A thin stand may require an additional postemergence herbicide application.
6. Estimate the yield potential of a replanted full stand (Table 1.6-5) later in the season.
7. Estimate the cost of replanting.
8. Compare the value of reduced stand to replanted stand. For example, assume the following:
   - Estimated yield of full stand at original planting date is 50 bushels per acre.
   - Average percent of row lost to gaps is 50 percent.
   - The average plant population is 70,000 plants per acre.

Table 1.6-3. Yield potential (% of optimum yield) depending on plant population and row spacing.

Population	Drilled (7.5-inch rows)	Planter (30-inch rows)
160,000	100	100
120,000	100	100
80,000	96	100
60,000	92	94
40,000	87	88
20,000	77	81
10,000	58	72

Source: Adapted from *Corn and Soybean Field Guide* (Purdue Extension, 2010).

Table 1.6-4. Yield response of full-season soybean to deficient stands.

	Plants per Acre (× 1,000)		
Stand Lost to Gaps (percent)	140	105	70
0	100	97	95
10	98	96	93
20	96	93	91
30	93	90	88
40	89	86	83
50	84	81	78
60	78	75	73

Source: University of Illinois.

Table 1.6-5. Approximate yield response of soybean to changes in planting date.

Date	Full Yield Potential (percent)
May 10	100
May 20	98
May 30	95
June 10	88
June 20	76
June 30*	70
July 10*	60

*Relevant only in areas where double cropping is practiced.
Source: Developed from Ohio, Indiana, Minnesota, and Pennsylvania data.

From Table 1.6-4, the estimated yield from the reduced stand would be 39 (50 × 0.78) bushels per acre.

The estimated yield from planting can be obtained from Table 1.6-5. Assume the original planting occurred on May 12, and the stand was evaluated on June 4 and could be replanted on June 5. The estimated yield would be

Table 1.6-6. Soybean growth stage descriptions.

Vegetative Stages	
Stage Number	*Description*
VE	Emergence; cotyledons visible
VC	Unifoliate leaves unrolled
V1	First trifoliate leaf unrolled; one set of trifoliate leaves
V2	Two sets of trifoliate leaves unrolled
V3	Three sets of trifoliate leaves
V(N)	n sets of trifoliate leaves unrolled

Reproductive Stages	
Stage Number	*Description*
R1	One flower at any node
R2	Flower at node immediately below the node with a completely unrolled leaf
R3	Pod is 1/2 cm (3/16 inch) long at one of the four uppermost nodes with a completely unrolled leaf
R4	Pod is 2 cm (3/4 inch) long at one of the four uppermost nodes with a completely unrolled leaf
R5	Seeds beginning to develop (can be felt by squeezing or are at least 1/8 inch long) at one of the four uppermost nodes with a completely unrolled leaf
R6	Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes with a completely unrolled leaf
R7	Pods yellowing (one normal pod on the main stem that has reached its mature pod color: brown or tan)
R8	95 percent of the pods have reached their mature pod color, approximately 5 to 10 days prior to harvest

approximately 45 bushels per acre, or 6 bushels per acre more than not replanting. Remember that the cost of replanting must be considered, and there is no guarantee that replanting will give a full stand.

Another alternative is to fill in an existing stand to bring it up to an ideal population. This would require less seed. Be sure to include some consideration of the plants lost in the replanting process. Soybean planted into an existing stand has far fewer negative effects than corn planted into an existing stand. If possible, repairing a planting with a planter rather than a drill may cause less damage to the stand.

Forage Production

Interest in using soybean for supplemental forage has increased over the past few years. The best varieties for forage soybean are generally late maturity (group V) soybean or varieties specifically developed for forage by the USDA-ARS (e.g., 'Tyrone'). The following are suggestions for growing soybean for forage:

- Seeding date: Early May to mid-July
- Seeding rate: 200,000 to 225,000 seeds per acre
- Row spacing: 7 to 30 inches; wider spacing can be used if planting in early May
- Seeding depth: 1.25 inches
- Fertilizer: Follow the soil test recommendations for soybean harvested for grain
- Herbicide use: Check the herbicide label for any restrictions on feeding to livestock
- Harvest date: Harvest during seed fill and before leaf drop; moisture will be between 70 and 75 percent

In most cases, forage soybean is used as a supplemental forage and planted following winter grain harvest. Soybean has also been planted following first cut in old alfalfa stands that will be rotated the following year.

Harvesting for Grain

Combine when moisture in the soybeans is 14 percent. Harvest may begin at a higher moisture content, but some drying will be required for safe storage. Delaying harvest to lower moisture contents may increase shattering losses and decrease seed quality.

Be very careful when harvesting. Four soybeans per square foot left in the field equals 1 bushel per acre. To keep harvest losses low:

- Drive slowly
- Check concave clearance
- Check cylinder speed
- Check sieves

- Check air velocity
- Synchronize ground speed and reel speed
- Leave a short stubble

Determination of Soybean Growth Stage

Knowledge of soybean growth stages is important to time pest scouting, apply certain pesticide sprays such as insecticides to control soybean aphid and foliar fungicides to control diseases, and document growth stage at the time of an injury event such as hail for insurance purposes.

Soybean growth stages are based on the vegetative (leaves and nodes) and reproductive (flowers, pods, and seeds) development of the plant and designated with the letters V and R. The V (vegetative) stages refer to the number of nodes with a fully expanded leaf. A leaf is considered fully expanded when the leaflets of the next node have unrolled far enough so that their edges are not touching. The vegetative stage is determined by counting the number of nodes—starting at the unifoliate leaf—that have fully expanded leaves.

For example, plants in the unifoliate stage are designated VC, plants with one trifoliate set of leaves unfolded are V1, and plants with five nodes with completely unrolled leaves are in stage V5. For R (reproductive) stages, with the exception of stages R1 and R2, examine the reproductive structures on the upper four nodes that have fully unrolled leaves. Stage R1 indicates a flower present at any node. Stage R2 indicates a flower immediately below the node with the uppermost unrolled leaf. The stages progress through pod and seed development to yellowing and physiological maturity (Table 1.6-6). For a detailed description of soybean growth stages, visit Iowa State University's website at https://crops.extension.iastate.edu/soybean/production_growthstages.html.

Part I, Section 7

Small Grains

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Spring Oat

Varieties

Choose a variety adapted to your area. On average, the later maturing varieties should not be grown in Area 3 (Figure 1.7-1) because low bushel weight and poor grain quality may result. The earlier varieties are best for the warmer areas and perform well in other areas of the state.

Poor-quality seed may limit yield and crop performance because of low germination (less than 85 percent), excessive foreign material, weed seed, and seed of other varieties or crops. Certified seed offers the best assurance of quality.

Spring oat varieties vary in yield, maturity, test weight, height, and lodging (Table 1.7-1). Spring oat performance tests are conducted annually at Cornell University. These results are available online at https://blogs.cornell.edu/varietytrials/small-grains-wheat-oats-barley-triticale/small-grains-cultivar-trial-results/.

Nutritional Requirements

Determine lime and fertilizer needs by soil test. Maintain a pH of 6.0 or above for oat seeded alone. Where legume seedings are made, maintain a pH between 6.5 and 7.0. In the absence of a soil test, refer to the most recent soil test available for the field; see Part I, Section 2 for more information. Spring nitrogen recommendations are given in Table 1.7-2. No adjustment is made to nitrogen recommendations for previous crops.

All the fertilizer may be broadcast prior to planting, or a portion can be applied with a drill and the remainder broadcast. To reduce fertilizer injury, do not apply more than 20 pounds (nitrogen) or 45 pounds (nitrogen + potash) per acre in the row with the seed.

Establishment

Spring oat is very sensitive to planting date and should be seeded early. As such, it is well adapted to no-till planting to avoid planting date delays. The target date for Area 1 (see Figure 1.7-1) is April 10–25; Area 2, April 1–15; and Area 3, March 15–30. Planting dates later than the above generally result in reduced yields. Plant seed 1 to 1.5 inches deep. Maintain a uniform seeding depth. The desired plant population for spring oat is 1.2 to 1.5 million per acre (28 to 34 plants per square foot). This requires a seeding rate of approximately 96 pounds per acre.

The seeding rate should be based on the number of seeds per acre rather than pounds per acre. Refer to Table 1.7-3 when estimating the appropriate seeding rate for various drill row spacings. Seeding rates shown in Table 1.7-3 are adequate if you are seeding under ideal conditions, but these rates should be increased for seeding under poor conditions such as a cloddy seedbed or a delayed planting date. Use only high-quality seed. Good stands are essential for high oat yields.

Figure 1.7-1. Small grain management areas in Pennsylvania.

Winter Barley

Varieties

Performance data are reported in the annual "Pennsylvania Barley and Winter Wheat Performance Trials" publication available from Penn State Extension county offices and online at extension.psu.edu. Winter barley varieties vary considerably in yield, maturity, and test weight. Hulless winter barley lines have lower yields but higher test weight and starch content. In hulless barley, the hull is not tightly attached to the bran and is removed from the grain during threshing. These were originally developed for the ethanol market and are now being used as a feed substitute for corn, particularly in poultry rations, as well as for human consumption.

Winter barley is less winter hardy than winter wheat. For this reason, winter survival is poor in most locations in Area 1 (see Figure 1.7-1). In Area 2, winter survival may be poor in approximately one year out of six, whereas in Area 3, winter survival should be adequate most years.

Poor-quality seed may limit yield and crop performance because of low germination (less than 85 percent), excessive foreign material, weed seed, and seed of other varieties or crops. Certified seed offers the best assurance of quality. Bin-run seed can be contaminated with weed seed and have lower than desired germination. Hulless barley can be damaged during combining and low germination tests can be common.

Nutritional Requirements

Determine lime and fertilizer needs by soil test. Maintain pH between 6.5 and 7.0. Winterkill may be more severe if pH is below 6.5 and/or phosphate availability is low. Barley responds to magnesium if the level in the soil is low. In the absence of a soil test, refer to the most recent soil test available

Table 1.7-1. Public spring oat varieties and their characteristics.

Recommended Variety	Management Area	Height	Maturity	Straw Strength	Yield	Bushel Weight	Barley Yellow Dwarf Virus Resistance
Blaze	All	Medium	Medium	3	5	4	3
Corral	All	Medium	Medium	5	5	5	5
Ogle	All	Medium	Medium	4	4	3	3
Rodeo	All	Medium tall	Medium late	4	5	3	2
Spurs	All	Medium short	Medium	5	5	5	3

See Figure 1.7-1 for small grain management area.
Ratings: 5 = best, 1 = poorest

Table 1.7-2. Spring nitrogen recommendations for small grains.

Small Grain	Nitrogen Recommendation (lb N/bu/A)	Typical Yield (bu/A)	Base Nitrogen Recommendation (lb N/A)
Winter wheat	1.0	60	60
Winter barley	0.8	80	60
Spring oats, spring barley	0.8	80	60

Base nitrogen recommendations for spring nitrogen are given for the typical yield; do not adjust for nitrogen applied in fall. This recommendation must be adjusted for different yields and residual nitrogen from manure applications. See Table 1.2-11.
For winter barley and winter wheat, if plants did not tiller well (reach growth stage 2) in the fall, topdress nitrogen by mid-March. Otherwise, topdress anytime up to growth stage 5. See Figure 1.7-2.
For spring oats and spring barley, not more than 20 pounds of nitrogen should be applied with the drill. Any additional nitrogen should be worked into the soil before planting.

Table 1.7-3. Small grain seed or plant densities expressed on a basis of square feet, plants per acre, or seeds per foot of row.

Seed or plant population		Plants or seeds per foot				
Per square foot	Millions/acre	6-inch row	7-inch row	7.5-inch row	8-inch row	10-inch row
24	1.05	12	14	15	16	20
26	1.13	13	15	16	17	22
28	1.22	14	16	18	19	23
30	1.31	15	18	19	20	25
32	1.39	16	19	20	21	27
34	1.48	17	20	21	23	28
36	1.57	18	21	23	24	30
38	1.66	19	22	24	25	32
40	1.74	20	23	25	27	33

For example, assuming 85 percent emergence, a target population of 1.3 million plants per acre (30 plants per square foot) would require 1.5 million seeds per acre, or 20 seeds per foot in 7-inch rows.

for the field; see Part I, Section 2 for more information. Spring nitrogen recommendations are given in Table 1.7-2.

Up to 20 pounds of nitrogen and all of the phosphorus and potassium may be broadcast before planting, or a portion can be applied with a drill and the remainder broadcast. To reduce fertilizer injury, do not apply more than 15 pounds (nitrogen) or 30 pounds (nitrogen + potash) per acre in the row with the seed.

Establishment

Ideally, seed winter barley between September 10 and 20 in Area 1, between September 15 and 25 in Area 2, and between

September 30 and October 5 in Area 3 (see Figure 1.7-1). In Area 3, winter barley could be seeded earlier, after September 20, if weather conditions are conducive. However, earlier seeded barley can be more susceptible to excessive fall growth, foliar disease development, and early heading and frost damage in the spring. Do not delay seeding because of dry soil. Seed 1 to 1.25 inches deep. Maintain a uniform seeding depth. Shallow seedings cause poor stands.

The desired population for winter barley is 1.2 to 1.5 million per acre (28 to 34 plants per square foot) This requires a seeding of approximately 96 pounds per acre. Hulless barley should be seeded at higher populations: at least 1.7 million and 2 million seeds per acre in high-yielding fields. The seeding rate should be based on the number of seeds per acre rather than pounds per acre. Refer to Table 1.7-3 when estimating the appropriate seeding rate for various drill row spacings. Seeding rates shown in Table 1.7-3 are adequate if you are seeding under ideal conditions; however, the rates should be increased for seeding under poor conditions such as a cloddy seedbed or a delayed planting date. When seeding later than the suggested dates, increase the seeding rate 30 percent.

Satisfactory yields depend on having approximately 40 heads per linear foot of row when planted in 7-inch rows. To achieve this, you need a stand of approximately 17 plants per foot of row. Winter grain plants have the ability to increase tiller production as the population is reduced. This reduces the effect of low populations on yield. However, if about 50 percent of the stand is remaining, or eight to nine plants per linear foot of row, yield losses will be substantial, and it is advisable to plant another crop later in the spring.

Winter Wheat

Varieties

Performance data are reported in the annual "Pennsylvania Winter Wheat and Winter Barley Performance Tests" publication, available from Penn State Extension county offices and online at extension.psu.edu. Varieties vary considerably in yield, maturity, and disease resistance. By selecting high-yielding lines with good resistance to powdery mildew, fungicides can be delayed or eliminated. A bearded variety should be considered for fields heavily grazed by deer.

Poor-quality seed may limit yield and crop performance because of low germination (less than 85 percent), excessive foreign material, weed seed, and seed of other varieties or crops. Certified seed offers the best assurance of quality.

Nutritional Requirements

Determine lime and fertilizer needs by soil test. Maintain pH between 6.0 and 7.0. Winterkill may be more severe if pH is below 6.0 and/or phosphate availability is low. In the absence of a soil test, refer to the most recent soil test available for the field; see Part I, Section 2 for more information. Spring nitrogen recommendations are given in Table 1.7-2. If plants did not tiller well (reach growth stage 2) in the fall, topdress nitrogen at "greenup" in late winter or early spring. Otherwise, topdress anytime up to growth stage 5 (Figure 1.7-2). Split nitrogen applications, with one at greenup and one at GS 5-6, could help reduce the potential for lodging and losses in a wet spring. This would be especially valuable for a crop with high yield potential that was well tillered in the early spring.

Up to 20 pounds of nitrogen and all of the phosphorus and potassium may be broadcast prior to planting, or a portion can be applied with a drill and the remainder broadcast. To minimize fertilizer burn, do not apply more than 15 pounds (nitrogen) or 30 pounds (nitrogen + potash) per acre in the row with the seed.

Establishment

Ideally, seed winter wheat between September 20 and October 3 in Area 1, between September 25 and October 8 in Area 2, and between October 1 and October 15 in Area 3 (Figure 1.7-1). Seed 1 to 1.25 inches deep. Maintain a uniform seeding depth. The desired plant population for winter wheat is 1.3 to 1.5 million per acre (28 to 34 plants per square foot). This requires a seeding rate between 1.5 and 1.7 million seeds per acre, or 20 to 23 seeds per foot in a 7-inch row. Use the lower rates in Area 3 and the higher rates in Areas 1 and 2.

The seeding rate should be based on the number of seeds per acre rather than pounds per acre. Refer to Table 1.7-3 when estimating the appropriate seeding rate for various drill row spacings. Seeding rates shown in Table 1.7-3 are adequate if seeding under ideal conditions; increase these rates when seeding under poor conditions such as a cloddy seedbed or a delayed planting date. When seeding more than two weeks following the fly-free date (the date after which Hessian flies are not expected to be active; see Hessian fly fact sheet at https://ento.psu.edu/extension), increase the seeding rate by 10 percent for each week delayed past that date. Do not delay seeding winter wheat because of dry soil. If fall pasture is desired, plant one to two weeks earlier and apply 40 pounds of nitrogen per acre in addition to recommended fall rates. When grazing, allow the plants to accumulate 3 to 4 inches of top growth before going dormant in the fall. In the spring, remove the cattle before growth stage 6 (see Figure 1.7-2).

Satisfactory yields depend on having at least approximately 40 heads per linear foot of row when planted in 7-inch rows. To achieve this, you need a stand of approximately 17 plants per foot of row. Winter grain plants have the ability to increase tiller production as the population is reduced. This reduces the effect of low populations on yield. However, populations can be reduced enough that the land area should

Figure 1.7-2. Growth stages of cereals.

be replanted into another crop later in the spring. This occurs when there is about a 50 percent stand remaining, or seven to nine plants per linear foot of row.

Other Small Grains

Malting Barley

Malting barley varieties are available as both winter and spring, having been selected specifically for this purpose. When growing barley for a malthouse, it is important to identify a variety that is acceptable to the end user. Malting barley varieties can be used for feed if necessary. Many malting barley varieties are two-row types rather than the common six-row feed types that we grow in the state. Management is critical to harvest disease-free, viable seed. Consider applying a fungicide to manage head scab and harvest on a timely basis to avoid any preharvest sprouting. More details can be found in the Penn State Extension fact sheet on malting barley at extension.psu.edu/malting-barley-in-pennsylvania.

Spring Barley

Spring barley is often stressed from heat and drought and is best adapted to Area 1 (see Figure 1.7-1). Yields are often about 60 percent of winter barley when grown under the same conditions in longer-season areas. Compared to spring oats, spring barley is less tolerant of low pH and poorly drained soils. Recent varieties such as Benefit, Bailey, Stephen, and Ontario have performed satisfactorily in Pennsylvania. Refer to performance information from Cornell University (https://blogs.cornell.edu/varietytrials/small-grains-wheat-oats-barley-triticale/small-grains-cultivar-trial-results/) for information on these and other varieties. The desired plant population for spring barley is 1.2 to 1.5 million per acre (28 to 34 plants per square foot). This requires a seeding rate of approximately 96 pounds per acre. The seeding rate should be based on the number of seeds per acre rather than pounds per acre. Refer to Table 1.7-3 when estimating the approximate seeding rate for various drill row spacings. Follow the spring oat recommendations for all other management requirements.

Spring Wheat

Yields and test weights are often low for spring wheat compared to winter wheats. Spring wheat is usually a hard red spring type that is not marketable in our conventional soft red winter wheat markets. It could be used to make a high-protein bread flour if there was a potential market. The variety Glenn has shown to be one of the earlier and better yielding spring wheats in our region. Refer to performance

information from Cornell University (https://blogs.cornell.edu/varietytrials/small-grains-wheat-oats-barley-triticale/small-grains-cultivar-trial-results/) for information on spring wheat varieties.

Buckwheat

Generally, buckwheat is grown under contract and varieties are specified by the processor. Current varieties available include Koto, Manisoba, Manor, and Keukett, along with common buckwheat.

Buckwheat is adapted to central and northern Pennsylvania where summer nights are cool. Buckwheat requires approximately 1,300 GDDs (86/50) to mature from planting to harvest. Optimum sowing dates for buckwheat are generally about 12 weeks prior to the first frost, or late June to early July in many areas. In some areas, buckwheat can be double-cropped following winter wheat. Plant at 0.5 to 1 inch deep and sow at 40 to 55 pounds per acre.

Ideally, maintain a pH between 6.0 and 6.5, but buckwheat can tolerate more acidic soils and produce reasonable yields at pH 5.5 to 6.0. Typical nutrient requirements are minimal for buckwheat with no fertilizer required on many high-testing soils. On lower testing soils, 15 to 20 pounds of nitrogen, 25 to 30 pounds of P_2O_5 and 0 to 20 pounds of K_2O can be applied.

Plan to harvest when three-quarters of the seeds are ripe (brown and hard). Windrowing for seven to ten days prior to harvest can decrease shattering losses and increase yields.

Yields of 20 to 30 bushels per acre are possible.

Winter Oats

Winter survival of winter oat lines has been erratic. Consequently, winter oat production is not recommended in Pennsylvania.

Winter Rye

Rye is a very adaptable and winter-hardy grain that is rarely grown for grain in Pennsylvania. It can be planted from September to December and still produce straw and grain. If high grain yields are desired, then selecting a variety with higher grain yield potential would be ideal. The traditional variety Danko is one example; an even higher-yielding option is one of the new hybrid rye varieties like Brasetto. These are later maturing than much of the early cover crop rye varieties but have much higher grain yields of up to 100 bushels per acre. Winter varieties cannot be planted in spring and harvested for grain or straw. Earlier planting generally results in higher yields. Rye is frequently grown as a cover crop or for forage or straw. Typical seeding rates for rye are 2 bushels per acre (112 pounds per acre), increasing to 2.5 bushels per acre for late seeding. Fertilizer requirements are similar to wheat, with recommended nitrogen rates of 50 to 90 pounds per acre, depending on yield potential. Rates near the upper end of this range may result in lodging if harvested for grain. For the hybrid rye, lower seeding rates and higher nitrogen rates are often recommended. Check with your seed supplier for details.

Winter Triticale

Triticale is a feed grain originally derived from a cross between rye and wheat. Several commercial varieties are available. The crop can be used for feed grain or forage production. It can be cut about a week later than rye for forage chopping. Varieties are generally taller and higher yielding than wheat for forage. The grain can be used as a substitute for corn in swine ration, and it also has a higher lysine content than corn. Triticale grain can be fed to all classes of livestock and poultry. Manage winter triticale similar to winter wheat.

Spelt

A limited market exists for spelt: either for feed or as a substitute for wheat in some food products. Spelt is a relative of wheat. The growth habit is similar to soft red winter wheat and the hulls remain on the grain and compose 20 to 30 percent of the grain weight. The nutritional value is similar to oats. Seed similarly as for winter wheat at a seeding rate of 100 to 120 pounds of hulled seed per acre with a drill set for oats at 3 bushels per acre. Fertilize similar to winter wheat, with the exception that lower nitrogen rates (approximately 70 percent of wheat) may help reduce the lodging potential of taller varieties. Herbicides are generally not labeled for spelt, so manage to create a dense stand that competes with weeds. Expect yields in the range of 2,500 to 3,000 pounds per acre.

No-Tillage Small Grain Establishment

Each of the small grain crops can be established using no-till seedings. No-till is especially well suited for oats and spring barley seedings because these crops respond well to early planting and yield less when planting dates are delayed by tillage. Wheat and barley can also be no-tilled successfully, but they often experience slower growth and are at more risk for head scab, especially when planted into corn residue.

Pay particular attention to spreading residue evenly across the field to ensure good seed-to-soil contact. Some growers have reported more success in corn stalks from planting on an angle to existing rows to minimize residue problems and reduce residue buildup. Consider increasing seeding rates by 15 percent above those recommended for conventional tillage. Also, burn down any existing weeds prior to establishment.

Managing Small Grains for Forage

The use of small grains for forage has increased over the past few years. This practice provides a feed source when the quantity of stored feed is low and aids in manure management by providing another time to apply manure, and winter grains can utilize nitrogen available in the rooting zone during the fall and early spring, thus reducing the potential for nitrogen to move into groundwater.

Winter types of small grains such as wheat, rye, barley, and triticale can be grazed in the fall and harvested for silage in the spring. When used for pasture, they should be planted in mid-August to early September and can be utilized for grazing from October to late December and again in early spring. If the small grain is to be harvested for silage, grazing should be discontinued prior to growth stage 6 (Figure 1.7-2) in the spring. When fall and spring silage production is desired, a mixture of spring oat and a winter grain is suggested since it is difficult to harvest a winter grain for silage prior to growth stage 6. Spring oat also can be seeded in mid-August for fall grazing or silage production.

Recent research indicates that it is best to harvest small grains for hay or silage between flag leaf emergence and the boot (growth stage 9). In most years, rye is ready in late April, barley in early May, and wheat and triticale in early to mid-May. Winter barley can also be direct cut for silage at the soft dough stage. There is only a narrow window to harvest before the crop becomes too dry. Triticale is becoming a popular alternative to rye because it is later maturing, high yielding, and has higher forage quality than rye. Monitor moisture carefully and then harvest rapidly. These crops can produce silage with an energy level slightly lower than corn silage (60 to 65 percent TDN). The potential harvest date is a major consideration in choosing which winter grain to grow for silage. The date should be matched to spring workload and labor availability. Grain or forage crops can be seeded after harvest.

Spring-seeded small grains can also be used for forage. Seed early (mid- to late March). Mixtures of spring grains and peas are available and should also be seeded early. Harvest at head emergence (growth stage 10), which is in early June. Grain or forage crops can be seeded after harvest. Spring oats can also be seeded in the late summer for supplemental forage. This can produce a high-quality forage crop in the fall. Oats can also be mixed with a winter grain, like rye or triticale, or annual ryegrass to provide forage in the following spring as well.

When planting small grains for forage, increase the seeding rate 30 percent. Follow the other management practices for growing small grains for grain. Use adequate nitrogen to promote tillering and achieve adequate protein in the crop. This will usually require 60 to 100 pounds of nitrogen per acre depending on the history of manure applications on the field.

Harvesting Small Grains

Cut when grain contains 14 percent or less moisture. Delaying harvest after grain has reached the desired harvest moisture and allowing it to rewet with showers or dew reduces bushel weight and grain quality in general. This is a major factor in low bushel weights. For wheat, harvesting at 17 to 18 percent moisture and drying can be an effective tactic for improving grain quality and aid in completing harvest earlier. Moisture content for storage should be 12 percent or lower. Avoid excessive cylinder speeds on combines to reduce the amount of broken kernels in the grain. Scouting fields for head scab and adjusting the combine to blow out chaffy kernels is one potential tactic to limit vomitoxin contamination in the grain.

Part I, Section 8

Forages

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The forage industry is a major agricultural enterprise in Pennsylvania and the northeastern United States. Forage crops constitute the major feed component of livestock diets, making forages the backbone of Pennsylvania's agriculture and rural economy.

Pennsylvania produces nearly 12 million tons of forage each year and ranks seventh among all states in forage production. It produces 5.1 million tons of hay annually on nearly 1.5 million acres. Alfalfa is the state's largest single forage crop, comprising slightly over 500,000 acres and more than one-half of total hay production. Pastures make up over 2.6 million acres in Pennsylvania.

Forages are environmentally friendly in that they can reduce soil erosion, pesticide usage, and fertilizer application. In addition, forages can improve soil structure, increase soil organic matter levels, and enhance agricultural profitability. Pennsylvania agriculture is synonymous with forages and their production and use. You can find more information about Pennsylvania forages at www.forages.psu.edu on the web.

Forages for Hay and Silage

Alfalfa

Alfalfa has the highest yield potential of the perennial forage crops grown in Pennsylvania. Yields in excess of 8 tons of dry matter and 4 tons of total digestible nutrients per acre have been obtained regularly. No other perennial crop is equal to alfalfa as feed for livestock, as a cash crop, or as an energy-efficient crop on soils where alfalfa is adapted.

Varieties

To capitalize on alfalfa's potential, choose high-yielding varieties with adequate winter hardiness and resistance to problem diseases. These varieties, when properly fertilized and managed, normally persist for three years or longer. Avoid using nonadapted common seedlots when growing alfalfa as a perennial forage crop.

Over the past 10 years, more than 200 alfalfa varieties or experimental lines have been evaluated in research trials at two locations in the state. A large number of varieties for which adequate data are available have performed satisfactorily in these trials. Results appear in the "Forage Variety Trials Report," an annual publication available online at extension.psu.edu under forage-variety-trial-reports.

A limited number of alfalfa varieties have a spreading growth habit and the potential to produce secondary roots. These varieties are referred to as "creeping" alfalfas. In a humid climate like Pennsylvania's, however, these varieties have shown growth habits similar to our more typical bunch-type alfalfas with no yield advantage. These branch-rooted varieties may better tolerate slightly wetter soils and are less prone to the root heaving that can occur when soils are damp and soils freeze and thaw. Multi-leaved varieties—those developed to have more than three leaflets per leaf—have not shown consistently improved quality or yield over traditional varieties. Producers should select varieties based on disease resistance, winter hardiness, and yield, not because they are multi-leaved.

Seeding Year Management

Seed alfalfa or alfalfa-grass mixtures on well-drained soils only. Seeding alfalfa following old alfalfa stands is not recommended, as this practice has led to stand establishment problems, which are thought to result from autotoxicity and in part from insect and disease buildup.

Soil Fertility

Have a soil test taken to determine lime and fertilizer needs prior to alfalfa establishment. Fields to be seeded to alfalfa should be limed to pH 6.5 to 7.0. For more information on soil fertility management in alfalfa, see Part I, Section 2: Soil Fertility Management of this guide. Starter fertilizer applications of up to 20-60-20 per acre are desirable at seeding time. Band placement is highly recommended. Plant nutrients recommended in excess of this amount should be incorporated into the seedbed before seeding. If soil test recommendations are followed at planting, additional applications of fertilizer in the fall of the seeding year are not necessary. In absence of the soil test, refer to the typical plant nutrient recommendations in Part I, Section 2.

Seeding Methods

Alfalfa or alfalfa-grass mixtures may be seeded using conventional seeding equipment such as a cultipacker seeder or grain drill on a firm, well-prepared seedbed, or they may be seeded directly into corn stalk or small grain stubble using a no-till seeder. No-till establishment requires special attention to weed and insect control, but if properly done it results in excellent stands with little or no soil losses. For specific recommendations, see "No-Till Forage Seeding," below. Plant as soon as a good seedbed can be prepared in spring, or for a mid- to late summer seeding, in early to mid-August. Late summer seedings need at least eight weeks of growth before the first killing frost.

Band seeding no deeper than ¼ inch is an excellent method of seeding. When band seeding or using the no-till seeder, you may reduce recommended alfalfa seeding rates by one-third. Press wheels used in conjunction with conventional band seeding provide additional stand insurance. If the seedbed is dry and press wheels are not used, cultipack before and after seeding in the same direction as the band seeding to ensure a firm seedbed. If annual crops such as oats or peas and triticale are used as a nurse crop, reduce the seeding rate

of the companion crop by 30 percent, and harvest when the small grain is in the boot or early heading stage for silage, hay, or greenchop. Do not apply additional nitrogen for the nurse crop.

Fluid seeding—distributing seed in a carrier of water or fertilizer solution—is a new technique generally limited to forage legumes. Because fluid seeding requires special equipment for good seed suspension and distribution, custom application is recommended. Fluid seeding is a broadcast method, so for best results prepare the seedbed as in conventional seeding and cultipack after seeding.

Seeding rates necessary for successful stands are related to the condition of the seedbed and method of seeding. For suggested seeding rates, see Table 1.8-5.

Use preinoculated seed or treat seed with proper inoculant. If seed is preinoculated, look for the expiration date on the tag to see if reinoculation is necessary. This may occur if seed is not used soon after purchase or stored improperly. Proper inoculation techniques are described in "Agronomy Facts 11: Inoculation of Forage and Grain Legumes."

Seeding Year Cutting Management

When alfalfa is spring seeded, the first cutting can be made 60 days after emergence if one cutting during the seeding year is allowed to reach early bloom before it is harvested. Normally up to two to three harvests may be made in the year of a spring seeding, depending on the length of the growing season.

Established Stand Management

Fertilization

High levels of phosphorus and potassium must be maintained in the soil for high crop yields and long-lived alfalfa stands. Determine lime and fertilizer needs by soil test. High alfalfa yields can reduce plant nutrient levels in soil rapidly. Thus, for top production and stand persistence, annual soil testing is recommended.

When a soil test indicates the need for fertilizer, topdress after first and/or last cutting. Split applications, one-half in the fall and one-half after the first cutting, may result in more efficient use of fertilizer, especially potash. Recent research suggests that, based on nutrient removal, a 0-1-4 ratio of N-P_2O_5-K_2O (nitrate, phosphate, potash) is best when high yields are anticipated. If the soil test shows 1 part per million (ppm) or less of boron, or if plant tissue has 25 ppm or less boron, then topdress with a fertilizer containing at least 2 pounds of boron per acre.

At present, no evidence indicates a general need for most other fertilizer nutrients. As industrial emissions of sulfur continue to decline in response to efforts to address acid rain, applications of sulfur as a fertilizer nutrient will be necessary. Refer to sulfur discussions in the soil fertility section of this Agronomy Guide.

A soil test is the best guide to alfalfa fertilization. In the absence of a soil test, refer to the typical plant nutrient recommendations in Part I, Section 2. For more information about forage fertilization, refer to the "Agronomy Facts: Soil Fertility for Forages" fact sheets 31A: "Pre-Establishment," 31B: "Establishment," and 31C: "Maintenance."

Cutting Management

Cutting management is an important tool in achieving high quality, high yields, and stand persistence. It can also be effective in reducing the impact of weed, insect, and disease pests.

Harvest schedules depend somewhat on the quality goals of the producer. Progressive dairy farmers have recognized the economic importance of producing high-quality forage and often cut early and more frequently to obtain greater than 20 percent crude protein, less than 30 percent acid detergent fiber, and less than 40 percent neutral detergent fiber. Such high-quality forage has the potential to increase forage dry matter intake and milk production while decreasing the requirement for supplemental energy in the form of grain (Table 1.8-1).

For additional information, refer to "Agronomy Facts 30: Forage Quality in Perspective" and "Agronomy Facts 44: Forage Quality Testing: Why, How, and Where?"

For high-quality alfalfa, make the first cutting at mid- to full-bud stage, as long as:

- Better adapted varieties with multiple pest resistance have been used.
- Adequate levels of lime, phosphorus, and potassium have been maintained.
- Insect pests have been monitored and controlled.

Frequent cutting pre- or early bud alfalfa is not recommended because there is a higher risk of losing the stand. As regrowth intervals become shorter, the alfalfa plant's ability to replenish root and crown energy reserves is likewise reduced. These reserves of energy are needed by the plant for the generation of new leaves and to survive during periods of stress and overwinter. Additionally, fiber levels may also be undesirably low when alfalfa is cut extremely early. If an alfalfa stand has been weakened by winter stress, make the first cutting at early to mid-bloom. For a description of forage growth stages, refer to Table 1.8-2.

In the past, it has been recommended that producers avoid cutting alfalfa during the critical six-week period prior to the average hard frost date (generally between early September and mid-October). This still should be considered if the stand is weak from repeated cutting during the pre-bud stage, low soil fertility, disease, or extreme climatic conditions (such as water-saturated soils). More recently, however, it

Table 1.8-1. Chemical composition of legumes and legume-grass mixtures at advancing stages of maturity.

	Chemical Composition			
	DM Basis (percent)			
Brief Description	**Crude Protein**	**Acid Detergent Fiber**	**Neutral Detergent Fiber**	**Relative Feed Value**
Legume, prebloom	>19	<31	<40	>151
Legume, early bloom, <20% grass, vegetative	17–19	31–35	40–46	125–151
Legume, mid-bloom, <30% grass, early head	14–16	36–40	47–53	103–124
Legume, full bloom, <40% grass, head	11–13	41–42	54–60	87–102
Legume, full bloom, <50% grass, head	8–10	43–45	61–65	75–86
Mostly grass, head	<8	>45	>61	<75

has been recognized that alfalfa can be cut even during this critical period as long as:

- Better adapted varieties with multiple pest resistance have been used.
- Adequate levels of lime, phosphorus, and potassium have been maintained.
- There are at least 45 days of regrowth before cutting.

If harvests are delayed until mid-October, leave a 4- to 6-inch stubble to protect the crown and catch snow for added insulation over the winter.

Harvest schedules for alfalfa-grass mixtures should be based on the growth stage of the alfalfa as it relates to the species of grass used in the mix. Because orchardgrass, perennial ryegrass, reed canarygrass, and tall fescue can tolerate more frequent cuttings without jeopardizing the grass stand, they may be harvested along with alfalfa that is cut four or more times per year.

Stands of timothy or smooth bromegrass mixed with alfalfa should not be cut until the grass is in the early head-emergence stage. They cannot tolerate frequently cut alfalfa and are therefore more compatible with less intensely managed alfalfa (three cuts or fewer per year).

For information on alfalfa for pasture, see "Alfalfa," below. For additional information, refer to "Agronomy Facts 7: Cutting Management of Alfalfa, Red Clover, and Birdsfoot Trefoil."

Special Considerations

If properly harvested and stored, alfalfa silage can provide a high-quality forage with fewer risks of damage due to weather. For high-quality silage, field wilt alfalfa to a moisture content of 60 to 70 percent before ensiling for conventional upright, bunk, or pit silos or round bale silage and to 40 to 60 percent moisture for sealed upright silos. Making a good, tight pack ensures a more rapid transition from aerobic fermentation (undesirable) to the anaerobic, or oxygen-free, stages of fermentation and depends on fineness of chop, moisture content, and rate of fill. Silage preservatives, additives, and inoculants may improve silage fermentation in some cases, but they are not a substitute for proper management.

Used at recommended rates and properly applied, organic acid preservatives make it possible to successfully store alfalfa hay when it has been baled at up to 25 percent moisture. In addition, chemical drying agents applied during mowing can reduce drying time.

Determining when to rotate from alfalfa to another crop such as corn can be difficult. Two rules of thumb, however, can be helpful in this decision-making process. Once alfalfa plant density drops below four or five plants per square foot or stem density drops below 40 to 50 stems per square foot, production frequently suffers such that it is no longer economical to maintain the stand.

Birdsfoot Trefoil

Birdsfoot trefoil is a deep-rooted perennial forage legume that is especially well suited to the moderate to somewhat poorly drained soils of northern and western Pennsylvania. Although birdsfoot trefoil is not as productive as alfalfa on good alfalfa soils, its yields have exceeded those of alfalfa on wetter soils. It normally outlives red clover by several years. Trefoil also is bloat free; in fact, no case of bloat has ever been recorded in animals grazing on this legume.

Varieties

Birdsfoot trefoil varieties are classified by growth habit into two types: Empire and European. Empire birdsfoot trefoils are better adapted for grazing since they have fine stems and a prostrate growth habit. European birdsfoot trefoils are better adapted for hay production since they have a more erect growth habit.

Seeding Year Management

Fertilization

Birdsfoot trefoil has a wider soil adaptation than alfalfa with regard to drainage, acidity, and fertility. Nevertheless,

it responds well to lime applications. Determine lime needs and fertilizer applications based on a soil test. Maintain pH between 6.0 and 7.0 for best results. In the absence of a soil test, and assuming a medium-fertility soil, plow down 0-45-135 per acre and apply 20-60-20 per acre in the row (band place if possible).

Seeding Methods

Birdsfoot trefoil or trefoil-grass mixtures may be seeded using conventional seeding equipment such as a cultipacker seeder or grain drill on a firm, well-prepared seedbed, or they may be seeded directly into corn stalk or small grain stubble using a no-till seeder. No-till establishment requires special attention to weed and insect control, but if properly done it results in excellent stands with little or no soil loss. For specific recommendations, see "No-Till Forage Seeding" later in this section.

Plant in April to late May. Midsummer seedings on a prepared seedbed are less reliable and are therefore not recommended. Band seeding no deeper than ¼ inch is an excellent method of seeding. When band seeding or when using the no-till seeder, you may reduce recommended trefoil seeding rates by one-third. Press wheels used in conjunction with conventional band seeding provide additional stand insurance. If the seedbed is dry and press wheels are not used, cultipack before and after seeding in the same direction as band seeding to ensure a firm seedbed. If oats are used as a companion crop, seed oats at a rate of not more than 1.5 bushels per acre and remove at heading stage for silage, hay, or greenchop. Do not apply additional nitrogen for the oats.

Use preinoculated seed or inoculate seed with proper inoculant. If seed is preinoculated, look for the expiration date on the tag to see if reinoculation is necessary. This may occur if seed is not used soon after purchase. Proper inoculation techniques are described in "Agronomy Facts 11: Inoculation of Forage and Grain Legumes."

Cutting Management

The seedling growth rate of birdsfoot trefoil is slower than that of alfalfa or red clover. However, under favorable growing conditions for seedings made without a companion crop, one harvest in the year of seeding is possible. Any cuttings made during the year of establishment should be delayed until the birdsfoot trefoil is in bloom.

Established Stand Management

Fertilization

A soil test is the best guide for sound fertilization. In the absence of a soil test, refer to the typical plant nutrient recommendations in Part I, Section 2. For mixtures with grass having 30 percent or less birdsfoot trefoil, use perennial grass maintenance fertilization as described in the table.

Cutting Management

Make the first cutting of established stands at early bloom and later cuttings at half-bloom (Table 1.8-2). Maintain a cutting height of not less than 3 inches to ensure maximum yields and persistence. Cutting lower reduces the number of axillary buds from which regrowth originates and removes the leaf area needed to produce carbohydrates for regrowth. It is important to allow trefoil a long recovery period in fall to restore its root reserves. Allow four to five weeks before the average hard frost date.

Special Considerations

If properly harvested and stored, birdsfoot trefoil silage can provide a high-quality forage with fewer risks of damage due to weather. For high-quality silage, field wilt to a moisture content of 60 to 70 percent before ensiling for conventional upright, bunk, or pit silos, or 50 to 60 percent for sealed upright silos. Making a good, tight pack ensures an oxygen-free environment and depends on fineness of chop, moisture content, and rate of fill. Used at recommended rates and properly applied, organic acid preservatives make it possible to successfully store birdsfoot trefoil hay when baled at up to 25 percent moisture.

For more detailed information about birdsfoot trefoil production, refer to "Agronomy Facts 20: Birdsfoot Trefoil."

Clovers

Clovers, like alfalfa, have a potential for causing bloat in animals but are generally shorter lived and less productive than alfalfa. They are, however, more tolerant of somewhat poorly drained and acid soils.

Species and Varieties

Red Clover

Red clover is a short-lived, relatively easy-to-establish perennial legume that grows on soils too acidic or too wet for alfalfa. It is one of the easiest legumes to establish using no-till techniques.

Disease resistance is important with red clover. In Pennsylvania, southern and northern anthracnose occur widely and may seriously reduce stand and yield of susceptible varieties. Several new red clover varieties currently on the market offer added yield by having resistance or tolerance to one or both of these diseases.

For more detailed information about red clover production, refer to "Agronomy Facts 21: Red Clover."

White Clover

White clover is a short-lived perennial with some reseeding capability. Ladino and Regal clovers are large white clovers, and Dutch or common white clover is a small type. Pure stands of ladino and other white clovers are not well suited for

Table 1.8-2. Developmental stages of legumes and grasses.

Stage of Maturity	Definition
Legumes	
Late vegetative	No visible buds, flowers, or seed pods; stem at least 12 inches tall
Early bud	Visible flower buds on at least one stem (1%)
Mid-bud	50% of the stems have at least one bud
Late bud	75% of the stems have at least one bud; no visible flowers
First bloom	Flowers on at least one stem (1%)
1/10 bloom	10% of the stems have at least one flower
Mid-bloom	50% of the stems have at least one flower
Full bloom	75% of the stems have at least one flower; no visible seed pods
Grasses	
Vegetative	Leaves only; stems not elongated (specify height)
Stem elongation	Stems elongating; specify early or late jointing
Boot	Flower head is enclosed in flag leaf sheath and not showing
Heading	Flower head emerging or emerged from flag leaf sheath but not shedding pollen
Anthesis	Flowering stage; anthers shedding pollen
Milk stage	Seed immature; endosperm milky
Dough stage	Well-developed seed; endosperm doughy
Ripe seed	Seed ripe; leaves green to yellow brown

Randomly select 100 stems from the field and determine the percentage of stems at the most mature stage of development.

silage or hay because of their low-growing, leafy growth habit, which makes them difficult to harvest mechanically. However, they make high-quality pastures for livestock and do well in years with frequent rain (refer to the information on pastures below). They have shallow root systems and lack sufficient drought tolerance to survive prolonged dry spells. Purchase certified seed to be certain of obtaining pure seed of the white clover variety desired.

For more detailed information about white clover production, refer to "Agronomy Facts 22: White Clover."

Alsike Clover

Alsike clover is a short-lived perennial legume that grows on wet, acidic soils. It is susceptible to the same diseases and insects that attack red and white clovers. Alsike clover growth is intermediate between red and white clover, growing tall enough to be cut for hay. It is less desirable where hot, dry summer conditions are common. Marketed seed is labeled only as alsike.

Sweet Clover

The cultivated sweet clovers, both yellow- and white-flowered types, are typically biennial. They are suitable for soil improvement and as nectar-producing plants for honey bees but generally are not grown for forage.

Seeding Year Management

Fertilization

Lime and fertilizer needs for all clovers should be determined by soil test. For best results, the soil pH at establishment should be between 6.0 and 7.0. Starter fertilizer applications of up to 20-60-20 per acre are desirable for clovers seeded on a prepared seedbed. Plant nutrients recommended in excess of this amount should be incorporated into the seedbed. Winter small grains seeded to clovers should not be top-dressed with nitrogen. In the absence of a soil test, refer to the typical plant nutrient recommendations in Part I, Section 2.

Seeding Methods

Clovers can be seeded with hand seeders early in the spring on soils honeycombed with frost. White clover has been established in pure grass pastures by grazing animals on white clover in the seed stage and then turning the animals into the pure grass pasture. Clover seed is dispersed in the manure. Clovers, especially red clover, may also be established using a no-till seeder and are the easiest legumes to establish using no-till techniques. They also can be seeded in April to early May, either alone or with spring oats as a companion crop, on a firm, well-prepared seedbed using conventional methods. If oats are used, reduce the seeding rate by 30 percent.

Band seeding no deeper than ¼ inch is an excellent method of seeding. Band seeding may reduce recommended clover seeding rates by one-third. Seed alone or with small grain companion crops. Press wheels, used in conjunction with band seeding, provide additional stand insurance. To ensure a firm seedbed when the seedbed is dry and press wheels are not used, cultipack before and after seeding in the same direction as band seeding.

Use preinoculated seed or inoculate seed with proper inoculant. If seed is preinoculated, look for the expiration date on the tag to see if reinoculation is needed. Reinoculation may also become necessary if seed is not used soon after purchase. Proper inoculation techniques are described in "Agronomy Facts 11: Inoculation of Forage and Grain Legumes."

Cutting Management

Under favorable growing conditions, red clover spring seeded without a companion crop and with chemical weed control may be harvested twice during the seeding year. Make the first cutting by August 1, before full bloom. A second cutting or grazing may be made about September 15 if moisture is adequate.

Red clover seeded with a companion crop can usually be harvested once during the seeding year between August 15 and September 15, before full bloom. Clipping or grazing red clover stands between mid-August and mid-September of the seeding year helps to maintain better stands into the following harvest season. If red clover is allowed to reach full bloom or a later stage in the seeding year, a serious stand reduction may result.

For further information on red clover cutting management, refer to "Agronomy Facts 7: Cutting Management of Alfalfa, Red Clover, and Birdsfoot Trefoil."

Established Stand Management

Fertilization

A soil test is the best guide for determining nutritional requirements. Clover stands should be topdressed annually as long as plant numbers are adequate. In the absence of a soil test, refer to the typical plant nutrient recommendations in Part I, Section 2.

Cutting Management

For established red clover stands, make the first harvest cutting at 25 to 50 percent bloom; make later cuttings at 50 percent bloom. Ladino clover responds best to rotational grazing. For additional information, refer to "Agronomy Facts 7: Cutting Management of Alfalfa, Red Clover, and Birdsfoot Trefoil." For additional information on clovers for pasture, see the pastures sections later in this chapter.

Special Considerations

If properly harvested and stored, red clover silage can provide a high-quality forage with fewer risks of damage due to weather. For high-quality silage, field wilt to a moisture content of 60 to 70 percent before ensiling for conventional upright, bunk, pit silos, or round bale silage, or to 50 to 60 percent moisture for sealed upright silos. Making a good, tight pack ensures an oxygen-free environment and depends on fineness of chop, moisture content, and rate of fill. Silage preservatives, additives, and inoculants may improve silage fermentation in some cases but are not a substitute for proper management.

Red clover is usually more difficult to cure for hay than are other legumes. Organic acid preservatives, when used at recommended rates and properly applied, make it possible to store red clover hay successfully when baled at moistures to 25 percent. In addition, chemical drying agents can improve the drying rate of red clover.

Cool-Season Grasses

Perennial, tall-growing, cool-season grasses play an important role in Pennsylvania agriculture, as feed for livestock when grown alone or in mixtures with legumes, and for soil and water conservation.

Species and Varieties

Orchardgrass

Orchardgrass is a moderately hardy, tall-growing, high-yielding bunch grass that attains more summer growth than other grasses under an intensive system of cutting management. Because of its growth characteristics, it persists well with alfalfa. Numerous varieties of orchardgrass have been evaluated in research studies. These results appear in the "Forage Variety Trials Report."

In general, early maturing varieties are suitable for pure grass hay or silage or with legumes for pasture. Do not use in mixtures with legumes for hay or silage. Medium- and late maturing varieties do well when combined with legumes for hay, silage, or pasture. Later maturing varieties are best to grow with alfalfa for hay or silage. "Common" orchardgrass is not a variety. Its maturity is not known, but it generally heads earlier than named varieties. It is for general use, but it should not be used in mixtures with legumes for hay or silage.

Several varieties of orchardgrass have been developed for use in pastures where severity of grazing is managed. See the Penn State "Forage Variety Trials Report" or consult your local seed dealer for information on these varieties. For more detailed information, refer to "Agronomy Facts 25: Orchardgrass."

Bromegrass

Smooth bromegrass is a leafy, late maturing, sod-forming grass that spreads by underground rhizomes and is rapidly propagated by seed. It can be used for silage, hay, or pasture, alone or in mixtures with alfalfa, ladino clover, or red clover. Numerous varieties of bromegrass have been evaluated in research studies. For more detailed information, refer to "Agronomy Facts 27: Smooth Bromegrass."

Prairie grass is a tall-growing bromegrass. It differs from smooth bromegrass in not having rhizomes and producing flower heads in every regrowth, especially in fall. Herbage and immature seed heads are palatable for livestock. Matua, the only variety available in the United States, persists best when managed like alfalfa. Susceptibility to powdery mildew can be a problem in some environments. Prairie grass is a newly introduced grass, and researchers are still evaluating its performance under environmental and management conditions common in Pennsylvania. For more detailed information, refer to "Agronomy Facts 39: Prairie Grass."

Timothy

Timothy is a widely adapted bunch grass with a relatively shallow and fibrous root system. It is less competitive with alfalfa and trefoil than other tall grasses and best suited for hay or silage in combination with alfalfa, red clover, or birdsfoot trefoil.

For more detailed information, refer to "Agronomy Facts 24: Timothy" or the "Forage Variety Trials Report."

Reed Canarygrass

Reed canarygrass is a tall, coarse, sod-forming perennial with high yield potential. It grows well in areas with extremely poor drainage and yields well on dry, upland sites. Older varieties are relatively high in an alkaloid that makes them less palatable as pasture, as compared to newer varieties.

For more detailed information, refer to "Agronomy Facts 26: Reed Canarygrass" or the "Forage Variety Trials Report."

Tall Fescue

Tall fescue is a deep-rooted, long-lived, sod-forming grass that spreads by short underground stems. In Pennsylvania it is used primarily for conservation purposes, but it is well suited either alone or with ladino clover for hay, silage, or pasture for beef cattle and sheep, including stockpiled pasture or field-stored hay for winter feeding.

Low-quality tall fescue forage, which can result in poor animal performance, is associated with the presence of a fungus (endophyte) growing in the plant. It is suggested that new seedings be made with endophyte-free or "friendly endophyte" varieties.

For more detailed information, refer to "Agronomy Facts 28: Tall Fescue" and the "Forage Variety Trials Report."

Perennial Ryegrass

Perennial ryegrass is a highly palatable bunch grass with no creeping growth habit. It is normally considered to be less winter hardy and slightly more digestible than other forage grasses, such as timothy and orchardgrass, but newer varieties appear to survive satisfactorily, especially when grown in mixture with legumes.

Different types of ryegrasses exist. Tetraploid perennial ryegrasses have larger leaves and are more suited for forage crop production than is diploid perennial ryegrass, which is more suitable for turf. Short-rotation ryegrasses are hybrids of perennial ryegrass and annual ryegrass and generally have a shorter stand life. They tend to have a more upright growth habit but continue to produce seed heads throughout the growing season, whereas true perennial ryegrasses produce seed heads only once during the late spring.

Perennial ryegrass varieties can differ in their maturity by over two weeks. Selecting varieties that mature at the same time as the anticipated harvest date in the spring is advised.

For more detailed information, refer to "Agronomy Facts 19: Ryegrass" and the "Forage Variety Trials Report."

Festulolium

Festulolium is a cross between fescue and perennial ryegrass. Theoretically, it should have the winter hardiness and persistence of fescue and the digestibility of perennial ryegrass. However, festulolium varieties exhibit considerable variability, with some varieties behaving more like fescue and others more like ryegrass. Consequently, it is important to know the performance record of a festulolium variety before it is selected.

Seeding Year Management

Fertilization

In general, grasses have a wider soil adaptation to drainage, acidity, and fertility than do legumes. Determine lime and fertility needs with a soil test. Maintain pH between 6.0 and 7.0 for best results. In the absence of a soil test and assuming a medium-fertility soil, for all perennial grasses seeded alone, plow down 0-45-135 per acre and apply 40-40-40 per acre (band place if possible) at seeding time.

Seeding Methods

All grasses described, except ryegrass, can be seeded alone on a well-prepared, firm seedbed in April and May or August. Best results have been obtained with late summer seedings.

Timothy may also be seeded in the fall with small grains.

Ryegrass should be seeded only in mixtures with legumes.

When no companion crop is used, band seed ¼ to ½ inch deep. Press wheels, used in conjunction with band seeding, provide additional stand insurance. If the seedbed is

dry and press wheels are not used, cultipack before and after seeding in the same direction as the band seeding.

Light, fluffy grass seeds, such as bromegrass and orchardgrass, present special seeding problems. If suitable equipment is available, seeds can be band placed, but they may "bridge over" in the conventional grain drill. Alternate methods include:

- Mixing seed with a small amount of superphosphate and sowing through the fertilizer attachment of your grain drill or fertilizer spreader.
- For spring seedings, mixing seed with a small amount of oats and sowing through the grain attachment of your grain drill. Caution: Be sure grass seed is placed no deeper than ¼ inch.

Seeding rates necessary for successful stands depend on the condition of the seedbed and method of seeding. When seeding a legume-grass mix, adjust the seeding rate according to the fertility status of the soil, the drainage characteristics of the soil, and the aggressiveness of the seeding species.

In an alfalfa-ryegrass mixture, reduce the seeding rate of the perennial ryegrass where the drainage is variable or fertilizer or manure nitrogen has been applied before seeding. The ryegrass seeding rate can be higher when seeding is done in a deep, well-drained soil that has had no previous nitrogen application.

Recommended seeding rates are given in Table 1.8-5.

Cutting Management

Seeding-year harvest management of perennial grasses depends on time and method of seeding, fertility, and other factors. However, under favorable growing conditions for a spring seeding made without a companion crop and fertilized with nitrogen, one harvest in the year of seeding is possible. Cut when grass is at least 10 to 12 inches high.

Established Stand Management

Fertilization

A soil test is the best guide for proper fertilization. In the absence of a soil test, refer to the typical plant nutrient recommendations in Part I, Section 2.

Nitrogen is extremely important for grass production. Economic returns can usually be achieved with an application of 50 pounds of nitrogen per ton of anticipated yield split over at least three times during the year: one-third of the total annual nitrogen in early spring when the grasses first green up and the remaining nitrogen divided and applied after each cutting. Nitrogen is not recommended after the last harvest of the year as much of it will end up in groundwater and winter-hardiness of some grasses can be reduced if N levels are high during late fall and winter.

Grass tetany is a livestock condition caused by low blood magnesium levels. It usually occurs in the spring, when high-producing livestock, such as lactating cows, are consuming primarily grass, and their demands for magnesium exceed the supply. This situation can be aggravated by excessive soil potassium levels. To reduce the possibility of tetany from grasses to be harvested for hay or silage, do not apply potash in early spring except when recommended by a soil test. After the first harvest, however, apply needed fertilizer to maintain a balanced soil fertility program. It may be helpful to give livestock high-magnesium supplements during spring.

Cutting Management

Generally, the best compromise between yield and quality is obtained when the first cutting is made at early head emergence from the boot (see Table 1.8-2). Timothy and smooth bromegrass are particularly sensitive to harvests made before this stage of growth. Harvesting cool-season grasses after the early head emergence stage leads to dramatic declines in forage quality (see Table 1.8-1).

Except for certain species and varieties, later cuttings of cool-season grasses usually are vegetative (all leaf material) and normally can be cut six to seven weeks after the first harvest.

Special Considerations

If properly harvested and stored, grass silage can provide a high-quality forage with fewer risks of weather damage than hay. For high-quality silage, field wilt to a moisture content of 60 to 70 percent before ensiling for conventional upright, bunk, or pit silos, or round bale silage, or to 50 to 60 percent moisture for sealed upright silos. Making a good, tight pack ensures an oxygen-free environment and depends on fineness of chop, moisture content, and rate of fill.

Silage preservatives, additives, and inoculants may improve silage fermentation in some cases, but they are not a replacement for proper management. Chemical drying agents have not been shown to improve the drying rate of grasses.

Perennial Warm-Season Grasses

Native perennial warm-season grasses such as switchgrass and big bluestem grow primarily in the warm part of summer and produce well in soils with a low moisture-holding capacity and low phosphorus as compared to cool-season grasses. Warm-season grasses grow best in deep, well-drained soils. Switchgrass is more tolerant of poorly drained soils than big bluestem. Although recognized as a summer component of a pasture system (see the information on pastures later in this section), these grasses can be harvested and stored as hay. Their establishment and management requirements are quite different from those of cool-season grasses, and first-time

Figure 1.8-1. Growth curves of various pasture components

users must pay special attention to the details of managing these grasses.

When managed properly, warm-season grass hay can provide good-quality forage, especially for beef cattle. In digestibility trials, the dry matter digestibility of warm-season grass hay cut at the late vegetative stage was 71 percent for cattle and 60 percent for sheep.

For more detailed information, refer to "Agronomy Facts 29: Warm-Season Grasses."

Species and Varieties

Switchgrass

This is a tall bunch grass that tolerates poorly drained soils, flooding, and perched water tables better than other warm-season grasses. Its primary growth is in midsummer and it can be used to complement a cool-season grass forage program by providing additional forage in the summer (Figure 1.8-1).

Cave-in-Rock is a highly productive variety that heads by early to midsummer.

Blackwell is a widely adapted fine-stemmed variety that heads by early to midsummer. It is shorter lived than Cave-in-Rock.

Big Bluestem

Big bluestem is a tall bunch grass that is more drought tolerant than other tall warm-season grasses and therefore better adapted to excessively drained soils with low water-holding capacity. Its primary growth is in midsummer and it can be used to complement a cool-season grass forage program by providing additional forage in summer (Figure 1.8-1).

Niagara is a variety especially adapted to conditions in the Northeast. Forage quality is good. It is tolerant to leaf spot and matures early in the summer season.

Seeding Year Management

Because warm-season grass seedlings compete poorly with weeds, avoid sites that have severe problems with perennial weeds like quackgrass or broadleaf weeds until they are controlled.

Fertilization

Although warm-season grasses are good producers on low-fertility soils, maintaining adequate phosphorus and potassium levels increases stand vigor and production when levels of these nutrients are low in the soil. Determine lime and fertility needs by conducting a soil test. Lime is not necessary if soil pH is above 6.0. In the absence of a soil test, apply 0-60-60 per acre. Nitrogen is not recommended for use at establishment because it leads to increased competition from weeds. However, on sites with low fertility, good weed control, and a good stand of grass, apply 25 to 30 pounds of nitrogen per acre.

Seeding Methods

Both species of warm-season grasses should be seeded alone either on a conventional, tilled seedbed or no-tilled into grain stubble (see "No-Till Forage Seeding," later in this section) between mid-April and late May. Early seeding helps break seed dormancy and improves establishment. The seedbed should be free of weeds, fine textured, and firm. Plowing, disking, harrowing, and rolling or cultipacking are generally required. Band seed with a drill with press wheels at a depth of ½ inch. If seeded broadcast or drilled without press wheels, a rolling or cultipacking after seeding is necessary to ensure a good firm seedbed.

If plowing and disking is done early, weeds can be allowed to germinate and then eliminated with a contact herbicide or a light harrowing or disking before seeding.

Switchgrass seed is hard and slick and can be handled without special drills. Big bluestem seed is chaffy and does not flow well unless it has been debearded, a process that removes the chaff and hair from this seed; therefore, debearded big bluestem seed should be used.

Recommended seeding rates are given in Table 1.8-5.

Cutting Management

Normally, the seeding year stand should not be harvested unless there is unusually good growth and the stand is vigorous. If a harvest is made, cut when plants reach 18 to 24 inches in height (late boot stage). Leave a 4- to 6-inch stubble. Allow enough time for at least 12 inches of fall regrowth before frost. Plants can be harvested after frost without being damaged.

Established Stand Management

Fertilization

Maintain a pH of 6.0 or higher. Apply phosphorus and potash based on soil test. Apply 75 pounds of nitrogen per acre annually in late May or June when plants are 12 to 14 inches tall. Do not apply in early spring.

Cutting Management

Cut when plants reach 18 to 24 inches in height (late boot stage). Leave a 4- to 6-inch stubble. Allow enough time for at least 12 inches of fall regrowth before frost. Plants can be harvested after frost without damage to them. Refer to "Pastures," below, for grazing recommendations.

Special Considerations

Because of slow germination and seedling growth, warm-season grasses may take two years to reach their maximum growth potential. Stands that appear poor at the end of the first year usually develop into good stands the second year. It is important to evaluate the stands at the end of the seeding year. If there are at least 1 to 3 seedlings per square foot in September, the stand is adequate.

If properly managed, a stand of warm-season grasses can last for many years. Because of the expense and difficulty of establishment, these grasses are best used as permanent sod pastures or hay fields. They are not as well suited as cool-season forage crops for crop rotation and should not be used for this purpose.

Annual Crops for Forage

Using annual crops for forage can be advantageous for a forage system. These crops provide supplemental feed during parts of the growing season when perennial forage crops traditionally decline in productivity. Although many annual forages are used as emergency crops during dry weather, they should be a planned part of the forage system and not simply grown in response to dry conditions. They also can act as interim crops between grazing rotations. Most annual forage crops are more satisfactory for pasture or silage than for hay.

Summer Annual Grasses

Forage Sorghum

Silages made from sorghum are considered high-energy silage crops because they contain more digestible energy than legume and cool-season grass silages. In general, it is easier to make high-quality silage from sorghum than it is from forage legumes because of high amounts of nonstructural carbohydrates (sugars), which enhance fermentation. The high-energy, low-protein characteristics of sorghum silage make it a good supplement for high-protein forage legumes.

Under adequate growing conditions, the yield of digestible nutrients per acre of forage sorghum is about 92 percent that of corn. The feeding value of sorghum silage is considered to be about 85 percent that of corn silage. Therefore, corn silage is usually the preferred high-energy silage grown in Pennsylvania. However, research has shown that fewer deer feed on sorghum than on corn. In addition, growing a certain percentage of the total high-energy silage acreage in sorghum may be a way to hedge against the higher risk of drought in light-textured, shallow soils.

Species and Varieties

Sudangrass

There is always a risk of prussic acid poisoning after frost in livestock grazing sudangrass; however, newer varieties produce low levels of prussic acid and greatly reduce this risk. In addition to using varieties low in prussic acid, do not graze sudangrass until it is at least 20 to 24 inches tall or during or immediately after a drought stress.

Brown midrib (BMR) varieties of sudangrass that have higher feeding value than non-BMR varieties are available. Seeds of newer varieties are becoming more readily available than in the past.

Sudangrass hybrids are made by crossing different lines or varieties of sudangrass. In general, hybrids have slightly higher yields and are slightly higher in prussic acid than non-hybrid sudangrass at comparable growth stages.

Sorghum × Sudangrass Hybrids

These hybrids are made by crossing different lines and varieties of sorghum with lines and varieties of sudangrass. In general, these hybrids have yielded more but are coarser stemmed and higher in prussic acid at comparable growth stages than either sudangrass or sudangrass hybrids. Sorghum × sudangrass hybrids appear to have the greatest potential when used for greenchop. For pasture, they are only slightly more productive than sudangrass and have a higher prussic acid content in early stages of growth. When cut at the normal stage for ensiling (at or after heading), they are inferior to corn in quality.

Millets

Millets are annual grasses suitable for grazing, greenchop, or hay. They grow 40 to 50 inches tall in about 60 to 90 days. Several types of millet are suitable for Pennsylvania conditions. Pearl millet regrows after harvest, while Foxtail millet does not, and Japanese millet grows best in wet soils. Sudangrass is generally superior to millet, except in the cold, poorly drained soils of northern Pennsylvania.

Teff

Teff is a grass that is tolerant of most soil types and limited rainfall conditions. It establishes and grows rapidly and can produce a hay crop in 9 to 12 weeks from seeding. Teff hay was initially considered a horse feed, but now it is used more for dairy because of its high palatability, digestibility, and ability to produce a crop with limited rainfall.

Fertilization

Forage sorghum and the other summer annual grasses require well-drained soils, except for Japanese millet, which tolerates cold, poorly drained soils. Determine lime and fertilizer needs by soil test. Maintain pH between 6.5 and 7.0 for best results. In the absence of a soil test, use the following as a guide, assuming a medium-fertility soil.

Sorghum. Apply 150-75-75. Apply limestone and fertilizer the same as you would for corn. Do not use row fertilizer when seeding with a grain drill.

Sudangrass and sudangrass hybrids. Apply 50-50-50 per acre. Do not apply fertilizer in contact with the seed. Plow down fertilizer during seedbed preparation. Follow with 50 pounds of nitrogen per acre after first grazing.

Sorghum × sudangrass hybrids. Apply the equivalent of 150-75-75 per acre, 100 pounds of nitrogen at plow down followed by 50 pounds after the first harvest. Significant amounts of nitrogen may be supplied by previous legume crops. See Part I, Section 2 for adjusting the nitrogen recommendation for the appropriate legume. When a previous legume crop is checked on the Penn State soil test information sheet, this residual nitrogen is taken into account in the recommendations and no further adjustment is necessary. Plow down fertilizer before seeding to ensure even distribution. Fertilizer in contact with the seed may delay emergence or even prevent germination.

Millet. Apply 40-40-40 per acre and disk in before seeding.

Seeding Methods

Forage sorghums grow best in warm weather and should be seeded at a uniform depth of 1 to 1.5 inches on a well-prepared seedbed at least 10 to 14 days later than the optimum planting date for recommended adapted corn hybrids. Seed at a rate of 5 to 8 pounds per acre.

Sudangrasses, sudangrass hybrids, sorghum × sudangrass hybrids, and millets do best in warm weather. They should be seeded at a uniform depth of 1 to 1.5 inches on a well-prepared seedbed at least 10 to 14 days later than the optimum planting date for recommended adapted corn hybrids. Later seedings, except for forage sorghums, may be made until about July 15. For suggested seeding rates of these species, refer to Table 1.8-5.

Teff should not be seeded in the spring until the threat of a frost has passed. Seeding at 5 pounds per acre is sufficient, but it must not be seeded deeper than 0.25 inches.

Harvesting

For direct-cut silage:

- Forage sorghums: soft to medium dough
- Sudangrass and sorghum × sudangrass hybrids: early head to early bloom
- Millet: early head to early bloom
- Teff: early head to early bloom

For greenchop, wilted silage, or hay:

- Sudangrass: at least 18 to 24 inches tall
- Sorghum × sudangrass hybrids: at least 30 inches tall
- Millet: early head to early bloom
- Teff: early head to early bloom

For pasture:

- Sudangrass: rotationally graze at 18 to 24 inches of growth
- Sorghum × sudangrass hybrids: rotationally graze at 30 inches of growth
- Millet: rotationally graze at 18 inches of growth
- Teff: not recommended for pastures because it pulls out of the ground easily due to its shallow root system

For faster recovery of summer annuals, leave at least 6 inches of stubble at harvest time. Sorghum × sudangrass hybrids can be harvested at more immature stages for wilted or low-moisture silage.

Well-cured hay made from the hybrids has fair to good quality; however, field curing can be a serious challenge. When these hybrids are harvested for dry hay, it is essential to use a hay conditioner.

Special Considerations

If summer annuals have been damaged by severe drought or frost, do not allow animals to graze fields having succulent, young, short growth, and do not rely on damaged material as the only source of feed. To allow prussic acid content to dissipate, do not graze frosted forage for seven to ten days after frosting.

For more detailed information about summer annual grass production, refer to "Agronomy Facts 23: Summer Annual Grasses for Supplemental or Emergency Forage."

Small Grains

Species and Varieties

- **Winter rye** matures earliest of winter small grains.
- **Winter wheat** is generally not as productive as rye that matures about 10 to 14 days after rye. Varieties of winter wheat grown for grain may also be used for forage.
- **Winter triticale** is a hybrid of wheat and rye that matures about 5 to 10 days after and can be as productive as rye.
- **Winter barley** is not as winter hardy as other small grains. Varieties of winter barley grown for grain also may be used for forage.
- **Spring oat** varieties that are grown for grain may also be used for forage. There are also forage oat varieties that have more and/or larger leaves than grain oat varieties.

Fertilization

Determine lime and fertilizer needs by soil test. Maintain pH between 6.5 and 7.0 for best results. In the absence of a soil test, refer to Part I, Section 2 for fertilizer guidelines at seeding. Nitrogen fertilization depends on prior crop and manure application. Use Table 1.7-2 as a guide.

Seeding Method

Refer to Part I, Section 7: Small Grains for establishment practices.

Harvesting

- **Greenchop or silage:** harvest all small grains at late boot to heading. Harvesting prior to seedhead emergence results in higher quality forage but lower dry matter yields.
- **Pasture:** begin grazing when adequate growth is available to support livestock. Heavy fall grazing reduces grain yields the following summer. Spring grazing may begin when plant growth has resumed. Small grains are injured by grazing after the growing point is above ground.
- **Rye, wheat, triticale, or barley:** both fall and spring grazing are possible.
- **Oats:** fall, late spring, and early summer grazing.

Legume and Grass Mixtures

Mixtures of annual legume and grass species can produce more forage than either species planted alone and achieve a higher quality than a grass alone. But the cost of seed is

Table 1.8-3. Characteristics of some perennial forages grown in the northeastern United States.

Species	Soil Moisture Adaptation	Soil Fertility Adaptation	Drought Tolerance	Periods of Production	Relative Maturity Classification[1]	Growth Habit	Height Classification
Cool-season grasses							
Kentucky bluegrass	Well-drained to moist	Good to medium	Poor	Early spring and late fall	Early	Dense sod	Short
Timothy	Well-drained to moist	Medium to fair	Poor	Late spring and fall	Medium-late to late	Bunch	Tall
Perennial ryegrass	Well-drained to moist	Good to medium	Poor	Early spring and late fall	Early to medium	Bunch	Short
Smooth brome-grass	Well-drained	High to good	Good	Spring, summer, and fall	Medium-late	Open sod	Tall
Orchardgrass	Droughty to moist	Medium to fair	Good	Early spring, summer, and fall	Early to medium	Bunch	Tall
Tall fescue	Droughty to moist	Medium to fair	Good	Early spring, summer, and fall	Medium-late	Variable[2]	Tall
Matua prairiegrass	Droughty to moist	Medium to fair	Very good	Early spring, summer, and fall[3]	Medium	Bunch	Tall
Reed canarygrass	Droughty to wet	Medium to fair	Very good	Early spring, summer, and fall	Medium-late	Open sod	Tall
Warm-season grasses							
Switchgrass	Droughty to moist	Poor to fair	Excellent	Summer	Very late[3]	Bunch	Tall
Big bluestem	Droughty to moist	Poor to fair	Excellent	Summer	Very late[4]	Bunch	Tall
Legumes							
Alfalfa	Well-drained	High to good	Very good	Spring, summer, and early fall	Medium-early	Bunch	Tall
Red clover	Well-drained	Good to medium	Fair	Spring, summer, and fall	Medium	Bunch	Tall
Birdsfoot trefoil	Droughty to wet	Medium to fair	Good	Spring, summer, and early fall	Medium-late to late	Bunch	Medium[5]
White clover, common	Moist	Medium	Poor	Spring and fall	Medium	Spreading	Short
White clover, Ladino	Moist	Good to medium	Poor	Spring, summer, and fall	Medium	Spreading	Short

[1] Relative time of heading or flowering and depends on not only species but also variety.
[2] Depends on harvest management: under lax cutting, bunch; under intense cutting, sod.
[3] Warm-season grasses mature in mid- to late summer, depending on species.
[4] Depends on fall management and winter temperatures.
[5] Depends largely on variety.

relatively high, a factor that should be weighed against the mixture's production potential and the harvested forage's value.

An infinite number of annual legume-grass combinations are available to grow as annual forage crops. These mixtures do not yield as much as corn silage, but their production in the spring or summer may fill a niche in a forage system. When selecting a mixture, make sure that it grows and can be harvested when the forage is needed. Double cropping following most of these mixtures is possible.

Fertilization

Mixtures are generally fertilized as a pure small grain because legume nitrogen fixation during the cool weather restricts legume nitrogen contribution to the mixture.

Seeding Method

Mixtures are seeded either in spring or late summer, depending on the mixture's components. Seeding in a prepared seedbed with a conventional drill has provided excellent establishment. Broadcast seeding is not recommended. Seeding rate varies with mixtures.

Table 1.8-4. Relative maturity of several perennial forage species and varieties.

Species and Varieties	Relative Maturity: Early											Late
Alfalfa												
Early maturing varieties												
Late maturing varieties												
Red clover												
All varieties												
Birdsfoot Trefoil												
Early maturing varieties												
Intermediate maturing varieties												
Late maturing varieties												
Crownvetch												
Bromegrass												
Saratoga Baylor												
Orchardgrass												
Early maturing varieties												
Late maturing varieties												
Reed Canarygrass												
All varieties												
Tall fescue												
All varieties												
Timothy												
Early maturing varieties												
Late maturing varieties												
Perennial Ryegrass												
Early maturing varieties												
Intermediate maturing varieties												
Late maturing varieties												

The beginning of a bar indicates relative time of maturity for earliest growing zones in the state. Bar length indicates the range in time of maturity over different growing zones in the state. When making up mixtures, choose species and varieties that mature at approximately the same time.

Harvesting

A few annual legume and grass mixtures can be grazed, but most achieve maximum productivity when harvested as silage. Harvesting is usually done when the grass in the mixture is between the boot and early head stages. Delays in harvesting reduce forage quality and offer limited increases in yield.

Forage Selection and Seeding Rates

Choosing the proper forage species for a pure stand or a mixture depends on how it adapts to various soil characteristics and how it is to be used. Table 1.8-3 gives characteristics of the more important perennial forages grown in Pennsylvania.

Highest-quality forage is achieved when all species and varieties are harvested at the recommended stages of maturity. A spread in forage harvest season can be obtained by a proper choice of species and varieties with the desired differences in maturation time. However, as forage harvesting equipment is larger with greater throughput capacity, a wide range of maturity may be undesirable. The relative maturities for the first cutting of several species and varieties are given in Table 1.8-4. Actual dates vary from year to year and location to location. When making up mixtures, choose species and varieties that mature at approximately the same time.

Table 1.8-5. Recommended forage mixtures and seeding rates.

Proposed Use of Forage	Depth and Drainage Characteristics of Field Soils				
	Deep, well-drained	Moderately deep, well-drained (moderately droughty)	Shallow, well-drained (droughty)	Moderately well-drained	Moderately and poorly drained
Hay or silage	1, 2, 4, 5, 6, 11, 14, 19, 20, 21, 22, 26, 27, 28, 31, 32, 34, 38	1, 3, 4, 5, 7, 14, 19, 20, 22, 25, 27, 28, 29, 32, 34, 35, 36, 37, 38, 39	5, 7, 19, 22, 25, 27, 28, 29, 32, 33, 34, 35, 36, 37, 38	5, 7, 8, 16, 21, 22, 25, 27, 28, 29, 32, 33, 34, 35, 36, 37, 38	5, 7, 8, 15, 22, 33, 37
Pasture	2, 4, 6, 9, 10, 12, 14, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 39	3, 4, 7, 14, 18, 19, 20, 22, 24, 25, 26, 27, 28, 29, 30, 31, 33, 39	5, 7, 10, 19, 22, 24, 25, 26, 27, 28, 29, 30, 31, 33	5, 7, 9, 12, 13, 17, 18, 22, 23, 24, 25, 26, 27, 29, 30, 31, 33	5, 8, 13, 18, 22, 24

Individual species and recommended mixtures are classified according to the soil depth drainage conditions and use for which they are suited. Each mixture has been given an identification number and is described in the text. Several mixtures are suggested in each category but are not listed in any order of preference.

Alfalfa Alone or in Mixtures
1. Alfalfa in pure stand, 15–18 lb
2. Alfalfa, 10 lb, with one of the following: orchardgrass, 3 lb; smooth bromegrass, 8 lb; tall fescue, 5 lb; timothy, 4 lb
3. Alfalfa, 10 lb, with one of the following: orchardgrass, 3 lb; reed canarygrass, 8 lb; tall fescue, 5 lb
4. Alfalfa, 10 lb, with perennial ryegrass, 4–8 lb

Birdsfoot Trefoil Alone or in Mixtures
5. Birdsfoot trefoil in pure stand, 10 lb
6. Birdsfoot trefoil, 6 lb, with one of the following: Pennlate orchardgrass, 3 lb; smooth bromegrass, 6 lb; Climax timothy, 2 lb; or perennial ryegrass, 6 lb
7. Birdsfoot trefoil, 6 lb; with one of the following: Pennlate orchardgrass, 3 lb; reed canarygrass, 6 lb; or perennial ryegrass, 6 lb
8. Birdsfoot trefoil (upright variety preferred), 6 lb, with one of the following: Climax timothy, 2 lb; or reed canarygrass, 6 lb
9. Birdsfoot trefoil, 6 lb; timothy, 2 lb, and Kentucky bluegrass, 6 lb

Crownvetch
10. Crownvetch, 10 lb, alone or with one of the following grasses: timothy, 4 lb; tall fescue, 6 lb; or Pennlate orchardgrass, 3 lb

Clovers
11. Red clover in pure stand, 10–12 lb
12. Ladino clover, 1 lb, red clover, 2 lb, and alsike clover, 1 lb, with one of the following: orchardgrass, 4 lb; timothy, 4 lb; reed canarygrass, 8 lb; smooth bromegrass, 8 lb; or perennial ryegrass, 5 lb
13. Ladino clover, 1 lb, alsike clover, 2 lb, timothy, 4 lb, and reed canarygrass, 8 lb
14. Red clover, 6 lb, with one of the following: timothy, 4 lb; perennial ryegrass, 5 lb; or tall fescue, 12 lb
15. Alsike clover, 4 lb, and timothy, 4 lb
16. Red clover, 4 lb; alsike clover, 2 lb, and timothy, 4 lb
17. Ladino clover, 1 lb; red clover, 2 lb; Kentucky bluegrass, 4 lb; timothy, 2 lb, and perennial ryegrass, 5 lb
18. Ladino clover, 1 lb, or red clover, 6 lb, and tall fescue, 10 lb (use endophyte-free seed)

Cool-Season Grasses Seeded Alone
19. Orchardgrass, 10 lb
20. Smooth bromegrass, 14 lb
21. Timothy, 8–10 lb
22. Reed canarygrass, 14 lb
23. Kentucky bluegrass, 14 lb
24. Tall fescue, 12 lb
25. Matua prairiegrass, 25 lb

Cool-Season Grass Pasture Mixture
26. Kentucky bluegrass, 8 lb; smooth bromegrass, and timothy, 4 lb (a good grass base for pastures, especially suited for horse pasture)

Warm-Season Grasses Seeded Alone
Seeding rates based on pure live seed [PLS = (% germination × % pure seed) ÷ 100]
27. Switchgrass, 8–10 lb PLS/A
28. Big bluestem, 10–12 lb PLS/A
29. Indiangrass, 10–12 lb PLS/A

Table 1.8-5. Recommended forage mixtures and seeding rates (continued).

Proposed Use of Forage	Depth and Drainage Characteristics of Field Soils
Annual Forages	
30. Turnips or swedes, 1.5 lb	
31. Rape or kale, 4 lb	
32. Sudangrass, 30 lb	
33. Sorghum × sudangrass hybrids, 25–30 lb	
34. Millet, 15 lb	
35. Forage sorghums, 8–12 lb	
36. Soybeans, 90 lb, and sorghum × sudangrass hybrid, 25 lb	
37. Soybeans (Group IV), 90 lb, and grain sorghum, 6–8 lb	
38. Pea, 100 lb, and small grain, 50 lb	
39. Spring oats and other small grains, 3 bu	

In Table 1.8-5, each forage species and mixture has been given an identification number; recommended seeding rates for pure seedings and mixtures are provided. (No-till forage seedings can be reduced 20 percent.) The numbered forages and forage mixtures have been classified by soil drainage characteristics and forage use.

No-Till Forage Seeding

Minimum or no-tillage establishment of forage crops is being practiced successfully on many Pennsylvania farms. Advantages include fewer soil and moisture losses, lowered fuel and labor requirements, seeding on an already firm seedbed, and much less time spent in stone removal. Research results from a two-year fuel consumption study conducted at Penn State indicate that conventional seeding of alfalfa requires about 6 gallons of diesel fuel per acre, whereas no-till seeding requires less than 1 gallon. This, along with other factors, represents a significant energy savings.

At first, no-till forage seeding was done to establish or reestablish a forage species or combination of species into already existing grass or grass-legume swards. More recently, no-till forage establishment following various row crops has allowed growers to take advantage of weed and pest control techniques normally provided by a sound crop rotation or an economical cropping system.

All forage species can be seeded no-till. No-tillage seedings of red clover have been the most successful, but alfalfa, birdsfoot trefoil, and crownvetch can also be seeded alone or with a forage grass. With no-till, perennial forage grass species can be seeded alone. Annual crops used for forage, such as summer annual grasses, small grains, and brassica crops, can also be no-tilled. The choice of varieties is the same for both conventional and no-tillage techniques.

Fertilization

Use a soil test to determine lime and fertilizer needs for any no-till forage seeding. Note that the Penn State soil test information sheet contains a separate crop category for no-till forage seedings.

In no-till systems, collect a normal soil sample of 6- to 8-inch depth to determine phosphorus and potassium needs and the pH of the topsoil layer. Follow the fertilizer and liming recommendations from the standard soil sample. However, in no-till management systems, if no lime is recommended from the standard depth soil sample, a second soil sample should be collected to determine whether an acid roof is developing at the soil surface from applications of nitrogen fertilizer. This soil sample should be collected from 1 to 2 inches deep and only needs to be measured for pH, which can be completed with a colorimetric field kit. If the pH of the surface layer is less than 6.2, then apply 2,000 lbs of calcium carbonate equivalent per acre to neutralize acidity at the soil surface.

Since limestone is not mixed into the soil mechanically, make lime applications at least six months before seeding to produce a pH change in the rooting zone. In addition, because phosphorus and potassium are not mixed with the soil mechanically in a no-till seeding, apply them before seeding as well.

Establishment

Equipment

No-till drills are necessary for successful establishment of no-till forage. The drills needed are essentially the same for seeding in sod and when following other crops. Many commercially available drills can do the job. A good drill should have individual-row flexibility, a wide range of easily changed depth adjustments, and be able to:

- Penetrate soil and/or residue properly. The drill must be heavily built, designed to carry additional weight, and have row-unit springs heavy enough to transfer that weight to the individual openers.
- Plant a wide variety of crops.
- Perform well in various crop residue conditions.
- Plant consistently well in both no-till and conventional seedbeds.

Following Corn

The greatest advantage of no-till forage seedings following corn is that they permit early planting, which in turn allows emerging forage seedlings to compete more effectively with germinating annual weeds. For adequate soil cover, plant alfalfa, red clover, or crownvetch (alone or with grasses) as soon as the soil surface is dry enough for good soil flow around the drill openers. Delay birdsfoot trefoil seedings until April or early May (two to three weeks after normal earliest seeding dates for alfalfa or red clover).

With early spring planting, an herbicide application may not be necessary at seeding. Although all perennial weeds should have been eradicated prior to forage establishment, which is often easily accomplished while an earlier crop of corn or soybeans is grown, if any grassy weeds or winter annual broadleaf weeds (i.e., anything "green") are present in the field, use Gramoxone 2S or glyphosate to control them. Phenoxy herbicide residues will damage forage seedlings; they are not recommended when seeding within two to three weeks after herbicide application.

Although most drills can handle corn grain residue, removing some of that residue (e.g., for animal bedding) often increases the uniformity of stand establishment. Most drills do not perform well when corn stalks are chopped and left on the soil surface; the seeding depth of small-seeded forages will be extremely variable, and their emergence will be challenged when seeds are placed too deep.

Be careful of triazine residue from the previous corn crop. Carryover of triazine residue is no greater in no-till seedings than in conventionally prepared seedbeds.

Monitor new alfalfa seedings for the potato leafhopper.

Following Small Grains

Because of moisture conservation, no-till forage seedings following a small grain germinate more quickly than do similar seedings made in conventionally prepared seedbeds in mid- to late summer. Accelerated germination usually leads to increased growth before the killing frost.

Good weed control in the small grain crop is essential to a weed-free environment for the new seedlings. One of the prescribed herbicide treatments outlined in Part II, Section 5: Small Grain Pest Management should be used at the proper time during small-grain growth.

Legume and Legume-Grass Mixtures

In all cases, allow at least seven to ten days after harvesting the small grain crop and removing straw before planting the forage crop. If time permits, delay planting until ⅓ to ½ inch of rain has fallen after harvest. This amount of rainfall allows volunteer small grain seeds to germinate, and the seedlings can be controlled with Gramoxone Extra. In any event, do not delay planting beyond the recommended seeding date for your area.

Brassicas

Rape, turnips, kale, and swedes germinate and form a canopy quickly. Using Gramoxone 2S immediately after small grain harvest generally provides adequate weed control. Seed immediately after spraying. For seeding rates, see "Forage Selection and Seeding Rates," above; for recommended fertility and management, see "Annual Forages for Pastures," below.

In Existing Sod

When possible, avoid planting legumes and/or legume-grass mixtures into an existing sod. Insects, diseases, and allelopathic activity reduce the likelihood of successful establishment. To avoid these risks, consider an alternative forage crop, such as a small grain (rye, wheat, oats), brassica, or summer annual grass. Using an alternative forage gives additional weed control to supplement a sound herbicide program, providing a better environment for successful establishment of subsequent no-till legumes or legume-grass seedings.

Small Grains and Brassicas

When planting small grains for forage or brassicas into sod, best control can be achieved with fall applications of Roundup/Ranger prior to fall preparation. If necessary, follow up with Gramoxone Extra the next spring for adequate grass suppression. See "Annual Crops for Forage," above, for specific information on seeding rates, fertility, and management.

Summer Annual Grasses

To stimulate grass production, apply 50 pounds of nitrogen per acre at early greenup of sod. Graze heavily or harvest an early cutting of hay. Allow 4 to 8 inches of regrowth. Apply glyphosate or Gramoxone 2S and plant immediately. See "Annual Crops for Forage," above, for specific information on seeding rates, fertility, and management.

Legume or Legume-Grass Mixtures

The prior use of any of the above-outlined crop alternatives greatly increases the chances for successful no-till establishment of legume or legume-grass mixtures. When this cannot be done and legumes or legume-grass mixtures are established directly into grass sod, note the following guidelines on sod suppression.

Sod suppression is possible through a combination of heavy grazing and the application of recommended herbicides. Either glyphosate or Gramoxone 2S may be used to control perennial grasses. Glyphosate should be applied when sod has regrown 8 to 10 inches. If Gramoxone Extra is used, apply immediately following grazing. A second application may be required in seven to ten days if regrowth is present. Do not apply any nitrogen in seeding year. Soil surface pH in old sods is critical. Test upper 2 inches to establish lime requirements.

Cutting Management

Seeding-year harvest management for no-till established seedings should be the same as for conventional seedings of the same species.

Pest Control

Except as indicated, weeds, insects, and diseases affecting no-till forage crops are similar to those affecting the same species seeded by conventional methods. Refer to Part II of this guide for more information.

Special Considerations

Many attempts have been made to use no-till establishment techniques to "thicken up" old legume stands, primarily alfalfa. This is not recommended. Research shows that, when alfalfa is seeded where it was grown the previous year, yields are lower than when it is seeded where another crop was grown prior to the new alfalfa seeding. Research indicates that a chemical released from the old alfalfa inhibits germination and seedling growth of new alfalfa; this inhibition is referred to as "allelopathy" or "autotoxicity." In addition, disease organisms build up their populations in older stands, and rotations help to reduce diseases by removing the host plants.

Forages for Pastures

A well-managed pasture program can often be the most economical way to provide forage for ruminant animals. On many farms where pasture makes up a significant portion of the forage program, feed costs are reduced by an estimated $0.50 to $1.00 per day per cow during the grazing season. However, to optimize the production and use of pasture, as well as animal performance, careful planning and sound management are important. Knowing your animals, plants, and soils, and being able to respond to their needs are skills that must be developed if pasture is going to make up a significant portion of your forage program.

Many possible pasture species can provide forage for grazing animals. Their use should be based on their suitability for the soil site, the animal enterprise, and the planned grazing management. Below is a brief description of some of these species. Table 1.8-6 is designed as a guide to help in planning for adequate pasture availability and forage quality for various animal enterprises over the whole grazing season.

For more information on varieties, establishment, and management of forage species, refer to the first part of this section.

Cool-Season Grasses

Cool-season grasses begin growth from mid-March (southeastern Pennsylvania) to mid-April (northern tier counties). They produce considerable forage in spring. In summer, production is depressed by high temperatures and moisture stress. If moisture supply is normal, production will increase slightly in September and early October and will cease by mid-October or mid-November. Most forage grasses produce highest yields on deep, well-drained (not excessively drained) soils. Some species, such as reed canarygrass, are capable of producing moderate to high yields on soils with very poor drainage, while other species do not persist in these soils.

Spring grazing of grasses can be started earlier by applying 50 pounds of nitrogen in March to hasten the spring green-up. Cows soon to freshen or with calves at side that are grazing grass pastures in early spring should have access to a magnesium-containing mineral supplement to help prevent grass tetany. Generally, cool-season grasses can begin to be grazed at 8 to 10 inches of growth in the spring.

Kentucky Bluegrass

Bluegrass is of high quality and palatable for grazing, particularly for horse pastures because it forms tough sods and resists trampling damage. The grass can tolerate close, continuous grazing but will produce low yields under this management. Because of its low productive capacity, bluegrass does not respond well to fertilizer above low rates. Its short growth makes harvesting for hay difficult.

Orchardgrass

Orchardgrass tolerates continuous grazing if the plant is not grazed below 3 to 4 inches. Production and persistence are better under rotational grazing to give the plant three weeks or more between summer grazings for recovery growth. Begin grazing when the plant reaches 8 to 10 inches in the spring and graze the earliest maturing varieties first. The tall growth and good yield potential make moderate fertilization rates feasible; surplus pasture can be harvested for winter hay or silage.

Reed Canarygrass

Reed canarygrass can tolerate continuous grazing, but yields are higher under a rotational system that gives three weeks or more of recovery between summer grazings. The growth potential of reed canarygrass pastures justifies moderate fertilizer rates. Harvesting pastures for hay or silage is feasible. New low-alkaloid varieties are more palatable for grazing animals.

Smooth Bromegrass

The pasture quality and palatability of smooth bromegrass are good, and it is very palatable to cattle, sheep, and horses. Bromegrasses tolerate moderate continuous grazing but produce more forage mass under a rotational scheme that allows three or more weeks of recovery. Moderate fertility rates are recommended for bromegrass, and excellent hay or silage can be produced from pastures in surplus growth periods.

Table 1.8-6. Suggested pasture components for different grazing purposes.

Animal	April to May	June to August	September to October	November to January[1]
Beef cows (calved in March)	Any of the cool-season grasses, preferably with legume (white clover, red clover)	Warm-season grasses	Cool-season grasses with or without legume	Stockpiled tall fescue
				Nitrogen fertilized
				Mixture with alfalfa, red clover, or trefoil
		All cool-season grasses with nitrogen fertilizer or legume (alfalfa, red clover)[2]	Stockpile tall fescue for later grazing	Corn stover fields
March calves	Graze with dams	Graze with dams; creep graze on grass-legume mixes; perennial ryegrass, or brassica crops	Same as in June to August	Sell as feeders or handle as stockers as below
Yearling steers and heifers (stockers)	Graze cool-season grass-legume pastures	Stockpiled birdsfoot trefoil	Cool-season grass-legume pastures (may need grain to fatten)	Stockpiled tall fescue
		Warm-season annuals		Nitrogen fertilized
		Cool-season grass-legume pastures (except tall fescue)		Mixture with alfalfa, red clover, or trefoil
	Top-graze pastures ahead of cows and calves in rotation	Top-graze ahead of cows and calves for rapid gains	Brassica crops	Late seeded brassicas
Lactating dairy cows	Cool-season grass-legume mixes, perennial ryegrass, timothy, bromegrass	Top-graze same species as in spring	Top-graze as in summer	Late seeded brassicas
			Spring-seeded brassicas	
Dry dairy cows, replacement heifers	Graze cool-season grass, grass-legume mixtures; some silage supplementation may be necessary			
Dairy beef steers	Top graze cool-season grass-legume mixtures (except tall fescue) or close graze and supplement with silage; graze brassica crops when available			
Ewes with lambs	Graze cool-season grass-legume mixtures	Graze cool-season grass-legume mixtures except tall fescue; stock-piled birdsfoot trefoil; brassica crops	As in June–August	Stockpiled tall fescue
				Nitrogen fertilized
				Mixture with legumes
			Brassica crops	Late seeded brassica
Dry ewes	Closely graze cool-season grass-legume mixtures			Stockpiled tall fescue
				Nitrogen fertilized
				Mixture with legumes
Lambs	Top-graze cool-season grass-legume mixtures	Top-graze cool-season grass-legume mixtures		Stockpiled tall fescue
		Brassica crops		Nitrogen fertilized
		Stockpiled birdsfoot trefoil		Mixture with legumes
				Late seeded brassicas
Horses[3]	Cool-season grass-legume mixtures; best grasses: timothy, Kentucky bluegrass, smooth brome; best legume: white clover	As in April–May	As in April–May	Stockpiled tall fescue
				Nitrogen fertilized
				Mixture with legumes

[1] Winter pasture availability depends on snow cover date.
[2] Keep close watch on cattle grazing fescue during this period; be ready to move to other pastures.
[3] Mares eight weeks before foaling should be removed from tall fescue pastures.

Timothy

Forage quality of timothy pasture is high; beef cattle, sheep, and horses eat it readily. Rotational grazing (three weeks or more of recovery) favors timothy production and persistence, but the plant tolerates moderate continuous grazing. Grazing can be started in spring at 8 to 10 inches of spring growth, but grazing when the flower stems are elongating can cause reductions in the stand. Moderate levels of fertilization are recommended. The tall growth of timothy allows mowing surplus pasture for hay and silage.

Tall Fescue

Fescue is quite tolerant of continuous grazing but produces higher yields under rotational grazing. It forms a tough sod, and established pastures hold up well under intense grazing. Grazing may begin in spring at 8 to 10 inches of new growth. Surplus pasture growth may be harvested for hay or silage.

Tall fescue is particularly well suited to "fall stockpiling" for early winter grazing because of its ability to grow well into the fall. In this practice, animals are removed from fescue pastures from August 1 to August 10, and 70 to 80 pounds of nitrogen per acre are applied. The resulting growth can be grazed in November to January, as snow cover permits. Stockpiled growth is of high quality through December.

Many quality problems of tall fescue are associated with the presence of a toxic endophytic fungus growing in the plants. New varieties of tall fescue that contain no endophyte or a novel "friendly endophyte" fungus are available and should be used when establishing new or renovating old pastures. Exclusive grazing of old fescue varieties during the summer occasionally leads to a condition known as "fescue toxicosis," in which cattle retain their winter coat, breathe rapidly, and gain poorly. Using improved tall fescue varieties eliminates this risk.

Annual Ryegrass

Annual ryegrass is a cool-season bunch grass native to Europe. It is highly adaptable to a wide range of soil types and can tolerate abuse by both livestock and the producer. It establishes relatively quickly and produces a very palatable and digestible forage. In Pennsylvania, annual ryegrass is planted most frequently in late summer, provides fall grazing, goes dormant over the winter, resumes growth in the spring, and then dies as the temperature and moisture stress increase in early summer.

Perennial Ryegrass

Pastures of perennial ryegrass are high in quality and animal acceptability. Cattle, sheep, and horses all perform well on the forage. It is an excellent species to use in creep grazing pastures for young animals. Perennial ryegrass that is grazed continuously results in poor stand life, and greater pasture yields result from rotational grazing systems that allow for three weeks or more of regrowth. Pastures may be grazed when spring growth reaches 8 to 10 inches in height. Hay yields may be low unless considerable time for accumulation is allowed. Grow this species in mixtures with legumes (alfalfa, red clover, white clover)—it may help prevent bloat if grazed with or instead of legumes.

Legumes

Legume species are important for economical production of pasture. Alfalfa, clovers, and birdsfoot trefoil all provide high-quality forage for grazing and do so without nitrogen fertilizer. These plants tend to be deep rooted and more tolerant of summer moisture shortages than grasses. From these three standpoints, legumes are a very important component of productive pasture programs.

Legumes in pasture programs call for more careful management than pure grass stands. Most legumes do not persist under continuous grazing and must be grazed rotationally. Pure stands of legumes, except birdsfoot trefoil, tend to cause bloat in cattle and sheep. Fertility (phosphorus and potassium) requirements are slightly higher for legumes than grasses. Mixtures of legumes and grasses make excellent pastures. Because of competition between grass and legume, however, managing grass-legume pastures is more complicated than managing pure stands of either one alone. Pasture management practices should usually be designed to favor the legume in the mixture.

Alfalfa

Alfalfa is a highly productive legume suited for harvesting or grazing. Animal gains are excellent, but care must be exercised to prevent bloat. Bloat control compounds (e.g., Poloxalene) must be used where pure alfalfa is grazed. Mixing a palatable grass, such as orchardgrass or perennial ryegrass, with alfalfa reduces bloat problems.

Alfalfa can be grazed starting in the late pre-bud stage in spring. Alfalfa pastures or grass-alfalfa mixtures must be rotationally grazed. The maximum grazing period for one subdivision pasture should be 10 to 14 days. After a subdivision pasture is grazed down, it should be given about 35 days to recover while other subdivision pastures are being grazed; therefore, three to five pasture subdivisions must be available. Clipping the pastures after grazing is important, particularly in spring when companion grass growth is stemmy. Pure alfalfa pastures are subject to severe trampling damage during prolonged wet periods. Adding grass to the mixture helps reduce this problem. When harvested during periods of grazing surplus, alfalfa and alfalfa-grass pastures produce excellent-quality hay or silage. For more information, refer to "Agronomy Facts 42: Grazing Alfalfa in Pennsylvania."

Red Clover

Red clover forage is high in protein and energy, and animals eat it readily. Gain rates on red clover are excellent, but bloat can be a problem in pure or mostly-clover stands. Palatable grasses in the mixture (timothy, brome, orchardgrass, and perennial ryegrass) decrease the risk of bloat.

Red clover can be grazed at the vegetative stage in spring. Clover/grass mix pastures should be rotationally grazed. Subdivision pastures should be grazed down in 10 to 14 days and then given 28 to 35 days to recover before grazing again. As clover stands begin to thin out during the second or third year, pastures can be managed like pure grass stands. Red clover seedlings are vigorous and can be reseeded in "run-out" pastures to maintain the legume without destroying the sod (see the sections on pasture establishment, renovation, and maintenance, below). Quality hay or silage can be made from clover/grass pastures during periods of pasture surplus.

Birdsfoot Trefoil

Forage is of excellent quality and does not cause bloat. Trefoil forage quality does not decrease rapidly with maturity as it does for cool-season grasses, alfalfa, and red clover. Because of this, spring growth of trefoil may be "stockpiled" for grazing in late June and July when other pastures are growing slowly.

Trefoil may be grazed starting at the bud stage in spring. For long persistence, trefoil should be rotationally grazed (10 to 14 days or fewer, followed by 28 to 35 days for recovery). To maintain sufficient stubble for quick regrowth, trefoil pastures should not be grazed under 3 inches. In emergencies, trefoil may be continuously grazed (up to six to eight weeks), as long as 3 to 4 inches of stubble are maintained and time for recovery growth is allowed prior to a killing frost (four to five weeks). Allowing the plants to go to seed (i.e., "stockpiling" spring growth until July 1) every two to three years aids in keeping dense stands of trefoil in pastures.

White Clover

White clover (common and ladino types) is widely grown in pastures. Its forage quality is excellent; beef cattle, sheep, and horses eat it readily. Bloat can be a problem in pure or predominantly white clover stands. Ordinarily, there is plenty of grass in the mixture to minimize this problem.

White clover may be grazed continuously or rotationally. White clover may be grazed closely (1 to 2 inches) without serious damage to stands, but closely grazed pastures must be given time to recover. If grazed rotationally with tall-growing grasses, the pastures should be grazed at intervals of three weeks or less to prevent the grass from shading out the clover.

Warm-Season Grasses

Switchgrass, big bluestem, Caucasian bluestem, and Indiangrass must be rotationally grazed (not shorter than 6 to 12 inches in summer) for persistent productivity. These grasses grow tall, and cattle generally begin grazing them from the top of the canopy down. For more information, see "Warm-Season Grasses," above.

Chicory

Forage chicory is a perennial suited to moderately or well-drained soils with medium to high fertility levels and a pH of 5.5 or greater. Chicory produces leafy growth that is higher in nutritive and mineral content (if managed properly) than alfalfa or cool-season grasses. It has a relatively deep taproot, making it tolerant to drought. Chicory provides excellent spring and summer forage for grazing animals.

Although chicory is a relatively new forage crop in the United States, it has been used in other countries for over 300 years. Much of the breeding for improved forage characteristics has been completed in New Zealand. For more detailed information about chicory, refer to "Agronomy Facts 45: Forage Chicory."

Annual Forages for Pastures

Varieties

Brassicas

Forage brassicas are high-yielding, high-quality, fast-growing annual crops. They are used primarily for grazing livestock and dairy animals. They are quick to germinate, and when seeded in the spring provide a hedge against summer drought. They fit well between crop rotations to provide forage in late summer or late fall. For more detailed information, refer to "Agronomy Facts 33: Use of Brassica Crops to Extend the Grazing Season."

Rape

Rape is a short-season, leafy brassica whose stems and leaves are eaten by the grazing animal. It can also be greenchopped. Rape regrows after harvest. Many varieties have been tested in Pennsylvania. Rangi, Windall, Dwarf Essex, Winfred, and Emerald have been shown to perform satisfactorily.

Turnips

Turnips are a short-season root brassica whose roots, stems, and leaves are used. It regrows after harvest. Purple Top, Forage Star, and Green Globe have been tested and shown to perform satisfactorily in Pennsylvania.

Kale

Kale is a long-season leafy brassica whose stems and leaves are used. Recent studies in Pennsylvania have shown that

Marrow Stem, Maris Kestral, and Premier show promise. Except for Premier, kale does not regrow after harvest.

Swede

Swede is a long-season root brassica whose roots, stems, and leaves are used. Calder has been found to be the most frost tolerant of all brassicas tested in Pennsylvania. Swede does not regrow after harvest.

Hybrids

Typhon, a Chinese cabbage-turnip hybrid, performs best under a multi-harvest system.

Fertilization

Determine lime and fertilizer needs with a soil test. In the absence of a soil test, apply 75-60-60 per acre. Brassicas require nitrogen, which should be applied at time of seeding.

Establishment

Brassicas grow best in moderately to well-drained soils. Brassica crops commonly are seeded at corn planting time for late summer grazing or in August for fall and winter grazing. No-till seeding into grain stubble or sod is recommended. Herbicides must be used to control weeds or suppress sod prior to planting (see "No-Till Forage Seeding," above). Plant seeds in 6- to 12-inch rows and place them no deeper than ½ inch. Apply nitrogen at seeding time.

For suggested seeding rates, see "Forage Selection and Seeding Rates," above.

Harvesting

- **Rape.** Rotationally graze, strip graze, or greenchop 90 to 120 days after establishment. Leave 6-inch stubble for quick regrowth.
- **Turnips.** Rotationally graze or strip graze 70 to 90 days after establishment.
- **Swede and kale.** Rotationally graze or strip graze 150 days after seeding.

Special Considerations

Brassica crops are very high in crude protein and energy but extremely low in fiber. Because of their low fiber content, brassicas should make up no more than two-thirds of the daily livestock diet. Brassicas should be supplemented with a higher-fiber grass pasture or long-stem hay.

Sudangrass or sorghum X sudangrass hybrids are ready for grazing about six weeks after seeding. These must be grazed rotationally (two weeks or less at a time) to avoid prussic acid (HCN) poisoning. Prevent animals from grazing large amounts of new growth high in HCN. Do not start grazing on drought-stressed regrowth of these grasses until the stress is relieved. Frosted forage should not be grazed for a week after frosting. These practices also help reduce danger of HCN poisoning.

Small grains such as oats, rye, wheat, or triticale can provide late fall and early spring grazing.

Other forage resources, such as corn stalks grazed after harvest, and the use of aftermath hay, can be planned into a full-season grazing program.

Matching Forages to Your Needs

You should consider several factors when selecting pasture forages for your grazing program. These include the desired production of the grazing animal, forage yield, quality, and suitability for the soil site. Use the following information to help you plan for adequate pasture availability and forage quality for various animal enterprises over the whole grazing season. Other variations can be used to suit the needs of individual producers.

Pasture Systems

Developing a pasture system that uses your land resources and fits in with your total animal, forage, and crop program is an important first step in pasture management. A major goal in pasture management is to provide quality pasture for the grazing animals throughout the grazing season. By using the various growth patterns of the many pasture species grown in Pennsylvania, the grazing season can last from April to December (Figure 1.8-1).

A pasture's present condition as well as its anticipated use should determine whether to reestablish, renovate, or leave a pasture as it is. Most pasture can be improved without renovation simply by proper liming, fertilization, and controlled grazing management. But if a pasture is to be reseeded or renovated, it should be done properly to ensure adequate results for your investment. Remember that the costs of establishment cannot be justified if pastures are not going to be managed properly.

Permanent Cool-Season Pasture

In most cases, permanent cool-season pasture is land not suitable for crop production because of poor soil characteristics or topography. These sites often are overgrazed and under-fertilized. With proper management, these pastures can provide significant amounts of forage for many dairy and livestock farms. Kentucky bluegrass, the species most tolerant of close grazing, is the cool-season grass commonly found in permanent pasture. In addition, more productive forage species such as tall fescue or reed canarygrass can be grown on permanent pasture sites, often with a legume. Other grasses also may be found in permanent pastures, but they do not persist as well.

Semi-permanent Cool-season Pasture

When properly managed, most perennial cool-season legumes and grasses grown for hay and silage also can be used for pasture. Often these pastures are incorporated into the crop rotation and, when grown on good soils and properly managed, can be very productive.

Warm-Season Pasture

Warm-season perennial grasses, including switchgrass, big bluestem, and Indiangrass, grow well from mid-June through September, can provide adequate pasture when cool-season pastures are inadequate, and are especially suited for beef cattle.

Annual Pastures

Grown in rotation with other crops, annual pastures containing brassicas, small grains, or summer annual grasses can provide supplemental spring, summer, or fall grazing.

Deferred or Stockpiled Pasture

This practice leaves paddocks or pastures ungrazed during certain seasons to accumulate forage for grazing needed when pasture production is not sufficient to maintain the herd or flock. For example, some forages, such as birdsfoot trefoil or crownvetch, can be "stockpiled" in the spring to be grazed during the summer slump in pasture production. Other forages, such as birdsfoot trefoil or tall fescue, may be stockpiled in late summer for late fall and winter grazing. In this way, grazing is made available during seasons when low productivity of pastures might force the producer to sell cattle or feed hay. For more information about stockpiling forages, refer to "Agronomy Facts 41: Strategies for Extending the Grazing Season."

Designing a Pasture System

After considering which species to grow and which pasture components to use, calculate the forage requirements of your herd or flock. Dry matter forage intake varies by animal species and class and is often influenced by what forage is offered and how much. To determine stocking rate and carrying capacity, animal units often are used; these figures provide a much better measure of pasture required than the actual animal numbers.

One animal unit is based on the daily forage intake of one 1,000-pound dry cow (about 25 pounds of dry forage per day). Table 1.8-7 gives some typical animal unit values for various species and classes of livestock. For information about pasturing horses, refer to "Agronomy Facts 32: Pasture and Hay for Horses."

Estimating the acreage required to pasture a herd or flock depends on not only the animals' feed requirements but also available forage produced. Pasture growth depends on plant species, soil characteristics, topography, fertilization, temperature, and soil moisture. Because of the variability in pasture growth, we can only estimate the amount of pasture required for grazing animals. Table 1.8-8 lists estimated acreages required for grazing animals on various types of pasture. To estimate how much pasture a herd or flock will need, use Table 1.8-7 to calculate the total animal units of the herd. For example, if a beef herd contains 25 dry cows weighing 1,300 pounds each and 15 heifers at 550 pounds each, there are 47.5 animal units (AU) in this herd.

25 cows × 1.3 AU per cow = 32.5 AU
+ 15 heifers × 1.0 AU per heifer = 15.0 AU
Total AU for herd = 47.5 AU

Second, use Table 1.8-8 to estimate how many acres the herd will need during each month of the grazing season. If the

Table 1.8-7. Animal units of various species and classes of livestock.

Livestock	Animal Units
Beef Cattle	
1,000 lb dry cow	1.0
1,300 lb dry cow	1.3
1,000 lb lactating cow (first 4 months after calving)	1.4
1,300 lb lactating cow (first 4 months after calving)	1.6
2,000 lb mature bull	1.7
550 lb growing-finishing heifer (1 lb/day gain)	1.0
550 lb growing-finishing steer (2 lb/day gain)	1.23
Sheep	
110 lb brood ewe	0.15
132 lb brood ewe	0.17
154 lb brood ewe	0.18
175 lb brood ewe	0.20
300 lb mature ram	0.40
110–132 lb replacement ewe, lambs, and yearlings	0.22
220 lb replacement ram, lambs, and yearlings	0.42
*Dairy**	
1,000 lb dairy cow (maintenance)	1.0
800 lb dairy cow (last 2 months of gestation)	1.0
1,000 lb dairy cow (last 2 months of gestation)	1.2
1,300 lb dairy cow (last 2 months of gestation)	1.5
1,500 lb mature dairy bull	1.4
2,000 lb mature dairy bull	1.9
550 lb growing dairy heifer	1.0

*Animal units for lactating cows are difficult to determine because of supplemental feeding.

Table 1.8-8. Estimates of acreage required to provide forage needs for one animal unit, assuming 70 percent pasture utilization.

Pasture Species	Pasture Production	Annual Yield (T/A DM)	Acres Required to Provide Forage Needs for One Animal Unit*								
			April	May	June	July	August	September	October	November	December
Kentucky bluegrass/ white clover	low	1.0	10.7	1.2	2.7	11.1	11.1	4.5	6.9	—	—
	medium	2.0	5.4	0.6	1.3	5.5	5.5	2.2	3.5	—	—
	high	3.0	3.6	0.4	0.9	3.7	3.7	1.5	2.3	—	—
Alfalfa/grass	low	3.0	—	0.6	0.9	1.2	1.2	1.8	3.1	—	—
	medium	4.5	—	0.4	0.6	0.8	0.8	1.2	2.1	—	—
	high	6.0	—	0.3	0.4	0.6	0.6	0.9	1.5	—	—
Red clover/grass	low	2.0	—	0.9	1.3	2.3	2.3	1.7	3.5	—	—
	medium	3.0	—	0.6	0.9	1.5	1.5	1.1	2.3	—	—
	high	4.5	—	0.4	0.6	1.0	1.0	0.7	1.5	—	—
Birdsfoot trefoil/ grass	low	2.0	—	1.0	1.1	1.8	1.8	1.8	9.2	—	—
	medium	3.0	—	0.7	0.7	1.2	1.2	1.2	6.2	—	—
	high	3.5	—	0.6	0.6	1.1	1.1	1.0	5.3	—	—
Tall grass plus nitrogen	low	2.0	5.4	0.8	1.3	2.8	2.3	1.8	9.2	—	—
	medium	3.0	3.6	0.5	0.9	1.8	1.5	1.2	6.2	—	—
	high	4.5	2.4	0.4	0.6	1.2	1.0	0.8	4.1	—	—
Warm-season grass	low	3.0	—	—	0.9	0.6	0.6	1.2	—	—	—
	medium	4.0	—	—	0.7	0.4	0.4	0.9	—	—	—
	high	5.0	—	—	0.5	0.3	0.3	0.7	—	—	—
Stockpiled tall fescue	low	3.0	3.6	0.6	0.9	1.5	—	—	1.7	1.5	1.6
	medium	4.5	2.4	0.4	0.6	1.0	—	—	1.1	1.0	1.0
	high	5.5	1.9	0.3	0.5	0.8	—	—	0.9	0.8	0.9
Spring-seeded brassicas	low	2.5	—	—	—	1.1	0.6	0.5	—	—	—
	medium	3.8	—	—	—	0.7	0.4	0.4	—	—	—
	high	5.0	—	—	—	0.6	0.3	0.3	—	—	—
Summer-seeded brassicas	low	2.0	—	—	—	—	—	—	1.4	0.6	0.6
	medium	3.0	—	—	—	—	—	—	0.9	0.4	0.4
	high	4.0	—	—	—	—	—	—	0.7	0.3	0.3
Corn stover		1.7	—	—	—	—	—	—	—	0.3	—

*Based on an animal unit consuming 25 pounds of dry matter (DM) forage per day with 70 percent of pasture utilized. Actual acreage will depend on pasture yield, dry matter intake, and efficiency of pasture utilization.

herd will be grazing low-producing Kentucky bluegrass and white clover pasture in May, approximately 57 acres is needed to support the herd.

7.5 AU × 1.2 acres per AU = 57 acres

The same herd grazing high-producing Kentucky bluegrass and white clover pasture would need only approximately 19 acres during May.

For more information about designing a pasture system, refer to "Agronomy Facts 43: Four Steps to Rotational Grazing."

Pasture Facilities

Fences

Fences are essential in pasture programs to secure and manage livestock for efficient use of pasture production. Properly designed and constructed fencing will return benefits in reliability, long life, and low maintenance.

Permanent Fence

For perimeter and other permanent fences, physical strength is required to hold and turn livestock. Properly set and spaced line posts along with high-tension wires are necessary to attain this strength. High-tensile wire provides twice the breaking strength of conventional barbed wire. Because of its high strength and ability to stretch without sagging, it is capable of being pulled up tighter along an entire fence line. This results in a stronger, more effective barrier with no loose or sagging wires to serve as starting points for stretching, breaking, and eventual penetration by livestock or predators. For more specific information on high-tensile fencing, refer to the publication NRAES-11, "High-Tensile Wire Fencing."

Electric fences usually require fewer, lighter fence posts and are easier and faster to erect than other fences. However, when the current is low, these fences are not strong enough to turn animals, and they require frequent inspection and maintenance. Three keys to an effective electric fence are (1) build it to control the animal in question, (2) make it flexible enough to withstand attacks by untrained animals, and (3) be sure it delivers a safe, effective shock every time the animal touches the wire.

Modern solid-state electric fence chargers provide very high voltages (5,000 volts or higher) at low impedances (high resistance to shorting out) and short impulse time. These chargers can energize several miles of fence. It is extremely important that the chargers and fence be properly grounded to achieve optimum performance. This may require that several ground rods be placed in a series. The problem of shorting out because of grass and weed contact with energized wires has been reduced but not eliminated by modern fence chargers.

Rotational grazing requires that large pastures be subdivided into several small pastures. This can create a large number of cross-fences. Cross-fences may consist of one, two, or three strands if electric fencing is used. Careful attention to fence charger selection, good grounding, and keeping fence strands free of weeds can ensure good animal control. If pastures are to be used for occasional hay harvest, removable cross-fences may be desirable.

Temporary Fences

Temporary fences can subdivide pastures during periods of rapid growth or fields that may later be used for cropping. For small paddocks, temporary fencing has economic advantages over permanent fencing. Temporary fencing materials (polywire, polytape, and polyrope) are light, easy to handle, and provide adequate conductance to confine most animals.

Water

Streams are a common source of water. Water quality and conservation of stream bank areas are best served if animals are restricted to watering at a few well-protected areas. Springs and seeps can be developed as drinking water sources for animals. These sources can be particularly helpful in rotational grazing systems, which require several water sources. Cooperative extension and Soil Conservation Service personnel can assist in locating and designing spring and seep development structures.

If water is piped to pastures, aboveground tubing is a relatively inexpensive method that can provide years of service if properly maintained. The availability of hydro-ram pumps (pumps that require no electricity) has increased the options for providing water to grazing livestock. If a permanent water system is to be installed, lines must be buried at least 36 inches deep to protect against freezing.

Shade

In most areas of Pennsylvania, shade would benefit grazing livestock only a couple days out of the grazing season if water is available. Therefore, the cost and negative aspects of providing shade, which include reduced grazing, trampling of plants, and concentrating manure (nutrient) in and around the shaded area, are greater than the potential benefits of shading.

Animal-Handling Facilities

Handling facilities (chute, headgate, holding pens) are very important in routine herd management, treatment, and calving difficulties. Designs for effective handling facilities are available in fact sheets from agricultural engineering extension specialists.

Pasture Establishment

Pasture seedings may be established using conventional or no-till techniques. These procedures are identical to those described for establishing forages for hay or silage. Since pastures often are established on sloping land, proper attention must be paid to erosion control measures.

Pasture Renovation

Over time, legumes and productive or palatable grasses may be lost from pasture because of overgrazing or diseases and pests. Renovation techniques can restore these stands to a high level of production without destroying the existing sod. There are three forms of renovation for such sites: limited tillage, no-tillage with chemical sod control, and no-tillage with animal grazing for sod control. All methods for introducing

grasses or legumes into existing sods depend on adequate fertility and proper pH. Soil samples should be taken a year ahead of renovation and any deficiencies should be corrected.

Limited Tillage

This method uses a disk or other tillage implement to disturb the sod surface. Sod should be tilled once or twice to destroy 30 to 50 percent of the surface and expose the soil. Seed should be broadcast on or drilled into the pastures in late winter or early spring. Pastures should be mowed, grazed, or treated with an appropriate herbicide to prevent excessive competition from surviving pasture plants or weeds.

No-Tillage with Chemical Sod Control

This technique uses herbicides to suppress sod growth and allow establishment of introduced species. If possible, the pasture to be renovated should be grazed closely the preceding fall to suppress spring growth vigor. If biennial or perennial broadleaf weeds are present, the pasture should be sprayed the previous autumn with 2,4-D or Banvel. In spring, the sod should be sprayed with Gramoxone 2S when 2 to 3 inches of new growth is present. Special no-till drills that are designed to cut a slit in the sod for seed placement have been successful. Seedings in May or later, particularly of alfalfa, have benefited from an insecticide at planting.

No Till Planting Using Grazing to Control Sod Competition

This technique succeeds best where the sod is open and not a dense cover, a condition promoted by heavy grazing the previous fall. Red clover is one of the easiest species to establish using this technique. Seed may be sown in late February through early April while the soil surface is still freezing and thawing. When the existing sod has 2 to 4 inches of new growth in spring, it should be grazed closely (1.5 inches) for a short period (one week or less). Then, when regrowth is 6 to 8 inches, the sod should be grazed closely again (3 inches). The pasture should be mowed at the early boot stage to remove tall stemmy regrowth. The pasture can then be rotationally grazed through the summer.

Frost Seeding

Frost seeding is a common method of introducing desirable species into an existing pasture. The technique involves spreading the seeds onto the pasture in late winter when the ground is frozen at night and thaws during the day. Freezing and thawing creates openings (honeycombs) in the soil surface into which seeds fall. If adequate seed-soil contact exists, germination occurs when the soil warms.

Frost seeding has proved most successful with clovers. The ground must be frozen when the seeds are spread. For this reason, frost seeding is usually done in the early morning before the temperature warms and the soil begins to thaw.

Pasture Maintenance

Fertilization

A soil test is the best guide for proper fertilization. In the absence of a soil test, refer to the typical plant nutrient recommendations in Part I, Section 2.

The desired production level and species present in the pasture determine the fertilization of a pasture. Maintaining a pH above 6.0 is necessary to keep legumes in the pasture. If legumes constitute greater than 30 percent of the pasture, then fertilizing with nitrogen is not recommended because the legume contributes adequate nitrogen through nitrogen fixation. Fertilize these pastures annually with phosphorus and potassium. If the pasture contains less than 30 percent legume, then fertilize as if the legume were not present.

Nitrogen is extremely important for grass production. Depending on the grass species, 150 pounds of nitrogen per acre, split and applied at least three times during the year—50 to 60 pounds per acre in early spring when the grass first greens up and 50 pounds per acre in early and late summer—may be needed to maintain production.

Manure can be used in place of fertilizers to supply plant nutrients, but this can lead to potential problems in a grazing situation. Grasses that have been exposed to manure tend to be less palatable, which may reduce animal intake. In addition, adding manure to a pasture increases the risk of parasite cycling in the grazing animals.

Pest Control

A properly maintained pasture promotes a vigorous sod that is highly competitive with most weeds. Insects and diseases can be expected to be the same in pastures as for plants managed for hay or silage. Refer to the "Pest Management" section of this guide for more information.

Grazing Management

Grazing management means controlling grazing animals on pasture. The two most important tools for influencing the level of animal output under grazing are concentration of animals per acre (stocking rate) and system of grazing management.

Grazing Pressure and Stocking Rate

The closeness to which a pasture is grazed is defined as grazing pressure. Grazing pressure is affected by both stocking rate (animals per acre) and available forage (pounds of forage per acre).

High grazing pressure causes close grazing and short pasture stubble. Animal performance is reduced because animals are forced to consume all portions of the pasture, including the poorer quality forage (Figure 1.8-2). Excessively high grazing pressure results in overgrazing.

Low grazing pressure refers to selective grazing with unlimited forage available to animals (Figure 1.8-2). Animal

Figure 1.8-2. Effect of grazing pressure on production per animal and per acre.

production rates (gain per head per day, etc.) usually are high at low grazing pressure. Very low grazing pressure, or under-grazing, results in wasted forage and consequent poor animal production per acre.

Optimum grazing pressure occurs when available forage matches animal needs; this is analogous to the quantity of forage offered daily to animals in confinement when rations are balanced. To maintain optimum grazing pressure, it is important to adjust the stocking rate so that available forage is maintained within an optimum range.

Available forage not only influences stocking rate but can also affect dry matter intake. As the amount of forage decreases, the per-animal intake decreases. Reducing available forage from 1,000 to 500 pounds per acre has been shown to reduce average intake by almost 40 percent. For optimum grazing, maintain available pasture at 1,000 to 1,500 pounds of dry matter per acre. On average, a 3- to 4-inch bluegrass/white clover sward has about 1,000 pounds of dry matter per acre; in tall grasses and legumes, 6 to 8 inches of growth will contain this amount.

Unfortunately, not all available forage in a pasture is used. Some of the forage is trampled or fouled by urine or manure and remains uneaten. The amount of available forage that is consumed is called utilized forage. At high grazing pressures, animals are forced to consume more of the available forage, resulting in a relatively high (greater than 80 percent) utilization rate. At low grazing pressures, animals will refuse to eat portions of the forage, thus decreasing the utilization rate—as the length of grazing period increases (lower grazing pressure), the percentage of utilization decreases (Table 1.8-9).

Grazing pressure affects not only animal performance but also the plant species in a pasture. Long periods of low grazing pressure commonly cause a loss of legumes from the stand. At the other extreme, long periods of high grazing pressure can result in a temporary or long-term decrease in pasture production. High to excessive grazing pressure for long periods with little or no opportunity for selective grazing also causes low animal intake and low gain rates.

Short periods of high grazing pressure can serve useful purposes. One to two weeks at high grazing pressure three or four times during the grazing season can help maintain legumes in the stand and utilize forage that might otherwise be wasted. It is important not to expose lactating cows or growing animals (calves, yearlings, lambs) to long periods of high grazing pressure. Beef cows and ewes can tolerate high grazing pressure after breeding.

Management Practices

How animals are managed on pastures can strongly affect forage production and persistence and animal production. Selection of grazing management practices is a key decision in designing a pasture management program. Some important grazing practices are listed below.

Continuous grazing. The entire pasture area is grazed continuously for periods of six weeks to the whole growing season. This method appears simple because it requires few fences and water sources and less monitoring of the pasture condition, resulting in the need for less labor. Uncontrolled continuous grazing uses a fixed stocking rate on a fixed land area and often leads to under- or overgrazing and poor pasture utilization.

Controlled continuous grazing methods try to maintain an optimum grazing pressure. Grazing pressure can be increased by increasing the stocking rate (adding animals) on a pasture or temporarily fencing out part of a pasture for hay harvest. High grazing pressure may be relieved by removing some animals from the pasture, allowing animals access to other pastures or hayfields, or feeding harvested feed to the animals on pasture. For Kentucky bluegrass and perennial ryegrass, maintain a grazing height of 2 to 3 inches. For tall grasses, maintain a grazing height of 4 to 5 inches.

Close continuous grazing can lower pasture production and decrease persistence of many grasses and legumes. Therefore, it is important to use forage species adapted to continuous grazing.

Clipping pastures with a rotary mower is a good practice if pastures are undergrazed and growth gets ahead of the grazing animals. Clipping removes this tall, rank vegetation and encourages new growth of higher-quality forage.

Since animals tend to congregate at water, soil nutrients from their waste become concentrated in one area of the pasture. Providing more than one source of water helps distribute nutrients more widely across the pasture.

To maintain a productive pasture in a continuously grazed system, it is important to avoid overgrazing. During periods of dry weather, remove the animals and give the pasture a rest.

Table 1.8-9. Suggested paddock sizes based on grazing period and available pasture in an intensive rotational grazing system.

Grazing Period (days)	Pasture Utilization (percent)*	Available Pasture (lb dry matter/A)		
		750	1,000	1,500
		Acres per Animal Unit		
1	80	0.042	0.031	0.021
2	75	0.089	0.067	0.044
3	75	0.133	0.100	0.067
4	70	0.190	0.143	0.095
5	65	0.256	0.192	0.128
6	60	0.333	0.250	0.167
7	60	0.389	0.292	0.194

*Estimates of the percentage of pasture actually consumed. Utilization is usually improved as grazing pressure is increased. To calculate paddock size, multiply the suggested acres per animal unit by the animal units in your grazing group (see Table 1.8-7). One animal unit = feed requirements of a 1,000 lb dry cow (25 lb dry matter/day)

Rotational grazing. The pasture area is divided into two or more subpastures, also called "paddocks," with each subpasture being grazed and "rested" in turn. Putting the whole herd in a small paddock results in rapid use of available forage. When a paddock is grazed off, animals are moved to a fresh one, allowing each paddock to be grazed more completely and to have a rest period. The rest period is critical for the continued productivity of some forage species.

Time that animals are on a paddock is referred to as the grazing period; time off the paddock is the rest period. Rotational grazing systems vary in design and intensity. Typical rotational grazing systems usually have fewer than seven paddocks with a grazing period of one to two weeks. Animals have a high degree of selectivity during the first part of the grazing period. With these lax systems, plants grazed at the beginning of the grazing period are likely to have regrowth that is eaten before the grazing period ends, resulting in lower productivity.

Intensive rotational grazing systems usually have more than seven paddocks with grazing periods of less than one week to as little as half a day. There is more control of what the animal eats, and typically better growth and persistence of pasture plants. When managing an intensive rotational grazing system, it is important to remember that the stocking rate is very high within one paddock and overgrazing can occur very rapidly. Animals must be moved when the available pasture falls below its optimum range. Allow grazing to begin when tall grasses reach 8 to 10 inches and remove animals when grass heights reach 3 to 4 inches. Begin grazing short grasses such as Kentucky bluegrass or perennial ryegrass when they reach 6 to 8 inches; remove animals when grass heights are 3 to 4 inches. To maintain milk production levels, you may need to remove highly productive dairy animals from paddocks before the plants reach these heights.

Rest periods should be based on the growth rate of the pasture and will vary depending on the season and weather conditions (Table 1.8-10). Growth rate is affected by soil productivity and fertility levels. In most pasture systems, areas vary in soil productivity, and growth rate also varies. Therefore, rest periods may vary even within a pasture system. The best way to manage this situation is not to use a set rotational scheme, but to move animals to those paddocks that have reached their optimum available pasture. Keep animals off a particular paddock until it reaches this level.

Table 1.8-10. Typical paddock rest periods for rotational grazing systems.

Season	Weather Conditions	Growth Rate	Rest Period
Spring	Cool, moist	Fast	10–14 days
Spring	Warm, dry	Medium	14–20 days
Summer	Hot, moist	Slow	30–35 days
Summer	Hot, dry	Very slow	40–60 days

Paddock size depends on the number and class of animals being grazed, the amount of available pasture at the beginning of grazing, and the desired grazing period. Table 1.8-9 provides some suggested paddock sizes for intensive rotational grazing. Adjustments may be necessary if the stocking rate changes. For flexibility, the use of temporary interior fences is recommended. The number of subdivisions needed for a rotational grazing system depends on the number of days the animals graze in a paddock and the maximum summer rest period needed.

Paddock number = (maximum summer rest period ÷ grazing period) + one
Example: (40 days rest ÷ 3 grazing days) + 1 = 14 paddocks

The species and class of grazing animal may determine the grazing period. Lactating dairy cows need

consistent-quality forage; therefore, the grazing period may be anywhere from half a day to two days. Beef cows, brood ewes, and most other ruminants do not require as consistent a quality of forage, and a grazing period of three or more days may suffice.

Stocking rate and available pasture are also important to managing a rotational grazing system. Spring management usually involves diverting some of the pasture for hay or silage. For more information about designing a pasture system, refer to "Agronomy Facts 43: Four Steps to Rotational Grazing."

"Creep" grazing. Excluding mature animals while allowing young calves and lambs access to high-quality, highly palatable forage is known as creep grazing. This can be achieved by raising the electric fence high enough to allow young animals to walk under but low enough to restrict the movements of larger, more mature animals. A special creep gate can also be used to allow young animals to graze the creep pasture and to return for suckling, much like a creep grain feeder. In rotational grazing systems, a creep gate can allow young animals to graze the next fresh paddock before mature cows or ewes.

Mixed grazing. Grazing of pastures by two or more species of animals (beef and sheep, sheep and goats, etc.) has advantages. Animal species differ in the types of forage they prefer. Beef cattle prefer legumes over grasses, while sheep prefer immature grasses and weeds over legumes. Goats consume shrubby vegetation and forage plants. Sheep, goats, and cattle tend to be complementary in their grazing habits; thus, two or more animal species can better utilize the forage together.

Goats also help control weedy vegetation. Co-grazing does not increase the overall animal-equivalent carrying capacity of a pasture. For purposes of stocking, a cow and calf may be considered equivalent to six average-sized ewes and lambs or nannies and kids. Co-grazing systems with sheep or goats should use rotational grazing (14 days or fewer per pasture) to minimize parasite larval survival and reinfection.

Part I, Section 9

Nontraditional Soil Amendments

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The industrial, commercial, and municipal sectors of Pennsylvania and surrounding states produce both large quantities and a wide variety of waste materials. Traditionally, most of these wastes were discarded by landfilling or incineration. In the more recent past, however, generators of these wastes, or by-products, have increasingly sought to find beneficial uses for them. This is being done for both environmental reasons (to recycle resources in the wastes and decrease the need for landfills and incinerators) and economic reasons (to avoid the cost of disposal and possibly gain some income from the waste). A beneficial use that has been identified for several by-product materials is application to agricultural land as soil amendments. Some by-product materials are intentionally being processed further to increase their value and make them more suitable as soil amendments. Examples of this include the composting of organic wastes such as leaves and grass, food processing wastes, sawdust, and sewage sludge.

All soil amendments, including traditional amendments such as chemical fertilizers and pesticides, have both beneficial and detrimental effects on soil and environmental quality. The positive and negative effects of most traditional soil amendments are clearly understood, and years of experience and research have helped us learn how to manage these materials to maximize their beneficial effects and minimize or eliminate any detrimental effects. While some by-product materials, such as sewage sludge or biosolids, have been extensively researched and are widely used, this is not the case for most of them. Some by-products may be used as a source of plant macro- and micronutrients; others may be used as a limestone substitute to neutralize soil acidity. Some may add organic matter to soils, while others may be used as a soil conditioner. Furthermore, these beneficial effects generally will be provided at no or very low economic cost to the farmer.

In some cases, the farmer may be paid to accept the material. These same materials, however, might contain trace metal and organic chemical contaminants that could negatively affect plants, animals, or humans. Some may contain disease-causing organisms, give off offensive odors, or generate a lot of dust when spread. Variability in by-product consistency and quality could lead to difficulties in transport, storage, handling, and determining appropriate application rates. Thus, a decision about whether or not to use a particular by-product requires careful investigation of both its possible benefits and drawbacks. Before using a by-product material, farmers should be certain that it will provide the benefits they are expecting. They also should have an equally clear understanding of its potential negative effects and problems.

Because of the great variety of by-product materials available, specific information about each one cannot be provided here. Following are general descriptions of various categories of by-products. For each type of material, the possible benefits and some possible negative effects and problems are given. It must be emphasized, however, that because by-products vary a great deal depending on how, when, and where they are produced, farmers must carefully investigate the characteristics of the particular material they are considering using. Although state and federal regulations provide some guidance and protection, it is ultimately up to farmers to determine if a by-product will truly benefit their production systems.

Composts

Composts technically should not be called by-product materials. Instead, they are intentionally produced from waste or by-product organic materials. Composting is nothing more than managing the natural process of decay to greatly accelerate the biological decomposition of organic materials. Properly produced composts are stable and will not undergo further rapid decomposition in the soil. Thus, the greatest benefit of composts for agricultural soils is the organic matter they add. Increasing soil organic matter content improves soil tilth, increases water infiltration and water storage, and increases cation exchange capacity. Composts contain low levels of plant nutrients and would equate to a very low analysis fertilizer. Most of the nitrogen in composts is in an organic form, and because of the stable nature of the organic matter in compost, it is converted to plant-available mineral nitrogen forms (ammonium and nitrate) at very slow rates. For most composts, only about 10 percent of the organic nitrogen will become available during the year following application.

One of the most critical characteristics of compost is its carbon-to-nitrogen (C:N) ratio. Fully mature and stable compost will have a C:N ratio between 30:1 and 10:1. If the C:N ratio is above 30:1, soil application of the compost could result in immobilization of soil nitrogen and a temporary unavailability of nitrogen to crops. High-quality compost will also be low in soluble salts and trace elements, will not contain recognizable feedstock (leaves, pieces of wood), and will be free of inert contaminants such as plastic, glass, and metal. High-quality compost also has a high commercial value and is generally sold in the landscaping and horticultural markets at prices that preclude its economical use for agronomic crop production. High-quality manure compost may be economically produced and used on-farm. Lower-quality composts may be economically feasible for field crop production, but farmers need to be careful about using them. Composts that are derived from animal manure are still considered a manure product and are subject to the Commonwealth's nutrient and manure management regulations (see "Manure Nutrient Management" in Part 1.2). All composts should be analyzed for stability, nutrient content, C:N ratio, soluble salts, trace elements, and inerts. Farmers should obtain several such analyses of the compost produced from a given source over a period of time. Penn State's Agricultural Analytical Services Lab offers a wide range of testing options to characterize the

physical, chemical, and biological qualities of compost. Similar testing programs are available from commercial labs.

Biosolids (Processed Municipal Sewage Sludge and Domestic Septage)

Biosolids result from the stabilization of solid, mainly organic materials produced during the biological treatment of municipal wastewater or sewage. Biosolids also may refer to domestic septage, the solid material that is pumped from septic tanks. Depending on how they are processed, biosolids may be a dilute suspension of solids in water that is sprayed, dribbled, or injected into the soil; a cakelike material that is spread like manure; or a very dry granular or pelletized material. Biosolids are the most extensively regulated of any nontraditional soil amendment. Explanations of regulations pertaining to the use of biosolids and more complete information regarding biosolids production, characteristics, and agronomic usage are provided in a series of four Penn State fact sheets titled "Land Application of Sewage Sludge in Pennsylvania." The individual fact sheets in this series are subtitled "A Plain English Tour of the Regulations," "What Is Sewage Sludge and What Can Be Done with It?," "Use of Biosolids in Crop Production," and "Biosolids Quality." It is the responsibility of the biosolids producer and applicator, not the farmer, to ensure all applicable regulations are followed. Nevertheless, farmers considering using biosolids should familiarize themselves with the regulations, biosolids characteristics, and recommendations and possible problems with agronomic use of biosolids.

Most biosolids available in Pennsylvania result from one of four stabilization methods: anaerobic digestion, aerobic digestion, alkaline stabilization, and composting. Biosolids are typically 50 to 60 percent organic matter on a dry weight basis. The organic fraction of alkaline-stabilized biosolids is somewhat lower due to the addition of lime. Each of these biosolids, as well as septage (which is usually stabilized by adding lime to the septage), has differing characteristics that affect its use and management. The major benefits of biosolids for crop production are the nitrogen and phosphorus they supply, as well as the addition of organic matter. Alkaline-stabilized biosolids contain excess lime and will neutralize soil acidity and supply calcium. These biosolids therefore also provide a liming value if the soil test indicates a need for lime.

Biosolids are generally applied to supply the nitrogen required by the next crop to be grown on a field. Total nitrogen content of most biosolids is in the range of 3 to 5 percent on a dry weight basis. The total nitrogen content of a particular biosolid will vary depending on the type of biosolids and the particular operating parameters used at the wastewater treatment plant. Application rates for these biosolids are determined similarly to those of manures. Most of the nitrogen in biosolids is in an organic form that is only available for crop uptake as it is mineralized. Availability of organic nitrogen in various biosolids during the first year after application is estimated to be 30 percent for aerobically digested and alkaline-stabilized biosolids, 20 percent for anaerobically digested biosolids, and 10 percent for composted biosolids. Biosolids contain some inorganic nitrogen as ammonium and nitrate. The inorganic nitrogen is assumed to be 100 percent crop available. Farmers using alkaline-stabilized biosolids should monitor soil pH to ensure it does not go too high. Soil pH above 8.0 could lead to micronutrient deficiencies and may alter herbicide activity.

In addition to nutrients, organic matter, and lime, biosolids also contain low levels of trace elements, organic chemicals, and disease-causing organisms. The levels of these contaminants and their implications are discussed more fully in the fact sheets listed above. Regulations developed by EPA that govern the use of biosolids in agriculture were designed to prevent any adverse effects from these contaminants on human health, crop and animal production, and environmental quality. The adequacy of the biosolids regulations is continuously being studied, and some changes can be expected in the future.

Food Processing Residuals

Food processing residuals (FPR) cover a wide array of by-product organic materials generated from processing agricultural products into human food or animal feed products. FPRs can include materials such as fruit and vegetable peels, seeds, pits, cheese whey, bone, hide, hair, feathers, process wastewater, and process wastewater treatment sludges. The primary agronomic benefits of most FPRs are a source of plant nutrients and organic matter. Process wastewater treatment sludges can be very similar to biosolids, except they generally will not contain trace element contaminants or pathogens. As with any by-product material, chemical analysis of the product is very important. Farmers need to know how much of and in what form nutrients are being supplied by the FPR. Most nitrogen in FPRs will be in an organic form and may be released very slowly as organic matter is mineralized.

Farmers using FPRs may face a number of management issues. Some may be highly putrescent and create immediate odor problems. Some may be difficult to handle and spread with conventional equipment. Some may have high carbon-to-nitrogen ratios (greater than 30:1) and cause temporary immobilization (unavailability) of soil nitrogen. Some, such as milk and cheese processing by-products, may have a very high oxygen demand because they decompose so rapidly. Overapplication of such materials could cause anaerobic

conditions to develop in the soil and literally smother crop roots. Careful investigation and chemical analysis are essential in making a decision to use an FPR.

Leaves and Grass Clippings

Rather than compost the leaves and grass they collect, some municipalities prefer to pay farmers to spread them on their fields. In addition to providing an income stream, these materials add organic matter and some nutrients to soils. Because leaves have a very high carbon-to-nitrogen ratio, the nitrogen they contain will be mineralized (become plant-available) very slowly. Leaf application also could lead to immobilization of soil nitrogen and a temporary shortage of nitrogen for crops. Leaves picked up in urban and suburban areas often contain some inert contaminants such as plastic bags, bottles, cans, and other municipal trash items. Another management issue with on-farm leaf mulching is timing of spreading operations. Most leaves will arrive late in the fall and must be spread within seven days. This could interfere with harvesting operations.

Slag

Slag is a by-product of the steel industry and consists primarily of calcium silicate minerals. Slags have nearly the same ability to neutralize soil acidity as agricultural limestone, and they have been used extensively as soil liming materials. There are two kinds of slag, air cooled and water quenched. Water-quenched slag is cooled rapidly with water, which causes the material to "pop" and generates porous, granular particles. Slags should be used just like conventional ground agricultural limestone. Application rates should be based on soil test liming recommendations and the calcium carbonate equivalency (CCE) of the slag. Most slags have a CCE in the range of 80 to 100 percent. As with any liming material, the fineness of the product is an important consideration. Both conventional agricultural limestone and slag react very slowly with soil acidity unless the material is finely ground. Ideally, the slag should meet the fine-sized specification for Pennsylvania agricultural liming materials. For a discussion of CCE and fineness of liming materials, see "Soil Acidity and Liming" in Part I, Section 2: Soil Fertility Management. Before using slag as a liming material, be sure it has been analyzed for CCE and fineness.

Some slags may contain elevated concentrations of trace elements such as iron, cadmium, chromium, copper, lead, molybdenum, nickel, and zinc. Concentrations of these trace elements will vary in slags from different sources. All of these metals occur naturally in soil, and many are essential plant nutrients. If concentrations in the slag are similar to soil concentrations, they present no problem. If they are present at substantially higher concentrations in the slag than in the soil, repeated application of the slag could significantly increase soil concentrations of the trace elements in soil. This could possibly lead to plant toxicity, increased plant uptake and transfer of metals to animals or humans, or other environmental problems. For example, concerns have recently been raised about excessive molybdenum concentrations in forages grown on soils that have received slag containing high levels of molybdenum. Molybdenum is an essential plant nutrient; however, molybdenum is toxic to ruminant animals when present at high levels in forage, causing molybdenosis. Before using a slag, be sure to obtain several laboratory analyses of the total concentrations of these trace elements.

Lime Kiln Dust and Cement Kiln Dust

Lime kiln dust (LKD) and cement kiln dust (CKD) are very fine particulates trapped in air pollution control systems of rotary kilns used to manufacture lime and portland cement. LKD and CKD are mixtures of dust from finely ground limestone fed into the kilns and fly ash from the fuel (coal, fuel oil, natural gas) used to heat the kilns. In the kilns, limestone (CaCO3) is converted to quick lime (CaO). Depending on the amount of lime-derived material in the dust, LKD and CKD can have a high CCE and be an effective soil liming material. As with slags, the CCE of these materials can vary widely depending on the source and composition. Farmers considering using LKD or CKD should obtain several analyses of the CCE of the material. Because these materials contain CaO, their pH often is around 12, compared to the pH of limestone at about 8.2. Application of LKD or CKD in excess of soil liming requirements could increase soil pH to levels above 8.2, the maximum pH obtainable with conventional limestone (CaCO3). High soil pH can lead to problems with crop nutrition and herbicide efficacy and carryover.

Kiln dusts are extremely fine materials. This can make handling and spreading more challenging than conventional ground ag limestone. Generation of excessive dust can be a problem, as can bridging and uneven flow in some spreading equipment. As with slags, LKD and CKD may contain significant amounts of some trace elements, mainly due to the fly ash they contain. Again, it is important to obtain analyses of total metal concentrations in the kiln dust. Some kilns double as waste incinerators and may include materials such as old tires and municipal solid waste in their fuel source. Incineration of these wastes could result in dusts contaminated with any number of organic and inorganic constituents. Dusts from waste incinerator kilns should not be used for liming soils.

Coal Ash and Flue Gas Desulfurization By-Products

These materials are generated during the combustion of coal, primarily at electric-power-generating stations and industrial boilers. Coarse, gritty material removed from the boiler bed is known as bottom ash, while fine particulate material removed from the combustion gases is known as fly ash. Characteristics of coal fly ash depend primarily on the type of coal burned and result in a Class C or Class F categorization. Class C ash results primarily from burning western U.S. coal and thus is rare in Pennsylvania. Class C ash is high in calcium, may have a CCE as high as 50 percent, and may be used as a soil liming material. Class F fly ash results from burning most eastern U.S. coal and thus is common in Pennsylvania. It is low in calcium and has no acid-neutralizing capacity. Thus, most coal ash produced in Pennsylvania has little, if any, agronomic value.

Coal ash may contain elevated levels of certain trace elements, most commonly boron, arsenic, and selenium. Boron is an essential plant nutrient but becomes toxic to plants at high concentrations, while arsenic and selenium are of more general environmental concern.

Most coal-fired boilers must remove sulfur dioxide from their emissions. This is usually done by reaction with lime and generates materials known as flue gas desulfurization by-products (FGD). There are numerous types of FGD by-products with very different characteristics. Most contain significant amounts of gypsum (calcium sulfate), some contain large amounts of fly ash, and many contain unreacted lime. Because of their gypsum content, FGD materials can provide a source of highly soluble calcium and sulfur for crop nutrition. FGD materials that contain unreacted lime may have CCEs ranging from 20 to 60 percent and have value as liming materials. FGD materials are usually very fine textured and can range in moisture content from a dry powder to a pastelike material to a slurry. Thus, the ability to haul and spread the material must be considered when deciding whether or not to use it. The relative amounts of gypsum, lime, and fly ash in FGDs can vary depending on boiler operating conditions, and trace element contents can vary depending on the coal being burned. Therefore, before using any FGD material, it is very important to obtain several chemical analyses that show its CCE and total concentrations of major and trace elements.

Scrap Wallboard

The primary ingredient in wallboard is gypsum or calcium sulfate ($CaSO_4 \bullet 2H_2O$). In contrast to limestone, which is very insoluble, gypsum is a highly soluble source of calcium (and sulfur). Gypsum has long been used as an agricultural soil amendment to supply calcium and sulfur needed for plant nutrition. It has also been used to promote movement of calcium deeper into the soil and alleviate subsoil aluminum toxicity. Research with ground scrap wallboard has shown that it performs as well as commercially produced gypsum. However, research with gypsum and waste wallboard conducted on agronomic crops in the northeastern United States generally has not shown beneficial effects on crop yield. Waste wallboard needs to be crushed or ground before application to agricultural soil and should be free of foreign objects such as nails, screws, and corner bead. Trace element contamination is normally not a problem with scrap wallboard; however, a complete trace element analysis should be obtained.

Water Treatment Residuals

These are sediments removed from water supplies during the preparation of potable water. Water is treated with a coagulant, most commonly alum, to cause clay and silt in the water to settle out quickly. The residual is a mixture of clay and silt minerals, some organic matter, and the coagulant. Although water treatment residuals have the appearance of a fine-textured soil, they do not appear to benefit agronomic crop production. Many water treatment residuals have the capacity to fix phosphorus, and research is being conducted to determine if soil application will reduce phosphorus in runoff from high P-test soils. Water treatment residuals are generally quite low in trace elements of environmental concern.

This brief overview of nontraditional soil amendments does not include all the possible by-product materials that may be available to farmers, nor does it fully describe all the possible benefits and problems that could be associated with any particular material. While many of these materials can provide benefits to soil quality and crop production, farmers must investigate each individual material carefully to be certain it will provide the expected result. Such investigation needs to look at both the positive and negative effects of the material on soil quality for sustained crop production. For most materials, this will require several chemical analyses of the appropriate major and trace elements and other properties. Determination of appropriate application rates and assessment of possible negative effects can only be done on the basis of such analysis.

Part I, Section 10

Cover Crops

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Purposes of Cover Crops

Cover crops cover the soil during fallow periods when a field would otherwise be unoccupied by living vegetation. They are an important component of sustainable cropping systems for the following reasons:

- Erosion control
- Organic matter increase
- Soil structure improvement
- Atmospheric nitrogen fixation
- Nitrate capture
- Soil water management
- Weed control
- Supplemental forage

Erosion Control

Cover crops help reduce erosion by protecting soil from raindrop impact and providing a physical barrier to runoff. A good cover crop for erosion control provides a quick and dense cover. A fine, fibrous root system helps improve aggregate stability and resistance to soil movement. After the cover crop is killed in no-till systems, surface residue mulch created by the dead cover crop provides continued protection against erosion. If the cover crop is plowed under with tillage, erosion protection after termination becomes small, although soil structure and infiltration rates are still improved.

Organic Matter Increase

Cover crops help increase soil organic matter content by adding crop residue above and below the ground. The total quantity of biomass produced by the cover crop, its carbon-to-nitrogen (C:N) ratio, and how it is managed will determine how much soil organic matter is likely to increase. Amounts of dry matter produced by cover crops depend on species (Table 1.10-1), time of establishment, growing conditions, and when the cover crop is killed (Figure 1.10-1). Cover crop residue with a low C:N ratio will decompose much faster than residue with a high C:N ratio. The C:N ratio is influenced by the crop type (Table 1.10-2) and at what growth stage the cover crop is killed (Figure 1.10-2). Legumes typically have lower C:N ratios than other cover crops at maturity. As Figure 1.10-2 shows, growing different cover crops together can be a way to lower the C:N ratio of the total biomass produced.

Soil Structure Improvement

Cover crops improve soil structure by protecting soil from rainfall impact and extreme temperature fluctuations, their roots physically enmeshing soil and creating biopores, exuding polysaccharides and other labile organic molecules that act like glues for soil particles, stimulating symbiotic fungi growing on cover crop roots, and providing food for other soil organisms. Mycorrhizal, symbiotic fungi live on roots of most cover crops with a few exceptions (most important, brassica crops such as forage radish, rape, cabbages, etc.). Mycorrhizae extend the root system, increasing soil particles' physical enmeshment of the root system. As the root grows, mycorrhizae higher up die off and release glomalin, which contributes to soil tilth. Many cover crops provide a substrate for mycorrhizae between main crops, guaranteeing a large population of mycorrhizae throughout the rotation.

Table 1.10-1. Typical aboveground biomass production and nitrogen accumulation in aboveground biomass of some cover crops and cover crop mixtures in southern Pennsylvania.

	Nonlegume Dry Matter Production (lb/A)	Legume Dry Matter Production (lb/A)	Total Nitrogen Content (lb/A)
Rye	5,000		50
Wheat	4,500		45
Barley	4,500		45
Hairy vetch		3,600	160
Red clover		2,500	91
Crimson clover		2,400	90
Hairy vetch/oats	1,700	2,700	119
Hairy vetch/rye	3,500	1,800	102
Hairy vetch/wheat	2,600	2,400	111
Crimson clover/oat	2,000	4,700	109
Crimson clover/sudax	2,500	3,600	106
Crimson clover/wheat	4,500	3,200	100

Cover crops established end of August/beginning of September and killed at the end of April/beginning of May.
All data except rye, wheat, and barley are personal communication from Rita Koch and Matthew Ryan, The Rodale Institute, Kutztown.

Figure 1.10-1a. Southeast Pennsylvania average cover crop biomass (spring 2004 and 2005).

Figure 1.10-1b. Central Pennsylvania average cover crop biomass (spring 2004 and 2005).

Establishment dates for central and southeastern Pennsylvania were as follows: rye and wheat, early October and mid-October; barley, mid-September and early October; annual ryegrass, rape, crimson clover, and hairy vetch, mid-September in both locations. Cover crops were planted after small grain harvest in fields without manure history and did not receive any nitrogen fertilizer. These data are from trials at Penn State (S. W. Duiker, "Establishment and termination dates affect fall-established cover crops," *Agronomy Journal* 106 [2014]: 670–78).

Table 1.10-2. Carbon-to-nitrogen (C:N) ratios of some cover crops.

Organic Material	C:N Ratio
Sawdust	250:1
Corn stalks	60:1
Rye at anthesis	40:1
Rye at mid-boot stage	20:1
Crimson clover	15:1
Young rye plants	14:1
Canola, radish	10:1 to 25:1*
Hairy vetch, red clover, Austrian winter pea	10:1 to 15:1

*C:N ratio increases with plant maturity and low soil nitrogen availability.
Source: Adapted from *Overview of Cover Crops and Green Manures* (ATTRA 2001); data from Charlie White.

Figure 1.10-2. Carbon-to-nitrogen ratio depends on crop type as well as time crop is killed.

Source: Clark, A. J., Decker, A. M., Meisinger, J. J., and McIntosh, M. S., 1997. "Kill date of vetch, rye, and vetch-rye mixture: I. Cover crop and corn nitrogen." *Agronomy Journal* 89:427–434.

Overall, the best cover crops for soil structure improvement are those that produce fibrous, extensive root systems such as gramineous (grassy) species. The roots of these species hold soil together and also find ways to penetrate dense soil. Taprooted species that penetrate subsoil create gateways for the roots of the succeeding crop. This way, a soybean crop following a deep-rooted cover crop such as daikon radish extracts moisture from deeper depths than if the soybean crop does not follow a cover crop. Plant species that produce large amounts of root biomass can also help alleviate soil compaction. That is probably why crops such as corn, sorghum, sudangrass, pearl millet, ryegrass, and rye have been observed to relieve the effects of compaction. Cover crops that grow during the winter are well suited to loosen hard layers in the soil because they can grow into those layers when they are softened by plentiful water (this is less likely in the summer). Further, taproots have been shown to have superior ability over fibrous roots to penetrate compacted soil.

Cover crops with a low C:N ratio will, when decomposing, release large quantities of organic molecules such as polysaccharides that improve soil structure. This is the reason why soil is mellow in the spring following a soybean crop. This effect is expected to last only as long as there is decomposable residue. Cover crops with a high C:N ratio will have a slower release of polysaccharides, which improves soil structure more slowly but for a longer time than cover crops with a low C:N ratio (Figure 1.10-3).

Atmospheric Nitrogen Fixation

Leguminous cover crops fix atmospheric nitrogen due to their symbiotic relationship with Rhizobium bacteria in their

Figure 1.10-3. Effect of ease of decomposition of cover crop biomass on soil aggregation.

roots. To ensure nitrogen fixation takes place, it is important to use seed inoculated with the appropriate Rhizobium strain (Table 1.10-3). The amount of nitrogen fixed is directly related to the amount of biomass produced by the leguminous cover crop because its nitrogen content and C:N ratio stay relatively constant.

Popular leguminous cover crops established in the fall include crimson clover and hairy vetch. Hairy vetch is winter-hardy throughout the state, and recent research has shown consistent winter survival of crimson clover in the southern half of Pennsylvania, even when planted after corn silage harvest. In a study conducted in Maryland, hairy vetch fixed approximately 2 pounds of nitrogen per acre per day from early March onward, totaling 150 pounds of nitrogen per acre when it was killed in early May. While crimson clover fixes less nitrogen, it does so earlier than hairy vetch.

If the cover crop can be established in the spring or summer, growers have more choices for leguminous cover crops, such as red clover, white clover, field peas, and sweet clover. Research has shown that leguminous cover crops do not need to be incorporated to obtain their maximum nitrogen benefit for the following crop. If incorporated, the leguminous cover crop will decompose more rapidly and release greater amounts of nitrogen early in the season and lower amounts later in the season. In fact, incorporating large quantities of a leguminous cover crop such as hairy vetch into the soil may lead to nitrate losses in water draining from the soil profile in a wet spring. Research with hairy vetch and rye/vetch mix has shown that much of the nitrogen requirement of the following corn crop can be provided by hairy vetch without incorporation. If the vetch is mixed with rye, the nitrogen will be released more slowly. Perennial leguminous cover crops that are used for conservation plantings or living mulches are crownvetch, birdsfoot trefoil, and flat pea. Considering the difficulty in planting leguminous cover crops after corn grain, the possibility of growing these perennial legumes permanently under corn has been investigated. Decades of Penn State research on living mulches of these species under corn has shown that the nitrogen contribution is negligible if the corn is vigorous due to high competition for light and other growth factors. On the other hand, if the living mulch is too vigorous, it may reduce corn yields. Finally, it has proved challenging to control weeds in this system without killing, and yet sufficiently suppressing, the living perennial mulch.

Table 1.10-3. *Rhizobium* inoculant types for leguminous species to obtain nitrogen fixation.

Rhizobium Group and Species	Legumes Treated
Alfalfa/medic group (*Sinorhizobium meliloti*)	Alfalfa
	Medic
	Yellow or white sweet clover
Cowpea, peanut, and lespedeza group (*Bradyrhizobium* sp. [Vigna])	Common lespedeza
	Cowpea
	Peanut
	Velvet bean
Crownvetch group (*Rhizobium* sp.)	Crownvetch
Dry and snap bean group (*Rhizobium leguminosarum* biovar *phaseoli*)	Kidney beans
	Snap beans
	String beans
	Wax beans
Lupin group (*Bradyrhizobium* sp. [Lupinus])	Lupin
Soybean group (*Bradyrhizobium japonicum*)	Soybeans
Trefoil group (*Rhizobium loti*)	Birdsfoot trefoil
True clover group (*Rhizobium leguminosarum* biovar *trifolii*)	Crimson clover
	Red clover
	White clover
	Other true clovers
Vetch/pea group (*Rhizobium leguminosarum* biovar *viceae*)	Austrian winter pea
	Common vetch
	Faba bean
	Field pea
	Flat pea
	Garden pea
	Hairy vetch
	Lentil
	Sweet pea

Different *Rhizobium* types treat different legumes (e.g., rhizobia for soybeans do not inoculate vetch). Use the right inoculants to obtain nitrogen fixation. Inoculant survives in the soil for several years, but inoculating every seeding is recommended to avoid failures.
Source: Adapted from "What Treats What?" (Ames, Iowa: Becker Underwood, 2008).

Nitrate Capture

Large amounts of nitrate are often present in the soil profile in the fall and winter after crops have been fertilized with manure or compost, a leguminous crop has been killed in the fall, or excessive inorganic nitrogen fertilizer was applied. In the winter, nitrates in the soil profile can leach below the root zone and pollute groundwater resources. In the summer, nitrate leaching is less likely because little precipitation percolates through the soil profile as a growing crop takes most of it up. For farmers, leached nitrate represents a loss of plant nutrients for the following crop. Cover crops can be used to capture the nitrogen released in the fall and winter, protecting it from leaching and recycling it into soil organic matter where, ultimately, it can be made available to future crops in the rotation as soil organic matter mineralizes. It is important to plant a vigorous, winter-hardy cover crop to capture nitrates from the root zone. Cereals/grasses such as rye, wheat, barley, triticale and ryegrass are good nitrate absorbers. Legumes are not good at nitrate capture. In Pennsylvania, cover crops that die in the winter, such as oats or forage radish, typically are not as effective at protecting nitrates from leaching because they don't absorb any more nitrate after winterkill. The more growth produced by the cover crop, the higher the amount of nitrate it takes up, so it is important to select the right species and use management to favor vigorous growth. When the cover crops are terminated and decompose, the nitrogen they release during the following growing season depends on the cover crop C:N ratio. Cover crops with a C:N ratio below 20 generally release nitrogen available for the next crop; a C:N ratio between 20 and 30 neither releases nor ties-up nitrogen during decomposition; and a C:N ratio greater than 30 will generally tie up nitrogen during decomposition. The nitrogen deficiency can be overcome by applying nitrogen fertilizer early in the growing season and placing it close to the seed.

Water Management

Cover crops reduce soil water content by transpiration when they grow, but they increase soil water content by reducing evaporation after they are killed and left as a mulch at the soil surface. Cover crop roots will improve infiltration by increasing soil porosity and structural stability and by reducing sealing and crusting of an otherwise bare soil surface if left as mulch at the soil surface. In a normal year, there is excess of precipitation over evapotranspiration (evaporation plus transpiration) in the winter months in Pennsylvania. Living cover crops can improve field trafficability and improve soil conditions for planting in moist springs by reducing soil water content. However, to avoid undesirable soil moisture depletion in a dry spring, the cover crop should be killed two or three weeks before the main crop is planted.

Weed Control

Cover crops contribute to weed suppression by introducing additional disturbance events within crop rotations that disrupt weed life cycles, providing direct competition for plant resources, and creating habitat that supports animals that feed on weed seeds. Fall sown cover crops can significantly decrease winter annual weed (e.g., marestail) pressure and contribute to suppression of perennial weeds (e.g., dandelion). To maximize the weed suppression potential of fall-sown cover crops, prioritize use of cover crop species that establish rapidly, have high fall biomass potential, and are winter-hardy. Winter cereal cover crops such as cereal rye can be sown as a monoculture or as the dominant species in mixtures to achieve these objectives. Consider the need for a fall burndown herbicide application prior to sowing to create a clean seedbed and give cover crops a competitive advantage. In no-till systems, cover crop surface residues, or mulches, are increasingly used as a weed suppression tactic. Research has demonstrated a positive relationship between cover crop biomass production and weed suppression potential. A cover crop surface mulch can provide significant suppression of small-seeded summer annuals, such as pigweeds and lambsquarters, but has less impact on large-seeded summer annuals (e.g., burcucumber), summer annual grasses (e.g., foxtails), and perennials (e.g., pokeweed). To maximize the weed suppression potential of surface mulches, consider delaying termination of winter cereals until planting (i.e., planting green) to increase biomass potential and create a more persistent mulch into the growing season. Cover crops rarely provide adequate weed control as a single tactic. However, we highly recommend optimizing management of cover crops for weed suppression as part of an integrated weed management (IWM) system in field crop production.

Supplemental Forage

A final objective for growing cover crops is for forage, either by harvesting or grazing. Farmers can plant the cover crop and then decide in the spring whether to harvest it, graze it, or leave it for soil improvement alone. Because many farmers have ruminant animals, using cover crops for forage has become very popular. Penn State research has shown that, depending on the year, up to 4 to 5 tons of dry matter per acre can be produced in a one-cut system or more than 6 tons per acre in a three-cut system (Table 1.10-4). Similar yields can be achieved with grazing. Planting the main crop may have to be postponed beyond the optimum planting date if a cover crop is harvested, especially in a three-cut system. Although less biomass will be left in the field as a mulch cover and to add organic matter content, farmers will be able to feed their animals without buying feed from off the farm and soil nutrients will be recycled through manure. In the end, with increased production and nutrient recycling on the farm and improved

Table 1.10-4. Average forage dry matter yields from short-lived annual forage trials in one- and three-cut systems (2012–2019).

	2012	2013	2018	2019
Forage	**Tons per Acre**			
Triticale + annual ryegrass (three-cut)	6.53	4.18	No data	No data
Annual ryegrass + crimson clover (three-cut)	6.53	No data	No data	No data
Annual/Italian ryegrasses (three-cut)	5.62	4.33	4.40	5.57
Forage radish + annual ryegrass (three-cut)	5.59	4.49	No data	No data
Triticale (one-cut)	5.45	4.50	3.34	2.49
Wheat (one-cut)	3.13	2.76	No data	No data
Rye (one-cut)	2.55	2.00	3.02	2.54
Barley (one-cut)	1.94	2.50	No data	No data
Annual ryegrass (one-cut)	No data	1.66	2.22	2.80

Forages received nitrogen fertilizer to boost production.
Source: Penn State Forage Evaluation Program.

conservation and soil properties, using cover crops for forage is positive from both an environmental and a production point of view.

Cover Crop Selection and Management

Cover crops can be annual, winter annual, biennial, or perennial in their life cycles and include species in the grass, legume, and other broadleaf functional groups ("forbs"). In Pennsylvania, cover crops are usually growing in the winter months after harvest and before planting of summer annual crops. However, opportunities exist to plant summer cover crops or short-lived cover crops in other niches of a crop rotation. Selection of a cover crop species or species mixture should be tailored to the available growth window in time and the functions needed from the cover crop. Table 1.10-5 lists the characteristics of the most commonly used cover crops in Pennsylvania. Figure 1.10-4 shows the percentage of annual crops followed by cover crops in some Pennsylvania counties.

Grasses

Grass cover crops such as rye, wheat, triticale, barley, oats, and annual ryegrass are typically planted in the late summer/

Figure 1.10-4. Percentage of annual cropland followed by cover crop in Pennsylvania (by county; 2016–2018).

Transect data collected by Capital RC&D with funding from the Pennsylvania Department of Environmental Protection. The percentages shown are for the fall/winter of either 2015–16, 2016–17, or 2017–18 and represent the sum of harvested (commodity) and not harvested (traditional) cover crops. When transect surveys were done in two years, the average for that county for the two years is presented. ND = no data.

Table 1.10-5. Characteristics of common cover crops.

Species	Life Cycle[1]	Hardy through Zone	Seeding Rate[2] (lb/A)	Seeding Depth (inches)	Seeding Date	Nitrogen Capture/ Fertilizer Equivalency (lb/A)	Advantages	Disadvantages
Cool-Season Grasses								
Winter rye (*Secale cereale* L.)	WA	3	30–112	1–2	Sept. to Nov. 1	Excellent nutrient scavenger (esp. N)	Most cold tolerant of commonly used cover crops; provides living cover in winter and spring, erosion control, weed suppression, nutrient recycling, organic matter improvement, soil tilth improvement; earliest small grain to mature	Regrowth may occur if not completely controlled; explosive growth in spring poses termination challenges; possible following crop suppression due to allelopathy or nutrient tie-up; may attract some insect pests
Winter wheat (*Triticum aestivum* L.)	WA	4	40–120	1–2	Sept. to Nov. 1	Excellent nutrient scavenger (esp. N)	Cold tolerant in most of PA; rapid growth; common varieties not as tall as rye and therefore easier to manage; provides living cover in winter and spring, erosion control, weed suppression, nutrient recycling, organic matter improvement, soil tilth improvement	Accumulates lower amounts of biomass than rye; possible following crop suppression due to nutrient tie-up; may attract some insect pests; matures after triticale
Winter triticale (*Secale cereal* × *Triticum aestivum*)	WA	3	40–120	1–2	Sept. to Nov. 1	Excellent nutrient scavenger (esp. N)	Intermediate between wheat and rye	Intermediate between wheat and rye; matures after barley
Winter barley (*Hordeum vulgare* L.)	WA	6	60–120	1–2	Sept. to Oct. 15	Good nutrient scavenger	Cold tolerant in southern parts of PA; common varieties not as tall as rye and therefore easier to manage in spring; provides living cover in winter and spring, erosion control, weed suppression, nutrient recycling, organic matter improvement, soil tilth improvement	Winter kill is possible; accumulates lower amounts of biomass than wheat; possible crop suppression due to nutrient tie-up; matures after cereal rye
Spring oats (*Avena sativa* L.)	SA	8	50–100	1–2	Aug. to Sept. 15	Average nutrient scavenger	Very easy to manage because winterkills; provides erosion control, weed suppression, nutrient recycling, organic matter improvement, soil tilth improvement in fall, rapid growth in cool weather; ideal for quick fall cover or nurse crop with legumes; may produce more biomass in fall than other winter small grains if planted early	Winterkills in most of PA, no living root system in winter and spring; erosion control may be limited in spring; high lodging potential; susceptible to diseases and insect pests

Table 1.10-5. Characteristics of common cover crops (continued).

Species	Life Cycle[1]	Hardy through Zone	Seeding Rate[2] (lb/A)	Seeding Depth (inches)	Seeding Date	Nitrogen Capture/ Fertilizer Equivalency (lb/A)	Advantages	Disadvantages
Annual ryegrass (*Lolium* spp.)	WA	5	10–20	0.25–0.5	Aug. to Sept. 15	Good nutrient scavenger	Cold tolerant in southern parts of PA; varieties not as tall as rye; provides living cover in winter and spring, erosion control, weed suppression, nutrient recycling, organic matter improvement, soil tilth improvement, high-quality fodder	May winterkill; may be difficult to control; low heat tolerance; may harbor insects; may reseed and become weed
Warm-Season Grasses								
Pearl millet (*Pennisetum glaucum*)	SA	NFT	10–15	0.25–0.50	June to early Aug.	Excellent scavenger	Heavy tillering, drought-tolerant, and adapted to low-fertility, sandy soils; can grow to 12 feet tall depending on variety; matures in 60–70 days; good forage	Very large biomass production can be challenging to manage
Sudangrass (*Sorghum bicolor*)	SA	NFT	35–40	1	June to early Aug.	Excellent scavenger	Quick growth; scavenges nitrogen; competes with weeds; large biomass producer; alleviates compaction; can grow 12 feet tall	Prussic acid production when young, drought stressed, or frosted—do not graze then; large biomass production can be challenging to manage
Japanese millet (*Echinochloa frumentacea*)	SA	NFT	20–25	0.25–0.50	June to early Aug.	Good scavenger	Very fast growth, mature and up to 4 feet tall in 45 days; resembles barnyard grass; suppresses weeds; adapted to poorly drained soils	Can become a weed if let go to seed; grows poorly on sandy soils.
Legumes								
Hairy vetch (*Vicia villosa* Roth)	WA	4	20–25	1–2	Aug. to early Sept.	80–160	Most cold tolerant and high biomass production; above-average drought tolerance; adapted to wide range of soil types; combines well with small grains	Requires early fall establishment; slow to establish; matures in late spring; high P and K requirement for maximum growth; can harbor pests; potential weed problem in winter grains; glyphosate not fool-proof for control
Clover, crimson (*Trifolium incarnatum* L.)	WA/ SA	5	10–15	0.25–0.5	Aug. to early Sept.	70–130	Fairly cold tolerant; rapid fall growth; high biomass production; matures midspring; above-average shade tolerance; forage use (no bloat); good nematode resistance	May winterkill; requires early fall establishment; poor heat and drought tolerance; residue has tough stems, difficult to no-till plant into

Table 1.10-5. Characteristics of common cover crops (continued).

Species	Life Cycle[1]	Hardy through Zone	Seeding Rate[2] (lb/A)	Seeding Depth (inches)	Seeding Date	Nitrogen Capture/ Fertilizer Equivalency (lb/A)	Advantages	Disadvantages
Clover, red (*Trifolium pratense* L.)	SLP (2–3 years)	4	8–10	0.25–0.5	Feb. to June	70–120	Survives winter; deep taproot; soils; tolerates wet soil conditions and shade; forage use, especially if mixed with grasses	Needs to be established before midsummer because initial growth slow; high P and K requirements for maximum growth; hard seed can persist creating volunteer problems; pure stand forage causes bloat; vulnerable to some pathogens, insects
Field peas (*Pisum* spp.) (e.g., Austrian winter pea)	SA/ WA	5	50–80	1.5–2	Aug. to Sept. 15	50–150	Rapid growth in cool weather; versatile legume; interseed with cereal and *Brassica* spp.; used as food or feed	May winterkill; shallow root system; sensitive to heat and humidity; susceptible to diseases, insect pests
Cowpea (*Vigna uncuiculata*)	SA	NFT	40	1.5–2	June to early Aug.	50–100	Also known as black-eyed peas; adapted to wide range of soil conditions; deep taproot can extract moisture from deep in profile	Performance has been erratic in PA trials
Sunnhemp (*Crotelaria juncea*)	SA	NFT	10	0.5–1.5	June to early Aug.	0–100	Fast growing, up to 9 feet tall in 60 days; competitive with weeds; drought tolerant; can reduce root knot nematode populations	No seed production in contiguous U.S.; stems fibrous with age
Other Crops								
Buckwheat (*Fagopyrum esculentum* Moench)	SA	NFT	35–50	0.5–1.5	Spring or late summer	Fair to good nutrient scavenger (esp. P, Ca)	Grows on wide variety of soils (infertile, low pH); rapid growth; quick smother crop and good soil conditioner	Limited growing season; not winter hardy; limited biomass accumulation; frost sensitive; occasional pests
Brassicas (Cruciferae family) (e.g., rape, radish)	WA	8	5–12	0.25–0.5	Spring or fall	Good nutrient scavenger (esp. N, P, Ca)	Quick establishment in cool weather; prevent erosion in fall (radish) and spring (canola, rape); radish easy to manage because winterkills; deep, thick root systems; compaction alleviation; nutrient cycling; weed suppression	Radish winterkills in all of PA, while canola/ rapeseed may winterkill in northern parts of PA; need high-fertility soil to thrive; radish leaves soil bare in spring, therefore mix with a small grain

[1] A = annual; WA = winter annual; SA = summer annual; SLP = short-lived perennial; LLP = long-lived perennial; NFT = no frost tolerance.
[2] Drilled seeding rate; for broadcast or aerial seedings or for seeding past optimum date, increase 25 to 50 percent.
[3] See Table 1.10-6 for recommended fall seeding dates by small grain management area.

fall. A grass cover crop is highly suited to scavenge residual nitrogen from the previous crop and manure and provides a dense cover for erosion protection, while its fibrous root system contributes to soil structure improvement and organic matter increase. However, if these cover crops are left to grow past boot stage, nitrogen immobilization can occur in the following crop. When the planting date for the cover crop is late (e.g., after corn grain harvest), rye, wheat, and triticale will have the best chance at establishment. If the previous crop was corn silage and the cover crop planting date can be achieved earlier, then species such as oats, annual ryegrass, and barley can also be considered.

Rye, wheat, triticale, and barley are all winter cereal grains and offer similar functionality in a crop rotation, but they have some important differences for management. First, there are differences in winter hardiness and planting dates. Winter hardiness and ability to establish the cover crop late in the fall goes in the order rye, triticale, wheat, barley. When grown to maturity, rye matures first, then barley, then triticale, and finally wheat. Rye grows fast in the spring and can be challenging to manage because it grows to be 6 feet tall. Common triticale, wheat, and barley varieties are shorter than rye, do not increase in height as quickly, and are therefore easier to manage. However, wheat and barley accumulate smaller amounts of biomass than rye and can be expected to have similar but smaller benefits for erosion control, soil quality improvement, nutrient capture, and water conservation. All of these cereal cover crops can be harvested for forage in the spring and offer high-quality forage when managed properly. All of these cover crops also need to go through a vernalization (cold) period before becoming reproductive and will therefore stay vegetative until after the winter.

Annual ryegrass is a unique grass species in its characteristics and management. It requires an earlier planting date than the cereals and reaches maturity slowly in the spring. Annual ryegrass has a deep, fibrous root system that is excellent for improving soil structure, increasing soil organic matter, and capturing nitrate. Annual ryegrass has a particularly high forage quality and can produce more tonnage than the cereals when multiple cuttings are made (see Table 1.10-4). However, because annual ryegrass matures more slowly in the spring, allowing it to reach the optimum growth stage for harvest can delay planting of the following crop. The final harvest in a three-cut system will typically take place in mid-June. This may call for a change in the rotation to follow annual ryegrass with a species adapted to later planting dates such as soybeans, sorghum, sudangrass, sorghum-sudangrass hybrids, or pearl millet. Increased winterkill may occur if annual ryegrass goes into the winter with more than 6 inches of growth. If this happens, grazing or mowing it in the fall is recommended. Furthermore, growth should be monitored closely in the spring to ensure it does not produce viable seed—annual ryegrass can become difficult to manage in subsequent crops.

Information on the forage quality and tonnage of different cereal and annual ryegrass varieties from results of the Penn State Extension Short-Lived Annual Grass Trials is available online at extension.psu.edu.

Spring oats and other less common spring varieties of small grains do not have to go through a period of vernalization before becoming reproductive. If planted early enough in the fall, oats will begin to produce a stem and sometimes a head before they winterkill. The result is that oats, when established in July/August, can produce more biomass than the winter cereals in the fall. The mature oat residue can be quite resistant to decomposition because of its high C:N ratio, and in this scenario, it can leave proper mulch cover into the spring. This makes a great seedbed for early planted crops, such as alfalfa or grass hay, or oats as an economic crop without needing to worry about killing the cover crop. However, no living roots will be present after a killing frost (about 15°F for oats, which typically occurs in December/January), and the soil improvement and nitrate capture achieved with oats is therefore smaller than with the winter cereals.

Warm-season grasses, including sorghum, sudangrass, sorghum-sudangrass hybrids, and millets, can be planted in the summer between June and early August when soil temperatures are greater than 65°F. In agronomic crop rotations, these warm-season grass cover crops are most often utilized for forage production or grazing since replacing a summer cash crop with a cover crop that will not be harvested is rarely economical. When planted in late summer after a small grain harvest, warm-season grasses can be used as a more traditional cover crop to capture soil nitrate, build organic matter, and provide soil cover. With sufficient warmth, these species will grow very quickly prior to the first killing frost and can provide significant residue cover through the winter. Warm-season grasses are more sensitive than oats to freezing temperatures and will die with the earliest frosts (32°F). As with oats, nitrate capture will be strong in the fall while the grasses are still growing, but no further nitrogen will be taken up after frost kill.

Legumes

Legume cover crops are generally planted prior to a nitrogen-demanding cash crop such as corn. A common rotational strategy for including a legume cover crop prior to corn is to frost seed red clover into a small grain crop. Other winter annual legumes, such as crimson clover, Austrian winter pea, and hairy vetch, can be planted in the late summer after a small grain harvest. Because nitrogen accumulation by the legume cover crop is mostly determined by the level of biomass production, legume cover crops should be allowed adequate time to grow in the spring prior to termination.

Red clover, ladino white clover, and biennial clovers such as yellow blossom sweet clover are usually established by frost seeding into a standing small grain crop. In frost seeding, cover crop seed is broadcast onto the soil surface in late winter and the freeze-thaw action of the soil will incorporate the seed into the soil. The seed then germinates when the soil temperature warms and the cover crop grows in the understory of the small grain crop. When the small grain crop is harvested, the cover crop will be released from competition and begin to produce significant quantities of biomass. Many farmers will mow the red clover cover crop once or twice in the fall to cut back any weed growth that might be occurring. It is also possible to mow red clover for a hay crop or graze it in the fall or spring, although nitrogen contributions to subsequent crops will be somewhat reduced with the removal of biomass. Seeding red clover in the late summer after a small grain crop is harvested is generally not recommended if it will be terminated after the winter due to its slow growth.

Winter annual legumes, such as crimson clover, Austrian winter pea, and hairy vetch, can be planted in late summer or early fall. These annual species have shorter life cycles than the perennial and biennial clovers, so they will grow more rapidly in the fall and/or spring. There are many tradeoffs between these three species of legumes that should be considered when selecting a species for use. The cost per acre is in the order crimson clover, hairy vetch, Austrian pea. Crimson clover requires the earliest planting date of the winter annual legumes but will reach its peak biomass and nitrogen content earliest in the spring. Crimson clover is reliably winter hardy in southeastern Pennsylvania and often overwinters in the colder regions of the state. Crimson clover has a tendency to become stemmy as it matures into flowering, which increases the C:N ratio and reduces the nitrogen that is released during decomposition. Austrian winter pea and hairy vetch have a greater maximum potential than crimson clover for nitrogen accumulation and fertilization value but will require more time in the spring to reach their potential. Austrian winter pea can tolerate the latest planting date of the winter annual legumes. Seeding Austrian winter pea and hairy vetch too early can lead to a high chance of winterkill when they get too rank before going into the winter (similar to annual ryegrass).

Broadleaves

The category of broadleaved cover crops is a catchall for the many species of cover crops that are not legumes or grasses, called "forbs." Commonly used cover crops in this category include forage radish, canola, mustard, and buckwheat.

Forage radish, canola, and mustard are all members of the brassica (Brassicaceae) family. These species can grow quickly in the fall and are highly responsive to nitrogen. Thus, they can be good scavengers of nitrogen, but their growth will be limited in low-nitrogen soils. Winter canola can survive the winter in southern Pennsylvania if established before mid-September, whereas forage radish winterkills at 17°F, and mustard is usually planted after the winter.

If established by or before mid-August, forage radish grows a large taproot in the topsoil and deep, fine roots into the subsoil. This rooting action, which has been termed "biodrilling," creates large macropores at the soil surface that can enhance water infiltration and increase soil tilth. The deep-growing roots can penetrate compacted layers of the subsoil, creating channels that roots of subsequent crops can follow to obtain water and nutrients deep in the soil profile. Forage radish suppresses winter weeds and can leave the soil bare in the spring since it decomposes quickly after winterkill. Therefore, mixing forage radish with a small grain such as oats, wheat, or rye is recommended. Because canola is winter hardy, it will keep the soil covered into the spring and continue to take up nitrogen. One of the earliest blooming cover crops, canola is highly attractive to pollinators. Canola also does a good job at suppressing weeds, but only if there is sufficient nitrogen available in the soil to meet its growth demands. Mustard can be frost seeded in late winter and provide a quick spring cover in crop rotations where a fall-seeded cover crop is not achievable.

Buckwheat is a cover crop known for its fast growth and ability to suppress weeds. Because buckwheat can go from seeding to flower in six weeks, it is well suited for short fallow periods in the rotation. Buckwheat thrives in low-fertility soil and helps cycle phosphorus into more available forms for the next crop in the rotation. Buckwheat also has flowers that are highly attractive to beneficial insects. However, it produces limited amounts of biomass.

General Guidelines for Establishing and Terminating Cover Crops

After selecting a cover crop species for a field, you need to determine the method of establishment, the seeding date and rate, and how to terminate it. Special considerations for mixtures will be discussed later. You can establish a cover crop after tilling the field or use no-till methods. The latter is much preferred for the reasons explained in Part I, Section 1: Soil Management of this guide. If you use tillage, make sure you prepare a proper seedbed. Till the soil at the right moisture content (not too wet, not too dry). If you use small-seeded cover crops, it is especially important to prepare a fine seedbed; otherwise, many seeds will be buried too deep, may not have good seed-to-soil contact, and could never produce viable seedlings. This typically means using primary tillage such as chisel plowing to open up the soil and uproot and cover weeds, then harrowing to break up large clods, and

finally more breaking of clods and some type of packing of the soil surface with a cultipacker or rolling basket to reduce air pockets between soil clods. It may be possible to do all three in a one-pass operation if your soil has good soil tilth. If you plant larger-seeded cover crops, the seedbed does not need to be as fine. Try to maintain as much residue cover as possible without interfering with your planting operation. Residue protects the soil from erosion, runoff, sealing, and crusting. Subsequently, use a drill or seeder to plant the seeds, making sure to avoid burying the seeds too deep yet still get good coverage. If you use no-tillage, make sure you monitor the weed population before harvesting the previous crop. If needed, terminate weeds with a burndown herbicide that does not have soil residual activity so you can plant the cover crop immediately after the herbicide application. However, if the field is clean (i.e., has few weeds), then applying burndown herbicide is not necessary and it is possible to drill the cover crop immediately after harvest—this means having the no-till drill in the field when you harvest your crop. Because timeliness is so important for cover crop growth in the fall, it is preferable to plant the cover crop as soon as possible after harvest. Make sure the seed is planted at the right depth and covered properly (see Table 1.10-5). You may need to add weight to the drill to get enough down pressure if the soil is compacted from harvest traffic. In long-term no-tillage, the surface soil tilth will improve, making it easier to get a good cover crop stand. Broadcasting the seed on the surface (such as by spinning, flying, or dropping it on using fertilizer drop tubes) has not been found to be a foolproof method of establishment and is only recommended when broadcasting before the leaf-drop of soybeans or when frostseeding small-seeded cover crops such as clovers into standing small grains in the late winter. In the first case, the leaves of the soybeans will cover the seed, helping protect it from dessication, and, with frostseeding, freeze-thaw action helps create a honeycombing effect that incorporates the seeds into the soil while soil moisture is typically high, usually resulting in success. In all other situations (such as after the main crop is harvested in the summer or fall or when interseeding in summer), broadcast seeding often fails because there is not enough seed-to-soil contact and the seeds do not absorb enough moisture for germination. Some farmers have had some success with broadcasting the seed after harvest and lightly disking it into the soil or using a vertical tillage tool to get some seed-to-soil contact, but this is still not as good of a method as drilling the cover crop.

Interseeding is another method of establishing cover crops. A lot of research at Penn State has been done on interseeding in field corn, which allows the cover crop to be established 4 to 5 weeks after corn is planted, so the cover crop is already present at main crop harvest time. Research has shown that it is important to guarantee good seed-to-soil contact when interseeding cover crops. Special interseeders are now available that can accomplish this successfully. In tilled systems (e.g., organic), the soil is loose and the cover crop seed can be broadcast and incorporated into the surface soil at the time of last cultivation. A few lessons that have been learned about interseeding cover crops into corn are that (1) the cover crop rarely has a negative effect on the main crop into which it is interseeded; (2) the cover crop needs to be shade tolerant because it has to survive for months under the main crop canopy (red clover and annual ryegrass have given the most consistent results); (3) your soil-applied residual herbicide program must be adjusted to prevent injury to interseeded cover crops; and (4) if the main crop is highly competitive, the interseeded cover crop may not survive.

Table 1.10-6. Recommended latest fall seeding dates for cool-season annual cover crops by small grain management zones in Pennsylvania.

Species	Zone 1	Zone 2	Zone 3
Winter rye	Oct. 10	Oct. 15	Oct. 25
Winter wheat	Oct. 1	Oct. 5	Oct. 15
Winter barley	n/a	Sept. 25	Oct. 1
Spring oats	Sept. 1	Sept. 10	Sept. 15
Annual ryegrass	Aug. 15	Sept. 1	Sept. 15
Crimson clover	n/a	Sept. 1	Sept. 15
Austrian winter pea	n/a	Aug. 25	Aug. 30
Hairy vetch	Aug. 15	Sept. 1	Sept. 15
Forage radish	Sept. 1	Sept. 7	Sept. 15
Rapeseed/canola	Sept. 1	Sept. 7	Sept. 15
Turnip	Sept. 1	Sept. 7	Sept. 15

See Figure 1.7-1 in Part I, Section 7 for small grain management zones.

While Table 1.10-5 provides a wide range in seeding dates, Table 1.10-6 provides region-specific recommended latest seeding dates for fall establishment of cover crops by small grain management area. These dates are consistent with USDA-NRCS technical guide specifications for Pennsylvania. Low seeding rates are justified when cool-season cover crops are planted early (late summer/early fall), especially when manure is applied to them in the fall. Another consideration when determining seeding rates is the end use of the cover crop. If the cover crop is planted to be grazed or used as forage, high seeding rates are justified to generate heavy biomass with high feed value while the stubble is left to provide cover crop services to the next crop. On the other hand, if the cover crop is used as a cover crop only and not terminated prior to planting (i.e., the main crop is planted into a green living cover crop that is terminated after planting), a low seeding rate is justified because the cover crop will still produce a lot of biomass with a high C:N ratio that lasts for a long period before it is decomposed.

Many new lessons are being learned about cover crops and Pennsylvania is a hotbed of innovation, so recommendations for termination are also changing. While in the past it was recommended to terminate cover crops at least two weeks prior to planting, recommendations for termination are now more nuanced. Cover crops can be killed using tillage, with herbicides, by mowing or rolling/crimping, by grazing, or harvested for forage. It is easier to incorporate cover crops by tillage before they are too big (i.e., smaller than 1 foot tall). However, if a leguminous cover crop is incorporated for nitrogen supply, the cover crop should be left to grow until it is flowering and then incorporated with a moldboard plow. It will be difficult to incorporate such a huge amount of biomass (e.g., 5,000 pounds of dry matter) with other tillage tools. Planting the main crop into the cover crop residue with a no-till planter is possible after killing the cover crop two weeks prior to planting with an herbicide. The advantage is that the cover crop will be crisp, dry, and easy to plant through. However, the biomass will be small and the cover crop residue will be consumed by soil organisms quickly and not provide many soil protection and improvement services. To help increase cover crop biomass, an alternative is to plant through the standing, green cover crop and kill the cover crop with an herbicide after planting the main crop, or you can roll/crimp the cover crop at a proper physiological stage so it will die without use of an herbicide. If herbicide use is an option, you can "plant green" with a normal no-till planter if the cover crop is not too thick or tall (i.e., smaller than 18 inches). If the cover crop is tall, using a roller/crimper to roll the cover crop onto the soil surface is recommended. In both cases, an herbicide would be applied after planting. Rolling/crimping can be done in a separate operation with a special roller/crimper or even a cultipacker. It is important that the cover crop is tall and flowering so it stays down on the ground. If it is short, it may not stay flat on the ground. Specialized roller/crimping attachments can also be mounted onto standard no-till planters, making this a one-pass operation. It is possible to kill the cover crop with rolling/crimping without using an herbicide. In this case, the cover crop needs to be rolled in the soft dough stage (for cereals) or when the first pods appear (for hairy vetch). We do not have experience with killing other cover crops with rolling/crimping alone. Planting green is still a new practice, but many farmers in Pennsylvania are customarily using it now. As a water management practice, it reduces soil moisture content until you terminate the cover after planting, and then the dead mulch conserves moisture after the cover crop has been killed.

Finally, the cover crop can also be harvested for forage either with machinery or by grazing, and then the main crop is planted into the cover crop stubble with a no-till planter. This generates additional value for the farmer, but it also creates additional risks for the main crop. The cover crop will use a lot of moisture when it is growing; if you take off the aboveground biomass, there will be limited mulch left to provide the residue cover needed to conserve moisture in the summer. Research from Virginia has shown that this system sometimes leads to reduced main crop yields due to increased moisture stress. Nonetheless, it has become quite a common practice in Pennsylvania with farmers growing triticale, wheat, or rye for silage in sequence with corn for silage.

Using Cover Crop Mixtures

Using a cover crop mixture can enhance and diversify the benefits that a cover crop provides. Table 1.10-5 is a starting point for developing a species mixture. Species in a mixture should complement one another, including growth periods, growth forms, and nutrient acquisition strategies.

Complementary Growth Periods

Winterkilled species and winter-hardy species can complement each other (see Table 1.10-5). Winterkilled cover crops often exhibit the ability to grow rapidly in the late summer and fall, favoring high nitrogen uptake, weed suppression, and erosion control in the fall until they winterkill. After winterkill, nitrogen uptake ceases, and weed suppression and erosion control will diminish as residues from the cover crop decompose on the soil surface. Winter-hardy cover crops will typically produce a small to moderate amount of biomass prior to going dormant for the winter, with the majority of growth occurring in the spring. An example of a beneficial combination of winterkilled and winter-hardy species is oats that grow fast in the fall with winter-hardy hairy vetch planted in late August/early September. The oats provide residue cover in the fall and winter and protect the tender hairy vetch that takes off in the early spring. When developing such mixtures, it is important to respect the planting dates of individual species to prevent wasted seed cost. Planting date for some species in a mixture may be too late, such as red clover in a mix planted in late August or forage radish or oats in a mix planted in October. It is also possible to plant a species too early, resulting in winterkill. For example, if Austrian winter pea is included in a mix that is planted in early August, it is likely that the pea will become very rank and can even start to flower before winter sets in, leading to susceptibility to winterkill. Finally, rate of growth and development of species in a mixture should be taken into account when developing a mixture. Winterkilled species often grow quickly in the fall, especially when there is high nitrogen availability, and can outcompete and smother their winterhardy companions. In these cases, seeding rates of the winterkilled species should be kept relatively low to allow for establishment of the winter-hardy species. Cover crops that mature quickly in the spring, such as canola, crimson clover, and cereal rye, will need to be terminated earlier in order to prevent residues from becoming too mature and lignified and to avoid live seed production

that becomes a weed in the economic crop. Including a late maturing cover crop species in a mix that will be terminated early does not give the late maturing cover crop species sufficient time to provide its maximum benefit. Cover crop species that mature later in the spring, such as triticale, wheat, annual ryegrass, red clover, hairy vetch, and Austrian winter pea, can be used in mixtures that will be terminated later.

Complementary Growth Forms

Different species in a cover crop mixture can compete with one another for space and light, reducing the potential for increased biomass production by a mixture. Selecting species with complementary growth forms helps alleviate competition between species. Three growth forms are distinguished: tall, open canopies; short, dense canopies; and vining. Tall, open-canopied species are especially compatible with vining species because the tall-canopied species creates a ladder that the vining species can grow up. It is important that species with tall, open canopies are not planted too densely, or they will shade out the understory species. It should also be noted that some cover crop species, such as cereal grains, will shift their growth form from a short, dense canopy to a tall, open canopy when maturing from vegetative to reproductive stages. An example is cereal rye and hairy vetch: the rye will shift from a short, dense canopy to a tall, open canopy in the spring, giving the vetch a ladder to grow up.

Complementary Nitrogen-Acquisition Strategies

Legume cover crops can obtain nitrogen from the soil and atmosphere, while nonlegume cover crops such as grasses and brassicas can only obtain nitrogen from the soil. Although legumes can take up soil nitrogen, they are less aggressive than grasses and brassicas at doing so. For soil with low nitrogen levels, legume cover crops will be most effective. For soils with excessive nitrogen levels (e.g., from manure, compost, or fertilizer), nonlegumes that are aggressive at scavenging soil nitrogen should be used. In soils with moderate nitrogen levels, a mixture of a legume and nonlegume can work well since the nonlegume will take up the soil nitrogen, protecting it against leaching, while the legume fixes nitrogen from the atmosphere, adding it to the plant-soil ecosystem. If the nitrogen level of a soil is not known, planting a cover crop mixture can be a useful strategy. If soil nitrogen availability is high, grasses and forbs will be favored, while legumes will be favored at low soil nitrogen availability.

Methods to Establish Cover Crop Mixtures

Common methods of cover crop establishment, such as drilling and broadcasting, can be adapted for the successful establishment of cover crop mixtures. Some of the challenges and opportunities associated with establishing cover crop mixtures include achieving the correct seeding depth, preventing seed from separating and settling in the drill box, selecting different row configurations, and determining the right seeding rate for each species in the mixture.

Seeding Depth

Cover crop species vary in their optimum seeding depth from 0.25 to 1.5 inches, so, what is the correct seeding depth for a mixture? A general rule of thumb is to plant shallow, or the small-seeded species may not be able to emerge, but there are other strategies that can be used. For example, many drills have a large and a small seed box. The large box, sometimes called the grain box, is optimized for large-seeded crops and the drop tubes from the large box direct seeds to the deepest point in the furrow created by the disk openers. The small box, sometimes called the legume or grass-seed box, is optimized for small-seeded crops. The drop tubes from the small seed box drop seed behind the disk openers, resulting in a shallower seed placement. The drop tubes from the small box can also be left hanging straight down to dribble seed on the soil surface. Dribbling seed on the soil surface can be a useful strategy in tilled soil where a cultipacker will be used to firm the soil after seeding. Small-seeded species with shallow planting depths can be placed in the small seed box, while large-seeded species with deeper planting depths can be placed in the large seed box. This approach has been the most effective for obtaining optimum seeding depths for various species in a mixture. An alternate approach to managing seed placement depth is to mix the seed of all species in one drill box and set the seeding depth to approximately 0.25 inch. In most cases, this will give satisfactory results. A final approach, which is more time and equipment intensive than other approaches, is to seed the large-seeded species to depth with a drill; make a second pass with a broadcast seeder, broadcasting the small-seeded species onto the soil surface; and then firm in the seedbed with a cultipacker.

Preventing Seed Separating and Settling

Many people new to using cover crop mixtures are concerned that seeds of different sizes mixed together in a drill box will separate and settle as the drill travels across a field. However, in practice, seed separation and settling has rarely been a significant issue. The seed sizes that are most likely to separate from each other when mixed together are small round seeds and large round seeds. When many different seed shapes and sizes, especially oblong grass seeds, are used in a mix, the packing arrangement becomes stabilized and seed separation is greatly reduced. Seed separation can be reduced even more if seeds can be placed into the small and large boxes of a drill as discussed in the seeding depth section above.

Selecting Different Row Configurations

One of the opportunities that emerges with using cover crop mixtures is planting different component species of the mixture in specific row configurations. This strategy can be used to minimize competition between species in a mixture. One common example is planting forage radishes in alternating rows with a companion species. On a drill with 7.5-inch spacing between rows, a good row configuration might be one row of radish alternating with two rows of the companion or two rows of radish alternating with two rows of the companion. Because forage radish has the tendency to outcompete other species in a mix, separating the radishes and companion species between rows allows the companion species to establish. Another reason for using specific row configurations is to concentrate the impacts of a certain species in the mix in strips across the field. An example of this approach would be to drill forage radish in strips 30 inches on center and then plant rows of a cash crop on top of the radish strips the following year. Because forage radish residues decompose quickly and the taproots alleviate compaction, the strips of soil where radishes were growing will be warmer, more friable, and have greater nutrient availability, creating favorable seedbed conditions for the next crop. A different species, such as cereal rye, could be planted between the radish rows to make up for some of the forage radish's drawbacks by continuing to grow in the spring, taking up nutrients, and providing plant cover for the soil.

Alternating-row configurations can be created easily with a drill that has two seed boxes. Simply place duct tape over openers inside each seed box to create the desired pattern and then place the set of seeds for each row type in the appropriate box. In a drill with one seed box, vertical baffles between openers spanning front to back of the drill box can be created with cardboard and duct tape. Fill each compartment created by the baffles with the appropriate seed to create the desired row configuration.

Determining Seeding Rates in the Mixture

Determine the appropriate seeding rates for each species in a mixture by starting with the suggestions below, planting a small acreage, observing the results, and then making adjustments as necessary. Be aware that results will vary across fields, years, and climate zones. As a starting point, divide the normal seeding rate of a species if planted alone by the number of species in the mix. Then make adjustments based on the competitiveness of each species. Certain species, such as forage radish, canola, oats, and sorghum-sudangrass, are highly competitive in a mix. Seeding rates of these species must be reduced more to prevent them from dominating the mixture. Successful seeding rates for these species in 2-3 species mixtures are 2 to 3 pounds per acre for forage radish, 3 to 4 pounds per acre for canola, 15 to 20 pounds per acre for sorghum-sudan-grass, and 20 to 40 pounds per acre for oats. Legume components of a mixture, which tend to be weak competitors, are more safely kept at their sole seeding rates to ensure establishment in the stand. These are just starting points that need to be adjusted based on your preferences.

Herbicide Persistence and Rotation to Cover Crops

The question about whether corn or soybean herbicide programs will pose a problem for establishing fall cover crops has become common, particularly in areas of severe drought where corn is harvested earlier than normal and the desire to plant a cover/forage crop is strong. If you look at the rotation crop restrictions for corn and soybean herbicides in this guide (see the tables in Part II, Sections 2 and 4), you will see that many products limit rotation to alfalfa and/or the clovers and some of the small grains. This is a good place to start when thinking about rotation to fall cover crops. However, these tables are inadequate because these cash crop rotation restrictions may be due to the concern for herbicide residues accumulating in forage or feed rather than carryover injury. If the crop is not going to be harvested and consumed by livestock or humans, then the primary concern is carryover injury and achieving an acceptable stand that provides the benefits of a fall or winter cover. Cover crops that are not harvested can be planted after any herbicide program, but the grower assumes the risk of crop failure.

Two factors become important when trying to predict the potential for carryover injury to rotational crops: (1) Assuming an herbicide has soil activity, how long does the herbicide last or persist in the soil? (2) How sensitive is the rotational crop to potential herbicide residues? Herbicides with short half-lives (the time it takes for 50 percent of the active ingredient to dissipate) are always less of a concern. Of course, several factors influence the rate of dissipation, such as rainfall, soil texture, and soil pH; however, most guidelines are generally for "normal" conditions (e.g., not severe drought). In general, products with a rotation restriction of four months or shorter for the species of interest, close relative, or sensitive species (e.g., clovers) should pose no problem. These products typically have half-lives of fewer than 30 days. Species sensitivity can play a role if only a small amount of residue is necessary to cause injury and the herbicide persists. Small-seeded legumes and grasses, such as the clovers and ryegrass, and mustard species, like canola, are very sensitive to some herbicides.

Table 1.10-7 provides some information on persistence and carryover for some commonly used corn and soybean herbicides. Some of this information is our best guess and only pertains to the eastern United States, not heavy Midwest soils or the western United States where soils have high soil pH and rainfall amounts are lower.

Table 1.10-7. Corn and soybean herbicide half-lives, cash crop restrictions, and their potential to injure fall cover crops.

Herbicide	Active Ingredient	Normal Rate per Acre	Half-Life (days)	Cash Crop Restrictions	Fall Cover Crops		Other
					OK to plant	Concern for	
Corn Herbicides							
2,4-D 4S	2,4-D	1–2 pt	7	Plant anything 30 days after application	All grasses	Wait 30 days before planting sensitive broadleaves	Amine formulations are more water soluble and can leach into seed zone
Accent 75DF/ Steadfast 75DF	Nicosulfuron/ Nicosulfuron + Rimsulfuron	0.66 oz/ 0.75 oz	21	Sensitive crops have 10- to 18-month restriction	Cereals, ryegrass	Small-seeded legumes, mustards, sorghum	More persistent in high-pH soils (> 7)
Atrazine 4L	Atrazine	1–2 qt	15-90	Can plant corn, sorghum, and soybean the following year (some products allow others)	Cereals, ryegrass, sorghum species	Legumes and mustards	More persistent in high-pH soils (> 7); rates < 1 lb/acre can allow more flexibility; half-life in PA probably closer to 30
Balance Pro 4L/ Balance Flexx 2L	Isoxaflutole	3 fl oz/ 6 fl oz	50–120	Small-seeded legumes and vegetables have 10- to 18-month restriction	Fall cereals	Ryegrass, legumes, and mustards	15 inches of cumulative precipitation required from application to planting rotation crops except soybean, barley, wheat, sorghum, and sunflower
Callisto (includes Acuron, Acuron Flexi, Halex GT, Harness Max, Instigate, Lexar, Lumax, Resicore, Revulin, Solstice, Zemax, etc.)	Mesotrione	3–6 fl oz	10–50	10 to 18 months for legumes and vegetables	All grasses	Small-seeded legumes, mustards	Sequential applications (PRE fb POST) increase the potential for injury
Clarity/Banvel 4S (DiFlexx, Distinct, Engenia, Status, XtendiMax/FeXapan)	Dicamba	16–24 fl oz	5–14	15 days per 8 fl oz per acre for small grains	All crops	Only at high rates or less than 120 days after application	Anything can be planted after 120 days with 24 fl oz per acre or less
Capreno 3.45SC	Tembotrione + Thiencarbazone	3 fl oz	15	4 months for wheat; 10 months for barley, sorghum, oats and alfalfa	Wheat, triticale, rye	Small-seeded legumes, mustards, sorghum	15 inches of cumulative precipitation required from application to planting rotation crops except wheat
Corvus 2.63SC	Isoxaflutole + Thiencarbazone	5.6 fl oz	50–120	4 months for wheat; 9 months for barley; and 17 months for alfalfa, oats, sorghum, and canola	Wheat, triticale, rye	Small-seeded legumes, mustards, sorghum	15–30 inches of cumulative precipitation from application to planting for sensitive crops
Harness 7E (Degree, Surpass, Warrant)	Acetochlor	2 pt	10–20	4 months for wheat; 9 months for alfalfa and clovers	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops are allowed after corn harvest

Table 1.10-7. Corn and soybean herbicide half-lives, cash crop restrictions, and their potential to injure fall cover crops (continued).

Herbicide	Active Ingredient	Normal Rate per Acre	Half-Life (days)	Cash Crop Restrictions	Fall Cover Crops		Other
					OK to plant	Concern for	
Impact/Armezon 2.8SC	Topromezone	0.75 fl oz	14	Alfalfa, canola, soybean and sunflower have a 9-month restriction	Wheat, barley, oats, and rye are allowed after 3 months; ryegrass	Although many broadleaves are restricted, Impact does not have much soil activity	We have not seen this herbicide carryover in PA
Laudis 3.5SC (DiFlexx Duo)	Tembotrione	3 fl oz	14	4 months for cereal grains; 10 months for sorghum, canola, and alfalfa	Cereal grains after 4 months	Unknown; small-seeded legumes, mustards could be a problem	Other crops may be seeded after a successful field bioassay
Peak 57WG (and Spirit)	Prosulfuron	1 oz	9–152	Range from 10 months for soybean and tobacco to 22 months for alfalfa and canola	Cereal grains and sorghum are labeled, other grasses	Small-seeded legumes, mustards	More persistent in high-pH soils (> 7)
Permit/Sandea 75DF	Halosulfuron	0.66 oz	9–27	9 months for alfalfa, clovers, soybean; and 15 months for canola	Cereal grains and sorghum after 2 months; other grasses	Small-seeded legumes, mustards	Halosulfuron also an ingredient in Yukon
Resolve 25DF (Resolve Q)	Rimsulfuron	2 oz	2–4	3 months for winter cereals; 10 months for many crops	Based on short half-life, most fall cover crops should be OK in PA	None	More persistent in drought conditions
Simazine 4L (Princep)	Simazine	1–2 qt	60	Can plant corn, sorghum, and soybean the following year (some products allow others)	Sorghum species	Cereals, ryegrass, legumes, and mustards	Soil pH > 7
Stinger 3S (Hornet, Resicore, Surestart)	Clopyralid	5 oz	40	Recrop intervals 10.5 to 18 months for legumes	All grasses	Small-seeded legumes	
Soybean Herbicides							
Assure II/Targa 0.88E	Quizalofop	8 oz	60	Most broadleaves	Most broadleaves	All grasses if less than 120 days or at high rates	Plant anything after 120 days
Authority 75DF (Authority First, Broadaxe, Sonic, Spartan)	Sulfentrazone	4 oz	32–302	12 to 24 months for legumes and some vegetables	Cereals and ryegrass	Small-seeded legumes, mustards, sorghum	Labeled on tobacco, sunflowers, transplanted tomato
Classic 25DF (Authority XL, Canopy, Envive, Fierce XLT, Synchrony, Trivence, Valor XLT, etc)	Chlorimuron	0.5–2 oz	40	12 to 30 months for small-seeded legumes	Cereals and ryegrass	Small-seeded legumes, mustards, sorghum	More persistent in high pH soils (> 7) and with higher soil applied rates

Table 1.10-7. Corn and soybean herbicide half-lives, cash crop restrictions, and their potential to injure fall cover crops (continued).

Herbicide	Active Ingredient	Normal Rate per Acre	Half-Life (days)	Cash Crop Restrictions	Fall Cover Crops		Other
					OK to plant	Concern for	
FirstRate 84WDG (Authority First, Sonic)	Cloransulam	0.3–0.6 oz	8–33	4 months for wheat; 9 months for alfalfa, corn, sorghum, oats; 12 months for barley; 18 months for tobacco	Wheat, triticale, rye	Small-seeded legumes, mustards, sorghum	Transplanted tobacco is 10 months for 0.3 oz per acre; 30-month restriction for sugarbeet and sunflower
Pursuit 2S (Authority Assist, Optill, Zidua Pro)	Imazethapyr	4 fl oz	60–90	Recrop restrictions range from 4 to 18 months	Wheat, triticale, rye, alfalfa, clover	Oats, ryegrass, sorghum; do not plant mustards	Any crop can be planted 40 months after Pursuit application
Raptor 1E	Imazamox	5 fl oz	20–30	Recrop intervals range from 3 to 18 months	Wheat, triticale, rye, alfalfa, clovers	Slight risk for mustards	Most cash crops allowed 9 months following application
Reflex 2E/Flexstar 1.88E (Warrant Ultra)	Fomesafen	1.5 pt	100	Recrop intervals range from 4 to 18 months	Cereal grains	Small-seeded legumes, sorghum; do not plant mustards	Since fomesafen is often applied postemergence; soil activity can surprise users
Scepter 1.5AS	Imazaquin	0.66 pt	60–90	Recrop intervals range from 11 to 18 months	Cereal grains	Small-seeded legumes, mustards	Carryover much more of a risk with drought
Select 2E	Clethodim	10 oz	3	Most broadleaves OK	All broadleaves	None, assuming at least 30 days	Plant anything after 30 days
Valor 51WDG (Afforia, Envive, Fierce, Surveil, Trivence, Valor XLT, etc.)	Flumioxazin	2.5 oz	12–20	Recrop restrictions up to 10 months for no-till alfalfa and clover; 12 months for no-till canola	All grasses	Small-seeded legumes and mustards	Based on the half-life, all nonfood/feed winter cover crops should be OK
Corn and Soybean Herbicides							
Dual II Mag 7.62E/Cinch	Metolachlor	1.67 pt	15–50	Labeled for use on many crops	Cereal grains, legumes	Annual ryegrass or other small-seeded grasses	Higher rates and later applications more of a potential problem
Glyphosate 4L	Glyphosate	0.75–1.25 lb ae	47	No restrictions preemergence	All	None	Glyphosate does not have soil activity at normal use rates
Gramoxone 2S	Paraquat	2 pt	1,000	No restrictions preemergence	All	None	Paraquat does not have soil activity at normal use rates
Harmony 50WDG	Thifensulfuron	0.125 oz	12	Any crop can be planted 45 days after application	No restrictions for wheat, barley, and oats	None with 45-day waiting interval	Harmony Extra also contains tribenuron

Table 1.10-7. Corn and soybean herbicide half-lives, cash crop restrictions, and their potential to injure fall cover crops (continued).

Herbicide	Active Ingredient	Normal Rate per Acre	Half-Life (days)	Cash Crop Restrictions	Fall Cover Crops		Other
					OK to plant	Concern for	
Liberty 2.34L	Glufosinate	22–36 fl oz	7	No restrictions for canola, corn, and soybean; small grains have 70-day restriction	All	Food or feed residues rather than crop injury may be a concern	Glufosinate does not have soil activity at normal use rates
Metribuzin 75DF (Sencor)	Metribuzin	0.33 lb ai	14–60	Recrop restrictions range from 4 to 12 months	Cereal grains and ryegrass	Slight risk for small-seeded legumes and mustards	Nonfood/feed winter cover crops allowed
Outlook 6E (Verdict)	Dimethenamid	16 fl oz	20	4 months for cereal grains and anything the following spring	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops should be OK after corn harvest
Prowl H2O 3.8CS	Pendimethalin	3 pt	44	Wheat and barley after 4 months; other rotational crops the following year	Cereal grains	Small-seeded legumes and annual ryegrass	We have not seen this herbicide carryover in PA; nonfood/feed winter cover crops should be OK
Python 80WDG (Hornet and Surestart)	Flumetsulam	1 oz	14–120	Range from 4 months for alfalfa and cereals to 26 months for canola	Cereal grains	Small-seeded legumes, mustards, annual ryegrass	Cover crops and forage grasses are restricted for 9 months
Sharpen 2.85SC (Verdict, Optill, Zidua Pro)	Saflufenacil	1-3 fl oz	7–35	Any crop can be planted 4 months after application	All	None	Reported to be more persistent in western Canada
Zidua 4.17SC	Pyroxasulfone	4 fl oz	20	4 months for wheat; 11 months for other small grains; 10 months for alfalfa	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops should be OK after corn harvest

This table does not directly address preharvest establishment of cover crops, such as interseeding or aerial seeding, which may be more restrictive. Cover crops that are harvested are subject to herbicide residue restrictions, which are not addressed in this table.

Part I, Section 11

Organic Crop Production

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The demand for a wide range of organic products drove organic production to become one of the fastest-growing segments of agriculture. Demand for organic products continues to grow and creates opportunities for Pennsylvania growers. Some U.S. producers are turning to organic farming systems as a potential way to lower input costs, decrease reliance on synthetic chemicals, capture high-value markets and premium prices, and boost farm income.

The Agricultural Marketing Service (AMS) of the U.S. Department of Agriculture (USDA) is the home of the National Organic Program (NOP), which developed, implemented, and administers national production, handling, and labeling standards for organic agricultural products. The USDA regulation defines organic production as "a production system that is managed in accordance with the Organic Foods Production Act and regulations in this part to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and preserve biodiversity." The national organic standards address the methods, practices, and substances used in producing and handling crops, livestock, and processed agricultural products. All agricultural products labeled or represented as organic must be in compliance with the regulations as of October 2002. Organic crops can be produced on land that has had no prohibited substances applied to it for at least three years. The regulations require that organic producers and handlers be certified by a state or private agency accredited under the uniform standards developed by the USDA unless the farmers and handlers sell less than $5,000 per year in organic agricultural products. For further information, visit the USDA AMS National Organic Program website at https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program or call 1-202-720-3252. This site includes a list of accredited certifying agents, consumer information, state information, NOP regulations and policies, and information for producers, handlers, and processors.

Organic farming systems rely on ecologically based practices, such as cultural and biological pest management, and virtually exclude the use of synthetic chemicals in crop production and prohibit the use of antibiotics and hormones in livestock production. Genetically modified [organisms] (GMO) crops are not allowed. Under organic farming systems, the fundamental components and natural processes of ecosystems, such as soil organism activities, nutrient cycling, and species distribution and competition, are used as farm management tools. For example, crops are rotated, planting and harvesting dates are carefully planned, and habitats that supply resources for beneficial organisms are provided. Soil fertility and crop nutrients are managed through tillage and cultivation practices, crop rotations, and cover crops, and supplemented with manure, composts, crop waste material, and allowed substances. Lists of allowed substances are available from accredited certifiers and provided on the USDA National List of Allowed and Prohibited Substances at https://www.ams.usda.gov/rules-regulations/organic/national-list. Products are reviewed by the Organic Materials Review Institute (OMRI) and can be accessed at https://www.omri.org/ or by calling 541-343-7600. Allowances and restrictions on materials and substances are reviewed regularly—always check with your certifier before using a new substance to determine if it is allowed in organic production or handling.

Several sources of information on organic production are available. The Alternative Farming Systems Information Center (AFSIC) is one of several topic-oriented information centers at the National Agricultural Library (NAL). The AFSIC serves as a clearinghouse that specializes in locating and disseminating information related to alternative cropping systems, including sustainable, organic, low-input, biodynamic, and regenerative agriculture. AFSIC's staff and resources can be accessed at https://www.nal.usda.gov/afsic or by calling 301-504-5755. The National Sustainable Agriculture Information Service is managed by the National Center for Appropriate Technology and provides information and other technical assistance to farmers, ranchers, extension specialists and educators, and others involved in sustainable agriculture in the United States. Their technical publications address current topics, internships, and resources in sustainable and organic agriculture and can be accessed at https://attra.ncat.org/, by calling 1-800-346-9140, or by emailing askanag@ncat.org.

eOrganic (https://eorganic.org/) is affiliated with the Extension Foundation (https://extension.org/), an online constellation of people, resources, and tools that support the Cooperative Extension system nationwide. eOrganic serves as an organic agriculture resource for farmers, ranchers, agricultural professionals, certifiers, researchers, and educators seeking reliable information on organic agriculture and certification, published research results, and farmer experiences. The information at eOrganic is collaboratively authored and reviewed by a community of university researchers and Cooperative Extension personnel, agricultural professionals, farmers, and certifiers with experience and expertise in organic agriculture. These resources can be accessed at https://eorganic.org/.

The *Penn State Organic Crop Production Guide* was developed by Penn State Extension faculty and staff along with industry experts. This guide features case studies of successful organic crop farmers in the Northeast and discusses details of organic farming practices for agronomic crops, including soil health and fertility, grain crops, forages, rotations and cover crops, as well as weed, insect, and disease pest management. The guide also provides information about calculating organic crop budgets, maintaining organic integrity, and National Organic Program standards. The Penn State Organic Crop Production Guide provides more in-depth coverage of the topics presented in this abbreviated chapter

and might be a more suitable resource for organic crop producers. It can be accessed at https://extension.psu.edu/penn-state-organic-crop-production-guide.

Although not exclusive to organic crop production systems, several "Agroecology in Practice" fact sheets are available from Penn State Extension that feature potentially useful topics for organic growers. These include "Introduction to Organic Farming," "Suppressing Weeds Using Cover Crops in Pennsylvania," "Managing Soil Health," and "Making the Most of Mixtures: Considerations for Winter Cover Crops in Temperate Climates." For estimating cost of production of organic grain crops and rotations, see "Organic Grain Crop Enterprise Budgets" (https://extension.psu.edu/organic-grain-crop-enterprise-budgets).

Pest Management in Organic Systems

Insects

The term "organic" describes production systems that optimize natural processes. Certified organic growers use a wide range of IPM practices that comply with USDA NOP regulations; see https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program or call 202-720-3252.

In organic systems, the goal is to alter the production system so that pests do not find plants and are controlled by natural enemies (biological control), or their damage is kept to a minimum (Table 1.11-1). Vigorous, healthy plants are more able to withstand damage caused by arthropods and disease. Therefore, healthy soil and plants are the foundation of organic production. Described below are general principles of insect pest management in organic production. More information on biologically based (biointensive) pest management, including information on suppliers of biological control agents, can be found in the ATTRA publication *Biointensive Integrated Pest Management*, available at https://attra.ncat.org/topics/insect-management/ or by calling 1-800-346-9140.

Biological Control

Biological control is the use of living organisms to maintain pest populations below damaging levels. Natural enemies of arthropods fall into three major categories: predators, parasitoids, and pathogens. Predators catch and eat their prey. Some common predatory arthropods include ladybird beetles, lacewings, syrphid flies, carabid (ground) beetles, minute pirate bugs, nabid bugs, big-eyed bugs, and spiders.

Parasitoids (sometimes called parasites) do not usually eat their hosts directly. Adult parasitoids lay their eggs in, on, or near their host insect. When the eggs hatch, the immature parasitoids use the host as food. Many parasitoids are very small wasps that are not easily noticed. Tachinid flies are another group of parasitoids. They look like large houseflies and deposit their white, oval eggs on the backs of caterpillars and other pests. The eggs hatch, then the larvae enter the host and kill it.

Pathogens are disease-causing organisms. Just as many other organisms get sick, so do insects. The main groups of insect-disease-causing organisms are insect-parasitic bacteria, fungi, protozoa, viruses, and nematodes. Biological control using pathogens is often called microbial control.

One very well-known microbial control agent that is available commercially is the bacterium *Bacillus thuringiensis* (Bt). Because not all formulations of Bt are approved for use in organic systems, it is important to check with your certifier. Several insect-pathogenic fungi are used as microbial control agents, including *Beauveria*, *Metarhizium*, and *Isaria*. These are most often used against foliar insect pests in greenhouses

Table 1.11-1. Organic crop production foundation principles and practices.

Biodiversity	Diversification and Integration of Enterprises	Sustainability	Natural Plant Nutrition	Natural Pest Management	Integration
Rotation	Rotation	Rotation	Rotation	Rotation	Rotation
Green manure	Animal manure	Green manure	Green manure	Green manure	Records
Cover crops	Composting	Cover crops	Animal manure	Cover crops	
Animal manure	Intercropping	Biocontrol	Composting	Composting	
Composting	Farmscaping	Farmscaping	Natural fertilizers	Intercropping	
Intercropping	Mulching	Animal manure	Foliar fertilizers	Biocontol	
Biocontrol		Composting		Farmscaping	
Farmscaping		Mulching		Sanitation	
Buffers		Buffers		Tillage	
				Fire	
				Natural pesticides	

or other locations where humidity is relatively high. Nuclear polyhedrosis (NPV) and granulosis (GV) viruses are available to control some lepidopteran pests (moths and butterflies).

Insect-parasitic (entomopathogenic or insecticidal) nematodes in the genera *Steinernema* and *Heterorhabditis* infect soil-dwelling insects and occur naturally or can be purchased. As with all biological control agents, it is especially important to match the correct microbial control agent with the correct pest in order for them to be effective.

Biological control can be applied (inundation or augmentation of natural populations) or natural (conservation of natural enemies). Many biological and microbial control agents are commercially available for purchase. Information about rates and timing of release are available from suppliers of beneficial organisms. The quality of commercially available biocontrol agents is an important consideration. Biological and microbial control agents are living organisms and, as such, must not be mishandled during shipping, storage, or application.

In many cases, purchasing biocontrol agents should not be necessary. Natural enemies are common and growers just need to know how to attract and keep the natural enemies in their systems by providing environmental conditions conducive to their survival. "Farmscaping" describes the creation of habitat to enhance the chances of survival and reproduction of beneficial organisms. For example, many adult predators and parasitoids feed on nectar and pollen, so it is essential to have these resources nearby. Having several species of pollen- and nectar-producing plants in an area will provide resources more continuously than only having one species. Organic mulches and crop residue moderate fluctuations of temperature and moisture and can provide hiding places for soil predators such as carabid and staphylinid beetles, spiders, and centipedes. Other habitats provided by farmscaping include water, alternative prey, perching sites, overwintering sites, and wind protection. The success of farmscaping efforts depends on knowledge of pests and beneficial organisms.

There are several well-functioning biological control systems in field crop systems. A major successful biological control program was the release of parasitoid wasps to control alfalfa weevil populations. There are six primary wasp species helping to regulate weevil populations, with three being the most common. These parasitoid wasps, along with a fungal pathogen, have successfully reduced the percentage of fields sprayed in Pennsylvania from nearly 100 percent in the 1960s and early 1970s to less than 5 percent in most years. Organic growers have the option of managing their forages to encourage maximum effectiveness of the wasps, thus eliminating the need for pesticides. Another example of the successful introduction of a beneficial organism is in the population regulation of cereal leaf beetles in cereal crops (wheat, barley, oats, rye, triticale, etc.) by a parasitoid wasp species. These wasps have again significantly reduced the number of fields sprayed to control the pest. Organic producers can manage to optimize the effectiveness of these parasitoids. Nature, either through effects of weather conditions or natural enemies, contributes to keeping pest numbers down.

Field crops have very few major insect pests that consistently cause economic losses. Exceptions are potato leafhopper in alfalfa and corn rootworm in corn. Potato leafhopper can be managed through the use of conventionally bred resistant or tolerant alfalfa varieties. Corn rootworm is managed by crop rotation, which is required in organic production systems. Other pests tend to be cyclical, and damaging populations are sporadic.

Cultural Control

Many organic cultural practices are best management practices that apply to all types of crop management systems and are discussed elsewhere in this guide. Some examples of cultural controls are crop rotation, sanitation, cover crops, conventionally bred resistant varieties, maintenance of biological diversity, appropriate planting dates, and plant spacing. As a general rule in field corn, early plantings have fewer losses to insect pests. Timing of cutting in alfalfa can be an effective management tool against potato leafhopper. Because the life cycle of the pest is about 28 to 30 days, cutting schedules of fewer than 30 days can reduce damage from leafhoppers. Although leafhoppers may reduce the quantity of forage harvest, increased protein content of the hay may partly offset this. Annual crop rotation is an effective method of eliminating corn rootworm injury. Continuous corn production in a field, which is not allowed in organic systems, allows eggs to be laid that will hatch the following year and result in larval feeding on corn roots.

When designing cultural controls for a production system, crop rotation and cover crops can lead to specific insect and other invertebrate pest problems. Slug populations can build up in sods and hay fields and then cause problems in field corn and soybean fields in the following years. The cover crop can provide an ideal environment for slugs since they need shelter from the sun, which will cause them to desiccate. Tillage between crops can help reduce slug populations before planting into the field. Other pests of field corn that can increase in frequency with cover crops and abundant residue include sod webworm, black cutworm, true armyworm, stalk borer, white grub, seedcorn maggot, and wireworm. Plowing under residues at least 10 to 14 days before planting can reduce the likelihood that high populations will survive to damage the crop; however, this may not be effective if wireworm and white grub populations are present. Planting corn or other large-seeded crops into fields in which sod, abundant plant residues, or animal manures have been recently incorporated by tillage can increase risk of losses from seedcorn maggot. Information on timing planting

to avoid seedcorn maggot can be found in "Seedcorn Maggot as a Pest of Field Corn" (https://extension.psu.edu/seedcorn-maggot-as-a-pest-of-field-corn).

Host-Plant Resistance

Although listed as a cultural mechanism, host-plant resistance is a major method to manage key pests in field crops. As transgenic, or GMO, varieties are not allowed, be sure that any resistance traits are due to conventional breeding. Conventionally bred alfalfa cultivars that are resistant to potato leafhopper are available. These cultivars are the result of traditional selection methods. The newest varieties now have about 70 to 80 percent resistance to potato leafhopper and have agronomic characteristic similar to nonresistant cultivars. Selection of these cultivars can greatly reduce the effects of this major pest of alfalfa. By eliminating major issues with this pest, the only other pest of concern is alfalfa weevil; with efforts to conserve its natural enemies, the frequency of losses can be greatly minimized.

Selecting a good corn variety can also minimize the impact of both European corn borer and corn rootworm. Over the years, plant breeders have increased tolerance and resistance of corn hybrids to these pests. Soybeans and small grain crops also have been bred to tolerate certain pests. However, this information is often not provided in crop seed guides. Wheat varieties that have resistance to Hessian fly and greenbugs are available. Conducting your own evaluations can provide significant information on which cultivars to grow in an organic system.

Physical and Mechanical Control

Methods in this category use some physical component of the environment—for example, temperature, humidity, or light—to suppress pest populations or damage. Some examples are tillage and flaming. Tillage can help minimize damage from slugs and other soil-associated pests directly by killing them and exposing soilborne stages to predation from birds, and indirectly by warming the soil and promoting rapid plant growth to outgrow feeding injury. Slugs can cause damage despite this practice in years with significant overcast and cool conditions. Conversely, tillage can promote some pests, such as seedcorn maggot, where there is abundant plant residue and a cool, wet spring. The female seedcorn maggot is attracted to lay eggs in soil into which abundant plant residues or manure have been tilled.

Organic Pesticides

Some types of pesticides are allowed in organic production. Lists of allowed substances are available from accredited certifiers and the National List; products are reviewed by the Organic Materials Review Institute. Always check with your certifier on the status of specific compounds to determine whether they are allowed, restricted, or prohibited in your organic system. Some products with allowable active ingredients may contain unacceptable adjuvants, so it is important to check the label and the certifying agency before using a material. Some examples of allowable active ingredients are *Bacillus thuringiensis* (Bt), insecticidal soaps, diatomaceous earth, kaolin clay particle films, azadirachtin, horticultural oils, and insect-parasitic (entomopathogenic) nematodes, fungi, and viruses.

Weeds

Managing weeds in organic systems uses many of the same techniques as conventional systems but relies on nonchemical control strategies. To plan an effective weed management program in organic systems, historical pest problems, soil management, crop rotation, machinery, markets, weather, time, and labor should be considered. Adjusting weed control strategies based on these factors and observing and avoiding potential problems is a big part of staying ahead of weed problems. The primary method for managing weeds in organic systems is the use of cultural strategies, which primarily focus on prevention, crop rotation, crop competition, and cultivation and mechanical strategies like tillage and flaming.

Prevention

In organic systems, prevention typically means keeping new weeds out and reducing the spread of existing weeds. In particular, minimizing the soil weed seedbank can be critical for successful weed management. Understanding weed biology is an important component in developing a preventive approach. Weed species vary in their vulnerability and resilience at different stages in their life cycle. For example, disking or cultivating a creeping perennial such as quackgrass or hedge bindweed in the spring may exacerbate the spread of underground rhizomes or other vegetative structures. Therefore, proper identification of the weed and knowledge of its life cycle, reproduction, and spread are important for developing management strategies. Some preventive tactics might be classified as sanitation—removing or destroying weeds in or near fields prior to them releasing seed. Weed seeds can live for a number of years, depending on the species and its position in the soil surface. This may mean removing weeds by hand before they produce seed. Weeds can also be introduced into fields via manure, compost, hay, straw, animal feed, contaminated crop seed, or other materials. Whenever you plan to plant, apply, or drive something in a field, learn whether weed seeds are present and evaluate the benefits versus potential risks.

Cultural Weed Control

Rotating crops and shifting planting dates are common cultural practices for managing weeds in organic systems.

Planting date will influence the type and number of weeds present. Organic growers should plan rotations so that weed species favored during one season will not be favored in another cropping sequence. This generally means mixing summer annual crops with fall-seeded species or perennials that allow for different weed management strategies. Delaying planting of some spring-seeded crops is common among organic producers. Although there is risk of some loss to crop yields from later planting, higher soil temperatures will help the crop emerge more quickly, and any weeds that emerge prior to planting can be killed before seeding. A false seedbed is a technique used in vegetable systems that can also be used with agronomic crops. A seedbed is prepared several weeks prior to planting and weeds are allowed to emerge. While they are still small, weeds are killed with shallow cultivation, flame weeding, or other nonselective methods. One or more flushes of weeds may emerge and be killed between seedbed preparation and time of planting. The success of a false seedbed depends on the weed spectrum and the time of planting. Delayed or later planted crops are generally more successful. Late emerging weeds could still be problematic.

Crop competition is another effective way to control weeds. Soil open to sunlight is available for weed growth and competition, whereas soil with a vigorously growing crop is less likely to be affected by weeds. Any tactics that allow the crop to establish quickly and dominate will help reduce the impact of weeds. Use high-quality, vigorous seed; adapted varieties; uniform, proper placement of the crop seed; optimal soil fertility; and plant populations that lead to vigorous crop growth and canopy closure. Essentially, any tactic that makes the crop more competitive against weeds is a cultural management method that is critical for successful organic production systems.

Mulches and Cover Crops

Mulches are also used to help manage weeds. The mulch provides a physical barrier that blocks light from reaching the soil surface, which reduces weed seed germination and survival of emerging seedlings. Plastic mulches are acceptable for some organic crops, but they are generally not practical for field crops. Mulches of organic material such as straw or cover crop residue are the most common types used in organic row crop systems.

Cover cropping can help manage weeds in several ways. Integrating cover crops into a crop rotation results in additional disturbance events that disrupt weed life cycles. In addition, cover crops compete with weeds that have a similar life cycle for light, moisture, nutrients, and space. Fall-sown cover crops can be particularly helpful for suppressing winter annual weeds or certain cool-season perennials. Cover crops and their residues can create physical barriers that smother weeds, suppress weed seed germination and growth, and lower soil temperatures. In general, greater cover crop biomass production results in greater weed-suppression levels. Mechanical and cultural control tactics should still be used to complement cover crops for weed management. For more information, see "Suppressing Weeds Using Cover Crops in Pennsylvania" at https://extension.psu.edu/suppressing-weeds-using-cover-crops-in-pennsylvania and "Making the Most of Mixtures: Considerations for Winter Cover Crops" at https://extension.psu.edu/making-the-most-of-mixtures-considerations-for-winter-cover-crops.

Mechanical Weed Control

Mechanical cultivation is generally critical for managing weeds in organic row crops like corn and soybean. Mechanical weed control includes the use of preplant tillage such as plowing, disking, and field cultivating. Tillage helps reduce the rate and spread of certain perennial weeds and can also kill emerged seedlings and bury seeds below the germination zone. Most organic corn and soybean producers prepare a conventionally tilled seedbed prior to planting a spring crop. Cultivation generally begins a few days after planting. Implements such as a rotary hoe, chain-link harrow, or tine weeder are dragged over the field to control weed seedlings beneath the soil surface. Displacing small seedlings exposes them to the drying effects of the wind and sun. Rotary hoes or similar implements are the best method for controlling weeds in the crop row. Operating a rotary hoe at 10 to 12 miles per hour will create enough drag to stir the soil and displace seedlings. Implements like rotary hoes are often used every five to seven days, as long as the weeds are germinating, or until the crop is too big. Similar implements work best in the afternoon when corn and soybean have less turgor pressure and are more flexible and resistant to damage. Do not rotary hoe soybeans when they are in the "hook" stage (the stem is exposed and the cotyledons have not yet opened above the ground). In general, up to three rotary hoe cultivations may be performed within two to three weeks after planting.

Crop rows planted 30 or more inches apart allow for row cultivation. Once soybeans have three trifoliate leaves and corn is beyond the two-leaf stage (V2) and 8 to 10 inches tall, a row cultivator can be used to control small weed seedlings. Shallow cultivation at 1 to 2 inches deep will avoid harming crop roots. Cultivation should continue at seven- to ten-day intervals until the corn is too tall and the soybean canopy closes the rows. Organic corn and soybeans generally require between one and three cultivations, depending on weed species, severity, and rainfall. Cultivation works best when performed during the heat of the day in bright sunlight when weeds will quickly desiccate and die. Rainfall shortly after cultivation or wet, cloddy soils may allow weeds to recover and survive. Hand-pulling escaped weeds will help ensure maximum crop yield and prevent future weed problems.

Mowing may be critical for managing weeds in forage crops or noncrop areas. It can kill or suppress annual and biennial weeds or restrict the spread of perennials. Repeated mowing reduces weed competitive ability, depletes carbohydrate reserves in the roots, and prevents seed production. Some weeds are readily consumed by livestock when young. A single mowing will not satisfactorily control most weeds. However, mowing three or four times per year over several years can greatly reduce and eliminate certain weeds, including Canada thistle. Also, mowing along fences and borders helps prevent the introduction of new weed seeds. Regular mowing can help prevent weeds from establishing, spreading into tilled fields, and competing with desirable forage crops.

Herbicides

Chemical weed control is generally not allowed in organic crop production systems. The USDA NOP does allow certain nonsynthetic soap-based herbicides to be used for farmstead maintenance (roadways, ditches, right-of-way, building perimeters) and in ornamental crops. In addition, several products that contain natural or nonsynthetic ingredients are classified as approved by OMRI. The OMRI listing does not imply product approval by any federal or state government agency.

Nonsynthetic (natural) postemergence herbicides contain plant-based ingredients and act as nonselective contact-type herbicides. They will injure or kill all vegetation they contact, including desirable vegetation. Knowing the weed species, size, and age and environmental conditions at application time is important for optimum performance. As a general rule, these products are only effective on small seedling weeds and activity increases with air temperature, humidity, and sunlight. Broadleaved seedlings are most susceptible, while grasses are harder to control. We suggest a minimum air temperature of 75°F, 50 percent relative humidity, and sunny conditions. Cool temperatures, low humidity, and cloudy conditions will reduce performance.

Similar to the requirements for use of all pesticides, the need to use herbicides derived from plant or animal sources should be explained in the grower's Organic System Plan and the farmer must obtain permission from their organic certifying agencies to use these materials. Individual certifying agencies can help decide the merits and need for allowable herbicides. Several products are labeled as organic herbicides, and additional products and ingredients are currently under review. A list of allowable materials is available from OMRI and on the USDA NOP website. It is strongly recommended that users confer with their certifiers before purchasing or applying an herbicide, as certifiers' lists of allowable materials may be more restrictive than the OMRI lists.

Remember that an adjuvant (e.g., surfactants and wetting agents) is often necessary to enhance herbicide performance. All synthetic adjuvants are prohibited, which includes most adjuvant products in the market. A number of plant-based adjuvants are available that are often derivatives of pine resin, yucca, or other plant-based substances. Some products contain acidifying agents as well as other ingredients touted to enhance pesticide or nutrient uptake. Check with your organic certifier concerning the allowance of these additives. Some allowable herbicide products already include surfactant-type adjuvants in their formulations. Penn State does not ensure the effectiveness or allowance of any of these products.

Diseases

Disease management for organic field crop production should focus on several aspects of plant disease management, including host resistance, site selection, exclusion, crop rotation, cultivation, and plant disease diagnosis. It is unlikely that all diseases can be avoided by utilizing any one of these management strategies alone. However, the damage of many plant diseases can be greatly reduced by the integration of these practices. The sections below provide more information regarding these management options.

Host Resistance

Many plant diseases can be effectively managed by selecting crop varieties that are naturally resistant to specific disease-causing organisms. Host resistance can be either partial or complete. Varieties with complete resistance are completely immune to attack by a specific pathogen or a "race" of the pathogen population. In contrast, varieties with partial resistance may still develop disease symptoms, but the disease will progress slowly and have less of an impact when compared to susceptible plants. The use of host resistance can be highly effective in reducing disease pressure. Knowing the pathogen or race of pathogen you wish to control is necessary to ensure that host resistance is targeted to the most important disease issues. Contact your seed dealer or Penn State Extension office for more information about resistant varieties. Resistant varieties must be conventionally bred and not transgenic.

Site Selection

Soil and environmental conditions can play a key role in disease development. Prior to planting a crop, it is important to understand what soil or environmental conditions may exist that can exacerbate disease development. Issues such as compacted soils or poor soil drainage can lead to root diseases in seedlings and mature plants. Low-lying areas or soil located next to a forest or river can have extended periods of dew or fog, which is a key factor in the development of many foliar diseases of crops. Optimum fertility and soil pH will also help ensure plant health and the ability to defend against pathogens.

Exclusion

Exclusion is the practice of keeping materials and objects that may be contaminated with a pathogen out of the production system. Some diseases are spread through seed, so it is important to purchase seed from a reputable source. Although some seeds are designated as "pathogen-free seed," it is impossible to be certain that a seed lot is entirely free of all pathogens. Other considerations include cleaning tools and equipment to avoid spreading diseased tissue and pathogens between fields, especially if you know of problems in one field (e.g., white mold of soybean or Phytophthora root rot).

Crop Rotation

Many pathogens that cause disease in field crops survive with crop residues left on the soil surface. A diverse crop rotation can reduce pathogens by omitting susceptible hosts in the field and allowing for crop-residue-harboring pathogens to decompose. During the decomposition of crop residues, the disease-causing organisms will be forced to compete with other organisms for limited resources (e.g., food, water, and space). The pathogen population will also decline as it is attacked by naturally occurring pathogens of that organism. Rotation to a nonhost crop for two to three years is desirable. Proper weed control is also important since weeds can act as alternative hosts to some crop diseases.

Cultivation

Tillage can also be used to hasten the decomposition of crop residues and encourage the decline of a pathogen population. In this case, the goal is to bury or place crop residues in contact with the soil so that it is quickly colonized by organisms involved with residue decomposition. These decomposer organisms will consume or compete with the disease-causing organisms, reducing their populations. However, many fields in Pennsylvania are not suitable for tillage because of soil erosion concerns, and producers should carefully evaluate the potential risk of erosion on their farm.

Plant Disease Diagnostics

An important step in disease management is the proper diagnosis of the pathogen and disease. As soon as certain symptoms become a problem in the field, it is important to determine the causal agent in a timely matter to help reduce the spread and potential impact. Once identified, information about the disease can then be used to determine the best control measures and reduce the impact on yield and quality. Infected plant samples can be sent to the Plant Disease Clinic, 220 Buckhout Lab, University Park, PA 16802 for proper diagnosis. Information for submitting samples is available at https://plantpath.psu.edu/facilities/plant-disease-clinic.

Applying Control Methods

Many products are available to help prevent fungal and bacterial diseases from developing. Products may include sulfur, lime, copper, or combinations of two or more. It is important that the product you use is allowed in organic operations. For a list of products, consult your certifier or the National List.

Soil Health and Fertility

The majority of soil science principles covered in Part I, Sections 1: Soil Management and 2: Soil Fertility Management of this manual are relevant to all crop producers regardless of their management strategies. The main exception for organic producers is that the USDA NOP restricts the use of chemical-based fertilizers and several organic-based products in certified organic cropping systems. It is important to check with the certifying agency before using any material as an organic soil amendment on certified crops and land. The NOP also requires organic producers to maintain and improve overall soil conditions while minimizing the risk of erosion and avoiding contamination of soil, crops, and water. NOP practice standards relating to soil fertility and nutrient management are described in detail in Section §205.203 at https://www.ams.usda.gov/rules-regulations/organic.

Soil fertility management is more than simply adding nutrients to crops, and the focus, especially in organic cropping systems, is on overall improvement to soil health and quality. Healthy soils encourage plant growth, supply nutrients at a time when they are needed by crops, improve soil aeration and water-holding capacity, and increase soil's resilience to compaction, erosion, and stress. Organic crop producers build healthy soil by managing soil organic matter (SOM), a complex mixture of living organisms, organic exudates, dead residues, and well-decomposed humus. Soil organic matter has a high cation exchange capacity (CEC) and supplies most plant nutrients to organic crops. Nitrogen (N) is usually the most important nutrient supplied by SOM, but SOM also contains most of a soil's sulfur (S), substantial amounts of phosphorus (P), and many micronutrients. Approved liming materials must be added separately to control pH as needed. Nutrients are released from stable organic compounds into inorganic, plant-available forms through the process of mineralization, which is determined by microbial activity and influenced by soil moisture, aeration, and temperature. Constantly changing soil environmental conditions make estimating mineralization rates and precise nutrient application and timing difficult. Nutrient, compost, and manure application recommendations and soil testing are covered in Part I, Section 2 of this guide and in the *Penn State Organic Crop Production Guide* (https://extension.psu.edu/penn-state-organic-crop-production-guide).

Soil organic matter can be added to soils by diversifying crop rotations, growing cover crops (see Part I, Section 10), reducing tillage, decreasing periods of fallow, and adding manures, composts, and other crop residues to the soil. It is important to note that use of sewage sludge (e.g., biosolids), field burning, and materials containing noncertified, synthetic substances is prohibited in organic cropping systems. Regardless of its source, as SOM is mineralized, nutrients are released into the soil solution and microbial "glues" form to create healthy, well-structured soil aggregates. These benefits are maximized when organic materials move through the process of mineralization in the soil as opposed to when stable materials are added to the soil after they have decomposed. Although allowing SOM to decompose in the soil may be ideal, supplying stabilized organic matter, such as mature compost, can increase SOM levels, improve overall soil health and structure, and stabilize nutrients that could otherwise contaminate air and water. Additionally, because adding decomposed residues to soils helps recycle waste products and may be a practical management consideration, using them properly as soil amendments is greatly encouraged. The key to effective SOM management is diversity and using a combination of practices to build SOM and improve soil health is recommended. Multiple strategies can also help overcome some of the uncertainties and challenges associated with SOM management. The biological aspect of soils dominates soil fertility management practices in organic cropping systems; however, improving a soil's biological conditions can, in turn, improve its physical and chemical characteristics since all factors are interrelated. Diversifying practices can help maximize benefits from all aspects. "Soil Health in Field and Forage Crop Production" (https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/pa/soils/health/?cid=nrcseprd940817) is a publication by Penn State Extension and the USDA Natural Resources Conservation Service that further discusses soil health management practices and cropping strategies.

Part I, Section 12

Farm Management: Enterprise Budgets

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An integral part of profitably managing agronomic crops is developing budgets for your individual crop enterprises. Budgets can be used to estimate profitability, project cash flows, provide a basis for credit, assist in farm planning, and develop least-cost feed rations.

Types of Costs

Enterprise budgets contain several cost components, and it can often be difficult to determine which should be considered for a given decision because production costs are unique to each farming situation. One of the most common classifications divides costs into variable costs and fixed costs. Variable costs are those that vary with output within a production period. Examples include seed, fertilizer, chemicals, fuel, repairs, and labor. Other terms used to describe variable costs include cash costs (or expenses), direct costs, and out-of-pocket costs.

Fixed costs include depreciation, taxes, interest on investment, land charges, and insurance. Sometimes a management fee is included as a fixed cost. These costs are "fixed" because they generally remain the same within a production period and do not vary with the level of output. Indirect, noncash, and overhead costs are other terms used to describe fixed costs.

Total costs are calculated by adding variable costs and fixed costs. Ideally, you want to earn a profit above total costs every year. This is not always possible because income received varies with prices and yields and is sometimes less than the total costs of production. Should you continue to produce under these circumstances? The answer may be yes if you are covering variable costs of production and it is a short-run condition. It is economical to continue production in the short run so long as income is higher than the variable costs of production. In other words, in the short run, you must receive a price that generates a return at least equal to variable costs. In the long run, however, market price and yield need to be high enough to cover total costs of production, including fixed costs. Otherwise, replacing machinery and equipment will become increasingly difficult, and as a result, the enterprise will not be financially sound after a period of several years.

The variable cost/fixed cost concept is critical to most short-run and annual farm decisions. For example, in Pennsylvania, most farmers must decide whether to plant corn, soybean, small grains, or forage. Generally, most of the fixed costs associated with the farm will not be affected by this decision. These crops typically compete for the same land and labor and require much of the same machinery and equipment. The most desirable crop is the one that generates the highest return using these fixed resources and thus the greatest return above variable costs.

For lenders, variable costs can be used in a cash-flow analysis to arrive at a per-unit cost of production based on the "cash-flow cost" principle. Cash-flow costs include all variable costs plus debt payment, taxes, and family living. However, cash-flow costs do not include noncash items such as depreciation and interest on equity. The cash-flow costs of production may be either more or less than the total of variable costs and fixed costs.

Application of the different classifications of cost can reveal large variations in per-unit costs of production. Each producer's output and financial situation is unique. Individual farmers must determine their costs of production in relation to their management decisions and income needs. For example, you could compute costs on the basis of an income and loss statement to determine the profitability of the business. However, a cash-flow statement would be needed to determine whether all financial obligations can be met—that is, if the business is liquid.

Sample Enterprise Budgets

Sample budgets for corn grain, corn silage, oats, barley, wheat, soybeans, double-crop barley with soybeans, double-crop wheat with soybeans, grain sorghum, forage sorghum, canola, alfalfa, and grass hay are given in Tables 1.12-1 to 1.12-8. These budgets were developed using a computerized budget generator and are based on Penn State's recommended production practices and projected 2023 commodity prices and input costs. The budgets were prepared to provide general information for several different uses. They do not apply directly to any specific area or individual fields. They should be used, with appropriate modifications, as guides for preparing budgets for your own situation. Adjustments to the assumed input costs and commodity prices may be necessary because of volatility in input costs and commodity prices. The budget layouts should help ensure that all costs are included in your estimates. Costs are often difficult to estimate in budget preparation because they are numerous and variable. Therefore, you should think of these budgets as a first approximation and then make appropriate adjustments using the "Your Estimate" column to add, delete, and adjust items to reflect your specific production situation.

Major subheadings in the budgets include receipts, variable costs, fixed costs, total costs, and net returns to management. They are defined as follows:

- Receipts are the gross returns from production. Because yields and prices are so variable, you should use representative values for your own operation.
- Variable costs are costs that vary depending on the level of production and include inputs such as seed, fertilizer, herbicides, insecticides, fungicides, and labor. Commercial fertilizers were used as the fertility source in all the

budgets, with the exception of the corn silage and forage sorghum budgets, which also use liquid dairy manure. Other variable costs that have not been included in the budgets might include crop management services, marketing, and storage.

- Fixed costs are costs that do not vary by level of production and are incurred by owning assets such as buildings, machinery, equipment, and land. Depreciation, insurance, principal and interest payments, and property taxes are examples of fixed costs. A flat charge for land of $100 per acre is included as a fixed cost in the sample budgets. Land charges are highly variable and can be either a variable cost (for rented land) or a fixed cost (for long-term leases and owned land). You should include rental charges or interest and principal payments plus property taxes to account for all your costs of crop production. If you own the land, figure your land charge based on the agricultural value of the land rather than its potential value for development.
- Total specified costs are the sum of variable and fixed costs but do not include costs for crop storage or marketing.
- Return to management is the profit attributable to your crop production and risk management skills.

Representative breakeven prices and yields are given at the bottom of each budget. The breakeven price is the minimum price required to cover all costs at the anticipated yield. The breakeven yield is the minimum yield required to cover all costs at the anticipated price. For a more detailed discussion of the use of crop budgets to improve crop decision making, see the farm management publication "Agricultural Alternatives: Budgeting for Agricultural Decision Making," available from your local Penn State Extension office or online at https://extension.psu.edu/budgeting-for-agricultural-decision-making.

Commodity Price and Input Costs

Agriculture will be facing an extended period of volatile commodity prices and input costs. This economic environment makes it especially important to monitor your cost of production (especially for fuel, fertilizers, and pesticides) and keep up with trends in the futures markets. Significant increases in labor costs and interest rates will also have an impact on your profitability. These budgets are a good starting point for developing your estimates but should be adjusted to reflect any changes in the international markets for inputs, commodities, and governmental policies, which can alter the marketplace and affect your profitability very quickly. The commodity prices used in the corn, soybean, wheat, and oat budgets reflect 2023 futures prices (as of late May 2022) for delivery at harvest (adjusted for local basis). The corn silage price is set at nine times the corn price (eight to ten times the corn price is a commonly used estimate for valuing corn silage). Barley and grain sorghum prices are set at 85 percent of the corn price (based on relative feed value). Forage sorghum is valued at 85 percent of corn silage (based on relative feed value). The canola price is based on the projected 2023 North Dakota price modified for transportation. Hay prices reflect the average price received for all hay of a particular type. Quoted hay prices often exhibit high variability because of the impact that local supply and demand conditions, quality differences, bale type (e.g., small rectangular, small round, large round, and large square bales), and transportation costs have on price. The estimated diesel price is for off-road diesel and reflects 2023 future prices (as of late-May 2022). However, energy prices are likely to continue to be volatile in future years because of potential supply disruptions, and this will impact not only the price of motor fuels but also the cost of pesticides, fertilizer, and grain drying.

Managing Risk in Agronomic Crops

Because of volatile commodity prices and increasing input costs, it is more important than ever to protect your investment in your growing crops with crop insurance. Crop insurance protection is available for most agronomic crops through a wide variety of plans, including crop-specific policies that provide yield or revenue protection, whole-farm coverage based on adjusted gross revenue, dollar coverage for hay based on the value of the crop, and the group risk pasture and forage plan based on a rainfall index. Most plans also offer optional coverage for prevented planting. Coverage for individual crops is based on your farm's actual production history (APH) and you select the type and level of coverage that makes sense for your risk management goal. The USDA Farm Service Agency also has programs designed to help you manage your risk, including the Noninsured Disaster Assistance Program (NAP).

Crop insurance costs are included in the budgets for those crops that are commonly covered by crop insurance in Pennsylvania. These costs are based on protection at the 75 percent coverage level for a medium-risk county (see footnotes on each budget for more details). These estimates are for illustration only; check with a crop insurance agent for product availability in your county and to explore other options (for example, use of trend-adjusted yields and choice of insurance unit) and coverage levels that may better suit your risk management needs. In Pennsylvania, there are crop insurance options available for corn, soybean, barley, oats, wheat, grain sorghum, pastures, and forages. The annual sales closing dates for crop insurance are March 15 for spring-seeded agronomic crops and September 30 for winter wheat and barley.

Table 1.12-1. Corn grain after soybeans production budgets, Pennsylvania, 2023 estimates.

Item	Conventional Tillage	Reduced Tillage	No-Till	Your Estimate
Receipts				
Corn grain	$1,056.00	$1,056.00	$1,056.00	
Variable Costs				
Seed	$115.20	$115.20	$115.20	
Lime	$16.00	$16.00	$16.00	
Fertilizer	$197.50	$197.50	$197.50	
Herbicides	$39.55	$39.55	$53.55	
Insecticides	$0.00	$0.00	$0.00	
Soil test	$2.00	$2.00	$2.00	
Labor	$27.40	$21.08	$13.64	
Fuel	$28.94	$22.38	$14.68	
Drying	$96.96	$96.96	$96.96	
Repairs and maintenance	$17.46	$12.08	$7.92	
Custom combining	$40.00	$40.00	$40.00	
Crop insurance*	$27.60	$27.60	$27.60	
Interest on operating capital	$13.98	$12.81	$12.94	
Other:				
Total variable costs	$622.59	$603.21	$597.99	
Fixed Costs				
Tractors	$13.85	$9.70	$4.82	
Equipment	$25.03	$17.97	$11.65	
Land	$100.00	$100.00	$100.00	
Total fixed costs	$138.88	$127.67	$116.82	
Total costs	$761.47	$730.88	$714.46	
Net returns to management	$294.53	$325.12	$341.54	
Breakeven Price				
@ 120 bu/A	$6.35/bu	$6.09/bu	$5.95/bu	
@ 160 bu/A	$4.76/bu	$4.57/bu	$4.47/bu	
@ 200 bu/A	$3.81/bu	$3.65/bu	$3.57/bu	
@ ___ bu/A				
Breakeven Yield				
@ $6.00/bu	126.9 bu/A	121.8 bu/A	119.1 bu/A	
@ $6.60/bu	115.4 bu/A	110.7 bu/A	108.3 bu/A	
@ $7.20/bu	105.8 bu/A	101.5 bu/A	99.2 bu/A	
@ $ ___ /bu				

*Crop insurance cost based on revenue protection (optional units, harvest price exclusion) at the 75 percent coverage level for a medium-risk county.

Table 1.12-2. Corn grain after corn production budgets, Pennsylvania, 2023 estimates.

Item	Conventional Tillage	Reduced Tillage	No-Till	Your Estimate
Receipts				
Corn grain	$975.00	$975.00	$975.00	
Variable Costs				
Seed	$115.20	$115.20	$115.20	
Lime	$16.00	$16.00	$16.00	
Fertilizer	$262.32	$262.32	$262.32	
Herbicides	$53.55	$53.55	$67.55	
Insecticides	$0.00	$0.00	$0.00	
Soil test	$2.00	$2.00	$2.00	
Labor	$28.78	$22.46	$15.02	
Fuel	$29.96	$23.40	$15.29	
Drying	$90.90	$90.90	$90.90	
Repairs and maintenance	$18.28	$12.95	$8.68	
Custom combining	$40.00	$40.00	$40.00	
Crop insurance*	$26.50	$26.50	$26.50	
Interest on operating capital	$15.94	$15.21	$14.89	
Other:				
Total variable costs	$699.43	$680.49	$674.35	
Fixed Costs				
Tractors	$14.45	$10.30	$5.12	
Equipment	$26.05	$18.99	$12.67	
Land	$100.00	$100.00	$100.00	
Total fixed costs	$140.50	$129.29	$117.79	
Total costs	$839.93	$809.78	$792.14	
Net returns to management	$135.07	$165.22	$182.86	
Breakeven Price				
@ 110 bu/A	$7.64/bu	$7.36/bu	$7.20/bu	
@ 150 bu/A	$5.60/bu	$5.40/bu	$5.28/bu	
@ 190 bu/A	$4.42/bu	$4.26/bu	$4.17/bu	
@ ___ bu/A				
Breakeven Yield				
@ $6.00/bu	140.0 bu/A	135.0 bu/A	132.0 bu/A	
@ $6.60/bu	127.3 bu/A	122.7 bu/A	120.0 bu/A	
@ $7.20/bu	116.7 bu/A	112.5 bu/A	110.0 bu/A	
@ $ ___ /bu				

*Crop insurance cost based on revenue protection (optional units, harvest price exclusion) at the 75 percent coverage level for a medium-risk county.

Table 1.12-3. Corn silage production budgets, Pennsylvania, 2023 estimates.

Item	Conventional Tillage	Reduced Tillage	No-Till	Corn and small grain silage	Your Estimate
Receipts					
Silage	$1,485.00	$1,485.00	$1,485.00	$1,960.20	
Variable Costs					
Corn seed	$129.60	$129.60	$129.60	$115.20	
Cover crop seed	$15.00	$15.00	$15.00	—	
Rye (cereal) seed	—	—	—	$52.50	
Lime	$16.00	$16.00	$16.00	$16.00	
Fertilizer*	$192.73	$192.73	$192.73	$301.17	
Herbicides	$53.55	$53.55	$67.55	$67.55	
Insecticides	$0.00	$0.00	$0.00	$0.00	
Soil test	$2.00	$2.00	$2.00	$2.00	
Labor	$28.62	$22.30	$14.86	$30.38	
Fuel	$28.75	$22.19	$14.08	$25.57	
Repairs and maintenance	$21.01	$15.68	$11.41	$18.54	
Custom chop, haul, and fill	$255.00	$255.00	$255.00	$346.80	
Crop insurance**	$28.70	$28.70	$28.70	$28.70	
Interest on operating capital	$16.81	$16.08	$15.69	$24.08	
Other:					
Total variable costs	$787.77	$768.83	$762.62	$1,028.49	
Fixed Costs					
Tractors	$16.02	$11.87	$6.69	$13.40	
Equipment	$30.43	$23.37	$17.05	$26.96	
Land	$100.00	$100.00	$100.00	$100.00	
Total fixed costs	$146.45	$135.24	$123.74	$140.36	
Total costs	$934.22	$904.07	$886.36	$1,168.85	
Net returns to management	$550.78	$580.93	$598.64	$791.35	
Breakeven Price					
@ 21 T/A (corn silage)	$44.49/T	$43.05/T	$42.21/T	$40.31/T	
@ 25 T/A (corn silage)	$37.37/T	$36.16/T	$35.45/T	$35.42/T	
@ 29 T/A (corn silage)	$32.21/T	$31.17/T	$30.56/T	$31.59/T	
@ ___ T/A					
Breakeven Yield					
@ $54.00/T	17.3 T/A	16.7 T/A	16.4 T/A	21.6 T/A	
@ $59.40/T	15.7 T/A	15.2 T/A	14.9 T/A	19.7 T/A	
@ $64.80/T	14.4 T/A	14.0 T/A	13.7 T/A	18.0 T/A	
@ $ ___ /T					

*Fertilizer rate adjusted assuming application of 8,000 gallons of dairy manure.
**Crop insurance cost based on yield protection (optional units) at the 75 percent coverage level for a medium-risk county.

Corn Budgets

(Tables 1.12-1, 1.12-2, and 1.12-3)

- Receipts: For the sample budgets, yields of 160 bushels per acre for a corn grain after soybean rotation, 150 bushels per acre for a corn grain after corn rotation (assumes grain yields measured at 13.5 percent moisture), and 25 tons of silage per acre are used. Grain is valued at $6.60 per bushel and silage at $59.40 per ton.
- Variable costs: Seeding rates of 32,000 kernels per acre for grain and 36,000 kernels per acre for silage are used for the budgets. Seed cost is based on a price of $3.60 per 1,000 kernels for transgenic corn. Labor is charged at $19 per hour and off-road diesel fuel at $3.75 per gallon. Fertilizer applied is 160-60-40 for the corn grain after corn rotation, 110-60-40 for the corn grain after soybean rotation (assumes 50 pounds of nitrogen provided by previous soybean crop), and 90-30-75 for corn silage (assumes the balance of nutrients come from application of 8,000 gallons of dairy manure [see "Sample Manure Calculations" in Part I, Section 2: Soil Fertility Management; adjust your fertilizer costs to account for any manure applications in your own budget]). A yearly charge for 0.5 ton of lime is included in all corn budgets. For grain production, a drying charge of $0.606 per bushel is also included. The cost of a rye cover crop seeded at a rate of 1 bushel per acre is also included in all corn silage budgets.

The weed management program varies depending on the tillage system. A preplant application of commonly used herbicides is assumed for managing weeds for all tillage systems and rotations. For no-till, a burndown application of glyphosate is used in addition to the preplant application. It is also assumed in the corn after corn and corn silage budgets that one-quarter of the acreage will be treated with a postemergence application of glyphosate. The pesticides used for developing cost estimates are for example purposes only; see Part II, Section 2: Corn Pest Management for a complete listing of recommended materials.

Small Grain Budgets

(Table 1.12-4)

- Receipts: For the sample budgets, yields of 90 bushels per acre for oats, 100 bushels per acre for barley, and 75 bushels per acre for wheat—and prices of $5.50 per bushel for oats, $5.60 per bushel for barley, and $11.00 per bushel for wheat—are used. In addition, the budgets include receipts for sale of 1 ton of oat straw, 1.5 tons of barley straw, or 1.5 tons of wheat straw (valued at $180 per ton).
- Variable costs: No-till practices are assumed for the small grain budgets. A seeding rate of 1.4 million seeds per acre is used for the small grain budgets. Labor is charged at $19 per hour and off-road diesel fuel at $3.75 per gallon. A 70-80-135 fertilizer for oats, 80-60-150 for barley, and 75-75-135 for wheat are assumed in the budgets (adjust your costs to account for any manure applications in your own budgets). A yearly charge for 0.5 ton of lime is included in all small grain budgets. The cost of one application of a fungicide is included in the barley and wheat budgets. No insecticides or drying charges are included in the small grain budgets.

The weed management program for the small grains consists of a burndown application of glyphosate and spring application of commonly used herbicides. The pesticides used for developing cost estimates are for example purposes only; recommended pesticides can be found in Part II, Section 5: Small Grain Pest Management.

Full-Season Soybean and Double-Crop Budgets

(Table 1.12-5)

- Receipts: For the sample full-season soybean budget, a yield of 50 bushels per acre valued at $14.20 per bushel is used. For the double-crop sample budgets, yields of 100 bushels of barley and 40 bushels of soybeans per acre and 75 bushels of wheat and 30 bushels of soybeans per acre—and prices of $5.50 per bushel for barley, $11.00 per bushel for wheat, and $14.20 per bushel for soybeans—are used. In addition, 1.5 tons of barley straw and 1.5 tons of wheat straw (valued at $180 per ton) are included in the double-crop budget receipts.
- Variable costs: No-till practices are assumed for both soybean and small grains. A seeding rate of 150,000 seeds per acre is used for the full-season soybean budget. Seeding rates of 1.4 million seeds per acre for the small grains and 220,000 seeds per acre for soybean are used for the double-crop budgets. Labor is charged at $19 per hour and off-road diesel fuel at $3.75 per gallon. Fertilizer rates are 0-40-60 for full-season soybean, 80-100-190 for barley/soybean, and 75-105-175 for wheat/ soybean. A yearly charge for 0.5 ton of lime is included in all soybean budgets. The cost of one application of a fungicide is included in the barley and wheat double-crop budgets.
- No insecticides or drying charges are included in the full-season soybean or double-crop budgets.

Because it is assumed that glyphosate-tolerant soybean varieties are planted, the herbicide program consists of a burndown application of glyphosate and one postemergence application of glyphosate. The weed management program for the small grains in the double-crop budgets consists of a burndown application of glyphosate and a spring application

Table 1.12-4. Small grain production budgets (no-till practices), Pennsylvania, 2023 estimates.

Item	Oats	Barley	Wheat	Your Estimate
Receipts				
Grain	$495.00	$560.00	$825.00	
Straw	$180.00	$270.00	$270.00	
Variable Costs				
Seed	$33.60	$39.20	$49.00	
Lime	$16.00	$16.00	$16.00	
Fertilizer	$245.07	$269.38	$248.65	
Herbicides	$18.50	$19.96	$19.96	
Fungicides	$0.00	$14.23	$14.23	
Soil test	$2.00	$2.00	$2.00	
Labor	$40.63	$38.49	$38.49	
Fuel	$29.78	$25.21	$25.21	
Drying	$0.00	$0.00	$0.00	
Repairs and maintenance	$11.35	$11.80	$11.80	
Custom combining	$38.00	$38.00	$38.00	
Crop insurance*	$13.10	$20.40	$18.40	
Interest on operating capital	$12.85	$19.91	$19.47	
Other:				
Total variable costs	$460.88	$514.58	$501.21	
Fixed Costs				
Tractors	$8.97	$10.81	$10.81	
Equipment	$18.46	$17.09	$17.09	
Land	$100.00	$100.00	$100.00	
Total fixed costs	$127.43	$127.90	$127.90	
Total costs	$588.21	$642.48	$629.11	
Net returns to management	$86.69	$187.52	$465.89	
*Breakeven Price***	$4.54/bu (at 90 bu yield)	$3.72/bu (at 100 bu yield)	$4.79/bu (at 75 bu yield)	
*Breakeven Yield***	74.2 bu/A (at $5.50/bu)	66.5 bu/A (at $5.60/bu)	32.6 bu/A (at $11.00/bu)	

*Crop insurance cost based on yield protection (optional units) at the 75 percent coverage level for oat and revenue protection (optional units, harvest price exclusion) at the 75 percent coverage level for barley and wheat (assuming medium-risk county).
**Adjusted for value of straw.

of commonly used herbicides. The pesticides used for developing cost estimates are for example purposes only; recommended pesticides can be found in Part II, Section 4: Soybean Pest Management and Section 5: Small Grain Pest Management.

Alternative Field Crop Budgets (Grain Sorghum, Forage Sorghum, and Canola)

(Table 1.12-6)

- Receipts: For the sample budgets, yields of 135 bushels of grain sorghum, 20 tons of forage sorghum silage, and 50 bushels of canola per acre are used. Grain sorghum is valued at $5.60 per bushel, forage sorghum silage at $50 per ton, and canola at $15 per bushel.
- Variable costs: No-till practices are assumed for the grain sorghum, forage sorghum, and canola budgets. Seeding rates of 12 pounds per acre for grain sorghum, 7 pounds per acre for forage sorghum, and 5 pounds per acre for canola are used for the budgets. Labor is charged at $19 per hour and off-road diesel fuel at $3.75 per gallon. Fertilizer applied is 75-40-40 for grain sorghum, 100-40-30 for canola, and 30-0-0 for forage sorghum (assumes the balance of nutrients come from application of 8,000 gallons of dairy manure [see "Sample Manure Calculations" in Part I, Section 2: Soil

Table 1.12-5. Full-season soybean and double-crop production budgets (no-till practices), Pennsylvania, 2023 estimates.

Item	Full-Season Soybean	Barley/Soybean	Wheat/Soybean	Your Estimate
Receipts				
Soybeans	$710.00	$568.00	$426.00	
Small grain	—	$560.00	$825.50	
Straw	—	$270.00	$270.00	
Variable Costs				
Soybean seed	$67.50	$99.00	$99.00	
Small grain seed	—	$39.20	$49.00	
Lime	$16.00	$16.00	$16.00	
Fertilizer	$68.60	$310.71	$296.65	
Herbicides	$48.88	$54.84	$54.84	
Fungicides	$0.00	$14.23	$14.23	
Soil test	$2.00	$2.00	$2.00	
Labor	$14.64	$54.90	$48.25	
Fuel	$15.00	$44.86	$37.31	
Drying	$0.00	$0.00	$0.00	
Repairs and maintenance	$9.16	$19.89	$17.26	
Custom combining	$40.00	$78.00	$78.00	
Crop insurance*	$15.10	$20.40	$18.40	
Interest on operating capital	$7.19	$27.97	$27.56	
Other:				
Total variable costs	$304.07	$782.00	$758.50	
Fixed Costs				
Tractors	$7.03	$13.56	$11.16	
Equipment	$14.18	$33.01	$28.95	
Land	100.00	$100.00	$100.00	
Total fixed costs	$121.21	$146.57	$140.11	
Total costs	$425.28	$928.57	$898.61	
Net returns to management	$284.72	$469.43	$622.39	
Breakeven Price				
Soybean	$8.51/bu (at 50 bu yield)	$8.66/bu (at 40 bu yield)	$11.55/bu (at 30 bu yield)	
Small grain**	—	$3.12/bu (at 100 bu yield)	$3.76/bu (at 75 bu yield)	
Breakeven Yield				
Soybean	29.9 bu/A (at $14.20/bu)	24.4 bu/A (at $14.20/bu)	24.4 bu/A (at $14.20/bu)	
Small grain**	—	55.7 bu/A (at $5.60/bu)	25.7 bu/A (at $11.00/bu)	

*Small grain crop insurance cost based on revenue protection (optional units, harvest price exclusion) at the 75 percent coverage level for a medium-risk county.
**Adjusted for value of straw.

Table 1.12-6. Alternative field crop production budgets (no-till practices), Pennsylvania, 2023 estimates.

Item	Grain Sorghum	Forage Sorghum	Canola	Your Estimate
Receipts	$756.00 (grain)	$1,000.00 (silage)	$750.00 (grain)	
Variable Costs				
Seed	$48.00	$28.00	$75.00	
Cover crop seed	$0.00	$15.00	$0.00	
Lime	$16.00	$16.00	$16.00	
Fertilizer*	$234.90	$104.50*	$172.59	
Herbicides	$38.88	$38.88	$28.00	
Soil test	$2.00	$2.00	$2.00	
Labor	$14.27	$11.10	$15.53	
Fuel	$15.08	$12.00	$16.01	
Drying	$57.78	—	$12.45	
Repairs and maintenance	$8.54	$9.36	$9.01	
Custom combining	$40.00	—	$38.00	
Custom chop, haul, and fill	—	$204.00	—	
Interest on operating capital	$10.78	$7.55	$13.13	
Other:				
Total variable costs	$486.23	$448.39	$397.72	
Fixed Costs				
Tractors	$4.59	$2.58	$5.13	
Equipment	$14.55	$17.92	$14.91	
Land	$100.00	$100.00	$100.00	
Total fixed costs	$119.14	$120.50	$120.04	
Total costs	$605.37	$568.89	$517.76	
Net returns to management	$150.63	$431.11	$232.24	
Breakeven Price	$4.48/bu (at 135 bu/A)	$28.44/T (at 20 T/A)	$10.36/bu (at 50 bu/A)	
Breakeven Yield	108.1 bu/A (at $5.60/bu)	11.4 T/A (at $50.00/T)	34.5 bu/A (at $15.00/bu)	

*Fertilizer rate for forage sorghum adjusted assuming application of 8,000 gallons of dairy manure.

Fertility Management; adjust your costs to account for any manure applications in your own budgets]). A yearly charge for 0.5 ton of lime is included in each budget. Drying charges are also included in the grain sorghum ($0.428 per bushel) and canola ($0.249 per bushel) budgets. Cost of a rye cover crop seeded at a rate of 1 bushel per acre is also included in the forage sorghum budget.

The grain sorghum and forage sorghum weed management programs include a burndown application of glyphosate, a preplant application of commonly used herbicides, and treatment of one-quarter of the acreage with a postemergence herbicide. It is assumed that a glyphosate-tolerant canola variety is planted, so the herbicide program consists of one burndown and one postemergence application of glyphosate. No insecticide costs are included in the grain sorghum, forage sorghum, or canola budgets. The pesticides used for developing cost estimates are for example purposes only; see Part II, Section 3: Grain Sorghum Pest Management for recommended materials.

Alfalfa Budgets

(Table 1.12-7)

- Receipts: For the sample budgets, yields of 2.5 tons of hay in the establishment year and 3.75 tons of hay and 2.5 tons of haylage (total yield equal to 5 tons of dry hay per acre) for production years are used. Alfalfa hay is valued at $275 per ton and alfalfa haylage at $115 per ton.
- Variable costs: Seeding rates of 18 pounds per acre for conventional tillage and 15 pounds per acre for no-till

Table 1.12-7. Alfalfa establishment and production budgets, Pennsylvania, 2023 estimates.

Item	Conventional Establishment	No-Till Establishment	Production	Your Estimate
Receipts				
Alfalfa hay	$687.50	$687.50	$1,031.25	
Alfalfa haylage	0.00	0.00	$287.50	
Variable Costs				
Seed*	$108.00	$90.00	$0.00	
Lime	$64.00	$64.00	$0.00	
Fertilizer	$138.55	$138.55	$275.00	
Herbicides	$14.62	$24.80	$0.00	
Insecticides	$3.74	$3.74	$3.74	
Soil test	$2.00	$2.00	$0.00	
Labor	$93.62	$79.86	$136.15	
Fuel	$68.79	$54.12	$95.61	
Repairs and maintenance	$31.30	$21.70	$36.24	
Crop insurance**	$11.20	$11.20	$26.50	
Interest on operating capital	$13.59	$12.05	$13.91	
Other:				
Total variable costs	$549.41	$502.02	$587.15	
Fixed Costs				
Tractors	$28.24	$18.91	$39.71	
Equipment	$46.43	$33.05	$50.67	
Land	$100.00	$100.00	$100.00	
Total fixed costs	$174.67	$151.96	$190.38	
Total costs	$724.08	$653.98	$777.53	
Net returns to management	-$36.58	$33.52	$541.22	
Breakeven Price				
@ 2.5 T/A	$289.63/T	$261.59/T	$311.01/T	
@ 5.0 T/A	—	—	$155.51/T	
@ 7.5 T/A	—	—	$103.67/T	
@ ___ T/A				
Breakeven Yield				
@ $225 /T	3.2 T/A	2.9 T/A	3.5 T/A	
@ $275 /T	2.6 T/A	2.4 T/A	2.8 T/A	
@ $325 / T	2.2 T/A	2.0 T/A	2.4 T/A	
@ $ ___ /T				

*Seed cost assumes use of traditional alfalfa varieties. Genetically modified varieties cost more; for example, glyphosate-resistant varieties cost around $3 to $6 per pound more than traditional varieties.
**Crop insurance cost based on forage seeding and forage production policies (dollar plan) at the 75 percent coverage level in a medium-risk county.

are used in the establishment budgets. Seed cost assumes use of traditional alfalfa varieties (genetically modified varieties costs more; for example, glyphosate-resistant varieties cost around $3 to $6 per pound more than traditional varieties). Labor is charged at $19 per hour. Off-road diesel fuel is budgeted at $3.75 per gallon. Fertilizer applied is 0-50-150 for establishment and 0-100-300 for production. An application of 2 tons per acre of lime is assumed in the establishment budgets.

The weed management program consists of one postemergence application of herbicide in the establishment year only for both conventional tillage and no-till and the addition of a burndown application of glyphosate for no-till. The insect management program consists of one insecticide application in the establishment year and once every production year. The pesticides used for developing cost estimates are for example purposes only; see Part II, Section 6: Forage Pest Management for recommended materials.

Grass Hay Budgets

(Table 1.12-8)

- Receipts: For the sample budgets, a yield of 1.5 tons of hay per acre is assumed in the year of establishment. In the production years, a yield of 2.5 tons of hay and 3 tons of haylage (total yield equal to 4 tons of dry hay per acre) is used for orchardgrass and 3 tons of hay per acre for timothy. Orchardgrass hay is valued at $225 per ton, orchardgrass haylage at $100 per ton, and timothy hay at $275 per ton.
- Variable costs: The establishment budget assumes conventional tillage and a seeding rate of 12 pounds per acre. Labor is charged at $19 per hour. Off-road diesel fuel is budgeted at $3.75 per gallon. Fertilizer applied is 30-30-90 for establishment and 160-80-240 for orchardgrass production and 100-60-180 for timothy production (adjust your costs in your own budgets to account for any manure applications). An application of 2 tons per acre of lime is assumed in the establishment budget.

The herbicide program consists of one annual application of 2,4-D amine in all three budgets. No insecticide costs are included in the grass hay budgets. The pesticides used for developing cost estimates are for example purposes only; see Part II, Section 6: Forage Pest Management for recommended materials.

Table 1.12-8. Grass hay establishment and production budgets, Pennsylvania, 2023 estimates.

Item	Conventional Establishment	Orchardgrass Production	Timothy Production	Your Estimate
Receipts				
Hay	$337.50	$562.50	$825.00	
Haylage	$0.00	$300.00	$0.00	
Variable Costs				
Seed	$52.92	$0.00	$0.00	
Lime	$64.00	$0.00	$0.00	
Fertilizer	$109.80	$220.00	$256.00	
Herbicides	$3.13	$3.13	$3.13	
Insecticides	$0.00	$0.00	$0.00	
Soil test	$2.00	$0.00	$0.00	
Labor	$57.62	$101.92	$111.63	
Fuel	$44.98	$73.71	$72.30	
Repairs and maintenance	$22.52	$29.05	$25.21	
Interest on operating capital	$7.33	$9.17	$7.43	
Other:				
Total variable costs	$364.30	$436.98	$475.70	
Fixed Costs				
Tractors	$22.02	$32.16	$26.49	
Equipment	$30.95	$39.93	$35.40	
Land	$100.00	$100.00	$100.00	
Total fixed costs	$152.97	$172.09	$161.89	
Total costs	$517.27	$609.07	$637.59	
Net returns to management	-$179.77	$253.43	$187.41	
Breakeven Price				
@ 1.5 T/A	$344.85/T	$406.05/T	$425.06/T	
@ 3.0 T/A	—	$203.02/T	$212.53/T	
@ 4.0 T/A	—	$152.27/T	—	
@ ___ T/A				
Breakeven Yield				
@ $225/T	2.3 T/A	2.7 T/A	2.8 T/A	
@ $275/T	1.9 T/A	2.2 T/A	2.3 T/A	
@ $ ___ /T				

Part II

Part II, Section 1
Pest Management

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Since the beginning of agriculture, crops have suffered losses to various kinds of pests. Although much progress has been made in managing pests, many persist, and crop losses continue to occur. Pests that contribute to crop losses in Pennsylvania include insects, weeds, diseases, nematodes, slugs, and wildlife.

Single pest management techniques are no longer considered reliable to combat most pests. Many management practices have limited periods of effectiveness, while others can create side effects worse than the crop damage. Success in managing crop pests depends on how well economically effective technologies, old and new, can be integrated while minimizing risk to health and the environment.

With increasing concern about food safety and water quality, the objectives of pest management are changing. Pest management decisions now must include environmental and human health risk considerations. While these factors are difficult to measure, they are of growing importance in crop production. Simplistic approaches such as routine applications of pesticides are no longer acceptable pest management practices. There are numerous effective pest management methods that when properly used reduce pest populations to economically acceptable levels. Using a combination of methods is the best approach to handling most pest problems.

Integrated pest management (IPM) may be defined as the use of multiple pest management tactics to efficiently produce crops, while minimizing the risk of undesirable environmental and health effects.

- IPM is a systematic approach to crop protection that utilizes increased information to make better pest management decisions, with an emphasis on integrating all available alternatives.
- IPM is a philosophy that promotes the collection of field-specific information to make rational pest management decisions. The goal is to increase information through field scouting and monitoring to facilitate selection of appropriate pest management alternatives, including judicious use of pesticides when necessary.
- The IPM philosophy does not advocate completely eliminating pesticides, but rather recommends their appropriate use as a final defense against pests whose populations cannot be maintained at acceptable levels using other pest management tactics.
- An important function of IPM is to help avoid the development of resistance to pesticides and other control measures. Historic overreliance on some pesticides favored populations of resistant pest populations, including insect populations that became resistant to hydrogen cyanide and DDT. Current overuse of glyphosate and other common pesticides carries similar risks; thus, the multifaceted approach favored by IPM holds potential to prevent the development of resistance.

Activities Involved in an IPM Program

Effective IPM programs require more intensive collecting of information than routine spray programs. Table 2.1-1 shows the differences in activities required for an IPM program versus a routine spray program. Although an IPM program is more time-consuming to implement, the returns to investment can greatly exceed those of a routine spray program, particularly for occasional pests. Except for weeds, all pests attacking field and forage crops in Pennsylvania fall into this category.

As shown in Table 2.1-1, the sequence of IPM activities includes: (1) monitoring fields to detect crop damage or the potential for crop damage, (2) identifying the cause(s) of crop damage, (3) determining the need for management, (4) evaluating management alternatives, (5) selecting the most appropriate management alternative(s), (6) implementing the selected management alternative(s), (7) assessing management strategy performance, and (8) keeping records of pest problems and the field performance of the management strategy. Routine spray programs are less time-consuming because the farm manager uses only one possible management strategy, usually a pesticide, to manage the pest. No attention is paid to whether the pesticide is applied in an optimal fashion or directed at the correct pest species.

Table 2.1-1. Comparison between activities of an ideal IPM program and a routine spray program.

Activity	IPM Program	Routine Spray Program
1. Monitor crop for indications of damage	Yes	No
2. Identify cause of crop damage	Yes	No
3. Determine need for management	Yes	No
4. Evaluate management alternatives	Yes	No
5. Select appropriate management alternatives	Yes	No
6. Implement management alternatives	Yes	Yes
7. Assess success of management alternatives	Yes	Yes
8. Maintain records on pest populations and effectiveness of management alternatives	Yes	No

Monitoring the Crop for Pest Damage

Reasons for Monitoring

The first step in an IPM program is to monitor fields for signs of pest damage or potential pest problems. Proper weed management involves a thorough inspection of each field after crop harvest to identify major weed species in the field. When an annual crop is to be grown in the field the following year, this information is used to assess the importance of each weed species and to select the appropriate management strategy to be used for the coming crop. In annual crops, fields also are monitored after the crop has emerged to assess the effectiveness of the selected management alternative and whether additional management tactics are needed. For establishing perennial crops, such as alfalfa, an assessment of weed species composition is conducted after harvest of the previous crop (usually in the fall), to determine the appropriate management alternative to be used during establishment. In an established crop, fields are monitored to determine the need for additional tactics to manage perennial and biennial weeds.

Except for seed treatments and foliar applications in small grains, fungicides are inconsistently profitable for managing diseases in field and forage crops. However, fields should be scouted to monitor the presence of crop diseases. By identifying diseases in a field, the farm manager can implement management tactics such as crop rotation, tillage, or selection of resistant cultivars. Disease scouting should be done frequently during the growing season.

Because of their natural mobility and reproductive potential, insects are among the most difficult pests to manage. A field badly infested with an insect pest one year may have very little damage the following year. Conversely, a field that has been free of insects for years suddenly may have severe insect damage. Figures 2.1-1 and 2.1-2 show how alfalfa weevil populations can vary between years and locations.

The unpredictable nature of insect damage has led many farmers to apply insurance insecticide treatments. Although insurance applications may help you sleep better at night, you may be using resources better employed in other farm enterprises. Routine field monitoring can prevent the unnecessary use of funds to manage pests that are economically insignificant and can help direct management efforts to those fields that can benefit.

For insect management, fields should be scouted every seven to ten days to adequately monitor changing pest populations. Longer periods between field monitoring can mean detecting pest damage only after significant losses have occurred. For pests such as true armyworm or black cutworm in corn, significant damage can occur within two to five days if fields are not watched closely.

In corn, monitoring should begin about a week after the crop has been planted. For fields prone to slug damage, monitoring populations in the weeks leading up to planting or even the previous fall can provide insight on the size of pest populations. Insect pests such as the seedcorn maggot, seedcorn beetle, wireworm, and white grub can feed on newly planted seed. Table 2.1-2 lists the key corn insect pests and the plant growth stages during which they can cause crop damage. Monitoring may be reduced after the pest management decision has been made for the corn rootworm, but

Figure 2.1-1. Percentage of alfalfa fields with above-threshold weevil infestation in Maryland, 1983 to 1989, and Pennsylvania, 1986 to 1989.

Figure 2.1-2. Percentage of alfalfa fields with above-threshold weevil infestation across locations in New York in 1988.

midseason pests such as western bean cutworm and brown marmorated stink bugs should not be ignored. In situations where European corn borer is prevalent and non-Bt corn varieties are used, continue monitoring to assess the degree of stalk lodging and ear droppage. This information is useful in assessing the population potential for the next growing season and in determining if another more resistant variety should be planted in the future.

In alfalfa, monitoring should begin when the crop begins to regrow in early spring. Early infestations of alfalfa weevil can be seen in March if conditions are warm. The potential for significant damage by this pest, however, does not occur until late April to mid-May. Monitoring from the beginning of spring growth to late April should involve only a quick visual inspection for signs of feeding. Table 2.1-3 lists the key pests of new seedings and established stands of alfalfa and cuttings where the pests occur. Monitoring can be terminated when potato leafhopper populations begin to decline around the middle of August.

Only a few economically important insect pests of soybean exist in Pennsylvania—namely, slugs and, in some areas, brown marmorated stink bugs. Soybeans are particularly sensitive to slug feeding because, unlike corn, the growing tip is above the ground and vulnerable to feeding; if the growing tip is eaten by slugs, the plant will die. Despite the small number of severe focal pest species, several insect pest species, most of which are leaf feeders (mostly caterpillar and beetle species), can still cause significant damage in a limited number of fields within a season, particularly if a few pest species are active at the same time. Table 2.1-4 lists the key pests of soybean and the stages of plant development when they are important. Monitoring should begin about a week after planting and continue until late podfill. After growth stage R6, few insect pests influence yield.

Scouting for insects in small grains should begin after plant emergence and continue until harvest. In wheat, corn leaf and English grain aphids and Hessian fly can attack young seedlings in the fall and early spring. Armyworm can clip off wheat heads as the grain begins to reach maturity. Table 2.1-5 lists the key insects of small grains in Pennsylvania.

Importance of Complete Monitoring

Monitoring crops for pests should not be a series of independent processes, but part of an overall integrated monitoring plan. For instance, scouts do not walk into an alfalfa field and look only for insect pests. Instead, they are observing insect numbers, diseases, weeds, the general health of the crop, and the stage of crop growth, while assessing potential problems. This information provides a baseline for future evaluations of crop health and helps measure the economic significance of

Table 2.1-2. Key times for corn insect activity.

Attacks the Seed
Seedcorn maggot
Seedcorn beetle
Slugs
Wireworm
White grub

Attacks Seedlings—Germination to Four-Leaf Stage (V4)
Billbugs
Black cutworm
Corn root aphid
Flea beetles
Garden symphylan
Grape colaspis
Seed corn beetle
Seed corn maggot
Slugs
Sod webworm
Stalk borer
True armyworm
White grub
Wireworm

Table 2.1-2. Key times for corn insect activity (continued).

Attacks Fifth Leaf (V5) to Silking (R1)
Black cutworm
Corn rootworm
European corn borer
Fall armyworm
Sod webworm
Stalk borer
True armyworm
Western bean cutworm
White grub
Wireworm

Attacks from Silking (R1) to Beginning of Grain Fill (R2)
Brown marmorated stink bug
Corn leaf aphid
European corn borer
Japanese beetle
Northern corn rootworm
Western bean cutworm
Western corn rootworm

Attacks from Grain Fill to Maturity
Brown marmorated stink bug
European corn borer
Grasshoppers

specific pests in the field. By routinely monitoring a field, the farm manager can note subtle changes in the crop and take corrective action before major problems occur.

The occurrence of multiple pests in a field can influence the potential damage from pests. For instance, a field with a heavy weed infestation will experience greater yield losses if an insect or disease problem also is present. In fact, weedy fields often attract insects because of the high humidity.

Certain weeds also are attractive to insects. Because common chickweed is a preferred host of the black cutworm, fields with heavy chickweed infestations have a significantly higher probability of developing a black cutworm problem. Therefore, fields with heavy chickweed infestations should be monitored closely for black cutworm infestations. Producers can reduce the potential for this pest by eliminating chickweed from fields at least ten days before planting.

Besides the interaction of multiple pests, plant growth stage can also influence pest damage. Because some diseases and insect problems occur only during specific growth stages of the crop, it is important to know what growth stages are susceptible to which pests.

By knowing the pest history of the field and what problems exist in it during a growing season, farm managers can develop a crop production strategy to reduce pest damage. This strategy should be integrated along with other management decisions such as fertility management, tillage method, and conservation management.

Monitoring Methods

Many pest problems can be identified simply by observing them in the field. Weeds and diseases typically fall into this category, as do some insect and mammalian pests. Others, however, require specialized equipment to estimate their numbers. For example, monitoring populations of corn soil insects such as the wireworm, white grub, seedcorn maggot, black cutworm, and rootworm larvae requires a shovel or trowel in addition to a visual damage inspection. These insects all feed below ground level and must be located by digging.

One method for monitoring wireworm populations involves burying corn or other grain in a mesh material. Because carbon dioxide is given off by the seed as it begins to sprout, larvae of the wireworm are attracted to the grain and can be found feeding in the corn contained in the mesh

Table 2.1-3. Key times for alfalfa insect activity.

Attacks New Seedlings
Emergence to First Cutting
Black cutworm
Garden symphylan
Potato leafhopper
Slugs
Variegated cutworm
Second Cutting
Grasshoppers
Pea aphid
Plant bug spp.
Potato leafhopper
Spotted alfalfa aphid
Attacks Established Stands and Fall Seedings
First Cutting
Alfalfa weevil
Second Through Fourth Cuttings
Alfalfa blotch leafminer
Clover leaf weevil
Clover root curculio
Grasshoppers
Pea aphid
Plant bug spp.
Potato leafhopper
Spittlebug
Variegated cutworm

material. This is an effective method of monitoring old sod fields before planting a corn crop. Economic threshold values have been established for this method.

Shelter traps, such as 1-by-1-foot pieces of white rolled roofing or plywood, can be effective monitoring tools for tracking populations of slugs. Prior to planting or even in the previous autumn, scatter ten or so of these traps across fields suspected of slug problems. Remove residue and place the traps right against the soil and return to them weekly.

Fields where four or so slugs per trap per week are found have a strong potential of receiving economically significant damage. This effort can reveal which fields have the highest populations or even when slugs hatch from eggs in spring. In response, growers may be able to plant these particular fields earlier or later to avoid peak slug activity.

Table 2.1-4. Key times for soybean insect activity.

Attacks the Seed
Seedcorn maggot
Attacks from Emergence (VE) to Second Node (V2)
Bean leaf beetle
Green cloverworm
Painted lady
Potato leafhopper
Slugs
Soybean aphid
Thrips
White grub
Wireworm
Attacks from Second Node (V2) to Maturity (R8)
Bean leaf beetle
Brown marmorated stink bug
Cabbage and soybean loopers
Grasshoppers
Green cloverworm
Japanese beetle
Mexican bean beetle
Potato leafhopper
Silver-spotted skipper caterpillar
Soybean aphid
Two-spotted spider mite
Attacks the Pods from Full Seed (R6) to Beginning Maturity (R7)
Bean leaf beetle
Brown marmorated stink bug
Grasshopper

Pheromone traps can be used to monitor the population of black cutworm adults that migrate into Pennsylvania during early spring. A pheromone trap contains the scent of the female moth, and this attracts the male. By calculating and summing 300 degree days from the time eight moths are collected, the period when larva feeding occurs can be calculated. This is useful in determining when to begin scouting fields.

Blacklight traps can be used to monitor the flight periods of some moth species. Important insects that can be monitored this way include European corn borer, true armyworm, fall armyworm, sod webworm, and corn earworm. Egg deposition usually is correlated with moth flight.

Table 2.1-5. Key insects that attack oats, wheat, barley, and rye.

In Spring
Aphid spp.
Cereal leaf beetle
True armyworm
In Early Summer
Grasshoppers
True armyworm
In Late Summer and Fall
Aphid spp.
Fall armyworm
Hessian fly
Slugs

Although light traps are useful monitoring tools, considerable experience is needed to sort out the economically important insects from the hundreds of other insect species collected in the trap.

Evaluating a field for European corn borer infestations requires a sharp knife to split the corn stalk. Larvae of this insect feed within the corn stem. This procedure, however, is used only to determine the magnitude of the infestation. By the time larvae move into the stem, it is too late to implement a management strategy for the present crop. This information, however, is useful in assessing whether a management strategy should be used the following year.

Monitoring for the alfalfa weevil requires a bucket and a pocketknife. When sampling for this pest, randomly select alfalfa stems, cut off the stem, and place the stem in a bucket. Beat the stems against the side of the bucket to dislodge and count alfalfa weevil larvae. This number then can be compared with established economic thresholds.

Evaluating potato leafhopper pressure in a field requires a sweep net, which is similar to a butterfly net but sturdier. Potato leafhopper numbers are determined by sweeping the field, which dislodges the leafhoppers from the alfalfa plant and deposits them in the net. Counting the number of leafhoppers captured, measuring the height of plants, and valuing the hay allow the farm manager to make a management decision. Scouting procedures and economic thresholds for alfalfa pests are discussed in the Penn State Extension publication "A Pest Management Program for Alfalfa in Pennsylvania."

Although numerous methods have been developed to scout crop pests, the best pest management tool is observation. If you take the time to scout fields during critical periods, you can avoid most significant pest damage. Information and organization are keys to successful pest management. In addition to scouting fields, an experienced crop manager or consultant can use field characteristics to help identify fields with a high probability of developing a pest problem. Table 2.1-6 shows field characteristics for corn that increase the likelihood of infestation by a given insect pest. Both weeds and diseases are affected by field conditions. For instance, weeds such as yellow nutsedge prefer moist environments and tend to be a problem in areas that are wet. Nutsedge, in turn, serves as a host for billbug infestations. Many fungal diseases are more common in wet fields. Knowledge of the properties and history of a field can be a very powerful tool in making variety selections and deciding on crop production techniques.

Identifying the Cause of Crop Damage

Identifying crop damage is only the first step in pest management. Once damage is recognized, the reason for the damage must be determined. This is a critical step because an improper diagnosis can be very expensive. For instance, misdiagnosing a boron deficiency as potato leafhopper damage will result in an unnecessary insecticide application plus the final cost of applying boron to the field, along with any lost yield due to the deficiency because it was not corrected at the appropriate time.

The reason for crop damage is not always obvious. Herbicide, disease, and insect damage can look much alike to the untrained observer. Poor plant emergence can be caused by diseases, insects, soil compaction, herbicides, or improper planting depth. Wilting plants can be caused by insects, diseases, or drought stress. In some cases, damage to a crop can occur before any visual symptoms are obvious. This is true, for example, with the potato leafhopper. By the time alfalfa leaves begin to turn yellow, the plant has been stunted and the protein content has been lowered. For this reason, field monitoring by an experienced person is essential for minimizing damage.

For an untrained person, determining the cause of crop injury can be frustrating. Therefore, an untrained person should seek help when faced with such a problem. Expertise can be found at the local Penn State Extension office, private consulting firms, a crop-management association, or a local ag dealer. Sometimes, a neighbor may be helpful in identifying causes of crop damage. Remember, however, the quality of advice can vary greatly.

If you need assistance, the first place to check is your local extension office. If staff cannot help with the problem, they will know where you can obtain assistance.

Table 2.1-6. Field characteristics that increase the likelihood of certain pests in corn.

Pest	Associated Field Conditions
Armyworm (true)	Corn planted into a rye mulch
	Corn planted into small grain
	Corn planted into grass sod
	Corn field edges adjacent to small grain or rye mulch
Billbug	Yellow nutsedge present
Black cutworm	No-till
	Winter annual weeds (particularly common chickweed present within 10 days of planting)
	Nearby alfalfa field (particularly a new seeding)
	River bottom land or fields with wet weedy areas
Corn rootworm larvae	Second year or more of corn
	Green silk corn present when adults were active the previous year
	Soils with high clay content
	Moderate soil moisture conditions from August to June
European corn borer (first generation)	Earliest planted corn fields in the area
	Corn over 24 inches tall when moths are present
	High plant densities and closed rows
European corn borer (second generation)	Latest planted corn fields in the area
	Corn plants silking (green silk) when moths are flying
	High plant densities
Seed corn maggot	Heavy manure applications
	Soils high in organic matter
	Damp and cool soil conditions
	Planting immediately or within one to two weeks into tilled, green vegetation
Slugs	No-till
	Heavy manure applications
	Dense stands of weeds
	Bordered by timber
Stalk borer	Corn planted in old alfalfa field with clumps of orchardgrass present
	Corn bordered by clump grasses like orchardgrass
	Corn planted into a rye mulch
White grub	Corn planted in a field that was in grass sod within the last two years
Wireworm	Corn planted in a field that was in grass sod within the last three years
	Silt-loam soils

Determining the Need for Management

After isolating the cause(s) of crop injury, it is necessary to determine if the amount of injury and potential for further injury warrant a management alternative. Entomologists and economists have developed indicators to help producers decide whether a particular management option is justified based on economic, social, and environmental constraints.

The most common decision rule used in pest management is the economic threshold. The economic threshold (ET) is the number of pests that, if present in the field at a given time, in all probability will increase and cause economic losses. This threshold contrasts with the economic injury level (EIL), which is the number of insects that cause a dollar loss equal to the cost of a management action. By implementing a management strategy when the economic threshold is reached, a farm manager keeps pest populations from

Figure 2.1-3. Relationship between the economic injury level and the economic threshold with changing economic and biological conditions.

reaching the economic injury level. Therefore, losses associated with an insect population above the economic injury level are prevented. The economic threshold provides a buffer period to allow adequate time to implement a management strategy.

The ET and EIL are not static; they vary as economic and biological conditions change. Factors that can influence these indices include weather conditions, plant growth stage, nutritional health of the crop, presence of other pests, market value of the crop, expected yield of the crop, and the cost and effectiveness of the pest management alternative used. Which of these variables to take into account in estimating ET values depends on how much is known about a pest's biology, its interaction with its host, and the economic environment.

Economic thresholds for the potato leafhopper and alfalfa weevil vary with crop height, cost of an insecticide application, and crop value. Corn rootworm ET values are dependent on whether beetles are being monitored for the first year of corn in a rotation or later years. When little information is available about a pest's biology and its interaction with its host, single simple threshold values are used. Because little is known about the influence these pests have on crop yield and quality, ET values are typically conservative toward using an insecticide treatment. Therefore, simple threshold values tend to err toward protecting the crop when the pest would not have caused an economic loss. Conservative thresholds prevent severe crop damage. Most thresholds established for field and forage crop insects are single simple thresholds.

Figure 2.1-3 shows how economic thresholds and economic injury levels can vary as the crop matures. In the case of alfalfa, lower numbers of potato leafhoppers are required to cause economic damage on the second cutting than the third cutting, because a higher percentage of the insect's population is female. The more rapid population growth in the second cutting is a direct result of the offspring produced by these females.

Evaluating, Selecting, and Implementing Pest Management Alternatives

The IPM concept is based on the premise that all crops can tolerate some levels of pests and that an established pest cannot be eradicated completely. Emphasis is on long-term management of pests to maintain their present level or reduce them to a tolerable level. The principles of IPM are much the same as those of past management methods, but the techniques are becoming more refined. For example, more emphasis is being given to how various management methods affect the overall cropping system. Rather than being focused on a single pest on a single crop, IPM is geared toward managing all pests for the total cropping system used on the farm.

When evaluating pest management alternatives, the farm manager first must determine if the alternative is feasible given available resources on the farm. Basically, it must be determined if enough labor and the proper equipment are available to undertake the pest management alternative. The availability of managerial time and labor is probably the two

biggest constraints in adopting certain pest management alternatives.

If you do not have time to devote to the management practice, can you hire such services? If crop consulting services are available in your area, they may provide an economical alternative to handling pest management activities yourself. A related question is whether there is enough flexibility in your cropping system to respond to pests using a particular pest management alternative. If concerns outside of the cropping program predominate—like producing a given type and quantity of feed or forage on limited acreage—then the selection of certain pest management alternatives (for example, crop rotation or alternative enterprises) may be of little or no practical value.

After considering possible resource constraints on your farm, you also must estimate and compare the economic feasibilities of the remaining pest management alternatives. While economic thresholds for many pests have been established for the use of pesticides, many pest management strategies have no straightforward decision rules to assist the producer in making informed, economical pest management decisions.

First, the manager must consider whether the expected benefits of a given pest management alternative exceed its expected costs over time. If several alternatives have expected benefits that exceed expected costs, isolate those that best fit into your operation. Give consideration to the highest level of cost that will be acceptable in implementing this particular pest management practice. If more than one falls into this category, select the one with the greatest expected return. The expected benefit of a pest management alternative is the value of damage averted (in terms of both quantity and quality). Costs of a pest management alternative include the value of any special equipment (amortized over the life of the asset), labor, machinery inputs, materials, managerial time, or services required for the alternative.

Most pest management techniques adaptable to IPM have been known for years, but some newer tactics, like incorporating cover crops into crop rotations, are still being studied to more fully understand their influence on pest and natural enemy populations and logistical constraints. Many were practiced before chemical pesticides came into prominent use. Basic management methods are similar for all crop pests. The five basic types of pest management strategies for agronomic crops include physical, cultural, genetic, biological, and chemical techniques.

Physical management techniques are direct or indirect measures that eliminate the pest or slow down the growth rate of the pest population. Examples: installing window screens to exclude pests from buildings, hand-picking hornworms off tomato plants, and cleaning crop seed to remove weed seed. An example of temperature as a physical management technique can be demonstrated with the corn flea beetle. If the sum of the average temperatures for the months of December, January, and February is below 90°F, beetle numbers will be reduced. Farmers can use temperature to help predict the abundance of certain pests.

Cultural management practices are used to provide less favorable conditions for pest development. For example, planting wheat after the fly-free date can greatly reduce damage from Hessian fly. Conventional tillage, which buries plant debris, destroys much disease inoculum and overwintering sites for stalk borers, armyworms, and slugs. Narrow row widths and optimum plant populations help agronomic crops compete with emerging weeds. Early harvest may help reduce losses from stalk rot in corn.

Although cultural management has the advantage of being part of routine crop production practices, it often does not adequately manage moderate to high pest levels.

Genetic management uses tolerance or resistance of plant varieties to certain pests. Varietal resistance is a preferred method for managing certain pests because it usually provides relatively long-term control at low cost. Examples include wheat varieties resistant to Hessian fly, alfalfa varieties resistant to anthracnose and potato leafhopper, and many corn varieties tolerant of or resistant to numerous leaf diseases and European corn borer and corn rootworms. Also, some crop varieties may be more tolerant of pests because they may outgrow pest damage.

Unfortunately, many pests have the ability to develop strains or races capable of overcoming varietal resistance. Therefore, a crop variety with good resistance to a certain pest may be effective only for a few years.

Biological management involves the use of other living organisms to manage pests. Some of these organisms are native to the area, while others are introduced. For example, parasitic wasps were released throughout the state from 1976 through 1978 to help manage the cereal leaf beetle. Several introduced parasites and a native fungal disease are helping to keep the alfalfa weevil in check. A native and naturally occurring fungal disease helps minimize the damage of pea aphids on alfalfa. Biological methods are usually relatively safe, economical, and long-term pest management tactics that need to be fostered and valued over time. No-till and cover crops, for example, when combined with IPM and implemented for a few years, can support substantial populations of natural enemies that can significantly contribute to pest control. Not surprisingly, insecticide and fungicide applications can disrupt populations of these organisms and the control they provide unless treatments purposefully avoid sensitive or active life stages (this approach takes detailed knowledge of local populations and their life cycles).

Chemical management involves the application of pesticides. The major advantage of this method is that it can be applied quickly to a given site according to need. It is about the only method a farmer can manipulate and rely on for

immediate results. Chemical pesticides, however, have some well-known disadvantages: they may be toxic to humans and other animals; many are harmful to beneficial insects, such as pollinators and predators; they usually reduce pest populations only temporarily; resistant strains of pests frequently develop; and some persist in the environment, further endangering many types of organisms. Even with these disadvantages, chemical management can be an important component of IPM, and pesticides are valuable tools in producing agronomic crops.

Assessing the Success of a Management Alternative

Once a management alternative has been implemented, it is a sound practice to evaluate its performance. If possible, leave one area untreated and examine it to determine crop yield in the absence of the activity. Without this area, there is no way of knowing, for some insects, if an action was economically beneficial. For instance, if no insects were present in a field and a management strategy was implemented based on an improper assessment of the problem, then the absence of an untreated area would make it appear that the management action was successful.

Although it is usually easier to select a field margin for the untreated area, this is a questionable practice because many insects tend to aggregate along field margins. Damage along the margin is much greater than it is deeper in the field. The best technique for assessing the benefits of a management strategy is to randomly select two or three small areas in the field to leave untreated. For pesticides in row crops, simply turn off the applicators on part of the rows to leave untreated areas.

The only situation where leaving untreated areas in a field is not a good way to measure the effectiveness of a management strategy is in fields infested with potato leafhopper. Potato leafhopper adults will migrate from treated areas into untreated areas, resulting in increased damage and causing insecticide application benefits to be overestimated.

By evaluating the success of each possible management strategy, you can determine the most effective approach to managing a pest or combination of pests. Evaluation also can help determine which management strategies are most effective under various conditions.

Keeping Records

Record keeping is an important component of any pest management program. Keeping records of pest occurrence and intensity, management activities, weather conditions, and effectiveness of management strategies within each field can provide valuable insights for future pest management. When no records are kept it can be difficult to remember from season to season what activities took place in a given field. This can be costly, for example, if a herbicide with carryover potential was applied to a field that then was planted to a sensitive crop the following year. Some insect species are attracted to certain weed types. By knowing the history of insect activity on a farm and which weeds are prevalent in a given field, the probabilities of damage for upcoming years can be assessed, and activities to prevent crop injury can be implemented.

An example of this type of record would be "moisture conditions and crop growth stage relative to other fields on the farm when corn rootworm beetles were active." Using this information, a farm manager can determine which corn fields most likely will need an insecticide treatment or rotation to another crop the next year.

Record keeping also is necessary to meet pesticide regulations. These require a farmer to keep information on pesticides applied to a field, when the pesticides were applied, and at what rate. Future regulations may require additional information about field activities.

To ensure the consistency of the records in a farm operation, one person should take responsibility for record keeping. When keeping good records is difficult because of time limitations, hiring a crop consultant may be advisable. In Pennsylvania, several organizations provide record-keeping services. A number of private consultants, crop management associations, farmer organizations, and ag chem dealers provide record-keeping services. Contact your county extension agent for information on such services in your area.

Good records serve many purposes; when interpreted properly they can provide insights into crop production problems, potential pest problems and their solutions, and crop fertility trends. They can serve as a measure of management improvement on the farm and as an indicator of business health. They may help in seeking operating loans and in meeting regulatory requirements. They also can help minimize the costs associated with income tax preparation.

Weed Management

Weeds and Their Impacts

There are numerous definitions of a weed. The following are some common definitions:

- A plant that is out of place and not intentionally sown
- A plant that grows where it is not wanted or welcomed
- A plant whose virtues have not yet been discovered
- A plant that is competitive, persistent, pernicious, and interferes negatively with human activity
- An invasive plant capable of causing disturbance to an ecosystem by displacing the natural flora

Weeds are plants capable of providing ecosystem services such as reducing soil erosion, sequestering carbon dioxide

from the atmosphere, and serving as habitat for beneficial organisms. However, in cropping systems, weeds are typically considered pests when their undesirable qualities often outweigh their benefits.

Classification of Weeds

Weeds are given a scientific name to identify them anywhere in the world. Keep in mind that the scientific name (i.e., genus and species) of a weed is universal, whereas its common name may differ from region to region. For example, velvetleaf is also known as buttonweed or butter print; common lambsquarters can be referred to as pigweed, goosefoot, fat-hen, or bacon-weed; and wild carrot is known as Queen Anne's lace.

In general, weeds are classified based on the number of cotyledons in their seed (e.g., dicots [broadleaves] and monocots [grasses and sedges]), life cycle, habitat, or physiology. The classification system according to their life cycle (how long they live) is also used commonly to help with management decisions. The three major life cycle groups are annuals, biennials, and perennials.

Annuals

Annuals are generally divided further into summer annuals and winter annuals. Summer annuals germinate in the spring, mature, produce seed, and die in one growing season. Large crabgrass, giant foxtail, smooth pigweed, common lambsquarters, common ragweed, velvetleaf, hairy galinsoga, and common purslane are examples of troublesome summer annuals.

Winter annual weeds germinate in late summer or fall, mature, produce seed, and then die the following spring or summer. Examples of winter annuals include common chickweed, henbit, shepherdspurse, downy brome, and annual bluegrass.

Biennials

Biennial weeds grow from seed at any time during the growing season. They normally produce a rosette of leaves close to the soil surface the first year, and then flower, mature, and die during the second year. A true biennial never produces flowers or seeds the first year. There are relatively few biennial weeds. Some examples include wild carrot, common burdock, bull and musk thistle, and poison hemlock.

Perennials

Perennial weeds have an indeterminate life cycle. They can be categorized into two groups, namely simple and creeping perennials. Simple perennials form a deep taproot and spread primarily by seed dispersal. Some examples of simple perennials include dandelion, broadleaf plantain, curly/broadleaf dock, autumn olive, and common pokeweed. Creeping perennials may be either herbaceous or woody, and can spread by both vegetative structures as well as seed. Some common herbaceous perennials include Canada thistle, common milkweed, hemp dogbane, creeping buttercup, slender speedwell, ground ivy, quackgrass, and yellow nutsedge. Some examples of woody perennials include poison ivy, multiflora rose, Japanese knotweed/bamboo, brambles, wild grape, and Virginia creeper. Creeping perennials become established by seed or by vegetative parts. Since perennial weeds live indefinitely, their persistence and spread are not as dependent on seed as the other two weed groups.

Weed Management Techniques

Over the past decade or so, there have been a number of rapid changes in weed management techniques and strategies. New directions in weed management include altering crop management practices, continuously rotating weed control approaches, considering environmental attributes, and using computer software and electronic information technology for decision making, record keeping, and data managing. Environmental concerns have resulted in cropping systems that utilize more no-till, cover crops, and organic crop production practices. Advancements in technology have allowed the use of lower-use-rate herbicides with reduced risks, genetically modified crops, GPS to enable precise and targeted herbicide applications, and machine learning with predictive models for weed and crop development. Despite these advances, chemical and mechanical methods are still widely used to control weeds in many settings. Knowledgeable professionals will continue to play an important role in diagnosing problems, interpreting information and results, and providing practical weed management recommendations.

Weed management is most effective and sustainable when an integrated approach using a variety of methods (cultural, mechanical, biological, and chemical) is followed. Relying on any single tactic can lead to severe problems, such as high costs and crop failure. In planning a weed management strategy, keep in mind the available equipment and time, land characteristics, weed spectrum, and yield objective. Management inputs such as herbicides may be reduced, but alternative approaches must be substituted if the production level is to be maintained.

Integrated Weed Management

Corn and soybean fields that are weed free for the first four to six weeks after planting (or until canopy closure) will often yield the same as fields that are weed free for the entire growing season. Occasionally, a late infestation of weeds such as burcucumber or common ragweed can interfere with crop harvest and build up the weed seed bank in soil. Weed control until canopy closure usually relies on soil-applied residual herbicides and the timely application of postemergence

herbicides. Also, it is not necessary to control all weeds in a field to achieve maximum yield. Usually, weed populations of 10 to 20 weeds per 10 square yards can cause severe yield loss. The impact of weed populations between 1 and 10 plants per 10 square yard is difficult to predict and would depend on the growth habit and competitive nature of the weed species. The decision to treat the field depends on the weed species present, crop vigor, weather conditions, and herbicide cost.

For more information, consult the publication *A Practical Guide for Integrated Weed Management in Mid-Atlantic Grain Crops* at https://growiwm.org/wp-content/uploads/2019/10/IWMguide.pdf?x71059.

Prevention

Preventive methods are intended to reduce the spread of weeds. It is usually easier to prevent the introduction of weeds than it is to control them after establishment. Examples of preventive practices include cleaning tillage and harvesting or mowing equipment of weed seeds and vegetative structures; planting certified, weed-free crop seed or sod; and controlling weeds in barnyards, around structures, and along fencerows, roadways, and ditch banks. Scouting areas to assess weed populations and controlling them before they spread is another means to prevent additional weed problems.

Early Season Weed Scouting

The first step to weed management is proper weed identification. The best method for timely identification is through field scouting. Initial reports on weed conditions in a field are recommended within two weeks after crop emergence to evaluate herbicide performance and determine if there is a need for rotary hoeing, cultivation, or postemergence herbicides. Earlier scouting will be needed in no-till fields where a burndown or early-preplant herbicide may have been applied. Identify and record all weed species found. Determine the severity of the infestation by counting the number of weeds found per 10 feet of row for large infestations or per 100 feet of row for smaller infestations in all areas sampled. Sample areas should represent no more than 5 acres, so sample enough areas to get an accurate count of the different weeds present in the field or on the farm. The approximate height and growth stage of both weeds and crop should be recorded. Along with weed reports, early soil moisture observations are important. They serve as indicators of herbicide effectiveness. Adequate moisture is necessary to activate soil-applied herbicides. Dry conditions may reduce mobilization of the herbicide, whereas too much rain can cause soluble herbicides to move downward below the zone where they are most effective; both conditions can result in inconsistent weed control.

In order to determine appropriate control methods or to choose herbicides, the manager needs to be able to identify weed seedlings and their life cycle when they are small. However, certain soil-applied herbicides allow weeds to germinate but arrest further growth and development; therefore, it would be prudent to determine if weeds are actively growing prior to subsequent herbicide applications. To control annual weeds, postemergence herbicides are most effective when applied to young and actively growing weeds. Later herbicide application timings are recommended to control perennial weeds that have emerged from perennating organs such as rhizomes. However, do not wait too long and let them compete successfully with the crop. Choose an appropriate systemic herbicide and an optimal application timing to allow adequate foliar uptake and translocation to underground parts while minimizing weed competition. Certain annual weeds, such as burcucumber, may germinate later on during the growing season and can interfere with harvest; therefore, continued monitoring after canopy closure may be required in such situations. The degree of control with herbicides will vary due to differences in weed species, growth stages, weather conditions, and herbicide application method.

Cultural Techniques

Cultural crop management techniques provide a healthy crop to best compete with weeds. Examples of cultural techniques include following soil test recommendations for fertilizer and lime; selecting the best varieties for the environmental conditions, planting optimal populations at the proper timing, proper mowing practices if applicable, scouting for pests and controlling them when necessary, and including crop rotations and cover crops in the system. Composting, ensiling, or feeding weeds or weed-infested crops to livestock can destroy the viability of certain weed seeds. The heat and/or digestive acids break down the majority of weed seeds. However, some seeds pass through livestock or the composting process unharmed and can germinate if spread back onto the land.

Cover Crops

Competition from a desirable vegetative cover can be an inexpensive and effective aid to weed management. Cover crops provide important benefits, such as soil and water conservation, and nutrient retention. Cover crops may help manage winter annuals such as horseweed in corn and soybean fields.

The following management factors should be considered to enhance weed suppression with your cover crops:

- Species selection: Choose cover crops based on your objectives. If weed suppression is an objective, select an aggressive species that will cover the ground quickly. If you desire a cover crop that will protect the soil through the fall and winter and suppress winter annual weeds, plant a winter cereal in late summer or early fall.
- Establishment date: Establishing a hardy winter cover, such as cereal rye, as early in the fall as possible will result in greater cover crop biomass over the winter

and rapid growth during the spring. Other establishment dates may be preferable for different cover crops depending on the species and your objectives.

- Planting considerations: The seeding rate and arrangement of the cover crop can influence weed suppression. Planting at higher-than-normal seeding rates and in narrow rows can influence the amount of soil cover, particularly in the first several weeks after seeding. Thick, dense cover crop stands can help reduce the establishment of weeds. Planting with a drill increases seed-to-soil contact and is more reliable for getting a good cover crop stand than broadcast seeding.
- Soil fertility: It is important to provide adequate soil fertility to cover crops to ensure they are competitive and successful. This is particularly true for small grains like cereal rye and wheat and forage radish, which require adequate nitrogen. Lime may be necessary to maintain or raise the soil pH for legumes like hairy vetch and red clover. Regular soil tests will help you determine how best to manage your cover crops so as to maximize their beneficial effects on weed suppression and soil quality.
- Termination timing: Allowing a cover crop to grow as long as possible before controlling it reduces weed populations through competition for light, nutrients, and moisture. In no-till, letting the cover crop achieve maximum dry matter production (often at flowering or beyond) will generally increase weed suppression. Keep in mind, however, that high-biomass cover crops can be more challenging to manage, may need shorter-season cash crops to allow for adequate cover crop growth, and may require specialized planting equipment or may increase the potential for some insect pest problems. Cover crops can be terminated mechanically or with herbicides. Each method has advantages and disadvantages. Mowing can be effective for some annual cover crops, but the mulch may degrade quite rapidly because it has been chopped. Plowing can be an effective physical control for cover crops, but the benefit of the weed-suppressive mulch in the subsequent cash crop is lost. The roller-crimper offers effective physical control of some annual cover crops, but without any accompanying herbicides, control is delayed until the winter annual cover crops are flowering and can be inconsistent. Rolling creates a longer-lived mulch layer than mowing. Herbicides can effectively control most cover crops, but product selection and application timing are important.
- We recommend online Decision Support Tools (DSTs) developed by the Northeast Cover Crop Council (https://northeastcovercrops.com/decision-tool/) for exploring various cover crop species and mixtures and best management practices for their use in field crop production systems.

Mechanical Techniques

Mechanical or physical techniques either destroy weeds or make the environment less favorable for seed germination and weed survival. These techniques include hand-pulling, hoeing, mowing, plowing, disking, cultivating, and digging. If adequate weed control is obtained from other methods such as herbicides, tillage or cultivation may not be necessary, which in turn may avoid soil crusting and soil erosion that can occur when soils are routinely tilled. Mowing removes the seed heads of most weeds and reduces the amount of spread of seed in an area. Mowing is used primarily for weed control in meadows, pastures, waste areas, and along roadsides. Digging or pulling is an effective method of controlling a limited number of weeds.

Biological Techniques

Biological weed control involves the use of other living organisms, such as insects, diseases, or livestock, for the management of certain weeds. In theory, biological control is well suited for an integrated weed management program. However, the limitations of biological control are that it is a long-term undertaking, its effects are neither immediate nor always adequate, only certain weeds are potential candidates, and the rate of failure for past biological control efforts has been fairly high. There have been a few success stories of weed species (e.g., St. Johnswort, prickly pear, multiflora rose, purple loosestrife, thistles) being managed or affected by insect or disease biocontrol agents. Herbivores such as sheep and goats can provide successful control of some common pasture weeds. Finally, conservation biological control may improve our ability to manage weeds and use less herbicide. This involves enhancing populations of natural enemies by manipulating field habitats to create more favorable environments for predator insects and rodents. Ground beetles, crickets, ants, and mice are some of the more common weed seed predators. In general, providing cover in the form of living or dead crops, causing less soil disturbance, and avoiding the use of toxic pesticides can encourage these biocontrol agents. Research continues in this area of weed management.

Chemical Techniques

Chemicals used for the control of weeds are called herbicides. Herbicides can be defined as crop (or desirable plant) protecting chemicals used to kill weedy plants or interrupt normal plant growth. Herbicides provide a convenient, economical, and effective way to help manage weeds. They allow fields to be planted with less tillage, allow earlier planting dates, and provide additional time to perform the other tasks that farm or personal life requires. Due to reduced tillage, soil erosion has been reduced from about 3.5 billion tons in 1938 to one billion tons in 1997, thus reducing soil from entering waterways and decreasing the quality of the nation's surface water.

Without herbicide use, no-till agriculture becomes impossible. However, herbicide use also carries risks that include environmental, ecological, and human health effects. It is important to understand both the benefits and disadvantages associated with chemical weed control before selecting the appropriate control.

Herbicides may not be a necessity on some farms or landscape settings, but without the use of chemical weed control, mechanical and cultural control methods become that much more important. There are many kinds of herbicides from which to choose. Many factors determine when, where, and how a particular herbicide can be used most effectively. Understanding some of these factors enables you to use herbicides to their maximum advantage.

No-Till Weed Management

Successful production of no-till crops requires control of existing vegetation at planting (cover crops and weeds) and broadleaf and grass weeds that emerge after planting. A diversity of herbicides and cover crop and residue situations makes it impossible to utilize a single program to efficiently control weeds and grasses in all situations. Herbicide selection based on weed identification histories of each field is necessary to achieve maximum yield potential. Fields with heavy crop residues may require the maximum labeled rate of residual herbicides for acceptable performance. Encapsulated formulations, when available, may be less readily absorbed by heavy crop residues and may perform more consistently.

Cultivation and mechanical weed control are very difficult or impossible and generally not considered an option in most no-till production systems. However, some companies manufacture high-residue cultivators that are designed for use in no-till/reduced-till systems. We have had a number of trials examining their effectiveness and generally two passes will provide about a 50 percent reduction in weed dry matter. Combining these tools with herbicides can provide a more integrated approach to weed management.

Existing vegetation is traditionally controlled by the nonselective herbicides, which are often tank-mixed with residual herbicides. Burndown herbicide options include paraquat or glyphosate and perhaps a growth regulator herbicide (Group 4) such as 2,4-D. No-till crop production tends to favor perennial weed populations because their root systems are not disrupted by tillage. No-till also favors small-seeded grasses and broadleaf weeds such as lambsquarters and pigweed rather than large-seeded weeds such as velvetleaf.

Escalating herbicide costs and interest in keeping herbicide use to a minimum encourage many people to consider the use of postemergence herbicide programs. Experience leads us to suggest that existing vegetation should always be controlled prior to planting. In the Mid-Atlantic region, soil moisture is often the factor most limiting yield. The decision to apply burndown herbicides early preplant, at planting, or as a delayed preemergence (spike) treatment to control existing emerged vegetation should always be made with consideration to the impact of the existing vegetation on the availability of soil moisture. Preemergence or postemergence herbicides that can provide residual weed control can then be selected that will control weeds that emerge after planting.

Herbicides

Some Considerations When Using Herbicides

The perfect herbicide does not exist. No single herbicide is capable of controlling all weeds that can develop in a crop or planting. Since every herbicide has advantages and disadvantages, selecting the correct herbicide(s) is crucial. Consider these points before you choose or apply any herbicide:

- Is it registered for use on the crop or area you want to treat? If it is, the directions for use and rate of application will appear on the label. Recommended rates for soil-applied herbicides may vary according to the soil texture and the amount of organic matter in the soil. Labels usually give a range of rates because soil types differ in the amount of herbicide that binds to soil particles. The application for postemergence treatments varies with weed size and climatic conditions. Weeds that are growing under dry conditions or during prolonged cool weather will not actively translocate a systemic herbicide. A higher herbicide rate may be needed than the rate used on weeds that are actively growing.
- Will it control the weeds that are causing the biggest problem, and does it take into account methods for managing herbicide resistance? Many weed control measures fail because the chosen herbicide will not control the weeds that are present.
- Can it be used effectively at the current stage of crop or weed growth? Very few herbicides can be applied at any stage during the growth cycle of a plant. Pendimethalin and metolachlor are good examples of how growth stage affects herbicide performance. They are excellent herbicides for annual grasses when applied before the grass weeds emerge. However, they are useless if applied after the weeds have emerged.
- Can the herbicide be used effectively and safely under the current conditions? Soil-applied herbicides must move into the soil to be taken up by roots and shoots of weed seedlings and perennial plant parts. Rainfall is usually adequate to provide soil incorporation of soil-applied herbicides, but in the absence of rainfall, weed control may be poor. The effectiveness of soil-applied herbicides can be reduced if the chemical is intercepted by debris from a previous crop, a prior application of livestock manure, thatch, or other barrier. Reduced-tillage cropping systems may require higher application

rates of soil-applied herbicides than are required by conventional systems, depending on the amount of crop residue. Vegetation remaining on the soil surface binds some of the herbicide and prevents even distribution of the herbicide. Herbicides can also be lost to runoff, leaching, or volatilization.

- Will the herbicide(s) interact negatively with other pesticides, fertilizers, or other inputs being used on the crop or area? Because of such interactions, injury or death to desirable plants may occur.
- Is the herbicide being applied to a "normal" or a genetically modified crop? Since genetically modified crops look similar to normal crops once growing, misapplication can occur and the crop can be unintentionally killed or severely injured. Make sure to record the type of crop that was planted in each field.
- Will carryover of the herbicide result in a residue that might affect the crop or cover crop you want to plant next in rotation? Herbicide carryover is a problem with chemicals that persist in sufficient quantity to injure succeeding plantings. Some examples of herbicides prone to carryover include the triazines (atrazine and simazine), dinitroanilines (Treflan, Curbit, Barricade, Prowl), ALS inhibitors (Classic, Cimarron, Steadfast, Outrider, Spirit, Pursuit, Python), and pigment inhibitors (Command, Balance, Callisto, Impact). These herbicides can provide season-long control of certain weeds. However, if an excessive rate was applied, the soil pH was above 7.0, or the weather during the growing season was cool and dry, natural breakdown of the chemicals may not occur and carryover may result. Read labels carefully for warnings about carryover and rotation. See Table 2.1-11 for rotation restrictions.
- What is the appropriate method of application (i.e., broadcast, band, directed, spot)? Is it convenient to use such as ready-to-use (RTU) products or does it require special equipment or need to be mixed with water before application? Are there other characteristics, such as compatibility with other herbicides when tank-mixing or staining, that make it difficult to use?
- Does the herbicide label recommend that a surfactant, crop oil, or other additive be used to improve leaf coverage or herbicide performance? Many postemergence herbicides require the use of an adjuvant in the mixture (see the herbicide spray additives section later in this chapter).
- Can this product be used safely on the intended planting? What is required to handle, mix, and apply it safely during and after use? Is it a restricted-use pesticide (RUP)?
- Can the herbicide injure nontarget plants in adjacent areas? Exercise caution to avoid drift, runoff, leaching to groundwater, and cross-contamination of other materials. Be especially alert to the potential for residues left in sprayers when spraying a different crop. This is discussed in more detail in a later chapter.

Classification of Chemical Weed Control

Herbicides can be classified several ways, including by weed control spectrum, labeled crop usage, chemical families, mode of action, application timing/method, and others. For this publication, herbicides will be grouped according to mode and site of action, which are also important in understanding herbicide resistance in weeds.

Timing of Application: Preemergence or Postemergence

Preemergence or soil-applied herbicides control weeds at the seed germination stage, or as they are emerging from the soil. Postemergence or foliar herbicides control emerged weeds. Combinations of preemergence and postemergence herbicides may be necessary to control the various types of weeds in an area.

Contact or Translocated

Contact herbicides kill or injure only the part of the plant with which the spray droplets come into contact, so adequate spray coverage is very important. Annual weeds may be killed, but regrowth of perennial weeds from belowground parts usually occurs following application of a contact herbicide. (On a side note, sometimes the term "contact" is used to describe an herbicide that is applied postemergence or sprayed directly on the weed and thus "contacts" the foliage of the plant. When used in this context, it may have a different meaning and the herbicide could have systemic activity throughout the plant, depending on the product.) Translocated (or systemic) herbicides are absorbed by the leaves or roots of the plants and move within the plant. They are needed to kill underground parts of perennial weeds.

Selective or Nonselective

Nonselective herbicides kill or injure almost all plants, while selective herbicides kill some plants but do little or no damage to others. Were it not for the fact that most herbicides can be applied just before crop planting or emergence, and even over-the-top after crop emergence, without excessive injury, herbicides would be of little value. Most of the herbicides labeled for use today will selectively remove most of the weeds without injuring the crop or planting. Selectivity is accomplished primarily by two methods: selectivity by placement and true selectivity. Selectivity by placement is accomplished by avoiding or minimizing contact between the herbicide and the desired crop. An example is wiping or directing an herbicide, such as glyphosate, on a weed without exposing the desired plant. Selectivity by this means is as good as any, as long as the excess herbicide is not washed off the weeds

and leached into the root zone where it might be absorbed by the root. Selectivity by placement also is accomplished when an herbicide that does not readily leach is applied to the soil surface for control of shallow-rooted weeds but does not leach into the root zone of a more deeply rooted crop such as fruit trees or established alfalfa. Selectivity that is true tolerance as a result of some morphological, physiological, or biochemical means is referred to as true selectivity. The herbicide can be applied to the foliage of the crop or to the soil in which the crop is growing without danger of injury. Although true tolerance may be the best type of selectivity, it is not perfect. Such things as crop growth stage, cuticle thickness, hairiness of the leaf surface, location of the growing point, air temperature and humidity, spray droplet size, and the surface tension of spray droplets all can influence herbicide activity. When conditions are ideal for herbicide activity, even true selectivity may not adequately prevent some crop injury.

Fumigants

Fumigants may kill all living things in the soil, including weeds, weed seeds, insects, and disease organisms.

Herbicide Mode and Site of Action

To be effective, herbicides must (1) adequately contact plants, (2) be absorbed by plants, (3) move within the plants to the site of action without being deactivated, and (4) reach toxic levels at the site of action. The term "mode of action" refers to the sequence of events from absorption into plants to plant death, or in other words, how an herbicide works to injure or kill the plant. The specific site the herbicide affects is referred to as the site or mechanism of action. Understanding herbicide mode of action is helpful in knowing what groups of weeds are killed, specifying application techniques, diagnosing herbicide injury problems, and preventing herbicide-resistant weeds.

A common method of grouping herbicides is by their mode of action. Although a large number of herbicides are available in the marketplace, several have similar chemical properties and herbicidal activity. Herbicides with a common chemistry are grouped into families. Also, two or more families may have the same mode of action and can thus be grouped into classes. Table 2.1-7 lists several groups of herbicides and information related to their mode of action.

The following section provides a brief overview of herbicide functions in the plant and associated injury symptoms for each of the herbicide classes found in Table 2.1-7.

Plant Growth Regulators (PGRs)—Groups 4 and 19

Also called auxins, synthetic auxins, and hormones, these herbicides are effective on annual and perennial broadleaf plants and usually have no activity on grasses or sedges, except at high application rates. They produce responses similar to those of natural growth-regulating substances called auxins. Application of artificial auxins, such as 2,4-D, upsets normal growth as follows:

- Cells of leaf veins rapidly divide and elongate, while cells between veins cease to divide. This results in long, narrow, straplike young leaves.
- Water content increases, making treated plants brittle and easily broken.
- Cell division and respiration rates increase, and photosynthesis decreases. Food supply of treated plants is nearly exhausted at their death.
- Roots of treated plants lose their ability to take up soil nutrients, and stem tissues fail to move food effectively through the plant.

The killing action of growth-regulating chemicals is not caused by any single factor but results from the effects of multiple disturbances in the treated plant.

Injury symptoms: Broadleaf plant leaves become crinkled, puckered, strap shaped, stunted, and malformed; leaf veins appear parallel rather than netted; and stems become crooked, twisted, and brittle, with shortened internodes. If injury occurs in grasses (e.g., corn), new leaves do not unfurl but remain tightly rolled in an onionlike fashion, and stems become brittle, curved, or crooked, with short internodes. A lesser effect in corn is the fusion of brace roots, noticed later in the season.

Amino Acid Biosynthesis Inhibitors—Groups 2 and 9

These herbicides are effective mostly on annual broadleaves, while a few in this large group have activity on grasses, nutsedge, and/or perennial plants. (Glyphosate [Roundup], for example, is a broad-spectrum herbicide and has activity on all types of plants; see Table 2.1-8.) These herbicides work by interfering with one or more key enzymes that catalyze the production of specific amino acids in the plant. When a key amino acid is not produced, the plant's metabolic processes begin to shut down. Different herbicides affect different enzymes that catalyze the production of various amino acids, but the result is generally the same—the shutdown of metabolic activity with eventual death of the plant.

Injury symptoms: Plants that are sensitive to these herbicides stop growth almost immediately after foliar treatment; seedlings die in two to four days, established perennials in two to four weeks. Plants become straw colored several days or weeks after treatment, gradually turn brown, and die.

Fatty Acid (Lipid) Biosynthesis Inhibitors—Group 1

These herbicides are rapidly absorbed by grasses and translocated to the growing points, where they inhibit meristematic activity, stopping growth almost immediately. They have no activity on broadleaf plants and are most effective on warm-season grasses such as Johnsongrass, shattercane, corn,

Table 2.1-7. Important herbicide groups for corn, soybean, small grains, commercial vegetables, and forages.

Herbicide Class/Mode of Action					
WSSA Group*	**Site of Action**	**No. Resistant in U.S.**	**Family**	**Common Name**	**Trade Name**
	Lipid Synthesis Inhibitors				
1	ACCase inhibitors (acetyl coa carboxylase)	15	Aryloxyphenoxy-propionate (fops)	fenoxaprop	Puma, Tacoma
				fluazifop	Fusilade
				quizalofop	Assure II, Targa
			Cyclohexanedione (dims)	clethodim	Select Max
				sethoxydim	Poast
			Phenylpyrazolin	pinoxaden	Axial XL
	Amino Acid Synthesis Inhibitors				
2	ALS inhibitors (acetolactate synthase)	52	Imidazolinone	imaxamox	Beyond, Raptor
				imazapic	Plateau
				imazapyr	Arsenal
				imazethapyr	Pursuit
				pyrithiobac	Staple
			Pyrimidinylthio-benzoic acid	flucarbazone	Everest
			Sulfonylaminocarb-onyltriazolinone	propoxycarbazone	Olympus
				thiencarbazone	Component of Capreno, Corvus
			Sulfonylurea	chlorimuron	Classic
				chlorsulfuron	Glean
				foramsulfuron	Option
				halosulfuron	Permit, Sandea
				imazosulfuron	League
				iodosulfuron	Autumn
				mesosulfuron	Osprey
				metsulfuron	Cimarron, others
				nicosulfuron	Accent Q
				prosulfuron	Peak
				rimsulfuron	Matrix, Resolve
				sulfosulfuron	Outrider
				thifensulfuron	Harmony
				tribenuron	Express
				triflusulfuron	Upbeet
			Triazolopyrimidine	cloransulam	FirstRate
				flumetsulam	Python
				pyroxsulam	PowerFlex
9	EPSP synthase inhibitor (5-enolpyru-vyl-shikimate-3-phosphate)	17	Organophosphorus	glyphosate	Roundup, Touch-down, others

Table 2.1-7. Important herbicide groups for corn, soybean, small grains, commercial vegetables, and forages (continued).

Herbicide Class/Mode of Action					
WSSA Group*	Site of Action	No. Resistant in U.S.	Family	Common Name	Trade Name
	Growth Regulators				
4	T1R1 auxin receptors (synthetic auxins)	10	Arylpicolinate	halauxifen-methyl	Elevore
			Benzoic acid	dicamba	Clarity
			Carboxylic acid	aminopyralid	Milestone
				clopyralid	Stinger
				fluroxypyr	Starane, Vista
				picloram	Tordon
				quinclorac	Facet
				triclopyr	Garlon, Remedy
			Phenoxy	2,4-d	Various
				2,4-db	Butyrac, various
				mcpa	Various
19	Auxin transport inhibitor	0	Semicarbazone	diflufenzopyr	Component of Status
	Photosynthesis Inhibitors				
5	Photosystem II inhibitors (mobile) different binding than 6 and 7	26	Phenylcarbamate	phenmedipham	Spin-Aid
			Triazine	atrazine	Atrazine
				prometon	Pramitol
				simazine	Princep
			Triazinone	hexazinone	Velpar
				metribuzin	Glory, Metribuzin, TriCor
			Uracil	terbacil	Sinbar
6	Photosystem II inhibitors (nonmobile) different binding than 5 and 7	1	Benzothiadiazole	bentazon	Basagran
			Nitrile	bromoxynil	Maestro
7	Photosystem II inhibitors (mobile) different binding than 5 and 6	11	Urea	diuron	Direx, Karmex
				linuron	Linex, Lorox
				tebuthiuron	Spike
	Nitrogen Metabolism Inhibitor				
10	Glutamine synthetase inhibitor	1	Amino acid derivative	glufosinate	Finale, Liberty, Rely
	Pigment Inhibitors				
12	Phytoene desaturase biosynthesis inhibitor	1	Pyridazinone	norflurazon	Solicam
13	DOXP synthase inhibitor (1-de-oxy-D-xyulose 5-phosphate)	1	Isoxazolidinone	clomazone	Command
27	HPPD inhibitors (4-hydroxy-phenyl-pyruvate-dioxygenase)	2	Isoxazole	isoxaflutole	Balance Flexx
			Pyrazole	pyrasulfotole	Component of Huskie
			Pyrazolone	tolpyralate	Shieldex
				topramezone	Armezon, Impact
			Triketone	mesotrione	Callisto
				tembotrione	Laudis

Table 2.1-7. Important herbicide groups for corn, soybean, small grains, commercial vegetables, and forages (continued).

Herbicide Class/Mode of Action					
WSSA Group*	**Site of Action**	**No. Resistant in U.S.**	**Family**	**Common Name**	**Trade Name**
	Cell Membrane Disrupters				
14	PPO inhibitors (protoporphyrinogen oxidase)	2	Aryl triazolinone	carfentrazone	Aim
				fluthiacet	Cadet
				sulfentrazone	Authority, Spartan
			Diphenyl ether	acifluorfen	Ultra Blazer
				fomesafen	Reflex
				lactofen	Cobra, Phoenix
				oxyfluorfen	Goal
			N-phenylphthalimide	flumiclorac	Resource
				flumioxazin	Château, Valor
			Oxadiazole	oxadiazon	Ronstar
			Pyrimidinedione	saflufenacil	Kixor, Sharpen
22	Photosystem I electron diverter	5	Bipyridylium	diquat	Reglone
				paraquat	Gramoxone
	Seedling Root Growth Inhibitors				
3	Microtubule inhibitors	6	Benzamide	pronamide	Kerb
			Dinitroaniline	ethalfluralin	Curbit, Sonalan
				oryzalin	Surflan
				pendimethalin	Pendulum, Prowl, others
				prodiamine	Barricade
				trifluralin	Treflan, others
			Phthalic acid	DCPA	Dacthal
			Pyridazine	dithiopyr	Dimension
	Seedling Shoot Growth Inhibitors				
8	Lipid synthesis inhibitors (not ACCase)	5	Phosphorodithioate	bensulide	Prefar
			Thiocarbamate	cycloate	Ro-Neet
				EPTC	Eptam, Eradicane
15	Long-chain fatty acid inhibitors	1	Acetamide	napropamide	Devrinol
			Chloroacetamide	acetochlor	Breakfree, Degree, Harness Topnotch, Warrant, others
				dimethenamid	Outlook
				metolachlor	Dual, Cinch, others
			Oxyacetamide	flufenacet	Define
			Pyrazole	pyroxasulfone	Zidua
16	Specific site unknown	0	Benzofurane	ethofumesate	Nortron
	Cell Wall Synthesis Inhibitors				
20	Cellulose inhibitor (site A)	0	Nitrile	dichlobenil	Casoron, others
21	Cellulose inhibitor (site B)	0	Benzamide	isoxaben	Gallery
29	Cellulose inhibitor (unspecified site)	0	Alkylazaine	indaziflam	Alion

*WSSA group refers to a system of classifying herbicides based on site of action, developed by the Weed Science Society of America.

Table 2.1-8. Selected glyphosate (Group 9) products and premixes for agronomic use.

Product and Amount of Glyphosate per Gallon*	Company	Product Rate (fl oz) Equivalent to:				Formulation**	
		0.375 lb ae	0.56 lb ae	0.75 lb ae	1.13 lb ae	Salt	Adjuvant Load
5 lb ae/6 lb ai							
Refuge	Syngenta	10	14	19	29	Potassium	None
Roundup Powermax 3	Bayer CropScience	10	14	19	29	Potassium	Fully loaded
4.5 lb ae/5.5 lb ai							
Abundit Edge	Corteva	11	16	22	32	Potassium	Fully loaded
Bullzeye HL-K	Growmark	11	16	22	32	Potassium	Fully loaded
Credit Xtreme	Nufarm	11	16	22	32	IPA + potassium	Fully loaded
Duplicator 6 (5.4 ai)	Drexel	11	16	22	32	diammonium	Partial
Gly Star K-Plus	Albaugh/Agri Star	11	16	22	32	Potassium	Partial
Honcho K6	Bayer CropScience	11	16	22	32	Potassium	Fully loaded
Mad Dog K6	Loveland	11	16	22	32	potassium	Fully loaded
Roundup PowerMAX	Bayer CropScience	11	16	22	32	Potassium	Fully loaded
Roundup WeatherMAX	Bayer CropScience	11	16	22	32	Potassium	Fully loaded
4 lb ae/5 lb ai							
Accord XRT II	Corteva	12	18	24	36	DMA	Fully loaded
Buccaneer 5	TENKOZ	12	18	24	36	IPA	Partial
Buccaneer 5 Extra (5.4 ai)	TENKOZ	12	18	24	36	IPA	Partial
Cornerstone 5 Plus	WinField	12	18	24	36	IPA	Partial
Credit 5.4 Extra	Nurfarm	12	18	24	36	IPA	Fully loaded
Durango DMA/Duramax	Corteva	12	18	24	36	DMA	Fully loaded
Gly Star 5 Extra	Albaugh/Agri Star	12	18	24	36	IPA	Partial
Helosate 5	Helm Agro	12	18	24	36	IPA	Partial
Mad Dog 5.4	Loveland	12	18	24	36	IPA	Partial
Tomahawk 5 (5.4 ai)	Winfield	12	18	24	36	Potassium	Partial
Sunphosate 5 Max	Wynca	12	18	24	36	IPA	Partial
3 lb ae/4 lb ai							
Buccaneer	Tenkoz	16	24	32	48	IPA	Partial
Buccaneer Plus	Tenkoz	16	24	32	48	IPA	Partial
Cornerstone Plus	WinField	16	24	32	48	IPA	Partial
Credit 41 Extra	Nufarm	16	24	32	48	IPA	Fully loaded
Envy	Innvictis	16	24	32	48	IPA	Partial
Envy Intense	Innvictus	16	24	32	48	IPA	Partial
Four Power Plus	Loveland	16	24	32	48	IPA	Fully loaded
Gly Star Original	Albaugh/Agri Star	16	24	32	48	IPA	Partial
Gly Star Plus	Albaugh/Agri Star	16	24	32	48	IPA	Partial
Glyphogan	ADAMA	16	24	32	48	IPA	Partial
Glyphogan Plus	ADAMA	16	24	32	48	IPA	Fully loaded
Helosate Plus Advanced	Helm Agro	16	24	32	48	IPA	Fully loaded
Hoss Ultra	Helena	16	24	32	48	IPA	Fully loaded

Table 2.1-8. Selected glyphosate (Group 9) products and premixes for agronomic use (continued).

Product and Amount of Glyphosate per Gallon*	Company	Product Rate (fl oz) Equivalent to:				Formulation**	
		0.375 lb ae	0.56 lb ae	0.75 lb ae	1.13 lb ae	Salt	Adjuvant Load
Imitator DA	Drexel	16	24	32	48	diammonium	
Imitator Plus	Drexel	16	24	32	48	IPA	Partial
Mad Dog	Loveland	16	24	32	48	IPA	Partial
Mad Dog Plus	Loveland	16	24	32	48	IPA	Fully loaded
Makaze	Loveland	16	24	32	48	IPA	Fully loaded
Rascal	WinField	16	24	32	48	IPA	Partial
Razor	Nufarm	16	24	32	48	IPA	Partial
Showdown	Helena	16	24	32	48	IPA + monoammonium	Partial
Sunphosate 41%	Wynca USA	16	24	32	48	IPA	Fully loaded
Tomahawk 4	Winfield	16	24	32	48	IPA	Partial

Currently, numerous products contain glyphosate. Most of them are labeled for burndown/preemergence and/or spot applications. The majority, but not necessarily all, of the products above are labeled for over-the-top application in Roundup Ready crops (namely, RR corn and RR soybean). Refer to the product label for additional information on crop use, formulation, application rates, and other use restrictions. Other glyphosate-containing products may be available in your area. Contact your local dealer for more details.

*Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. Acid equivalent (ae) is only the weight of the glyphosate acid, which is herbicidally active. Active ingredient (ai) is the weight of the glyphosate acid plus the salt. It is best to refer to ae when comparing glyphosate products and rates.

**Glyphosate can be formulated as different salts: isopropylamine (IPA), monoammonium, diammonium, dimethyamine (DMA), or potassium. Some glyphosate products contain all the necessary adjuvants (i.e., fully loaded). Others contain only a limited amount and additional surfactants must be added to the tank before application. All brands of glyphosate recommend adding ammonium sulfate (AMS) if using hard water as a carrier or under other challenging conditions. If using AMS, always add it to the spray solution before glyphosate. Refer to product label for more information.

fall panicum, giant foxtail, and crabgrass. Cool-season grasses like quackgrass, annual and perennial ryegrass, orchardgrass, timothy, and small grains are not as sensitive as warm-season grasses. Some of these herbicides are weaker on perennial species than other products. They are frequently referred to as "postgrass" herbicides.

Injury symptoms: Growing points are killed first, resulting in the death of the leaves' inner whorl. Older, outer leaves of seedlings appear healthy for a few days, and those of perennials for a couple of weeks, but eventually they also wither and die. After several weeks, the growing points begin to rot, allowing the inner leaves to be pulled out of the whorl. Sensitive grasses commonly turn a purplish color before dying.

Seedling Growth Inhibitors (Root and Shoot)—Groups 3 and 8

Herbicides in this group prevent cell division primarily in developing root tips and are effective only on germinating small-seeded annual grasses and some broadleaves.

Injury symptoms: Seeds of treated broadleaved plants germinate, but they either fail to emerge or emerge as severely stunted seedlings that have thickened, shortened lower stems, small leaves, and short, club-shaped roots. Seedlings of taprooted plants, such as soybeans and alfalfa, usually are not affected, nor are established plants with roots more than a couple inches deep.

Grass seeds germinate but generally fail to emerge. Injured seedlings have short, club-shaped roots and thickened, brittle stem tissue. Seedlings die from lack of moisture and nutrients because of the restricted root system.

Seedling Growth Inhibitors (Shoot)—Group 15

Herbicides in this class are most effective on annual grasses and yellow nutsedge. Depending on the product, some will control small-seeded annual broadleaves. These herbicides cause abnormal cell development or prevent cell division in germinating seedlings. They stop the plant from growing by inhibiting cell division in the shoot and root tips while permitting other cell duplication processes to continue. Then follows a slow decline in plant vigor.

Injury symptoms: Germinating grasses normally do not emerge. If they do, young leaves fail to unfold, resulting in leaf looping and an onionlike appearance. The tip of the terminal leaf becomes rigid, not free flapping (flaglike). The leaves of broadleaved plants turn dark green, become wrinkled, and fail to unfold from the bud. The roots become shortened, thickened, brittle, and clublike.

Photosynthesis Inhibitors (Mobile)—Groups 5 and 7

These herbicides are effective primarily on annual broadleaves, while some provide control of grasses as well.

Photosynthesis-inhibiting herbicides block the photosynthetic process so captured light cannot be used to produce sugars. In the presence of light, green plants produce sugar from carbon dioxide and water. Energy is needed for carbon, hydrogen, and oxygen atoms to rearrange and form sugar. To supply this necessary energy, electrons are borrowed from chlorophyll (the green material in leaves) and replaced by electrons split from water. If chlorophyll electrons are not replaced, the chlorophyll is destroyed and the plant's food-manufacturing system breaks down. The plant slowly starves to death due to lack of energy.

As soil-applied treatments, these herbicides permit normal seed germination and seedling emergence but cause seedlings to lose their green color soon afterward. With the seeds' food supply gone, the seedlings die. These herbicides are more effective on seedling weeds than on established perennial weeds. Herbicides such as prometon (Primitol) and tebuthiuron (Spike) are considered soil sterilants. Soil sterilants are nonselective chemicals that can kill existing vegetation and keep the soil free from vegetation for one or more years.

Injury symptoms: In broadleaved plants, early seedling growth appears normal, but shortly after emergence (when energy reserves in cotyledons are depleted), leaves become mottled, turn yellow to brown, and die. In most cases, the oldest leaves turn yellow on the leaf margins first, the veins remain green, and eventually the plant turns brown and dies. Herbaceous and woody perennials starve very slowly because they have large energy reserves in roots or rhizomes to live on while photosynthesis is inhibited. The herbicide may have to effectively inhibit photosynthesis for a full growing season to kill trees or brush. This kind of death may be slow, but it is certain.

Photosynthesis Inhibitors (Nonmobile, "Rapid-Acting")—Group 6

Herbicides in this group have activity primarily on annual and some perennial broadleaves and are applied to the plant foliage. The mode of action is the same as the mobile photosynthesis inhibitors.

Injury symptoms: Their activity within the plant is similar to that of the mobile photosynthesis inhibitors, except the injury occurs at the site of contact, causing "leaf burning" and eventual death of the plant.

Cell Membrane Disrupters—Groups 14 and 22

These herbicides control mostly broadleaves. Certain products have some activity on grasses, and paraquat (Gramoxone) provides broad-spectrum control of many different species.

These herbicides are referred to as contact herbicides and they kill weeds by destroying cell membranes. They appear to burn plant tissues within hours or days of application. Good coverage of the plant tissue and bright sunlight are necessary for maximum activity. The activity of these herbicides is delayed in the absence of light.

Injury symptoms: All contact herbicides cause cellular breakdown by destroying cell membranes, allowing cell sap to leak out. Affected plants initially have a "water-soaked" appearance, followed by rapid wilting and "burning" or leaf speckling and browning. Plant death occurs within a few days.

Pigment Inhibitors—Groups 12, 13, and 27

These herbicides provide control of many annual broadleaves and some grasses. These products are referred to as "bleachers" because they inhibit carotenoid biosynthesis or the HPPD enzyme by interfering with normal chlorophyll formation.

Injury symptoms: Symptoms are very evident and easy to identify. Affected plants either do not emerge or emerge white or bleached and eventually die. Older leaf tissue is affected first.

Phosphorylated Amino Acid (Nitrogen Metabolism) Disrupters—Group 10

This herbicide (glufosinate) provides broad-spectrum control of most annual grasses and broadleaves and some perennials. It affects growth by disrupting nitrogen metabolism, thus interfering with other plant processes. It is a contact herbicide with slight translocation throughout the plant. Good spray coverage and sunlight are important for maximum efficacy.

Injury symptoms: Injury is similar to that of the cell-membrane-disrupter herbicides. Sensitive plants show "leaf burning," yellowing and browning, and eventual death after a week or so. Perennials generally take longer for symptoms and death to occur.

Unknown Herbicides

This category contains miscellaneous products for which the mode of action and family are unknown. Dazomet (Basamid) and metam (Vapam) are considered soil fumigants. These products are applied to the soil and covered with a gas-tight tarp, where they are converted to gases and penetrate the soil to kill weeds, diseases, and nematodes. Endothall (Aquathol) is used for aquatic weed control. Fosamine (Krenite) is used in noncrop areas to control perennial weeds and brush.

Other compounds such as pelargonic acid (Scythe), fatty-acid herbicides, and clove oil and vinegar are contact, nonselective, broad-spectrum, foliar-applied products that are sometimes used for weed control in organic crop production settings. However, because they basically "burn" only the plant tissue they contact, there is potential for plant regrowth.

Table 2.1-9. Common herbicide safeners used as commercial products.

Safener	Approximate Date of Introduction	Herbicide(s)	Crop	Other
1,8-naphthalic anhydride (NA)	1971	EPTC and butylate	Corn	Seed treatment
Benoxacor	1985	Metolachlor	Corn	Premixed with herbicide
Cloquintocet-methyl	2006	Pinoxaden	Wheat, cereals	Premixed with herbicide
Cyposulfamide	2009	Numerous (Groups 4 and 27)	Corn	Premixed with herbicide
Dichlormid	1972	EPTC, butylate, acetochlor	Corn	Premixed with herbicide
Fenchlorazole-ethyl	1992	Fenoxaprop	Wheat, cereals	Premixed with herbicide
Fluxofenim	1986	Alachlor, metolachlor	Sorghum	Seed treatment
Furilazole	1991	Acetochlor	Corn	Premixed with herbicide
Isoxadifen	2001	Numerous (Groups 2 and 4)	Corn	Premixed with herbicide
Mefenpyr-diethyl	1989	Pyrosulfotole	Wheat	Premixed with herbicide

Trade Name, Formulation Notations, and Premixes

In certain publications, many herbicides are listed by trade name (or product name) and formulation—for example, Roundup 4S or Permit 75WDG. Roundup is the trade name and 4S stands for 4 pounds of active ingredient (glyphosate) per gallon of product in a soluble (S) formulation. Permit is formulated as a water-dispersible granule with each granule (or certain unit) containing 75 percent active ingredient (halosulfuron) in a water-dispersible granule (WDG) formulation. The remaining parts of the formulation contain inert ingredients, which have no effect on weed control. Additional information about formulation and ingredients can be found in another part of this publication and on the product's label and SDS (safety data sheet).

Premixes contain two or more herbicide active ingredients mixed into one product by the manufacturer. The actual premix formulation can vary but commonly contains two or more herbicides that are already used together. The primary reason for using premixes is convenience. Many herbicide products are now marketed as premixes.

Herbicide Safeners

Herbicide safeners, also called antidotes or protectants, are chemicals that help prevent injury to crops without reducing weed control. Early discovery of compounds capable of safening herbicides started in the late 1940s with the phenoxy herbicides, but commercialization really started with seed treatments and soil-active safeners in the 1970s and early 1980s. In general, herbicide safeners allow crops with fair tolerance to an herbicide to metabolize or detoxify the herbicide more quickly, thus providing increased crop safety. To date, safeners have only been developed for grass crops such as corn and wheat with few advances in dicot or broadleaf crops. Some of the more notable of these safeners includes dichlormid (Eradicane, Sutan, and some acetochlor formulations), benoxacor (Dual II), and the seed treatment Concept (fluxofenim), which allows chloroacetamide herbicide use in sorghum. More recently, a number of Group 2 (ALS) and other herbicides use isoxadifen (Accent Q, Resolve Q, Status, Steadfast Q, etc.), which provides increased safety from foliar applications. The most recently launched safener is cyprosulfamide, which provides preemergence and foliar safening with several herbicides. Cyprosulfamide is used in a number of Bayer CropScience products, including Balance Flexx, Corvus, Capreno, and DiFlexx. See Table 2.1-9 for common herbicide safeners used as commercial products.

Generic or Post-Patent Products

The pace of novel herbicide active ingredient commercialization has greatly slowed over the last 25 years and many herbicides are going off patent. Also, several new manufacturers have entered the herbicide market and are reintroducing older active ingredients. Most original brands still dominate, but the post-patent product market is growing. It can be challenging to find all post-patent herbicides sold in our region, but we have tried to summarize some of the more common ones in Table 2.1-10. Other generic herbicide products may be available in your area. Be cautious and consider all factors when looking at generic herbicide alternatives, especially guarantees for resprays on product failures. Contact your local dealer for details.

Herbicide Spray Additives (Adjuvants)

Additives, or adjuvants, are substances in herbicide formulations or that are added to the spray mixture to improve herbicidal activity or application characteristics. Over 70 percent of all herbicides recommend the use of one or more adjuvants in the spray mixture. In general, there are two types of adjuvants: formulation and spray. Formulation adjuvants are "already in the container" from the manufacturing process. These help

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use.

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Acetochlor	Arrest Arrest Plus Asset-S Plus Essensa	Sharda	Corn	Harness
Atrazine	Atrazine 4L Atrazine 90 DF	Sipcam Winfield	Corn Sorghum	Aatrex
Bentazon	Bashazon Broadlook	Sharda UPL	Corn, sorghum, soybean	Basagran
Acetochlor + atrazine	Acellus ATZ*/Xcelerate ATZ 5.6L	Growmark	Corn	Harness Xtra, Breakfree, Degree Xtra, Keystone (NXT)
	Cadence ATZ* NXT	Loveland		
	Confidence Xtra*	WinField		
	Electra* Etcetra	Sharda		
	Fearless Xtra*	Helm Agro		
	Overtime ATZ* NXT	Helena		
	Tremor ATZ*	WinField		
	Volley ATZ* (NXT)	Tenkoz		
Acetochlor+fomesafen	Forrest	Sharda	Soybean	
Acetochlor+mesotrione	Recite	Sharda	Corn	
Acetochlor + flumetsulam + clopyralid	Definite	Sharda	Corn	SureStart, SureStart II, Tripleflex
	Smackdown	Loveland		
	Staunch II	Tenkoz		
	Threesidual/Trisidual	WinField		
	True Set II	Atticus		
Acifluorfen	Acifin 2L	Summit Agro	Soybean	Ultra Blazer
	Avalanche Ultra	WinField		
	Derecho	Atticus		
	Levity	Innvictis		
	Sharda Acifluorfen	Sharda		
	Uproar	Winfield		
Bromoxinil	Deadbolt	Willbur-Ellis	Corn, sorghum, small grains	
Chlorimuron	Curio	Nufarm	Soybean	Classic
	Sheridan 25 WG	Helm Agro		
Chlorimuron + metribuzin	Cloak	Nufarm	Soybean	Canopy*
	Metrixx Plus	Sharda		
	Resist	Tenkoz		
Chlorimuron + tribenuron	Cloak EX	Nufarm	Soybean	Canopy EX
	Fallout	Corteva		

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use (continued).

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Clethodim	Arrow 2 EC	ADAMA	Soybean, alfalfa	Select, (Select Max)
	Avatar*	Innvictis		
	Ceridan 2 EC	Atticus		
	Clense*/Section*	Winfield		
	Dakota	Rotam North America		
	Envoy Plus	Valent		
	Intensity*	Loveland		
	Shadow*/Trizenta*	UPL		
	TapOut	Helena		
	Vaquero	Willbur-Ellis		
	Volunteer	Tenkoz		
Clopyralid	Bite	Sharda	Corn, pasture, small grains	Stinger
	Clean Slate	Nufarm		
	Savant	Innvictus		
	Sonora	Alligare		
	Spur	Albaugh		
	Stigmata	Atticus		
Clopyralid+flumetsulam	Jacket	Sharda	Corn	
Cloransulam	Ankur	Sharda	Soybean	FirstRate
	FrontRunner	Atticus		
	Traject 4 dimeSC	Summit Agro		
	Willowood Cloran DF	Generic Crop Science		
Dicamba	Topeka Detonate Clarifier Sterling Blue	Rotam Tenkoz Winfield Winfield	Corn, small grains, sorghum	Clarity
Dimethenamid-P + atrazine	Commit ATZ*	WinField	Corn, sorghum	Guardsman Max
	Sortie ATZ*	Helena		
Flumioxazin	Flumigard	Alligare	Soybean (or alfalfa, depending on label)	Valor*, Chateau
	Joya	Rotam North America		
	Outflank/Warfox	ADAMA		
	Panther*/Tuscany*	Nufarm		
	Varsity*	Innvictis		
	Zaltus*	Atticus		
Fluroxypyr	Comet	Nufarm	Corn, small grains, pastures	Starane
	Fancy/Flurox	Sharda		
	Flagstaff	Alligare		
	Stark Ultra	Atticus		
	Stave	Invictis		

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use (continued).

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Fomesafen	Agent 1.88	WinField	Soybean	Reflex, Flexstar
	Andros*	Rotam North America		
	Battle Star	Albaugh		
	Foma*	Drexel		
	Forsyte 1.88 SL	Atticus		
	Rumble	ADAMA		
	Shafen	Sharda		
	Sinister	Helena		
	TopGun*	Loveland		
	Vamos	Innvictis		
Fomesafen + imazethapyr	Camo	Albaugh	Soybean	—
	Torment	ADAMA		
Fomesafen + *S*-metolachlor	MetalliS PFX	Atticus	Soybean	Prefix
	Sharp	Sharda		
	Quake	Tenkoz		
Glufosinate	Autonomy	Tenkoz	LibertyLink corn and soybean, others	Liberty
	Cheetah*	Nufarm		
	Fever	Invictus		
	Forfeit 280	Loveland		
	Inflame 280	Atticus		
	Interline	UPL		
	Lifeline	UPL		
	Legrium 280 SL	Growmark		
	Opportunity	Sharda		
	Para Shot	Sharda		
	Reckon 280 SL	Solera		
	Refer	Summit Agro		
	Scout	Valent		
	Surmise/X-Out	Albaugh		
	Total*	WinField		
Halosulfuron	Halomax 75	Aceto	Corn, sorghum	Permit, Sandea
	Herbivore	WinField		
	Profine 75	Aceto		
	Promote/Stadia	Atticus		
	Proventix 75 WDG	Innvictis		
Imazethapyr	Imazethapyr 2 SL	ADAMA	Soybean, alfalfa	Pursuit
	Pemex	Atticus		
	Praxis	Sharda		
	Thunder	Albaugh		

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use (continued).

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Imazethapyr + glyphosate	Extreme	Helm Agro	Soybean	Extreme
	Praxis Plus	Sharda		
	Thunder Master	Albaugh		
Lactofen	Boa Phoeniz	Sharda UPL	Soybean	Cobra
Mesotrione	Argos	Helm Agro	Corn, sorghum	Callisto
	Bellum	Rotam		
	Bridle/Incinerate	WinField		
	Cavallo 4 SC	Atticus		
	Incinerate	WinField		
	MesoStar	Sharda		
	Mesotrione	Albaugh		
	MesoTryOne	Drexel		
	Motif	UPL		
	Quartz	Sipcam		
	Sotrion	Growmark		
	Undercover	Innvictis		
Mesotrione+Acetochlor	Optero	Rotam	Corn, Sorghum	
Mesotrione+Metolachlor	Evinco	Rotam	Corn, sorghum	
	Stalwart 2W Coyote	Sipcam UPL		
Mesotrione + metolachlor + atrazine	Ravine	Altitude Crop Innov.	Corn, sorghum	
	Rixa/ Vilify	Rotam		
	Stalwart 3W	Sipcam Agro		
	TriZar	Drexel		
	TrizMax	Drexel		
Mesotrione + *S*-metolachlor + atrazine	Entrax EZ	Growmark	Corn, sorghum	Lexar, Lumax
	Omni Xar	Helena		
Mesotrione + metolachlor + glyphosate	Mes-O-Sate	Drexel	Corn	Halex GT
Mesotrione + rimsulfuron	Equip	Rotam	Corn	
Metolachlor	Helmet	Helm Agro	Corn, soybean, sorghum	Dual
	Metalica	Sharda		
	Me-Too-Lachlor*	Drexel		
	Meto Star	Sharda		
	Parallel*	ADAMA		
	Priority	AgriStar		
	Punch	Sharda		
	Stalwart*	Sipcam		
	Visor*	Innvictis		

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use (continued).

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Metolachlor + atrazine	Parallel Plus	ADAMA	Corn, sorghum	Bicep
	Payback ATZ	Real Farm		
	Ravine	Altitude		
	Stalwart Xtra*	Sipcam		
	Triangle	Tenkoz		
	Trizmet II	Drexel		
	Visor ATZ	Innvictis		
Metolachlor + imazethapyr	Pummel	ADAMA	Soybean	—
Metolachlor + metribuzin	Galvan	Innvictis	Soybean	Boundary
	Headwin	Sharda		
	Ledger	Tenkoz		
	Me-Too-Lachlor	MTZ		
	Stalwart MTZ	Sipcam		
	Tailwind	ADAMA		
Metribuzin	Derive75*	Innvictis	Soybean, corn, alfalfa	Formerly Sencor
	Dimetric*	WinField		
	Glory	ADAMA		
	Mauler	Valent		
	Metribuzin 75*	Loveland		
	Metriclude*	Winfield		
	Metricor*	UPL		
	Metrixx*	Sharda		
	Me-Try-Buzin*	Drexel		
	Omni Metribuzin	Helena		
	Rancor*	Atticus		
Metsulfuron-methyl	Ally XP	FMC	Pasture	Cimarron* (DuPont no longer sells the single-ai product for pastures)
	Clean Pasture DF	Control Solutions		
	MSM 60	Alligare		
	Patriot	Nurfarm		
	Plotter/Romestol	Rotam North America		
	PureStand	Nufarm		
	Rometsol	Rotam		
	Tide MSM 60	Tide Int.		
Nicosulfuron	Primero*	Rotam North America	Corn	Accent Q

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use (continued).

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Paraquat	Bonedry	Sinon	All	Gramoxone
	Devour	Innvictis		
	Helmquat	Helm		
	Omni Paraquat	Helena		
	Para-Shot 3.0	Sharda		
	Parazone 3SL	ADAMA/AMVAC		
	Purgatory 3 SL	Atticus		
	Quik-Quat	Drexel		
	Tigris Paraquat	Tigris		
Pendimethalin	Acumen	Tenkoz	Corn, soybean	Prowl 3.3EC, (Prowl H2O)
	AquaPen 3.8/ Pin-dee 3.3 EC	Drexel		
	Framework	WinField		
	Pavilion	Innvictis		
	Satellite*	UPL		
	Stealth	Loveland		
Quinclorac	Prize	Sharda	Pasture	Paramount/Facet
	Quinstar 4L	Albaugh		
Rimsulfuron	Grapple	Nufarn	Corn	Resolve, Matrix
	Hinge/Inflict	Rotam North America		
	Pruvin	ADAMA		
	Tetris SG	Atticus		
Rimsulfuron+nicosulfuron	Sparrow	Rotam	Corn	
Rimsulfuron+thifensulfuron	Stringent	Rotam	Corn	
S-metolachlor	Brawl*/Charger*	Tenkoz	Corn, soybean, sorghum	Dual Magnum, Dual II Magnum
	Charger Max	Winfield		
	Moccasin	UPL		
	StreliuS II	Atticus		
	Visor S-MOC*	Innvictis		
S-metolachlor + atrazine	Brawl II ATZ	Tenkoz	Corn, sorghum	Bicep II Magnum
	Charger MAX ATZ*	WinField		
	Visor S-MOC ATZ	Innvictis		
S-metolachlor + metribuzin	Ledger	Tenkoz	Soybean	Boundary
	MetalliS MTZ	Atticus		
	Moccasin MTZ	UPL		
	Presidual	Winfield		
	Tyrant	Helena		

Table 2.1-10. Selected generic (or post-patent) alternative herbicides for agronomic use (continued).

Common Name	Trade Name	Manufacturer	Labeled Crops	Alternative to:
Sulfentrazone	Antares*	Helena	Soybean	Authority 75DF, Spartan
	Aquesta	Atticus		
	Blanket 4F	Tenkoz		
	Boycott	UPL		
	Intensa	Sharda		
	Shutdown	UPL		
	Sulfin 4SC	Summit Agro		
	Surepyc	Amvac		
	Vandal 4SC	Innvictis		
	Zone 4F	Helm Agro		
Sulfentrazone+imazethapyr	Compensa	Sharda	Soybean	
Thifensulfuron	Thief	Loveland	Corn, soybean, small grains	Harmony*
	Treaty	Nufarm		
	Volta	Rotam North America		
Thifensulfuron + tribenuron	Audit*	UPL	Corn, soybean, small grains	Harmony Extra SG
	Civility Extra	Innvictis		
	Rapport*	Nufarm		
	Treaty Extra	Nufarm		
	Volta Extra	Rotam North America		
Tribenuron	Taqua	Rotam	Barley, oats, wheat	Express
Triclopyr	Boulder 6.3	Alligare	Pasture	Garlon*/Remedy Ultra
	Relegate	Nufarm		
	Triclopyr*	Albaugh/Alligare		
Triclopyr + 2,4-D	Candor	Nufarm	Pasture	Crossbow
	Chaser 2 Amine	Loveland		
	Crossroad	Albaugh		
Trifluralin	Trust	Winfield	Corn, soybean wheat	Treflan

*Product contains multiple formulations.

Figure 2.1-4. Surfactant.

with mixing, handling, effectiveness, and providing consistent performance.

Spray adjuvants can be divided into special-purpose adjuvants and activator adjuvants. Special-purpose adjuvants include compatibility agents, buffering agents, anti-foam agents, drift retardants, and others that widen the range of conditions for herbicide use. Activator adjuvants are commonly used to enhance postemergence herbicide performance by increasing herbicide activity, absorption, and rainfastness and decreasing photodegradation. These include surfactants (i.e., "surface active agents"; Figure 2.1-4), crop oil concentrates, vegetable oil concentrates, wetting agents, stickers-spreaders, N-fertilizers, penetrants, and others.

Commonly used surfactants are non-ionic surfactants and organosilicones, which are typically used at a rate of 1 quart per 100 gallons (0.25 percent v/v) of spray mixture. Crop oil concentrates are 80 to 85 percent petroleum based plus 15 to 20 percent surfactant, while vegetable oil concentrates contain vegetable or seed oil in place of petroleum oil. Oil concentrates are typically included at a rate of 1 gallon per 100 gallons (1 percent v/v) of spray mixture. In general, oil concentrates are "hotter" than surfactants, so they provide better herbicide penetration into weeds under hot/dry conditions, but they are more likely to cause greater crop injury under normal growing conditions. Nitrogen fertilizers, such as UAN (a mixture of ammonium nitrate, urea, and water) or AMS (ammonium sulfate), are used in combination with surfactants or oil concentrates to increase herbicide activity and reduce problems with hard water. Many blended adjuvants are available that include various combinations of special purpose adjuvants or activator adjuvants.

Be sure to include the proper adjuvant(s) for the herbicide being used. Most herbicide labels specify the type and amount of additive to use. Failure to follow the recommendations can result in poor weed control or excessive crop injury.

Managing Herbicides

Environmental Hazard Warnings

Some herbicide labels carry "Environmental Hazard Warnings" on the label. The environmental hazard may specify a "water-quality advisory," which requires special precautions for coarse-textured (sandy) soils, soils with a shallow water table, and soils with other potential water-contamination risks. Herbicides with water-quality advisories have been detected in small amounts in water supplies after normal agricultural use. Additional environmental dangers include toxicity to fish and wildlife and hazards to endangered species. Check the label or specific hazard warning information before using a product.

Herbicide Use Rate

The recommended use rates of soil-applied herbicides often vary with soil texture, organic matter content, and tillage systems. The use of soil-applied herbicide rates that are incorrect for the soil texture, pH, and organic matter may result in poor weed control or crop injury. Consult the herbicide label for the proper herbicide rate for your soils.

Most of the herbicides recommended in this publication are selective. At the recommended rate of application, they will selectively control or injure weeds but not seriously damage the crop in which these weeds are growing. In using selective herbicides, you should carefully follow the recommended application rate and follow instructions related to the use of surfactants and other additives. Using higher herbicide rates or additives that are not recommended may result in severe crop injury. You must accept the responsibility if you use an herbicide in a manner other than that directed on the herbicide label.

Herbicide Persistence and Crop Rotational Intervals

Herbicides are applied to the soil to manage weeds. It is desirable for the chemicals to control weeds during the season of application, but they should not persist and affect subsequent crop growth. The length of time that an herbicide remains active in the soil is called "soil persistence" or "soil residual life." With some herbicides, there may be a fine line between controlling the weeds for the entire growing season and then planting a sensitive rotation crop. Anything that affects the breakdown of herbicides will affect persistence. Herbicides vary in their potential to persist in the soil. Some herbicide families that have persistent members include the triazines (Group 5), uracils (Group 7), ureas (Group 7), sulfonylureas (Group 2), dinitroanilines (Group 3), isoxazolidinones (Group 13), imidazolinones (Group 2), and pyridines (Group 23). Several factors determine the length of time herbicides

will persist. These factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. The factors within each of these categories can strongly interact with one another.

Soil Factors

The soil factors affecting herbicide persistence include soil composition, soil chemistry, and microbial activity. Soil composition is a physical factor that is determined by relative amounts of sand, silt, and clay (the soil texture) and the organic-matter content. An important chemical property of the soil that can influence herbicide persistence is pH. The microbial aspects of the soil environment include the type and abundance of soil microorganisms present. Soils containing more clay and organic matter (heavier) tend to bind herbicides more strongly and they will persist longer. Also, higher soil pH (>7) can be more problematic for some herbicides.

Climatic Factors

The climatic variables involved in herbicide breakdown are moisture, temperature, and sunlight. Herbicide degradation rates generally increase as temperature and soil moisture increase because both chemical and microbial decomposition rates increase with higher temperatures and moisture levels. Cool, dry conditions slow down herbicide degradation. Carryover problems are always greater the year following a drought. If winter and spring conditions are wet and mild following a previously dry summer, the likelihood of herbicide carryover is lower.

Herbicide Properties

An herbicide's chemical properties affect its persistence. Properties include water solubility, vapor pressure, and susceptibility of the molecule to chemical or microbial alteration or degradation. Much of this boils down to the herbicide half-life, or the time it takes for 50 percent of the active ingredient to dissipate. Several factors influence the rate of dissipation such as rainfall, soil texture, and soil pH, among others. The basic manufacturers, along with universities and some other research organizations, have evaluated the persistence of herbicides in soil for local conditions, and it can vary widely.

Avoiding Herbicide Persistence in Subsequent Crops

There are several ways to avoid herbicide carryover problems. First, check the crop rotation intervals on the herbicide label and do not plant a sensitive crop prior to the specified time. Second, always apply the correct rate of any pesticide for your specific soil type and weed problem. This means applying the lowest rate of the chemical consistent with obtaining the desired effect. Higher rates of more persistent products certainly carry more risk of injury to following crops. Accurate acreage determination, chemical measurement, proper sprayer calibration, and uniform application are essential for avoiding misapplication problems. Always read the label before applying any herbicide.

Herbicide persistence problems may also be avoided by choosing less persistent products. Check the herbicide label for crop rotation intervals before selecting any material. With all pesticides, use the appropriate rates and application timings. The use of selective tillage, herbicide combinations, and tolerant crops and varieties will also help reduce the risk of carryover crop injury. Wise herbicide use will ensure the continued availability of these important weed management tools for the future. Table 2.1-11 provides the cash crop rotation restrictions for common herbicides that are used in multiple crops. These restrictions are the label guidelines and may be due to concerns about herbicide residues accumulating in forage or feed or carryover injury.

Herbicide Persistence and Rotation to Cover Crops

The question about whether corn or soybean herbicide programs will pose a problem for establishing fall cover crops has become a common one, particularly in areas of severe drought where corn is harvested earlier than normal and the desire to plant a cover/forage crop is strong. If you look at the rotation crop restrictions for corn and soybean herbicides in this guide, you will see that many products limit rotation to alfalfa and/or the clovers as well as some of the small grains. This is a good place to start when thinking about rotation to fall cover crops. However, cash crop rotation restrictions are also based on the potential for herbicide residues to accumulate in forage or feed rather than carryover injury. If the crop is not going to be harvested and consumed by livestock or humans, then the primary concern is carryover injury and achieving an acceptable stand that provides the benefits of a fall or winter cover. Cover crops that are not harvested can be planted after any herbicide program, but the grower assumes the risk of crop failure.

Two factors become important when trying to predict the potential for carryover injury to rotation crops: (1) how long does the herbicide last or persist in the soil, assuming that it has soil activity, and (2) how sensitive is the rotation crop to potential herbicide residues? Herbicides with shorter half-lives (the time it takes for 50 percent of the active ingredient to dissipate) are always less of a concern. Most guidelines are generally for "normal" conditions (e.g., not severe drought). In general, products with a four-month or less rotation restriction for the species of interest, close relative, or sensitive species (e.g., clovers) should pose little problem. These products typically have half-lives of less than 30 days. Species sensitivity can play a role if only a small amount of residue is necessary to cause injury and the herbicide persists. Quite often, small-seeded legumes and grasses, like the clovers and ryegrass, and mustard species, like canola, are more

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops.

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
2,4-D[1]	3	3	3	1	3	0.25–1	1	3	3	3	1	3	3	3	3	0.25–1[1]	1	3	1	3	3	3	1	1	1	1
Accent/ Accent Q	10[1]	10[2]	10	10	10[2]	NR	10–18[1]	10–18[1]	10[2]	10[2]	10[2]	10	10[2]	10[2]	10	0.5	8	10[2]	10	10[2]	10[2]	10[2]	10[1]	4	4	4
Acuron	18	18	18	10	18	NR	10	18	18	18	10	18	18	18	18	10	4	18	NR	18	18	18	10	4	4	4
Acuron Flexi[23]	10	18	18	10	18	NR	10	18	18	18	10	18	18	18	18	10	4	18	NR	18	18	18	10	4	4	4
Acuron GT	10	18	18	10	18	NR	10	18	18	18	10	18	18	18	18	10	4.5	18	NR	18	18	18	10	4.5	4.5	4.5
Afforia (2.5 oz)	4[24]	4[24]	4[24]	1	4[24]	0.5[24]	1	4[24]	4[24]	4[24]	1.5	3	4[24]	4[25]	3	NR[24]	4[24]	4[24]	3	1.5	4[24]	4[24]	4[24]	3	3	1[24]
Aim	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Antares Complete	12	18B	18B	12-18[1]	18B	4-10[1]	12-18[1]	18B	18B	18B	12	18B	18B	18B	18B	NR	18B	18B	18B	18	4[9]	18B	12	4.5	18B	4.5
Anthem Flexx (5.46 oz)	10	18	18	4	18	NR	10[25]	11	18	18	4	11	18	18	11	NR	11[25]	18	NR	18	9	18	NR	11[25]	11[25]	4[25]
Anthem Maxx (4.87 oz)	10	18	18	4	18	NR	10[25]	11	18	18	4	11	18	18	11	NR	11[25]	18	NR	18	9	18	1	11[25]	11[25]	4[25]
Armezon/ Impact (0.75 oz)	9	18	18	9	18	NR	9	9	18	18	9	9	18	18	9	9	3	18	NR	18	18	18	9	3	3	3
Armezon PRO (16–20 fl oz/A)	9	18	18	9	18	NR	9	9[3]	18	18	9	9[3]	18	18	9[3]	9	4	18	NR	18	18	18	9	4	4	4
Assure II	4	4	4	NR	4	4	4	4	4	4	4	NR	4	4	NR	NR	4	4	4	4	4	4	4	4	4	4
Atrazine	SY	SY	SY	NY	SY	NR	NR	SY	SY	SY	NY	SY	SY	SY	SY	NY	SY	SY	NR	SY	SY	SY	SY	NY	NY	NY
Authority Edge	12	18[9]	18	12[1]	18	4	10–18[1]	9	18	18	4	9	18	18	9	NR[1]	12–18[1]	18	12	18	18	18	4	11–18[1]	11–18[1]	4–10[1]
Authority Elite/ BroadAxe XC	12	2[9]	12B	18[4]	12B	10	10	12B	12B	12	4	12B	12B	12B	12B	NR	12	12B	18	10	4	12B	4	4.5	4.5	4.5
Authority First/ Sonic	12	30B	30B	12–18[1]	30B	10–18[1]	12	12	30B	30B	12	9	30B	30B	12	NR	12	30B	10–18[1]	30[1]	30B	30B	18	12	12	4
Authority MTZ	12	18	18	18[4]	18	10	12	18	18	18	12	18	18	18	18	NR	18	18	18	12	NR[9]	18	12	4	4	4
Authority Supreme	12	18[9]	18	12–18[1]	18	4	10[1]	9	18	18	4	9	18	18	9	NR[1]	12[1]	18	10	18	18	18	4	11[1]	11[1]	4[1]

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Authority XL	12–18[1]	18	18	18	18	10–18[1]	10–18[1]	36	36	36	18	36	36	18	36	NR	12–18[1]	36	18	10–18[1]	12–18[1,9]	18	36	4	4	4
Autumn Super[1]	18B	18B	18B	10	18	1	18B	18B	18B	18B	18B	18B	18B	18B	18B	2	18B	18B	9	18B	18B	18B	18B	9	18B	3
Axial Bold, Axial Star, Axial XL	3	1	3	3	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	NR	3	NR
Axiom	12	12B	12	8	12B	NR	12	12B	12B	18	12B	12B	12B	12B	12B	NR	12	12B	12B	12B	12B	12B	1	12	12	0.23–4
Balance Flexx[1]	10[1]	18	18	10[1]	18	NR	6	18	18	18	11	18	18	18	18	6	18	18	6	12	18	18	6	6	4	4
Basagran	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Basis	10[6]	18	10[6]	1[6]	10	NR	10[6]	18	18	18	18	10	18	18	10	10[6]	9	18	10	18	1	18	NR	3	3	3
Basis Blend[6,]	10[6]	18	10[6]	1[6]	10	NR	10[6]	18	18	18	1.5	10	18	18	10	10[6]	9	18	10	1.5	1	18	1	3	3	3
Beyond	3	9	18	9	9	8.5[8]	9	NR	9	9	9	NR	9	9	NR	NR	9	9	8.5	9	9	9	9	9	4	3[8]
Bicep products	SY	SY	SY	NY	SY	NR	NR[10]	SY	SY	SY	NY	SY	SY	SY	SY	NY	SY	SY	NY	SY	SY	SY	SY	NY	NY	NY
Boundary	4.5	12	12	12	12	4	12	12	12	18	12	8	12	12	12	NR	12	12	4	12	12	12	NR	4.5	12	4.5
Buctril/ Maestro	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cadet	AH	AH	AH	AH	AH	NR	AH	AH	AH	AH	AH	AH	AH	AH	AH	NR	AH	AH	NR	AH	AH	AH	AH	AH	AH	AH
Callisto	10	18	18	10	18	NR	NR	18	18	18	10	10[1]	18	18	10[1]	10	NR	18	NR	10	18	18	10	4	4	4
Callisto Xtra	NY	18	18	NY	18	NR	NR	18	18	18	NY	18	18	18	18	NY	18	18	NR	NY	18	18	NY	NY	18	NY
Canopy[1]	10	18	12	10	18	10	12	30	30	30	18	12	30	18	12	NR	30	30	18	10[9]	10[9]	18	30	4	4	4
Canopy Blend	10	18	18	18	18	10[26]	18	30	30	30	18	12	30	18	18	NR	4	30	18	18[9]	10[9]	18	30	4	30	4
Canopy EX	10	18	12	10	18	10[1]	10[1]	30	30	18[1]	8	12	30	18	12	0.25[1]	4	30	18	10[9]	10[9]	18	18[1]	4	4	4
Caparol	12	5	12	5	12	5	12	12	12	8	12	5	12	12	12	12	12	12	5	12	12	12	12	12	12	12
Capreno[1]	10-18	18	18	10	18	NR	10	18	18	18	11	18	18	18	18	10	10	18	10	12	18	18	18	10	18	4
Chaparral	SYB	SYB	SYB	SYB	SYB	NY	NY	SYB	SYB	SYB	SYB	SYB	SYB	SYB	SYB	SYB	NY	SYB	SYB	SYB	SYB	SYB	SYB	NY	NY	NY
Chateau (up to 3 oz)[11]	5[11]	12B	5[11]	2[11]	12B	0.5–1	1[1]	12B	12B	12B	NR	4	12B	12B	4	NR	5[11]	12B	4	2	12B	12B	5[11]	4	4	2
Cimarron Max/ metsulfuron[1]	12[1]	NYB	12[1]	NYB	NYB	NYB	NYB	NYB	NYB	NYB	NYB	NYB	NYB	NYB	NYB	NYB	10	NYB	NYB	NYB	NYB	NYB	NYB	10	NYB	1

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Cimarron Plus	4	B	4–12[1]	B	B	12[1]	B	B	B	B	B	B	B	B	B	12[1]	10	B	B	B	B	B	B	10	NYB	1
Clarity	4	4	4	0.75–1.5[5]	4	NR	NR	4	4	4	4	4	4	4	4	0.5–1[5]	0.5–1.5[5]	4	4	4	4	4	4	0.5–1.5[5]	0.5–1.5[5]	0.5–1.5[5]
Classic[1]	12	18	12	9	18	9	9	30	30	30	15	9	30	18	9	NR	3	30	18	10[9]	10[9]	18	30	3	3	3
Cobra	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Command/ Up-stage	12	9	12	NR[12]	9	9	9	12	9	12	9	NR[1]	NR	NR[1]	9	NR	12	NR[1]	9	NR	9[9]	9	9	12	12	12
Corvus	17	17B	17B	10	17B	NR	17B[1]	17B	17B	17B	11[1]	17B	17B	17B	17	9	17	17B	9	12[1]	17B	17B	17	9	4	4
Crossbow[30]	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Curbit	AH	AH	AH	AH	NR	AH	AH	AH	NR	AH	NR	AH	AH	NR	AH	NR	AH	NR	AH	AH	AH	NR	AH	AH	AH	AH
Curtail	10.5–18[1]	10.5–18[1]	10.5B	10.5B	10.5B	1	10.5–18[1]	10.5B	10.5B	10.5–18[1]	10.5B	18	10.5B	10.5B	10.5B	10.5–18[1]	1	10.5B	10.5–18[1]	10.5B	10.5B	10.5B	18	1	10.5B	1
Dacthal	8	AH	8	8	8	8	8	8	AH	AH	8	8	AH	8	8	8	8	8	8	8	AH	NR	AH	8	8	8
Degree Xtra	SY	SY	SY	NY	SY	NR	NR[10]	SY	SY	SY	SY	SY	SY	SY	SY	NY	SY	SY	NR	NY	SY	SY	SY	SY	SY	AH
Devrinol	12	NR	12	12	12	12	12	12	12	12	12	12	NR	12	12	12	6	12	12	NR	NR	12	12	6	6	6
DiFlexx	4	4	4	2	4	NR	2	4	4	4	4	4	4	4	4	2[1]	2	4	4	4	4	4	4	2	4	2
DiFlexx Duo	10	18B	18B	10	18	NR	10	18B	18	8/18[27]	11	10	18B	18	10	8	4	18	4	12	10	18	10	4	4	4
Distinct[1]	1	4	4	1	4	0.25	1	4	4	4	4	4	4	4	4	1	1	4	4	4	4	4	4	1	1	1
Dual products	4	2[1]	9	NR	12	NR	NR[10]	NR	12	2[1]	NR	NR	2	2[1]	NR	NR	4.5	12	NR	NY	2[1]	12	NR	4.5	4.5	4.5
DuraCor	24B	24B	24B	24B	24B	12	24B	24B	24B	24B	24B	24B	24B	24B	24B	24B	12	24B	12	24B	24B	24B	24B	12	12	12
Elevore	9	15B	9	1	15B	0.1-0.5[1]	0.5	15B	15B	15B	9	9	15B	15B	15B	0.5	0.5	15B	15B	15B	15B	15B	24B	0.5	0.5	0.5
Enlist Duo	NI	NS	NS	1[32]	NS	0.23–0.5[32]	NS	NS	NS	NS	NS	NS	NS	NS	NS	1[32]	NS	NS	0.2–0.5	NS	NS	NS	NS	NS	NS	NI
Envive	10	18	12	10	18	10	12	30	30	30	8	12	30	18	12	NR	10	30	18	10[9]	12[9]	18	30	4	4	4
Eptam	NR	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	NR	AH	AH	AH	AH	AH	AH	AH	NR	AH	AH	AH
Evik	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	3	11	11	11	11	11	10	3	3	3
Expert	SY	SY	SY	NY	SY	NR	NR[10]	SY	SY	SY	NY	SY	SY	SY	SY	NY	SY	SY	NY	SY	SY	SY	SY	NY	NY	NY
Extreme	4	18	4	18	18	8.5[8]	18	NR	18	40B	NR	NR	18[9]/ 40B	40B	2	NR	18	40B	18	9.5	18[9]/ 40B	18	26	4	4	3

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Facet L	24B	10	24B	10	10	10	NR	10	10	10	10	24B	24B	10	10	10	10	10	10	24B	24B	10	24B	10	10	NR
Fierce/Fierce EZ	10	18	18	1–2[1]	18	0.25–1[1]	18	11	18	18	4	11	18	18	11	NR	11–12[1]	18	18	12	18	18	4	11–12[1]	11–12[1]	1–2[1]
Fierce XLT[1]	18	18–30	18	18–30	18–30	10–18	18	18–30	18–30	18–30	18–30	18–30	18–30	18–30	18–30	NR	18–30	18–30	18–30	18[9]	18[9]	18–30	18–30	18	18	4
Finesse Cereal and Fallow (0.4 oz)	B	B	B	18	B	18	4–18[1]	B	B	B	B	B	B	B	B	18[14]	10	B	B	B	B	B	10	10–16[1]	0–4[1]	0–4[1]
FirstRate	9	18	18	9	18	9	9	9	18	18	9	9	18	18	9	NR	9	18	18	18[15]	18	18	18	12	18	4
Flexstar/ Flexstar GT	18	18	18	NR	12	10	18	4	12	18	10	4	1 0[9]/12	10	NR	NR	18	12	10	18	10[9]/12	10	NR	4	4	4
FulTime/Key-stone	15	SY	SY	NY	SY	NR	NY	SY	SY	SY	SY	15	SY	SY	SY	NY	15	SY	NR	15	SY	SY	15	15	15	15
Fusilade/ Fusion	2	2	2	NR	2	2	2	2	2	NR	NR	1	1	1	1	NR	2	2	2	2	2	2	2	2	2	2
Glyphosate products	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	NR	NR	NR	NR
Goal/ GoalTender	2	1	2	0.25	2	10	10	1–2	2–3[1]	4[1]	2	2	1[9]	2	2	0.25	10	3	10	2	1[9]	1–2[1]	2	10	10	10
Gramoxone/ paraquat	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
GrazonNext HL	24B	24B	24B	24B	24B	12	24B	24B	24B	24B	24B	24B	24B	24B	24B	24B	12	24B	12	24B	24B	24B	24B	12	12	12
Grazon P+D	B	B	B	B	B	B	8	B	B	B	B	B	B	B	B	B	8	B	B	B	B	B	B	2	2	2
Halex GT	10	18	18	10	18	NR	NR[10]	18	18	18	10	10[1]	18	18	10[1]	10	4.5	18	NR	10	18	18	10	4.5	4.5	4.5
Harmony Extra SG	1.5	1.5	1.5	0.5	1.5	0.5	0.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	NR	1.5	NR
Harmony SG	1.5	1.5	1.5	0.25	1.5	NR	NR	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	NR	NR	1.5	1.5	1.5	1.5	1.5	1.5	NR	1.5	NR
Harness	9	SY	9	NS	SY	NR	NR[10]	SY	SY	SY	NY	NS	SY	SY	NS	NS	NS	SY	NR	NS	SY	SY	NS	NS	NS	4
Harness Max	10	18	18	10	18	NR	NR[10]	18	18	18	18	18	18	18	18	10	NY	18	18	18	18	18	18	NY	NY	4
Harness Xtra	SY	SY	SY	NS	SY	NR	NS	SY	SY	SY	SY	SY	SY	SY	SY	NS	SY	SY	NR	SY	SY	SY	SY	SY	SY	SY
Hornet WDG	10.5[1]	26B	26B	18	26B	NR	12	10.5[1]	26B	26B	18	18[16]	26B	26B	18[16]	10.5	4	26B	18[16]	18	26B	26B	18	4	4	4

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Huskie	4[1]	1	1	1	1	4	0.25	1	1	9[1]	1	9	1	1	9	4	1	1	1	1	1	1	9	0.25	1	0.25
Impact Core	9	18	18	10	18	NR	9	18	18	18	10	18	18	18	18	10	9	18	NR	18	18	18	10	9	9	4
Instigate	18	18	18	10	18	NR	10	18	18	18	10	10[1]	18	18	10[1]	10	9	18	10	10	18	18	10	4	4	4
Karmex	24	24	24	NR	24	NY	NY	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Kerb[1]	NR	3–6	NR	3–5	3–6	12	12	3	3–6	3–6	12	3–4	3–6	3–6	3–4	3–4	12	3–6	12	12	3–6	3–6	3	12	12	12
Keystone NXT	SY	18	SY	NY	18	NR	NY	SY	18	18	SY	SY	18	18	18	NY	SY	18	NR	SY	18	18	SY	15	15	15
Laudis	10	18	18	10	18	NR	10	18	18	8[1]	11	10	18	18	10	8	4	18	NR	12	10	18	10	4	4	4
LeadOff (1.5 oz)	10	18	10[1]	1	10	NR	10	18	18	18	1.5	10	18	18	10	1[1]	9	18	10	1.5	1	18	1	3	3	3
Lexar/Lexar EZ	18	18	18	NY	18	NR	NR[10]	18	18	18	NY	18	18	18	18	NY	NY	18	NR	18	18	18	18	NY	NY	NY
Liberty	6	2.3	6	NR	6	NR	6	6	6	2.3	6	6	6	6	6	NR	2.3	6	NR	6	6	18	2.3	2.3	2.3	2.3
Lightning	9.5	40B	40B	9.5[1]	40B	8.5[8]	18	9.5	40B	40B	9.5	9.5	40B	40B	9.5	9	18	40B	18	9.5	40B	40B	26	9.5	4	4
Lorox/Linex	4	4	4	4	4	NR[1]	NR[1]	4	4	4	4	4	4	4	4	NR[1]	4	4	4	4	4	4	NR[1]	12	4	4
Lumax/Lumax EZ	18	18	18	NY	18	NR	NR[10]	18	18	18	NY	18	18	18	18	NY	NY	18	NR	18	18	18	18	4.5	4.5	4.5
Marvel	18	18	18	NR	18	10	18	18	18	18	10	10	4[9]	18	NR	NR	4	18	18	18	4[9]	18	NR	4	4	4
Matrix	4	12	18	10	10	NR	18	10	18	10	18	8	12	12	10	4	9	18	10	18	NR	12	NR	12	12	4
Maverick	18	18	18	18	18	NR	18	18	18	10	18	18	18	18	18	10.5	18	18	NR	18	18	18	18	18	18	4-6
Metribuzin products	4	18	18	18	18	4	18	18	18	18	18	8	18	18	18	4	18	18	4	18	4	18	12	4[1]	18	4[1]
Milestone	24B	24B	24B	24B	24B	12	24B	24B	24B	24B	24B	24B	24B	24B	24B	24B	12	24B	24B	24B	24B	24B	24B	12	12	12
Optill[1]	4	40B	4	18	18	8.5[8]	18	4	40B	40B	4	4	18	40B	4	0–1	18	40B	18	9.5	18	40B	26	9.5	4–18	4[8]
Osprey	10	10	10	3	10	3	3	10	10	10	3	3	10	10	10	3	10	10	10	10	10	10	10	1	10	0.25
Outlook[1]	4–6	6–9	6–9	4	6–9	NR	NR[10]	6–9	6–9	6–9	NR	4	6–9	6–9	6–9	NR	4	6–9	NR	6–9	6–9	6–9	6–9	4	4	4
Outrider	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	3B	NR
Overdrive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PastureGard HL	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	4	NI	NI	NI	NI	NI	NI	4	NI	4

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Peak (0.25 oz)[1]	22	22	22	10	22	1[8]	1	22	22	22	10	10	22	22	10	10	NR	22	10	10	22	22	22	NR	NR	NR
Permit	9	15	9	4	2	1[8]	2	NI	9	18	6	9	10	9	2	9[1]	2	9	3	36	2	9	9	2	2	2
Permit Plus	9	15	9	4	2	1	2	NI	9	18	6	9	10	9	2	9[1,14]	2	9	3	36	2[9]	9	9	2	2	2
Perpetuo	10	18	18	2–4	18	NR	6–8[1]	11	18	18	2–4[1]	9–11[1]	18	18	11	NR	18	18	8	18	18	18	4	18	18	1–4
Poast	NR	NR	NR	NR	NR	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	30	NR	1[7]	NR	NR	NR	NR	1	1	1
PowerFlex HL	9	12	12	3[1]	12	9	3	12	12	12	9	9	12	12	12	3[1]	9	12	9	12	12	12	9	9	12	1
Prefar[1]	4	NR	4	4	NR	4	4	4	NR	NR	4	4	NR	NR	4	4	4	NR	4	4	NR	NR	4	4	4	4
Prefix	18	18	18	1	12	10	18	4	12	18	4	4	10[9]	10	NR	NR	4.5	12	10	18	10[9]	10	1	4.5	4.5	4.5
Princep 4L	SY	SY	SY	NY	SY	NR	NY	SY	SY	SY	NY	SY	SY	SY	SY	NY[17]	SY	SY	NY	SY	SY	SY	SY	NY	NY	NY
Prowl H2O	6[1]	NY	NY	NR	NY	NR[18]	NY	NR	NR	NY	NR	NR	NR[1]	NY	NR	NR	NY	NR	NR[18]	NR[1]	NR[1]	NR	NR[1]	4[1]	NY	4[1]
Pursuit[1]	4	40B	4	18[19]	40B	8.5[8]	18	NR	40B	40B	NR	NR	18[9]	40B	2	NR	18	40B	18	9.5	40B[9]	40B	26[1]	9.5[1]	4	4
Python	4	26B	9	18	26B	NR	12	4	26B	26B	4	4	26B	26B	4[1]	NR	4	26B	18[1]	9	26B	26B	12	4	4	4
Raptor	3	9	18	9	9	8.5[8]	9	NR	9	9	9	NR	9	9	NR	NR	9	9	8.5	9	9	9	9[1]	9[1]	4	3
Realm Q	10	18	18[1]	10	18	NR	10	18	18	18	10	10[1]	18	18	10[1]	10	9	18	10	10	18	18	10	4	4	4
Reflex	18	18	18	NR	12	10	18	4	12	18	4	4	10[9]	10	NR	NR	4	12	10	18	10[9]	10	NR	4	4	4
Remedy Ultra[30]	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Resicore	10.5[28]	18	18	12	18	NR[28]	10.5[28]	18	18	18	18	18	18	18	18	10.5[28]	10.5[28]	18	10.5	18	18	18	18	10.5[28]	10.5[28]	4
Resolve SG (1 oz)	10	18	10[1]	1	10	NR	10	18	18	18	18	10	18	18	10	10[14]	9	18	10	18	1	18	NR	9	18	3
Resolve Q (1.25 oz)	10	18	10[1]	1	10	NR	10	18	18	18	1.5	10	18	18	10	2[1]	9	18	10	1.5	1	18	NR	3	3	3
Resource	1	1	1	1	1	NR	1	1	1	1	1	1	1	1	1	NR	1	1	1	1	1	1	1	1	1	1
Reviton (2 oz)	5	5	5	0.5	5	NR	5	5	5	5	5	5	5	5	5	0.25	5	5	5	5	5	5	5	5	5	NR
Revulin Q	10[1]	18	18	10	18	NR	10[1]	18	18	18	18	18	18	18	18	10	8	18	10[20]	18	18	18	10[1]	4	4	4
Ro-Neet	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH
Sandea	9	15	9	4	2	1[8]	2	36	9	18	6	9	10	9	2	9[1]	2	9	3	36	2	9	9	2	2	2
Scepter[1]	18	18	18	18	18	9.5[13]	11	11	18	18	11	18	18	18	11	NR	11	18	18	9.5	18	18	18	11	18	3

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Select/Select Max	NR	NR	NR	NR	NR	0.2	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	1	1	NR	NR	NR	1	1	1
Sentrallas	4	4	4	4	4	NR	NR	4	4	4	4	4	4	4	4	4[1]	NR	4	4	4	4	4	4	NR	4	NR
Sequence	4	NY	9	NR	NI	NR	NR	NR	NI	NI	NI	NR	NY	NI	NR	NR	4.5	NI	NI	NY	6[1]	NI	NY	4.5	4.5	4.5
Sharpen (1 oz)[1]	4	4	4	1.5	4	NR	NR	4	4	4	4	NR	4	4	4	0–1	NR	4	0.5	4	4	4	4	NR	NR	NR
Shieldex	9	9	12	9	9	NR	9	9	9	12	9	9	12	9	9	9	3	9	NR	12	9	9	9	3	3	3
Sierra[1]	24	24	24	24	24	11	24	24	24	24	24	11	24	24	24	9[14]	24	24	24	24	24	24	9	9	24	NR
Sinate	9	18	18	9	18	NR	9	18	18	18	9	9–18[1]	18	18	9–18[1]	9	3	18	NR	18	18	18	9	3	3	3
Sinbar	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Solicam	16	24B	24B	1–16[1]	24B	24B	24B	24B	24B	24B	1–16[1]	24B	24B	24B	24B	1.5–16[1]	24B	24B	24B	24B	24B	24B	24B	24B	24B	24B
Sonalan	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	NR	AH	AH	AH	AH	NR	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH
Spartan	12	NR	12B	18	12B	10	10[1]	NR	12B	12B	12B	12B	12B	12B	12B	NR	12	12B	18	NR	NR[9]	12B	12B	4	4	4
Spartan Charge	12	NR[9]	12B	12–18[1]	12B	4	10[1]	12B[1]	12B	12B	NR	12B	12B	12B	12B	NR	12	12B	12	NR	NR[9]	12B	4	4	4	4
Spin-Aid	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	AH	4	AH	AH	AH	AH	AH	AH	4	4	4
Spirit	18	10	18	10	18	1[8]	10	18	18	18	18	10	18	18	10	10	3	18	8	10	10	18	10	3	3	3
Spur	10.5	NR	10.5B	10.5–18B	10.5–18B	NR	10.5	10.5B	10.5–18B	10.5	10.5B	18B	10.5B	10.5–18B	10.5B	10.5–18	NR	10.5B	NR	10.5B	10.5B	10.5–18B	18B	NR	10.5B	NR
Starane Ultra	4	4	4	4	4	NR	NR	4	4	4	4	4	4	4	4	4[31]	NR	4	NR	4	4	4	4	NR	NR	NR
Status	1[5]	4	4	1[5]	4	0.25	1[5]	4	4	4	4	4	4	4	4	1[5]	1[5]	4	4	4	4	4	4	1[5]	1[5]	1[5]
Steadfast Q	10[1]	18	10[1]	10	10–18	NR	10–18	10–18	10–18	10–18	10–18	10	10–18	10–18	10	0.5	8	10–18	10[20]	10–18	10–18	10–18	10[1]	4	4	4
Stinger	10.5	NR	18	18B	18B	NR	10.5	18B	18B	10.5	18B	18B	18B	18B	18B	10.5[1]	NR	18B	NR	18B	18B	18B	18B	NR	NR	NR
Storm	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	NR	3.3	3.3	3.3	3.3	NR	1.5	3.3	3.3	3.3	3.3	3.3	3.3	1.5	1.5	1.5
Stout	10[1]	18	10[1]	10	18	NR	10	18	18	18	18	10	18	18	10	0.5	8	18	10[20]	18	18	18	10[1]	4	4	4
SureStart/ TripleFLEX	NY[1]	26B	NY[1]	26B	26B	NR	12	26B	26B	26B	26B	NY	26B	26B	26B	NY[1]	NY	26B	18[1]	18	26B	26B	18	NY	NY	4
Surpass NXT	9	NI	9	NY	NI	NR	NR[10]	NY	NI	NI	NI	NY	NI	NI	NY	NY	NY	NI	NR	NY	NY	NI	NY	NY	NY	4

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

Trade Name	Alfalfa	Cabbage	Clover	Cotton	Cucumber	Field Corn	Grain Sorghum	Lima Bean	Muskmelon	Onion	Peanut	Peas	Pepper	Pumpkin	Snap Bean	Soybean	Spring Oat	Squash	Sweet Corn	Tobacco	Tomato	Watermelon	White Potato	Winter Barley	Winter Rye	Winter Wheat
Surveil	10	30B	30B	9	30B	9	9	9	30B	30B	9	9	30B	30B	9	NR	9	30B	18	10[21]	30B	30B	18	30B	30B	3
Synchrony XP[1]	12	18	12	9	18	9	9	30	30	30	15	9	30	18	9	NR	3	30	18	9[9]	9[9]	18	30	3	3	3
Targa	4	4	4	NR	4	4	4	4	4	4	4	NR	4	4	NR	NR	4	4	4	4	4	4	4	NR	4	NR
Tavium	6	6	9	1.4[1]	12	NR	6	6	12	6	6	6	6	6	6	1[1]	4.5	12	NR	NY	6	12	6	4.5	4.5	4.5
Treflan	NR	NR	5	NR	5	12–14[33]	12–14[33]	NR	5	5	NR	NR	NR[9]	5	NR	NR	12–14[33]	5	12–14[33]	5	NR	5	NR	NR	NR	NR
Trivence	10	18	18	18	18	10[1]	18	30	30	30	18	12	30	18	30	NR	18	30	18	18[9]	12[9]	18	30	4	30	4
TriVolt	17	17	17	10	17	NR	17	17	17	17	12	17	17	17	17	9	17	17	9	17	17	17	17	12	12	4
Ultra Blazer	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	NR	3.3	3.3	3.3	3.3	NR	1.3	3.3	3.3	3.3	3.3	3.3	3.3	1.3	1.3	1.3
Valor SX/Valor EZ (up to 3 oz)	5[11]	6–12B	5[11]	2[11]	6–12B	0.5–1[1]	1	6–12B	6–12B	6–12B	NR	4	6–12B	6–12B	4	NR	5[11]	12	4	2[11]	6–12B	6–12B	5[11]	4	4	2[11]
Valor XLT[22]	12	18	12	10	18	10	10	18	18	18	18	12	18	18	12	NR	18	18	18	10[9]	12–18[9]	18[1]	18	4	4	4
Varisto	3	9	18	9	18	8.5[29]	9	NR	9	9	9	NR	9	9	NR	NR	9	9	8.5	9	9	9	9[29]	9[29]	4	3[29]
Verdict	7	7	7	6	7	NR	NR	7	7	7	7	4	7	7	7	NR	4	7	4	7	7	7	7	4	4	4
Vida	1	1 day	1	NR	1 day	NR	1 day	1 day	1 day	1 day	1	1 day	1 day	1 day	1 day	NR	1 day	1 day	1	1	1 day	1 day	NR	1 day	1 day	NR
Warrant	9	NI	9	NR	NI	NR	NR[10]	NY	NI	NI	NR	SY	NI	NI	NY	NR	NY	NI	NY	NY	NI	NI	NY	NY	NY	4
Warrant Ultra	18	NI	18	1	NI	10	18	NY	NI	NI	10	10	NI	NI	NY	NR	4	NI	12	NI	NI	NI	NI	4	4	4
XtendiMax[1]	4	4	4	1[1]	4	NR	0.5[1]	4	4	4	4	4	4	4	4	1	1	4	4	4	4	4	4	1	1	1
Yukon	9	15	9	4	9	1[8]	2	NI	9	18	6	9	10	9	2	9[1]	2	9	3	NI	2[9]	9	9	2	2	2
Zeus XC	12	NR[9]	12B	18	12B	10	10[1]	NR	12B	12B	4	NR	12B	12B	12B	NR	12	12B	18	NR	12B[9]	12B	12B	4	4	4
Zidua/ Zidua SC (3 oz or 5 fl oz)[1]	10	18	18	4	18	NR	10	11	18	18	4	11[1]	18	18	11	NR	11	18	NR	18	18	18	4	11[1]	11[1]	4[1]
Zone Defense	12	4[34]	4[34]	18	12	10	10	4[34]	4[34]	12	NR	4[34]	12	12	12	NR	12	12	18	1	4[9,34]	4[34]	4[34]	4	4	4

AH = after harvest, B = bioassay of soil recommended before planting, NI = no information, NR = no restrictions, NS = next season, NY = next year, SY = second year following application.

The information listed in this rotation restriction table is our interpretation of label statements. Consult the label if two or more of these materials are applied during the same season. Herbicide labels are constantly changing; therefore, this list is not a substitute for the most recent herbicide label.

[1] Read the label for additional restrictions due to application rate, timing, geographical region, rainfall, soil pH, tillage, variety, or supplemental labeling.

[2] 18 months with a soil pH > 6.5. At rates greater than 2.1 oz/A, a rotation interval of 30 months and a successful field bioassay are required.

[3] Rotation interval for lima bean is 18 months if Armezon PRO is applied at greater than 20 fl oz/A. Rotation interval for pea and snap bean is extended to 18 months if Armezon PRO is applied at greater than 25 fl oz/A.

Table 2.1-11. Herbicide rotation restrictions (months after application) for cash crops (continued).

[4] Cotton may be planted after 12 months where Authority Elite/BroadAxe was applied at rates less than 36 oz/A, Authority MTZ DF at rates less than 17 oz/A, or Authority First/Sonic at rates less than 5 oz/A and the following conditions are met: medium and fine soils, pH < 7.2, and rainfall or irrigation must exceed 15 inches after herbicide application and prior to planting cotton.
[5] Following application of Clarity and a minimum of 1 inch of rainfall or overhead irrigation, a waiting interval of 21 days is required per 8 fl oz/A applied prior to planting cotton, 30 days per pint restriction for soybean, and 20 days per pint restriction for small grains. If less than 1 inch or rainfall or irrigation is received after application and Status is applied at greater than 5 oz/A, the rotation interval is 4 months.
[6] If Basis rate is 0.33 to 0.5 oz/A or Basis Blend rate is 1.25 oz/A, alfalfa, sorghum, pea = 18 months; soybean, snap bean = 10 months; STS soybean = 1 month; spring oat = 9 months; if Basis rate is greater than 0.5 oz/A or Basis Blend rate is 2.5oz/A, cotton = 10 months and 18 months if greater than and less than 15 inches of rainfall or irrigation occur after application and prior to planting, respectively; STS soybean = 4 months; if Basis rate is 0.33 oz/A or Basis Blend rate is 0.825, soybean = 0.5 month.
[7] NR for Poast Protected corn hybrids.
[8] NR for IMI (IR/IT) or Clearfield (CL) varieties.
[9] Transplanted.
[10] Use safener with seed.
[11] Cotton may be planted no-till or strip-till after 14 or 21 days when applied at 1 oz/A or 1.5 to 2 oz/A, respectively. For winter wheat, at rates up to 2 oz/A, the rotation interval is 7 days for no-till or minimum-till wheat and 30 days for conventional-till wheat. At least 1 inch of rainfall/irrigation must occur between application and cotton, field corn, grain sorghum, tobacco, or wheat planting, or crop injury may occur. For alfalfa, clover, potato, and spring oats the rotation interval is 5 months if the soil is tilled prior to planting or 10 months if no tillage is preformed prior to planting. At lower rates of Valor/Rowel/Chateau, rotation interval for many crops is reduced. Chateau may be applied to potato following hilling at a rate of 1.5oz/A. Consult labels for more specific information.
[12] Command may be applied preemergence to cotton only if Di-Syston or Thimet insecticides are applied in furrow with the seed at planting.
[13] Corn hybrids that are classified as IMI-corn or as tolerant (IT) or resistant (IR) may be planted in the spring of the year following regardless of rainfall or time interval from chemical treatment to corn planting. Rotation interval varies by tillage type and use rate. Consult the label for specific rotation intervals.
[14] Rotation interval is shorter for STS soybean.
[15] Transplanted tobacco = 10 months if ≤ 0.3 oz/A.
[16] If Hornet WDG rate is < 4 oz/A, snap beans, peas, and some varieties of sweet corn = 10.5 months.
[17] If no more than 2 lb ai applied the previous year.
[18] Regardless of tillage, be sure to plant corn at least 1.5 inches deep and completely cover with soil.
[19] Cotton may be planted 9.5 months following Pursuit if all of the following criteria are met: Pursuit is applied to peanuts only; soil texture is sandy loam or loamy sand only; and greater than 16 inches of rainfall/irrigation is received following application of Pursuit through October of the application year.
[20] The rotation interval for the sweet corn varieties 'Merit', 'Carnival', and 'Sweet Success' is 15 months.
[21] Transplanted tobacco may be planted 10 months after application of 2.1 oz/A of Surveil. Tobacco in seeded nurseries may be planted 18 months after application of 2.1 oz/A of Surveil and following a successful field bioassay. At rates greater than 2.1 oz/A, a rotation interval of 30 months and a successful field bioassay are required.
[22] Rotation intervals based on soil pH less than 7.0. In Pennsylvania, rotation interval for clover, lima bean, muskmelon, onion, pepper, spring oat, squash, and white potato is 18, 30, 30, 30, 30, 30, 30, and 30 months, respectively. Consult seed corn agronomist regarding inbred sensitivity to Valor XLT/Rowel FX prior to planting inbred seed corn lines.
[23] If applied after June 1, rotating to crops other than corn (all types) may result in crop injury.
[24] For Bolt or non-Bolt soybean and minimum- or no-till field corn, if Afforia is used on coarse textured soils, such as sands and loamy sands, or on high-pH soils (>7.9), extend time to planting by 7 additional days. For minimum- or no-till wheat in the states of DE, MD, NJ, or VA, Afforia may be applied at a minimum 7 days before planting. Do not us on Durum wheat and do not irrigate between emergence and spike. Wheat must be planted at least 1 inch deep. Do not graze until wheat has reached 5 inches in height. For conventional-till field corn, grain sorghum, cotton, and wheat, at least 1 inch of rainfall/irrigation must occur between application and planting or crop injury may occur. For alfalfa, cabbage, clover, cucumber, lima bean, muskmelon, onion, pepper, pumpkin, spring oat, squash, sweet corn, tobacco, tomato, watermelon, and white potato, the rotation interval is 4 months if the soil is tilled prior to planting. If no tillage is performed prior to planting these crops, the rotation interval is extended to 8 months.
[25] Rotation interval for spring oat, or winter barley at 5.7 oz/A or greater rates is extended to 18 months. For winter wheat, at 5.7 oz/A or greater rates, the rotation interval is extended to 6 months.
[26] Seed corn inbred lines vary in sensitivity to herbicides; therefore, users should seek advice from seed corn agronomist regarding inbred sensitivity to Canopy Blend prior to planting inbred seed corn.
[27] For onion, the rotation interval for irrigated and nonirrigated is 8 and 18 months, respectively.
[28] For corn, if the original corn crop is lost, do not make a second application. Injury may occur to soybean planted the year following application on soils having a calcareous subsurface layer if products containing atrazine were used at rates greater than 0.75 lb/ai atrazine per acre in tank mixtures and/or sequentially with Resicore. If Resicore is applied after June 1, rotating to crops other than corn or grain sorghum the next spring may result in crop injury.
[29] NR for Clearfield corn (field and seed). For wheat, planting non-Clearfield cultivars in areas receiving less than 10 inches of precipitation from time of application up until wheat planting may result in wheat injury. Injury potential increases if less than normal precipitation occurs in the 2 months just after Varisto application. For barley, the rotation interval at pH > 6.2 and > 18 inches of rainfall/irrigation, pH < 6.2 and < 18 inches of rainfall/irrigation and with moldboard plowing, and pH < 6.2 and < 18 inches rainfall/irrigation and without moldboard plowing is 9, 9, and 18 months, respectively. For potato, the rotation interval at pH > 6.2 and > 18 inches of rainfall/irrigation and pH < 6.2 and < 18 inches of rainfall/irrigation is 9 and 18 months, respectively.
[30] Rotation information is unknown for this product. Contact manufacturer for recommendations.
[31] In Delaware and Virginia, a Special Local Needs Label 24(c) has approved a 3-month plant-back restriction for soybean after an application to winter wheat.
[32] NR for Enlist varieties.
[33] In areas receiving 20 inches of rainfall or irrigation; 12 months after a spring application or 14 months after a fall application of Treflan 4L or 4EC. Labelled for these crops or after crop plants have emerged.
[34] Rotation is 8 months in no-till.

sensitive to large-seeded species like winter annuals, hairy vetch, or Austrian winter pea.

Herbicide-Resistant Crops

Herbicide-resistant crops are available for use in crop production systems. Corn, soybean, sorghum, alfalfa, and canola varieties are currently the key agronomic crops with herbicide resistance that can be grown in the Northeast. Herbicide resistance in crops results from two different procedures: tolerance selection and genetic engineering techniques. Tolerance selection involves selecting naturally occurring herbicide-tolerant cells from a particular crop cultivar or cell culture and incorporating them into crop varieties and hybrids using traditional breeding techniques. Genetically engineering herbicide-resistant plants (also called a GMO) involves transferring a gene with a certain trait from one organism to another (e.g., from bacteria to plant) using complex technology. The transferred genetic trait(s) is then incorporated into crop varieties using breeding techniques. (The same genetic engineering technology is used to create crop protection against insect pests—e.g., Bt corn.) Several crop protection chemical companies and seed companies are involved in developing and marketing these crops. Following is a brief summary of the herbicide-resistant corn and soybean varieties currently available or soon to be released. See the corn and soybean chapters of this guide for detailed information on herbicide use for these crops.

Clearfield (CL) corn is non-GMO that was developed by tolerance selection to be resistant to imidazolinone herbicides (e.g., Pursuit, Scepter). Although these hybrids initially were introduced to help manage herbicide carryover, Pursuit and Pursuit-containing products such as Lightning can be applied directly to the CL corn hybrids as part of the weed management program.

Enlist corn and soybean are genetically engineered (GMOs) to resist 2,4-D. In addition to 2,4-D resistance, Enlist corn is resistant to the aryoxyphenoxy-propionate herbicides (fops), such as Assure II (quizalofop). Enlist corn and soybean are also stacked with Roundup Ready and LibertyLink traits. A new low-volatility 2,4-D formulation (2,4-D choline or Colex-D) has been developed for use with this technology and is available as Enlist One (2,4-D) and Enlist Duo (2,4-D + glyphosate).

Inzen Z herbicide-tolerant sorghum is a non-GMO trait that provides tolerance to certain Group 2 or ALS-inhibitor herbicides. Zest WDG (nicosulfuron) from Corteva is the product that is co-marketed with Inzen Z sorghum.

LibertyLink (LL) corn and soybean are genetically engineered (GMOs) to allow over-the-top applications of Liberty (glufosinate) herbicide. This program provides broad-spectrum control of annual broadleaves and grasses of low to moderate pressure. Sequential applications or tank mixtures may be required for new weed flushes and perennials.

Roundup Ready alfalfa, corn, canola, and soybean were developed using genetic engineering techniques (GMOs). They have an altered target site not sensitive to glyphosate and allow postemergence applications of glyphosate directly to alfalfa, corn, canola, and soybean. Glyphosate-resistant weeds are becoming an increasing issue in Roundup Ready crops.

The STS and BOLT soybean/herbicide systems enhance crop safety from certain sulfonylurea herbicides such as Harmony (thifensulfuron) and Classic (chlorimuron). STS is a non-GMO, but Bolt also includes the GMO glyphosate-resistant trait. Although these varieties were developed to be used in combination with STS-labeled herbicides, they also provide greater safety from many of the ALS (Group 2) herbicides. The BOLT herbicide-resistance trait provides enhanced resistance to additional herbicides such as Basis Blend (rimsulfuron).

XtendFlex soybeans are genetically engineered (GMOs) to allow over-the-top application of dicamba, glufosinate, and glyphosate. Three different dicamba-containing products (Engenia, XtendiMax, Tavium) are specially formulated for reduced drift and labeled for Xtend soybean. All other dicamba products are not allowed. In addition, a number of stewardship guidelines are required, including using low-drift nozzles, at least 15 GPA carrier, and making applications only when certain environmental conditions exist to reduce the potential for off-site movement. In the Mid-Atlantic region, this technology is best suited for burndown application in no-till for control of winter annual weeds, including horseweed/marestail. Over-the-top application and use in double-crop soybean are not encouraged due to greater concern for off-target movement.

Herbicide-Resistant Weeds

A number of weed species that once were susceptible to and easily managed by certain herbicides have developed resistance. These weeds are no longer controlled by applications of previously effective herbicides. As a result of repeated use of a certain type of herbicide on the same land, many different species of weeds have developed resistance to these chemicals. Globally, resistance has developed in all herbicide modes of action in about 262 weed species and the number of species continues to increase each year. (More information about herbicide-resistant weeds and herbicide modes of action can be found at weedscience.org.) It is believed that within any population of weeds, a few plants have sufficient tolerance to survive any herbicide that is used. Since only the survivors can produce seed, it is only a matter of time until the population of resistant weeds (or biotypes) outnumbers the susceptible type. Depending on the herbicide family and weed species, resistance can occur within five to 20 years.

Table 2.1-12. Weed species prone to resistance and of concern in the Mid-Atlantic region.

	WSSA Site of Action Number															
	1	2	3	4	5	6	7	8	9	10	11	13	14	15	22	27
Broadleaf Species																
Amaranth, palmer		■	▒	▒	▒				■				▒	▒		▒
Chickweed, common		■		▒	▒											
Horseweed/marestail		■			▒		▒		■						■	
Lambsquarters, common		▒			■				▒							
Pigweed, redroot/smooth		■			■	▒	▒		▒				▒			
Ragweed, common		■			▒		▒		■				■			
Ragweed, giant		▒							▒							
Waterhemp		▒		▒	▒				▒				▒			▒
Grass Species																
Barnyardgrass	▒	▒	▒	▒	■		▒	▒	▒			▒		▒		
Foxtail, giant	▒	■			■											
Goosegrass	▒	▒	▒		▒				▒				■		▒	
Johnsongrass	■	■	▒						▒							
Ryegrass, Italian	■	■					▒		▒	▒	▒			▒	▒	
Shattercane		■														

■ Species confirmed to be resistant to a particular site of action in the Mid-Atlantic United States

▒ Species confirmed to be resistant to a particular sit of action worldwide

Reasons or mechanisms for resistance vary depending on the herbicide family. Resistant biotypes may have slight structural or biochemical differences at the cellular level from their susceptible counterparts that make them less sensitive to certain herbicides, and therefore they are not killed. Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help when designing programs that prevent the introduction and spread of herbicide-resistant weeds.

Growers, consultants, and those working with herbicides to manage weeds should know which herbicides are best suited to combat specific resistant weeds. The Weed Science Society of America (WSSA) developed a grouping system to help with this process. Herbicides that are classified as the same WSSA group number kill weeds using the same mode of action. Therefore, choose a combination of different herbicide modes of action that each contribute to the control of the target weeds. In other words, make sure to have at least two unique modes of action that are effective against the same weed during the season whether in tank mixtures or sequential applications. Try to avoid using the same products and herbicide mode of action every year. This is especially important on weeds that are typically prone to resistance such as pigweed species, common lambsquarters and ragweed, horseweed, and foxtail species (Table 2.1-12). WSSA group numbers can be found on many herbicide product labels (Figure 2.1-5) and used as a tool to choose herbicides in different mode of action groups so mixtures or rotations of active ingredients can be planned to better manage weeds and resistant species. Keep in mind that many products contain similar active ingredients even though the products may have different trade or brand names. Using a different product or brand does not guarantee that you are selecting a different herbicide mode of action. Refer to Table 2.1-7 for herbicide, or WSSA, mode of action group numbers and corresponding herbicides. Other resources, such as university pest guides or recommendations, can provide effectiveness ratings of numerous herbicides on many different weed species to help with this process of developing appropriate weed management programs.

Figure 2.1-5. Herbicide group numbers on product labels.

Dependence on a single strategy or herbicide family for managing weeds will increase the likelihood of additional herbicide resistance problems in the future. Management programs to combat herbicide resistance should emphasize an integrated approach. Some management guidelines for an integrated approach include using herbicide tank mixtures containing more than one herbicide mode of action that are active on similar weeds, shorter residual herbicides, crop rotations that allow for application of different herbicide classes, judicious and noncontinuous use of herbicide-resistant crops in a rotation, nonchemical control measures, and combinations of weed management techniques such as avoiding spreading resistant weed seed with machinery or in manure and ensiling to help destroy weed-seed-infested forage.

Reducing the risk for developing herbicide-resistant weed populations requires incorporating a number of guidelines in managing your fields.

- Spray only when necessary.
- Use alternative methods of control whenever possible such as mechanical cultivation, cultural tactics such as delayed planting (row crops) or use of cover crops, mowing (forage crops), and preventive methods such as use of weed-free seed.
- Rotate crops and their accompanying herbicides' site of action.
- Limit the number of applications of herbicide(s) with the same site of action in a given growing season.
- Use mixtures or sequential herbicide treatments having different sites of action that will control the weeds of concern.
- Scout fields after herbicide application to detect weed escapes or shifts.
- Clean equipment before leaving fields infested with or suspected to have resistant weeds.

Insect Management

Successful insect pest management must be based on knowing (1) what insect species are likely to be pests; (2) when these species are usually active; (3) whether these insect species are present in your fields; and (4) whether these insects are occurring in economically damaging populations. The first two items can be learned from a variety of sources, including this guide, other extension publications, fellow agricultural workers, and on-farm experience. However, growers must keep in mind that insect populations are dynamic, changing with time—just because an insect species was problematic last year does not mean it will be problematic again. The same rationale applies to historically relevant pest species. For example, in recent years populations of European corn borer, which historically has caused significant yield loss in Pennsylvania corn fields, appear to be near historic lows, likely due to widespread adoption of transgenic Bt varieties. Thus, conventional wisdom for managing particular pest species needs to be revised when the populations decrease substantially. Search for the most current information on particular pest species and call your extension office if you cannot find the information you seek. The latter two items (pest presence and population size) can only be learned by walking fields, inspecting crop plants, and sampling for insects and/or their damage.

Scouting for insect pests and their damage is a vital part of an integrated pest management (IPM) program and is usually the only way to determine whether an economically damaging population of an insect pest species is present.

The main goal of IPM is keeping pest populations below an economically important level (see Figure 2.1-3 and associated text); therefore, failing to regularly assess pest levels could cause you to miss an opportunity to treat an infestation and keep it below the economic injury level. Conversely, basing treatments on a calendar, gut feeling, or the potential of a threat could lead to unnecessary treatments.

Besides wasting time and money, unnecessary insecticide applications can have detrimental side effects, particularly the killing of beneficial insect species. For example, pollinators of different types (e.g., honey bees, bumble bees, butterflies, flower-visiting flies) can be abundant in agricultural fields, particularly when soybean, alfalfa, and clover are in bloom, but generally speaking any time pollen is available. Unfortunately, these flower-visiting insect species tend to be more sensitive to many insecticides than the insect pest species themselves and are easily killed by unnecessary or poorly timed insecticide applications. (Most insecticides are highly toxic to bees, as stated on the label, but other beneficial insects are often similarly susceptible.)

Unnecessary applications, such as insurance sprays or unjustified tank-mixes of insecticides with other agricultural chemicals, can be particularly hard on insect predators and parasitoids, which can provide important levels of natural control. Killing these valuable natural enemies can lead to outbreaks of secondary pests, which are typically kept in check by these natural control agents, or even promote a resurgence of the target pest species because populations of plant-feeding insects tend to recover from insecticide applications more quickly than natural enemy populations.

Some crop species (e.g., soybean and alfalfa) can harbor large populations of natural enemies, but using a variety of IPM tactics can also promote predators and parasitoids in agricultural settings. Woodlots, meadows, conservation lands, and field borders with a diversity of plant species can support large natural enemy populations that will move into adjacent agricultural fields. Of course, these areas can also harbor pest species (e.g., bean leaf beetles, cutworms, groundhogs), so their benefits need to be evaluated, but university-based research has documented that on-balance these habitats are

beneficial. Similarly, research in England has shown that strips of natural vegetation in agricultural fields (i.e., "beetle banks") can significantly contribute to natural enemy populations, which can kill plant-feeding insects and even consume weed seeds. Natural enemy-populations can also be bolstered by agronomic practices such as reduced tillage and cover crops, which minimize disturbance and provide hospitable habitats for predators and parasitoids.

Natural enemies can also be conserved by insecticide selection and usage. Some insecticides can have a small negative influence on predators and parasitoids when compared to the target pest (e.g., Bt, seed treatments, insect growth regulators, azadirachtin, spinosad). Using lower rates of insecticides can also be useful, decreasing the impact the chemicals have on "good" insects. Lastly, timing of applications can reduce their severity. For example, many pollinators and natural enemies are often more active in the morning. Therefore, applications later in the day can help conserve these beneficial insect species.

Disease Management

Successful disease management should start with cultural practices, and chemicals should be used only as needed. Best management practices that help reduce disease occurrence and severity include using hybrids or varieties with genetic resistance to common diseases, certified seed, crop rotation, residue management, soil fertility, proper drainage, and good sanitation. Though the use of these practices will not control all diseases, their combined effects will help minimize many of the yield-limiting diseases.

The use of genetically resistant hybrids or varieties can help manage diseases that are known to occur. Many disease resistance genes confer more than one trait to the plant that can withstand changes in pathogen populations and ensure some protection from yield loss. In some cases, the disease resistance was based on a single gene, and changes in pathogen populations resulted in catastrophic failures (e.g., the Irish potato famine due to late blight in the 1840s, wheat stem rust in 1917, and corn hybrids carrying T-cytoplasms in 1970–1971 by southern corn leaf blight). History may again repeat itself if the UG99 strain of wheat stem rust makes it to the United States. Currently, UG99 has overcome the defensive genes of about 90 percent of the wheat planted around the world, with fungicide application being the only method of controlling this yield-limiting disease until resistance can be found.

Since many diseases can be spread by seed, the use of certified seed has reduced the introduction of diseases. Many pathogens of field crops can survive the off-season, or overwinter, on infected crop debris (stalks, leaves, and/or roots). The use of crop rotation from a susceptible host to nonsusceptible crops allows time for normal competition from the environment and other microbes to reduce the pathogen population (corn to soybeans to wheat versus continuous corn). The use of residue management, whether complete tillage, light disking, or vertical tillage, that helps get crop residue to the soil surface increases the decomposition rate and reduces inoculum levels.

Soil fertility directly affects plant growth and development as well as host defenses. Plants that are under nutritional stress or imbalance are more likely to be affected by diseases; therefore, regular soil testing is advised to maintain adequate soil fertility. Excessive nitrogen application can also increase disease development by causing a flush of lush growth, increasing canopy humidity, and growing faster than plant defenses can develop.

Available water and high humidity are two very important factors in disease development. Areas of compaction, such as head rows where trucks or wagons have been parked, can lead to poor drainage. These areas can be hot spots for seedling and root diseases. Wet spots or areas of standing water during the spring or fall are indications of poor soil drainage and are likely areas for disease development. Fields in valleys, near rivers, or near woods can often have fog or longer durations of dew and high humidity. These can be places where diseases will start since available water is essential for disease development. Although we cannot control the environment, the choice of resistant hybrids or varieties and row spacing (wider rows reduce canopy humidity) may help reduce disease severity.

Good sanitation practices can help prevent the spread of disease issues from one field to another. Soilborne pathogens such as the fungi that cause white mold and soybean sudden death syndrome can be moved by tillage and other field operations to previously uninfested areas. Once proper diagnosis is made of one of these soilborne diseases, care should be taken to be sure that equipment is cleaned before moving on to another field.

Fungicides and Fungicide Resistance

Fungicides are very useful tools when necessary. Often, low levels of disease never reach an economic threshold to warrant application, but under certain situations chemicals are necessary. The main concern with fungicide application is the development of resistance or tolerance to a chemical group. Due to the quick reproduction of most plant disease-causing agents, there is a high likelihood of resistance occurring if chemical use is widespread.

Many of the older formulations of fungicides relied on multiple modes of action. A product such as sulfur (FRAC Group M), whose mode of action is not well understood, has been used since roughly 1000 BC to control wheat rust and other foliar diseases. Copper (FRAC Group M) has been used as both a fungicide and bactericide since 1807 and is

known to have multiple modes of action. The chloronitriles, a group that includes Chlorothalonil (Bravo, Echo, Equus), are broad-spectrum contact fungicides with multiple modes of action. The multiple modes of action have reduced the likelihood of fungi gaining resistance.

Strobilurins (FRAC Group 11) are a group of site-specific (i.e., targeting one enzyme in the mitochondrial metabolic pathway) fungicides that were originally derived from a wood-rotting fungus found to defend itself against other

fungi. Strobilurins may also be referred to as QoI, or quinone outside inhibitors. These chemicals are considered preventative fungicides that have the ability to control a diverse array of fungal diseases in many crops. Although considered locally systemic, these products are not as systemic as Roundup (which moves throughout the plant to the roots). Strobilurins are often able to move translaminar (from one side of the leaf to the other) or spread throughout the leaf. Strobilurins are very effective fungicides, and strobilurin-resistant fungal isolates have been found in the field.

Triazoles (FRAC Group 3) are also a group of site-specific fungicides that target one enzyme in the ergosterol pathway, an essential pathway in many fungal pathogens. This group of chemicals may also be called DMIs, or demethylation inhibitors. The triazoles are able to both be a protectant and have some curative, or "kick-back," activity. Many of the triazoles are more systemic across the leaf than strobilurins, and some may move into new growth. Triazoles do not move down through the plants. These are extremely effective fungicides, and triazole-resistant pathogens have been found in fields.

A group of chemicals more recently introduced as a tool for field crop disease management is the SDHIs (succinate dehydrogenase inhibitors), or carboximides, which are classified as FRAC Group 7. SDHIs work by preventing fungi from producing the energy they need to complete their life cycles. Like strobilurins, these are considered preventive products and will be most effective when applied before infection or shortly after disease onset. SDHIs are locally systemic in plant tissue. This active ingredient is often used as part of a premixed product that includes other chemistries.

To help reduce the occurrence of fungicide-resistant pathogens, the Fungicide Resistance Action Committee (FRAC) has been formed to (1) identify existing or potential resistance problems; (2) gather and distribute information involved with fungicide research, distribution, registration, and use; (3) provide guidelines and advice on fungicide use to reduce the risk of resistance developing, and to manage it should it occur; (4) recommend procedures for use in fungicide-resistance studies; and (5) stimulate open liaison and collaboration among universities, government agencies, advisers, extension workers, distributors, and farmers. Table 2.1-13 provides all of the FRAC Groups and modes of action. The FRAC Group(s) can be found on the label of all fungicide products for easy identification and to facilitate product rotation.

Pesticides and Their Application

Pesticide Formulations

Pesticides are not sold as pure chemicals but as mixtures or formulations of one or more active ingredients with various additives. Surfactants (emulsifiers, wetting agents, etc.) or various diluents may be used to change the activity of a pure herbicide to the user's advantage. The type of formulation determines toxicity to plants, uniformity of plant coverage, and stability in storage. Pesticides are formulated to permit uniformity and ease of application as liquid sprays or dry granules.

Additional information on pest management in Pennsylvania can be obtained from Penn State Extension's various publications, available online at extension.psu.edu or by calling 1-877-345-0691.

Formulations for Spraying

Emulsifiable concentrates (EC or E) are liquid formulations with an active ingredient that is dissolved in one or more petroleum-based solvents. An emulsifier is added to cause oil to form tiny globules, which disperse in water. The formulation then will mix readily with water for proper application. Emulsifiable concentrates usually contain between 2 and 8 pounds of active ingredient per gallon.

Emulsifiable gels (EG) are herbicides that traditionally are emulsifiable liquids formulated as gels. The gels typically are packaged in water-soluble bags (WSB) and are stable at temperatures ranging from -20 to 50°C. In addition, the gelling process reduces the need for nonaqueous solvents compared to standard nonaqueous EC-type formulation processes.

Wettable powders (WP or W) are finely ground dry particles that may be dispersed and suspended in water. They contain from 25 percent to 80 percent active ingredient. Suspensions of wettable powders appear cloudy. Wettable powders are nearly insoluble and require agitation to remain in suspension. Atrazine and linuron are formulated as wettable powders.

Soluble liquids (SL) and soluble powders (SP) dissolve in water to form a true solution. Once the liquid or powder is dissolved, the spray mixture requires no additional mixing or agitation. However, few pesticides are available as solubles because most pesticide active ingredients are not very soluble in water.

Table 2.1-13. Fungicide modes of action.

FRAC Group	Mode of Action	Chemical Family (Group)	Active Ingredients
1	Mitosis and cell division	Benzimidazoles	thiabendazole
		Thiophanates	thiophanate-methyl
2	Respiration	Iprodione	iprodione
			vinclozolin
3	Sterol synthesis	Imidazoles	imazalil
		Piperazines	triforine
		Pyrimidines	fenarimol
		Triazoles	bitertanol
			cyproconazole
			difenoconazole
			fenbuconazole
			flusilazole
			ipconazole
			metconazole
			myclobutanil
			propiconazole
			prothioconazole
			tebuconazole
			tetraconazole
			triadimefon
			triadimenol
			triticonazole
4	Nucleic acid synthesis	Acylalanines	metalaxyl
			metalaxyl-M (mefenoxam)
7	Respiration	Benzimides	flutolanil
		Pyrazole-4-carboximides	fluxapyroxad
		Pyridinecarboximides	boscalid
			carboxin
			fluoppyram
9	Protein synthesis		cyprodinil
11	Respiration	Methoxyacrylates	azoxystrobin
			picoxystrobin
		Methoxy-carbamates	pyraclostrobin
		Oximino acetates	kresoxim-methyl
			trifloxystrobin
		Oxazolidine-diones	famoxadone
		Dihydro-dioxazines	fluoxastrobin
		Imidazolinones	fenamidone
12	Signaling		fludioxonil
13	Signaling		quinoxyfen

Table 2.1-13. Fungicide modes of action (continued).

FRAC Group	Mode of Action	Chemical Family (Group)	Active Ingredients
14	Lipids and membranes		chloroneb
			dicloran
			quintozene (PCNB)
		1,2,4-thiadiazoles	etridiazole
17	Sterol synthesis		fenhexamid
19	Cell wall synthesis	Peptidyl pyrimidine nucleosides	polyoxin
21	Respiration	Cyanoimidazole	cyazofamid
22	Cell division	Thiazole carboximides	ethaboxam
24	Protein synthesis		kasugamycin
25	Protein synthesis		streptomycin
27	Unknown		cymoxanil
28	Cell membrane permeability		propamocarb
29	Respiration	2,6-dinitro-anilines	fluazinam
30	Respiration	Tri phenyl tin compounds	fentin hydroxide
33	Unknown	Ethyl phosphonates	fosetyl-Al
			phosphorous acid and salts
40	Cell wall synthesis	Cinnamic acid amides	dimethomorph
		Mandelic acid amides	mandipropamid
41	Protein synthesis		oxytetracycline
P	Host plant defense induction	Benzo-thiadiazole bth	acibenzolar-S-methyl
M	Multisite contact activity	Inorganic	copper
		Inorganic	sulphur
		Dithiocarbamates and relatives	ferbam
			mancozeb
			maeb
			metiram
			thiram
			ziram
		Phthalimides	captan
		Chloronitriles (phthalonitriles)	chlorothalonil
		Guanidines	dodine
NC	Not classified	Diverse	mineral oils
			organic oils
			potassium bicarbonate

Dry flowables (DF), also called water-dispersible granules (WDG, WG, DG), are wettable powders formed into prills so they pour easily into the sprayer tank without clumping or producing a cloud of dust. Nearly insoluble, they require agitation to remain in suspension. Atrazine and many ALS herbicides also are formulated as dry flowables.

Flowables (F) or water-dispersible liquids (LF), suspension concentrates (SC), and aqueous suspensions (AS) are finely ground wettable powders already suspended in a liquid carrier so they can be poured or pumped from one tank to another. They usually contain at least 4 pounds of active ingredient per gallon of formulation. Flowables are nearly insoluble in water and require agitation to remain in suspension. Suspoemulsion (SE) is a combination formulation of an SC and oil-based emulsion (E). Atrazine and Callisto are formulated as flowables or SCs.

Microencapsulated (ME or MT) and capsule suspension (CS) pesticides are encased in extremely small capsules that can be suspended in a liquid carrier and pumped and applied with normal equipment. Microencapsulated formulations are nearly insoluble in water and require agitation to remain in suspension. The active ingredient is slowly released over a period of time, often resulting in better pest control. Prowl H2O is formulated in microcapsules, which extend the soil activity and improve weed control.

Liquid Pesticide Mixes

Solutions are homogeneous mixtures of two or more substances. A solution may be either clear or colored and cannot be separated by mechanical means. An example is 2,4-D amine dissolved in water.

Emulsions are formed when one liquid is dispersed in another, as 2,4-D esters dispersed in water. Emulsions appear milky when dispersed in water and without agitation, the liquids may separate.

Suspensions are mixtures of finely ground insoluble particles of pesticide, such as atrazine 80W, suspended in the water or liquid fertilizer carrier. Since these formulations have a specific gravity greater than water, they tend to settle to the bottom of the tank; therefore, continuous mixing (agitation) is required to maintain a uniform mixture.

Fumigants are gases at room temperature when not pressurized. They commonly come as liquids in pressurized containers as, for example, liquid ammonia. The liquid must be injected or released under a gas-tight tarp to prevent its being lost to the air. Specialized application equipment is required.

Premixes are not formulations, but combinations of two or more herbicides premixed by the manufacturer. Premixes commonly combine two or more herbicides that are used together anyway, and they may contain any of the herbicides discussed above. The primary reason for using premixes is convenience. Since 1980, numerous premixes have been released for use on corn and soybeans, and the future surely will bring more.

Water-soluble bags (WSB) are available for a number of pesticide products and formulations. Pesticides (generally DF or WDG) are packaged in polyvinyl alcohol-based bags that readily dissolve in water. WSBs offer improved handling safety, reduced waste disposal, and unit-dose convenience.

Dry Pesticide Formulations

Granular (G) pesticides are formulated with a premixed carrier that has a low percentage of active ingredient. They are applied directly (dry) without further dilution. The carrier may be fertilizer, clay, lime, vermiculite, or ground corn cobs. The performance of granulated herbicides, compared to that of sprayable formulations, varies with the herbicide. Granular forms generally require more rainfall for activation than do sprayable formulations.

Advantages:

- Water is not needed for application.
- Equipment required for application is relatively inexpensive.
- Selectivity may be improved because granular particles fall off leaves and sift through crop canopy to the ground.

Disadvantages:

- Heavy, bulky, and troublesome to store or ship.
- Small granules subject to drift.
- Application is not as uniform as that of sprays.

Pellets are like granules but are compressed into larger cylinders about 1/4 inch long. Herbicides formulated as pellets usually contain from 5 percent to 20 percent active material and are applied by hand to control clumps of brush. For brush control in forests or permanent pastures, they also may be applied with spinner spreaders mounted on helicopters or aircraft. Pellets gradually break down from rainfall and leach into the soil for root uptake.

Mixing and Application

Be aware that improper sprayer calibration, nonuniform application, calculation errors, or use of the wrong chemicals can cause herbicide injury to the crop. Apply only the recommended amount of herbicide. Slight increases in rates could result in crop injury or leave residues that might injure succeeding crops. Recalibrate sprayers frequently and adjust them for increased output resulting from normal nozzle wear. Be sure there is sufficient agitation in the sprayer tank to prevent settling of wettable powders, dry flowables, or flowables. Do not stop in the field with the sprayer on, spill herbicide

when loading, or dump unused herbicides in anything except a holding tank.

Take the following steps when mixing herbicides:

- Always be sure the sprayer has been checked for uniform application and calibrated properly for application at the recommended rate.
- Calculate the amount of pesticide to add to the sprayer tank based on the active material in each gallon of pesticide concentrate, or the percentage of active ingredient of dry pesticide formulations.
- Read and follow instructions on the manufacturer's label pertaining to personal hazards in handling.
- Fill the sprayer tank with at least half the volume of water or fertilizer solution you ultimately will need.
- Start moderate agitation and keep it going.
- Add compatibility agents if needed. For maximum benefit, they must be in solution before pesticides are added. (To determine pesticide compatibility, see next section.)
- Add, mix, and disperse dry pesticides (wettable powders, dry flowables, or water-dispersible granules). These formulations usually contain wetting and dispersing agents that aid in mixing.
- Add liquid flowables and allow thorough mixing. Liquid flowables also contain wetting and dispersing agents.
- Add emulsifiable concentrates (ECs) and allow thorough mixing.
- Finish by adding water-soluble formulations (2,4-D amine, etc.).
- Add any surfactants, crop oil concentrates, etc., last. Crop oils especially do not mix and disperse well if added first.
- Add the remainder of the water or liquid fertilizer and maintain agitation while spraying until the tank is empty.

Caution: Never pour concentrated herbicides into an empty tank. Never allow a sprayer containing mixed chemicals to stand without agitation, as heavy wettable powders may clog nozzles or settle into corners of the sprayer tank.

Compatibility of Pesticides

Pesticides are not always compatible with each other or with the water or liquid fertilizer carrier. Lack of compatibility may result only in the formation of a gel, precipitate, or sludge that plugs up screens and nozzles. But extreme incompatibility may produce a settling out of material that can harden like concrete in the bottom of the tank and in hoses, pumps, and other internal parts of the sprayer. The result may be total loss of the pesticide and use of the sprayer. Incompatibility also can reduce effectiveness or cause crop injury.

Herbicides may be combined with liquid fertilizers to minimize trips over the field; however, information is scarce concerning the compatibility of herbicides with specific fertilizer solutions. Herbicide-fertilizer solution combinations may form a gel or precipitate that settles to the bottom of the sprayer tank or that will not flow through the sprayer equipment.

Tank-mixing several pesticides, although convenient, may create other problems. Foliar activity may be enhanced and result in crop leaf burn, or the activity of one or more of the pesticides may be reduced ("antagonism").

To prevent the main water tank or liquid-fertilizer measuring tank from becoming contaminated, commercial applicators may want to mix the herbicides and other ingredients in a separate holding tank. The herbicide mixture then is sucked into the main line as the truck tank is being filled and is thoroughly mixed by the truck's agitation system. Compatibility problems are more likely to result when concentrated herbicides are mixed together, so a compatibility test should be done before new mixtures are tried.

Use only labeled tank mixtures or mixtures recommended by experienced scientists whose recommendations are backed by research. Compatibility of selected herbicides and insecticides is given in Part II, Section 2. For all unlabeled tank mixtures, a jar test is strongly recommended to test for compatibility. The compatibility of herbicide-fertilizer combinations should be tested before large batches are mixed. In some cases, adding a compatibility agent (Compex, Unite, or comparable surfactants) may help maintain component dispersion.

The following "two-jar test" may be used to test the compatibility of herbicides with each other or of herbicides and other pesticides with liquid fertilizers.

1. Add 1 pint of carrier (water, liquid fertilizer) to each of two quart jars.
2. Add 1/4 teaspoon of compatibility agent to one jar (equivalent to 2 pints per 100 gallons of spray solution).
3. To each jar, add the required amount of pesticide in the order suggested above for tank-mixing herbicides. Shake well after each addition to simulate continuous agitation.
4. When all ingredients have been added, shake both jars for 15 seconds and let stand for 30 minutes or more. Then, inspect the mixture for flakes, sludge, gels, or nondispersible oils, all of which may indicate incompatibility.
   - If, after standing for 30 minutes, the components in the jar with no compatibility agent are dispersed, the herbicides are compatible and no compatibility agent is needed.
   - If the components are dispersed only in the jar containing the compatibility agent, the herbicide is compatible only if a compatibility agent is added.

- If the components are not dispersed in either jar, the herbicide-carrier mixture is not compatible and should not be used.

Spray Nozzle Selection and Use

Manufacturers of spray equipment have developed new "second generation" nozzles that provide additional protection against spray drift by reducing the amount of very fine drops created by the spray pattern. The design objective for a spray nozzle is to create a pattern of spray drops of a specific size distribution and spray distribution pattern. With a new nozzle, the application pattern from a series of nozzles in a row is evenly distributed across the spray path if the nozzles are set at the recommended height above the crop canopy.

The nozzle orifice is a precisely engineered device that creates the drops of a certain average size at a specific pressure and with a designed spray distribution pattern, such as a flat fan spray. If the nozzle is damaged or worn, the average size of the droplet is changed with many more fine droplets created, and the spray distribution pattern is modified so that the uniformity of the spray along the boom is reduced.

With the increasing number of crop protection chemicals available, the applicator must be able to select a nozzle that is appropriate not only for the chemical (contact or systemic) but also for the application rate. In addition, environmental conditions such as wind and relative humidity affect the potential for spray drift, and this must be considered in selecting the appropriate nozzle.

A variety of spray nozzles are available to provide the applicator with a means of getting the right size spray drops to reduce spray drift, and to deliver the appropriate liquid flow rate so that the field application speed can be maintained.

Using damaged or worn nozzles is potentially damaging to the crop and also not economical. The cost of new nozzles often can be recovered with chemical cost savings from one or two applications. Some of the new nozzles available are:

1. Modified flat fan for better drop size control over wider variation of pressures.
2. "Turbo" nozzles that create larger drops but maintain a consistent drop size throughout a wider range of pressures.
3. Air injection nozzles that create extra-large drops for reduced spray drift. The drop contains a small bubble of air that bursts on contact with the leaf, spreading out the drop contents after contact, but keeping a large drop size during travel from the nozzle to the leaf.

One strategy for refitting sprayers is to use a rotating nozzle body that holds from three to five nozzles of different types. A specific nozzle appropriate for the type of chemical and drop size required can be selected by rotating the nozzle body without changing the calibration or pressure settings of the sprayer.

Spray Nozzle Selection Procedure

1. From the chemical application label, determine the application rate in gallons per acre with recommended tank mix of water and active ingredient. The chemical label will often recommend spray drop size or type of nozzle.
2. Here is where the control for spray drift starts. If you have more than one nozzle to select from, select a nozzle size and type considering the wind and relative humidity conditions you expect to encounter in the field. Very low relative humidity causes the spray drops to evaporate more quickly and allows the active ingredient (as a vapor) to drift across or off the field. Drop sizes less than 200 micrometers (50 micrometers equal the diameter of a human hair) evaporate quickly and are subject to spray drift in even light to moderate wind. Spraying in winds of more than 4 to 5 miles per hour is not recommended. Manufacturers' catalogs provide data on the drop sizes produced by each nozzle at different spraying pressures.
3. From the manufacturer's catalog tables for the type of nozzle mounted on your sprayer, select the operating pressure that will create spray drops that are not subject to drift. Higher spray pressures increase the gallons per minute (GPM) output from the nozzle, but create smaller spray drop sizes. The goal is to balance the GPM from the nozzle without making driftable spray drops. Select the GPM output from the nozzle, based on drop size and pressure. You may want to purchase new nozzles if you decide to upgrade to second generation nozzles of a different capacity and type. Always make it a practice to use the lowest spray pressure possible without disrupting the spray pattern.
4. Select a desired spraying speed or spraying pressure. You will be balancing these two factors to get the right drop size and sprayer speed to reduce spray drift, while still getting the recommended application rate.
5. You now have a preliminary spray speed in mph or GPM per nozzle, the sprayer nozzle spacing in inches, and the gallons per acre (GPA) recommended application rate. Use either of the following formulas, depending on whether you want to set the pressure and calculate the spraying speed, or set the speed and calculate the GPM per nozzle, which sets the sprayer pressure:

$$\text{mph} = (5{,}940 \times \text{GPM}) \div (\text{GPA} \times \text{nozzle spacing in inches [W]})$$
$$\text{GPM} = (\text{mph} \times \text{GPA} \times \text{W}) \div 5{,}940$$

If the calculated spraying speed is too slow for you, you must increase pressure (which may increase spray drift), or

select a different size or different type of nozzle. For example, you could increase pressure by changing from a flat fan (medium-sized drops) to a Turbo TeeJet, which would provide a coarse drop size at increased pressure. You could then use an increased GPM for the nozzle and drive the sprayer faster.

If the required nozzle GPM is larger than the catalog value GPM that gives the right drop size, you can slow down the sprayer speed or choose a different nozzle type (providing larger drop sizes). This allows the application rate per acre to be met with a slower sprayer speed and reduced nozzle pressure, or the required GPM per nozzle to be met with increased pressure. For example, if your sprayer had a flat fan TeeJet XR8004 installed and you wanted the nozzle to provide coarse-sized drops, the maximum pressure that would do this is 20 psi, and the nozzle would deliver 0.28 GPM at that pressure. But the required GPM at a spray speed of 6 mph is 0.4. This can be delivered at 40 psi, but the drop size at that pressure is medium sized. (There is a potential for spray drift with this drop size, because of expected winds and low relative humidity.) To solve this problem, you could choose an air injection nozzle, which would provide 0.4 GPM but also would provide a very coarse drop size at 40 psi.

The selection of nozzle type, nozzle capacity, and durability of material is becoming more important as the selection and variety of crop protection chemicals increases. The spray equipment supplier and nozzle manufacturer's catalogs can provide important advice on the proper selection of nozzles. Consult your local cooperative extension educator for fact sheets that provide additional guidance in nozzle selection.

Off-Target Movement

Off-target movement, sometimes called drift, is the movement of any pesticide to areas not intended for treatment. There are three primary forms of off-target movement: spray drift (also known as physical drift), volatility (also known as vapor drift), and sprayer contamination. Spray drift is when, during application, droplet or particle drift occurs as spray droplets or dust particles are carried by air movement from the application area to other places. Vapor drift takes place after application as herbicides evaporate (volatilize) and yield fumes (gases) that are carried on wind currents and deposited on soils or plants outside of the treated areas.

Herbicide off-target movement may injure sensitive crops, ornamentals, gardens, livestock, wildlife, or people, and may contaminate streams, lakes, or buildings. It may contaminate crops and cause illegal or intolerable residues. Excessive drift may mean poor performance in the desired spray area because the application rate is lower than expected.

Drift control should be considered with each pesticide application. Here are some ways to prevent severe drift problems:

- Use sprayer nozzles especially designed for drift reduction.
- Use low-volatile or nonvolatile formulations.
- Use low spray-delivery pressures (15 to 30 psi) and nozzles with a larger orifice.
- Use drift-inhibiting adjuvants in the spray mixture when spraying under less-than-ideal conditions.
- Use nozzles that allow for lowered boom height.
- Avoid application of volatile chemicals at high temperatures (>85°F).
- Spray when wind speed is low (less than 10 mph) or when the wind is blowing away from areas that should not be contaminated.
- Use higher spray volumes during applications (e.g., 20 to 30 gallons per acre versus 5 to 10 gallons per acre).
- Spray during the early morning or evening hours when there is usually less wind (however, applications should not be made if wind speed is less than 3 mph).
- Leave border areas unsprayed if they are near sensitive crops.

Boom Sprayer Setup and Calibration

Advances in agricultural chemicals have made precise application of herbicides and pesticides much more important, not only because of the cost of the chemicals but also because of the danger of off-target spray drift. The economic impact of spray drift comes not only from the loss of chemicals that should have been applied to the crop, but also from the potential damage the chemicals may cause to adjoining crops, the contamination of surface and ground water supplies, and health risks to animals and people. Legal liability costs have been rising recently, justifying added attention to properly calibrated and operated spraying equipment.

Reasons for Calibrating

- Chemicals should be applied at the proper rate to be effective and safe without causing pollution. The calibration test tells us the application rate with our selected nozzles, pressure, sprayer design, and travel speed.
- The operator must know the application rate (from the chemical label) to determine the proper amount of
- chemical(s) to add to the sprayer tank. Once the actual application rate is known, it is easy to determine the acreage that a tankful or part of a tank will cover. Then, the proper amount of chemical to add to the tank can accurately be determined.
- Applying a chemical at the wrong rate is disadvantageous. Using more than the desired amount of chemical is wasteful, may violate label rates, and may pollute the environment. Too low an application rate probably will

not be effective, and money will have been wasted on the material and its application.

- Actual application rates in the field may vary from nozzle catalog values, because of pressure gauge error, wheelslip, speedometer error, and friction loss in the plumbing. A catalog is satisfactory for selecting the correct nozzles, but the sprayer must be checked under actual operating conditions to adjust the pressure for the exact application rate required.

Precalibration or Start-of-Season Checkout

1. Before the spraying season or the first use of the season, the sprayer should be thoroughly checked for mechanical operation. Engines, pumps, hoses, valves, and electronic controls should be inspected, and worn parts repaired or replaced. The wheels, tank, and mechanical parts should be inspected and the equipment lubricated. Belts, pulleys, PTO shafts, and shaft guards should be checked for wear, and all guards must be in place. Consider the economic impact on the crop if the sprayer malfunctions during a critical spraying operation and parts must be ordered. Make sure the nozzle spacing on the boom is uniform. Make accurate measurements and adjust—do not estimate. Check that all nozzles on the boom are from the same manufacturer, have the same part number, and are the same size.
2. The spray nozzles and all strainers should be checked. Remove strainers and make sure they are clean. Clean nozzles in soapy water with a toothbrush or a nozzle-cleaning brush. Do not use any hard or metallic tools to clean the nozzles. Check pressure gauges to make sure they are in calibration and reading correctly. An inaccurate pressure gauge will cause an improper application rate. This is a good time to replace nozzles. The cost of new nozzles usually is recovered within one or two spray applications. Consider upgrading to stainless steel nozzles. The sprayer owner should always purchase at least one extra or spare nozzle of the same type and size as those on the boom. This nozzle is not to be used for spraying, but only for calibration.
3. Clean the sprayer tank, piping, screens, and nozzles. This is important, especially with the use of chemical-resistant crops where sprayer contamination could cause significant crop damage to nonresistant crops. A good cleanser is sudsy ammonia, which can be purchased at most grocery stores in gallon or half-gallon containers. Washing soda (sal soda), another grocery store item, or trisodium phosphate may be used.

In general, cleaning involves first flushing the sprayer and tank with water. Then, add 25 gallons of water to the tank and add 1 quart of household ammonia or sudsy ammonia if the tank has held organophosphates or carbamate insecticides. Ammonia will detoxify these chemicals. For other spray chemicals, to the 25 gallons of water in the tank, add 1 pound washing soda and 1/4 pound powdered detergent (or enough liquid detergent) to make a sudsy solution. Two pounds of trisodium phosphate (available at paint stores or hardware stores) may be substituted for the washing soda. Agitate the solution and operate the sprayer for at least two minutes. Let the solution stand in the sprayer for at least two hours (or overnight for hormone herbicides, salt or amine formulations). Flush the cleaning solution out of the sprayer and rinse it with clean water.

After cleaning, check the nozzles and screens again, as they may have captured scale and sediment loosened by the cleaning solutions.

Sprayer Calibration

Before the spray activity, or especially before changing spray chemicals, clean and flush the sprayer with clean water. The proper nozzles and nozzle discharge rate, speed, and operating pressure will have been selected previously for the proper application rate.

1. On an area that best represents the average topography for the area to be sprayed, measure and mark off a distance of 100, 200, or 300 feet. The goal for this operation is to calibrate the tractor's speedometer or tachometer so that the proper speed can be maintained during application.
2. Fill the sprayer tank about half full of water before the sprayer speed calibration.
3. With the tractor traveling at this desired spraying speed, time and record the seconds needed to travel the calibration distance.
   ____ seconds
4. Using the formula or the table below, calculate the actual speed driven through the calibration distance compared to the desired application speed. Adjust the speed and note the speedometer or tachometer reading until the desired speed is achieved.
5. Note and record the engine rpm and the gear selection, so the same speed is used during calibration and application.
   _____ mph _____ rpm
   _____ gear _____ range
6. Place one new nozzle of the type and size to be used during the spraying on the sprayer boom in the position closest to the pump or the control valves.
7. Add water to the sprayer (if necessary), engage the pump, and adjust the pressure regulator to the desired boom pressure selected from the catalog tables for the nozzle to be used. (This nozzle and desired output were

$$\text{Speed (mph)} = \frac{\text{Distance (feet)} \times 60}{\text{Time (seconds)} \times 88}$$

Speed (mph)	Time required, in seconds, to travel a distance of:		
	100 feet	200 feet	300 feet
0.5	136	273	409
1.0	68	136	205
1.5	45	91	136
2.0	34	68	102
2.5	27	55	82
3.0	23	45	68
3.5	19	39	58
4.0	17	34	51
4.5	15	30	45
5.0	14	27	41
5.5		25	37
6.0		23	34
6.5		21	31
7.0		19	29
7.5		18	27
8.0		17	26
8.5		16	24
9.0		15	23

determined during the precalibration nozzle selection.) Using a measuring container, collect the liquid from the new nozzle for one minute. Adjust pressure until the amount collected equals the desired nozzle output in GPM. (If your container is calibrated in fluid ounces, divide the amount collected in ounces by 128 to convert to gallons.) You have now set the correct sprayer pressure. Replace the new nozzle with the regular sprayer nozzle.

8. The next step is to calibrate all of the nozzles to make sure they are within the calibration standards. Collect the output from each nozzle for 1 minute and measure the volume. If the output from any boom nozzle is less than the output from the new nozzle, the nozzle is dirty or clogged and the strainer and nozzle should be cleaned. If the volume collected is more than 110 percent of the new nozzle output (10 percent more than the new nozzle output), the nozzle is worn and should be replaced. Both the nozzle application rate and spray distribution pattern will be unacceptable for precise spraying and drift control. If more than two nozzles on the boom are 10 percent greater or less than the new nozzle rate, replace all of the nozzles on the boom, as this is an indication of excessive wear.
9. Setting boom height. Even with properly calibrated spray nozzles and correct pressure settings, the spray distribution pattern may not be acceptable unless the boom height is properly adjusted. The nozzle spray pattern is designed so that when the boom height is set for the nozzle spacing on the boom, the spray is evenly applied across the boom width. The boom height is measured from the top of the plant canopy to the nozzle and is specific for the nozzle spray pattern (for example, a 110-degree flat fan or an 80-degree or 60-degree spray pattern have different boom height settings). Ground level is the target for preemergence herbicides, while the top of the weeds or cover crop is the target for postemergence sprays.

   The manufacturer's catalog recommends the correct boom height for each type and size of nozzle. Since individual fan nozzles deliver more spray in the middle of the patterns than at the edges, boom height needs to be adjusted so that the patterns overlap. Flat fan patterns should overlap 40 percent of nozzle spacing, and flooding fan patterns should overlap 50 percent on the target regardless of the nozzle spacing or spray fan angle.

   A simple check is to spray water on a clean concrete or asphalt road or parking lot and observe the drying patterns. On a warm sunny day, the water will dry in two to four minutes. Heavy (wet) streaks under each nozzle indicate that the boom is too low. If the target is not at ground level, check the overlap at ground level and then raise the boom the appropriate amount.

   A more sophisticated method is to attach strips of water-sensitive paper to boards laid across the swath width. Spray over the water-sensitive paper at normal operating conditions. The yellow paper will turn blue where each spray drop is deposited. Evaluate the uniformity by observing the portion of the paper target that changes color.

   As a rule of thumb, boom height settings less than the manufacturer's recommendations will result in uneven distribution such as banding or striping. Boom height settings higher than the manufacturer's recommendations will increase the uniformity, but also increase the potential for spray drift, because of the greater distance between the nozzle and the plant.
10. As a final precaution, be sure to wear protective gloves, goggles, and waterproof clothing when cleaning or calibrating sprayers or adding chemicals.

Sprayer Cleanout

Modified from "Sprayer Clean-out Guidelines: Avoiding Crop Injury Due to Contamination," PAT-30 (November 1997), Iowa State University of Science and Technology, Ames, Iowa

Crop injury due to contaminated sprayers is a continuing

problem for both vegetables and field crops. Herbicide residues can be dissolved with time, and some herbicide formulations are very effective at removing residues. This problem can be avoided by ensuring that sprayers are properly cleaned between tank loads. Sprayer cleaning is particularly important before you begin spraying a different crop or the same crop but with a different herbicide resistance trait. When determining the correct cleanout procedure, it is important to consider the product's site(s) of action, carrier, and additives. They all have an impact on what cleaning solutions to use and potential damage to sensitive crops.

Rinsate disposal. Clean the sprayer in an area that will not contaminate water supplies, streams, or crops and that is inaccessible to children, pets, and livestock. Pay particular attention to sensitive vegetation that is in the runoff area. The best method for rinsate disposal is in the field in a manner consistent with the product's label. The easiest way to do this is to have rinse water available in the field, on either the sprayer or the support vehicle.

Tank-cleaning agents. A tank-cleaning agent's function is to penetrate, loosen, and dissolve herbicide residues, and then remove them through dilution. In some cases, the agent will provide deactivation or decomposition of the herbicide.

- Commercial tank cleaners are recommended on many product labels and help remove water and oil-soluble herbicides.
- Household ammonia, a commonly recommended cleaning agent, is effective at penetrating and loosening deposits and residues in the spraying system. Although ammonia does not decompose herbicides, it increases the solubility of some herbicides by raising the pH.
- Chlorine bleach can decompose residues of most sulfonylurea and other herbicides into inactive compounds. However, some tank-mix partners may inhibit the decomposition. Care must be used with chlorine bleach. Chlorine bleach can combine with fertilizers containing ammonia to produce dangerous chlorine gas, which is irritating to the eyes, nose, throat, and lungs. Also, rinsate containing chlorine bleach is not labeled for application to cropland.
- Kerosene or fuel oil should be used to remove oil-based herbicide formulations such as 2,4-D esters. Following the oil rinse, the system should be cleaned with detergent or ammonia.

Removing precipitated pesticides. Tank-mixing more than one pesticide can sometimes result in the chemicals forming a "gunky mess" in the bottom of the tank. The result is that the pesticides are not compatible with one another and the pesticides will settle out (form gunk). If your tank does end up with incompatible pesticides gunking up the bottom, use a compatibility agent (usually at a pint per 100 gallons; follow directions).

Surfactants and fertilizer additives. When switching from a growth regulator herbicide (Group 4; dicamba, Stinger, and others) to a postemergence application in soybeans, special care should be taken if the application involves surfactants or fertilizer additives. Such materials are particularly adept at removing these herbicides from poly tanks, hoses, and strainers. It is recommended that a small amount of fertilizer or crop oil be flushed through the system before the application.

General cleaning guidelines. To avoid drying and hardening of pesticide residues, and potential corrosion and damage to equipment, clean the sprayer immediately following an application. If you are continuing with the same pesticide the next day, flushing with water is sufficient. However, if you are switching products or crops, a more thorough cleaning is required.

Be sure to clean the entire sprayer system, not just the tank. Operate the pump and flush the cleaning solution through all hoses, strainers, screens, nozzles, and the boom. Small amounts of residue left in these areas can be sufficient to cause serious damage to a sensitive crop.

Most injury occurs when switching between crops. The following procedure is recommended when there are no specific cleaning requirements given on the label.

1. Drain the sprayer tank and lines and rinse tank, boom, and lines with water for a minimum of five minutes.
2. Fill the tank with clean water and *one of the following cleaning solutions* per 100 gallons of water:
   - 1 gallon of household ammonia or
   - 8 pounds of trisodium phosphate cleaner detergent or
   - commercial tank cleaner (follow instructions)
3. Flush the solutions through the entire sprayer system. For growth regulator herbicides (2,4-D, Clarity, Distinct, Stinger, etc.), let the solution stand overnight. Add more water to fill tank and agitate solution for at least 15 minutes and flush through the nozzles. Drain the tank.
4. Remove the nozzles, screens, and strainers and clean them separately in a bucket of cleaning agent and water.
5. Rinse the entire system with clean water.

Using Pesticides Safely

Pesticide Toxicity

For all pesticides to be effective against the pests they are intended to control, they must be biologically active, or toxic. Because pesticides are toxic, they are also potentially hazardous to humans and animals. Any pesticide can be poisonous or toxic if absorbed in excessive amounts. Pesticides can cause skin or eye damage (topical effects) and can also induce allergic responses. However, if used according to label directions and with the proper personal protective equipment (PPE), pesticides can be used safely. For this reason, people who use pesticides or regularly come in contact with them

must understand the relative toxicity and the potential health effects of the products they use.

The risk of exposure to pesticides can be illustrated with the following simple equation:

Hazard of Pesticide Use = Toxicity × Actual Exposure

Toxicity is a measure of the ability of a pesticide to cause injury, which is a property of the chemical itself. Pesticide toxicity is determined by exposing test animals to different dosages of the active ingredient. Tests are also done with each different formulation of the product (for example, liquids, dusts, and granulars). By understanding the difference in toxicity levels of pesticides, a user can minimize the potential hazard by selecting the pesticide with the lowest toxicity that will control the pest.

Applicators may have little or no control over the availability of low-toxicity products or the toxicity of specific formulated products. However, exposure can be significantly reduced or nearly eliminated by using personal protective clothing and equipment (PPE). For example, over 90 percent of all pesticide exposure comes from dermal exposure, primarily to the hands and forearms. By wearing a pair of chemically resistant gloves, this exposure can be reduced at least 90 percent. Therefore, by wearing the correct PPE, the hazard of pesticide use can be reduced to an insignificant level for the applicator.

Acute Toxicity and Acute Effects

Acute toxicity of a pesticide refers to the chemical's ability to cause injury to a person or animal from a single exposure, generally of short duration. The four routes of exposure are dermal (skin), inhalation (lungs), oral (mouth), and eyes. Acute toxicity is determined by examining the dermal toxicity, inhalation toxicity, and oral toxicity of test animals. In addition, eye and skin irritation is also examined.

Acute toxicity is usually expressed as LD_{50} (lethal dose 50) or LC_{50} (lethal concentration 50). This is the amount or concentration of a toxicant required to kill 50 percent of a test population of animals under a standard set of conditions. LD_{50} values of pesticides are recorded in milligrams of pesticide per kilogram of body weight of the test animal (mg/kg), or in parts per million (ppm). LC_{50} values of pesticides are recorded in milligrams of pesticide per volume of air or water (ppm). To put these units into perspective, 1 ppm is analogous to 1 inch in 16 miles or one minute in two years.

The LD_{50} and LC_{50} values are found in the product's Safety Data Sheet (SDS), which is available from the supplier or product manufacturers when pesticide products are purchased. Most are also available from various online sources, including the manufacturer's website. For many reasons, especially in an emergency situation, maintaining a file with

General Guidelines for Pesticide Safety
ALWAYS READ THE LABEL!

Only use pesticides when necessary. Before using any pesticide product, always read the label, as it is a legal document. The label provides information on which pests can be controlled, on which crops the pesticide product can be used, and the recommended rates and times of application. Any "off label" use is a violation of both Federal and state laws. Correct use of pesticides is essential to protect human, animal, and plant health as well as to protect the environment. Additionally, proper use will ensure chemical residues on crops and animals do not exceed legal limits (tolerances).

- Before using any pesticide, read the label.
- Become familiar with current federal and state pesticide laws and regulations.
- Follow all safety precautions on the label.
- Wear protective clothing and use protective equipment (both are referred to as PPE) according to instructions on the pesticide label.
- Minimum clothing requires long pants, long-sleeved shirt, socks, and shoes. In addition, chemically resistant gloves (nitrile, butyl, or neoprene) and unlined rubber boots should be worn.
- Be careful when handling pesticide materials to avoid spilling on skin or clothing.
- Never eat, drink, smoke, or use tobacco products while applying pesticides.
- When selecting pesticides, consider type of formulation and the application equipment required.
- Avoid drift to nontarget areas, which may endanger other plants or animals. Dusts drift more than sprays and airblast sprayers create more drift than boom sprayers.
- For record-keeping requirements, record the date, time, location, amount of each pesticide used, and any other required information as soon as possible.
- Bathe or shower in hot, soapy water after applying pesticides.
- Wash clothing worn while applying pesticides separate from other laundry, in hot, soapy water. Contaminated clothing must be handled with the same precautions as the pesticide itself.

copies of the label and SDS for each pesticide product used is highly recommended.

The LD_{50} and LC_{50} values are useful in comparing the toxicity of different active ingredients as well as different formulations of the same active ingredient. The lower the LD_{50} value of a pesticide, the less it takes to kill 50 percent of the test population, and therefore the greater the acute toxicity of the chemical. Pesticides with high LD_{50} values are considered the least acutely toxic to humans when used according to the directions on the product label.

Signal Words

Acute toxicities are the basis for assigning pesticides to a toxicity category and selecting the appropriate signal word for the product label. Pesticides that are classified as "highly toxic," on the basis of either oral, dermal, or inhalation toxicity, must have the signal words DANGER and POISON (in red letters) and a graphic of a skull and crossbones prominently displayed on the package label. PELIGRO, the Spanish word for danger, must also appear on the label of highly toxic chemicals. Acute oral LD_{50} values for pesticide products in this group range from a trace amount to 50 mg/kg. An exposure of a few drops of a highly toxic material taken orally could be fatal to a 150-pound person.

Some pesticide products are labeled with the signal word DANGER without the skull and crossbones symbol. A DANGER signal word does not provide information about the LD_{50} value of the chemical. Instead, this signal word alerts the user of potentially more severe skin or eye effects from the product (caused by its irritant or corrosive properties).

Pesticide products considered "moderately toxic" must have the signal words WARNING and AVISO (Spanish) displayed on the label. Acute oral LD_{50} values range from 50 to 500 mg/kg. An exposure of 1 teaspoon to 1 ounce could be fatal to a 150-pound person.

Pesticide products classified as either "slightly toxic or relatively nontoxic" are required to have the signal word CAUTION on the pesticide label. Acute oral LD_{50} values are greater than 500 mg/kg.

Chronic Toxicity and Chronic Effects

Any harmful effects that occur from repeated small doses over a period of time are called chronic effects. The chronic toxicity of a pesticide is determined by observing symptoms of test animals, which result from long-term exposure to the active ingredient.

Some of the suspected chronic effects from exposure to certain pesticides include birth defects (teratogenesis); fetal toxicity (fetotoxic effects); production of tumors (oncogenesis), either benign (noncancerous) or malignant (cancerous/carcinogenesis); genetic changes (mutagenesis); blood disorders (hemotoxic effects); nerve disorders (neurotoxic effects); and reproductive effects. The chronic toxicity of a pesticide is more difficult to determine through laboratory analysis than is acute toxicity. The product's SDS also contains information regarding chronic symptoms of pesticide exposure.

Symptoms of Pesticide Poisoning

The symptoms of pesticide poisoning can range from a mild skin irritation to coma or even death. Different classes or families of chemicals cause different types of symptoms. Individuals also vary in their sensitivity to different levels of these chemicals. Some people may show no reaction to an exposure that may cause severe illness in others. Because of potential health concerns, pesticide users and handlers must recognize the common signs and symptoms of pesticide poisoning.

The effects, or symptoms, of pesticide poisoning can be broadly defined as either topical or systemic. Topical effects generally develop at the site of pesticide contact and are a result of either the pesticide's irritant properties (either the active and/or inert ingredient) or an allergic response by the victim. Dermatitis, or inflammation of the skin, is accepted as the most commonly reported topical effect associated with pesticide exposure. Symptoms of dermatitis range from reddening of the skin to rashes and/or blisters. Some individuals exhibit allergic reactions when using pesticides or when these materials are applied in or around their homes or places of work. Symptoms of allergic reactions range from reddening and itching of the skin and eyes to respiratory discomfort often resembling an asthmatic condition.

Systemic effects are quite different from topical effects. They often occur away from the original point of contact, as a result of the pesticide being absorbed into and distributed throughout the body. Systemic effects often include nausea, vomiting, fatigue, headache, and intestinal disorders.

Seeking prompt medical attention is important; however, the development of certain symptoms is not always the result of exposure to a pesticide. Common illnesses such as the flu, heat exhaustion or heat stroke, pneumonia, asthma, respiratory and intestinal infections, and even a hangover can cause symptoms similar to pesticide exposure. Carefully consider all possible causes of your symptoms.

Responding to Pesticide Poisoning Symptoms

Be alert for the early symptoms of pesticide poisoning. Responding immediately and appropriately when pesticide exposure is suspected will help minimize the effects of exposure and, in extreme cases, may save a life. If you are having symptoms but are unsure if they are pesticide related, at least notify someone in case your symptoms become worse. At this time, call the National Poison Center at 1-800-222-1222 for guidance on the proper response to your symptoms. This number will direct your call to the nearest poison center, which is staffed on a 24-hour basis.

If safe to do so, take the pesticide container to the telephone. (However, if the pesticide container is contaminated, write down the product name and percentage of active ingredients, and take that to the phone.) The product label provides medical personnel information such as active ingredients, an antidote, and an emergency contact number for the manufacturer of the product. If you must go to the hospital or doctor's office, take the entire container, including the label, with you. In order to avoid inhaling fumes or spilling the contents, make sure the container is tightly sealed and never put it in the enclosed passenger section of a vehicle.

If the Safety Data Sheet (SDS) is available, take this with you also because it frequently contains additional information for medical personnel. In addition to posting emergency numbers or having them readily available by a telephone, keep these numbers in all service vehicles involved in transporting pesticides. Additional pesticide information can also be obtained by contacting the National Pesticide Information Center (NPIC) located at Oregon State University at 1-800-858-7378. The NPIC provides a variety of unbiased information about pesticides to anyone in the United States. (Medical professionals and government agencies can call NPIC at 1-800-858-7377.)

First Aid for Pesticide Poisoning

Reviewed by J. Ward Donavon, medical director of Pinnacle-Health Toxicology Center, Harrisburg Hospital

Immediate and appropriate action, such as providing first aid, may be necessary to prevent serious injury to a victim of pesticide poisoning. The situation can be a life-or-death matter. The product label should be one of the first sources of information in a pesticide exposure emergency, in addition to calling the National Poison Center (1-800-222-1222) and 911. First aid is only the "first response" and is not a substitute for professional medical help.

General First Aid Instructions

- Most important, be sure to protect yourself by wearing appropriate protective clothing and equipment if there is a likelihood of being directly exposed to a pesticide while administering first aid or removing the victim from an enclosed area.
- Have current labels and Safety Data Sheets (SDS) available.
- Have emergency response telephone numbers readily available.
- Assemble a first aid kit with necessary supplies.
- Always have a source of clean water available. In an extreme emergency, even water from a farm pond, clean water irrigation system, or watering trough could be used to dilute the pesticide.
- If oral or dermal exposure has occurred, the first objective is usually to dilute the pesticide and prevent absorption.
- If inhalation exposure occurs, first protect yourself, and then get the victim to fresh air immediately.
- Never give anything orally to an unconscious person.
- Become familiar with the proper techniques of artificial respiration; it may be necessary if a person's breathing has stopped or become impaired.

Specific First Aid Instructions

If the victim is not breathing:

- FIRST—Evaluate the surroundings of the victim. Protect yourself from pesticide exposure prior to and while giving assistance.
- SECOND—Administer artificial respiration and call 911.
- THIRD—Call National Poison Center (1-800-222-1222).
- FOURTH—Decontaminate the victim immediately; wash thoroughly and quickly. Speed is essential.
- If the victim is breathing:
- FIRST—Evaluate the surroundings of the victim. Protect yourself from pesticide exposure prior to and while giving assistance.
- SECOND—Decontaminate the victim immediately; wash thoroughly and quickly. Speed is essential.
- THIRD—Call 911 if the victim has ill effects from the exposure.
- FOURTH—Call the National Poison Center (1-800-222-1222).

If the pesticide has been spilled on the skin or clothing, remove any contaminated clothing immediately and thoroughly wash the skin with soap and water. Avoid harsh scrubbing, as this enhances pesticide absorption. Rinse the affected area with water, wash again, and rinse. Gently dry the affected area and wrap it in a loose cloth or blanket, if necessary. If chemical burns of the skin have occurred, cover the area loosely with a clean, soft cloth. Avoid the use of ointments, greases, powders, and other medications unless instructed by medical personnel.

Heavily contaminated clothing should be disposed of properly. If clothing is not heavily soiled, wash all contaminated clothing separately from any other laundry in hot water, at a high water level, and with a heavy duty liquid detergent. Run the washer through a complete cycle with detergent and no clothes to remove pesticide residue before another wash. Store washed protective clothing separately from other clothes. Also, do not store protective clothing and equipment in pesticide storage areas.

If the pesticide has entered into the eyes, hold the eyelid open and immediately begin gently washing the eye with

clean running water. Do not use chemicals or drugs in the eye wash water. Continue washing for 15 minutes. If only one eye is involved, avoid contaminating the other one. Flush under the eyelids with water to remove debris. Cover the eye with a clean piece of cloth and seek medical attention immediately. If contact lenses are worn, remove and discard the contacts, then wash the eyes as described above.

If the pesticide has been inhaled, get the victim to fresh air immediately. However, do not attempt to rescue someone who is in an enclosed area unless you are wearing appropriate protective equipment. Have the victim lie down and loosen their clothing. Keep the victim warm and quiet. If the victim is convulsing, watch their breathing and protect their head. Keep the chin up to keep air passages free for breathing. If breathing stops, administer artificial respiration and call 911. Call the National Poison Center (1-800-222-1222) after the victim is stabilized for further advice.

If the pesticide has been swallowed, contact the National Poison Center (1-800-222-1222) and provide them with the name and approximate amount of material that was ingested. Call 911 immediately if the victim has symptoms from the exposure. If the pesticide has entered the mouth but has not been swallowed, rinse the mouth with large amounts of water. Inducing vomiting is rarely advised for any poisoning, including pesticide poisonings.

If a petroleum product (kerosene, gasoline, oil, lighter fluid, EC pesticides) has been swallowed, call the National Poison Center (1-800-222-1222) and 911 immediately for further instruction.

If a corrosive poison (a strong acid or alkali) has been swallowed, dilute with water or milk immediately. Consult the National Poison Center (1-800-222-1222) and 911 immediately. The victim may experience severe pain and have extensive mouth and throat burns. Fortunately, most commonly used pesticides are not corrosive, but some household disinfectants and germicides fall into this category.

Safe Storage of Pesticides

- Read the label for specific storage instructions and precautions.
- Store pesticides in a clean, cool, dry, and well-ventilated building. Always lock the area to prevent entry by children and untrained persons. Mark the storage facility with an appropriate warning sign.
- Maintain proper temperature control. For example, if emulsion-type materials freeze, the emulsion may be destroyed, resulting in loss of effectiveness and possible serious plant injury.
- To avoid the danger of cross-contamination, do not store herbicides with other pesticides.
- Keep dry materials above liquid materials.
- Do not store pesticides where food, water, feed, seeds, fertilizers, or personal protective clothing and equipment (such as respirators) can become contaminated.
- Store pesticides in their original containers. Never store pesticides in any food or drink containers.
- Do not remove the labels.
- Keep lids tightly closed.
- Check containers frequently for leaks.
- Clean up spilled chemicals promptly and properly. Dispose of broken or damaged containers and any pesticide waste in an approved and safe manner as directed on the product label.
- Keep an inventory of all chemicals. Mark each container with the year of purchase.
- Inform your local fire department of any chemicals (including fertilizers) stored in large quantity.

Safe Disposal of Pesticides

- Read the pesticide label for specific disposal instructions.
- Avoid disposal problems by purchasing only the amount of material needed for one growing season. Do not stockpile.
- Use proper personal protective clothing and equipment when you dispose of pesticide wastes and containers.
- Mix only the amount of pesticide required for a particular application. If you mix too much, use the surplus by applying the material at the recommended rate to one of the crops listed on the label.
- Do not dump pesticides or pesticide rinsates on the ground or pour them down sinks, toilets, or other drains, including storm sewers.
- Pressure rinse or triple rinse empty pesticide containers with water and pour the rinse water into the spray tank. Drain 30 seconds each time.
- After rinsing metal, plastic, or glass containers, puncture, break, crush, or in some way render unusable. Recycle plastic containers through the Plastic Pesticide Container Recycling Program sponsored by the Pennsylvania Department of Agriculture (PDA). Contact your regional PDA office for further information. Disposal in a sanitary landfill is desirable if conducted in accordance with local regulations.
- If stated on the label and permitted by local ordinances, combustible containers can be burned. However, do not burn pesticide containers near residential areas or where the smoke can contact humans. Avoid exposure to the smoke; it may contain toxic vapors. Bury the ashes, since they also may be toxic.
- Send large metal drums to a reconditioning company.

- Before disposing of pesticide concentrates, check with PDA's CHEMSWEEP Program, which provides disposal options for unwanted and outdated pesticide concentrates free of charge.
- Do not reuse empty pesticide containers for any purpose.
- Clean up thoroughly after handling and disposing of pesticides.

Current Status of Restricted-Use Pesticides in Pennsylvania

Under the authority of the amended Pennsylvania Pesticide Control Act of 1973 and the amended Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), applicators who apply restricted-use pesticides (RUPs) in the production of an agricultural crop must be certified as a private applicator or must work under the direct supervision of a certified applicator. Furthermore, only certified applicators can purchase restricted-use pesticides. The pesticide dealer is required by law to record the name, address, and certification number of the purchaser of RUPs, as well as the identity of the product, amount sold, and date of purchase. Commercial and public pesticide applicators must be certified to use both general and restricted use pesticide products.

The official list of Pennsylvania's RUPs includes all pesticide products designated as restricted-use by the U.S. Environmental Protection Agency, and, in the interest of the public health and welfare of the citizens of the Commonwealth, any other product designated for restricted-use by the secretary of agriculture, Commonwealth of Pennsylvania. If a pesticide is restricted use, it will be clearly marked on the label.

Worker Protection Standard for Agricultural Pesticides

In 1992, the U.S. Environmental Protection Agency (EPA) revised its Worker Protection Standard (WPS), which addresses the protection of agricultural workers from pesticide exposure (40 CFR Part 170). The WPS includes requirements designed to reduce the risks of illness or injury to agricultural workers and pesticide handlers from occupational or accidental exposure to pesticides in the production of agricultural plants on farms and in nurseries, greenhouses, and forests.

The WPS expands the scope of prior worker protection regulations to identify two types of agricultural employees:

- Pesticide handlers: those who handle agricultural pesticides (mix, load, apply, clean or repair contaminated equipment, act as flaggers, etc.)
- Agricultural workers: those who perform tasks related to the cultivation and harvesting of plants on farms or in greenhouses, nurseries, or forests where pesticides are used

The WPS holds growers/employers responsible for compliance. The regulations expand requirements for the employer to make sure that employees are provided with the following:

- Warnings about pesticide applications
- Clean and properly maintained personal protective equipment (PPE), which employers must ensure is used
- Restrictions on reentry by personnel to treated areas (all pesticides used on farms and in forests, nurseries, and greenhouses have specific restricted entry intervals
- (REIs) that are listed on the label under the "Agricultural Use Requirements" section)
- Decontamination facilities
- Pesticide safety training and information
- Notification of pesticide applications and information about the pesticide(s) used
- Maintained contact with handlers when applying highly toxic pesticides
- Emergency assistance when required
- A pesticide safety poster placed in an area where it can be seen easily by all workers and handlers
- Information for pesticide handlers and early entry workers about pesticide label safety information
- A centrally located listing of recent pesticide applications on the premises

Under the WPS, labels now include statements specifying personal protective equipment, restricted-entry intervals (REIs), and (on some pesticide labels) a requirement to provide both oral warnings and posting of treated areas.

EPA developed these regulations with the non-English-speaking worker specifically in mind. Safety warnings, information, and training must be given in "a manner the worker can understand."

The Pesticide Safety Fact Sheet "EPA Worker Protection Standard for Agricultural Pesticides" describes these requirements in some detail and is available online at extension.psu.edu.

Part II, Section 2

Corn Pest Management

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A well-planned pest management program for corn involves using multiple strategies. These should include preventive techniques such as monitoring, cultural controls, mechanical or physical controls, biological controls, host-plant resistance, and chemical control tactics. Preventive techniques may start with planting weed-free crop seed or choosing an alternative field or planting date. Regularly monitoring for pests is an important predictive tool. Rotating crops to disrupt pest life cycles and planting adapted varieties are good examples of cultural controls. Mechanical or physical controls may include tillage and mowing to disrupt certain pests. Biological controls may include using insect or disease organisms or even grazing animals in pasture production systems. New hybrids are available that have built-in protection from numerous pests. Finally, chemical controls are an important component of many IPM systems, but their use should be based on sound management decisions. See Part II, Section 1 of this guide for more information about designing an integrated pest management program.

This guide provides chemical control suggestions based on university research and manufacturer recommendations. Management information for common corn pest problems is outlined in the following pages under "Weeds," "Insects," and "Diseases." For more information on corn management and hybrid selection, see Part I, Section 4. This publication strives for accuracy; however, omissions, inaccuracies, or dated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Herbicide- and Insect-Resistant Corn Hybrids

Herbicide- and insect-resistance traits are available in several corn hybrids. Some of these traits are the result of transgenic events involving introduction or transfer of one or more genes from a different plant or organism. Consumer concern about these transgenic crops has affected some export markets. Overreliance on glyphosate-resistant crop varieties, mainly soybeans and corn, and associated glyphosate use has led to widespread evolution of glyphosate-resistant weeds, which are forcing growers to consider other approaches for managing weeds in no-till fields. Similarly, widespread reliance on Bt corn hybrids to target corn rootworms appears to have led to evolution in many states, including Pennsylvania, of *populations of western corn rootworm, corn earworm, and western bean cutworm that are resistant to some Bt toxins*. Aside from transgenic manipulations, other herbicide- or insect-resistance traits can result from more traditional plant

breeding techniques; the marketability of these crops has not been affected by consumer concern.

Information about herbicide or insect resistance, other agronomic traits, yield potential, and marketability is available for many of these hybrids. Others may be relatively new with little public exposure or performance information.

Consult university variety testing results, other public variety tests, and local seed dealers for performance information about newer hybrids.

Herbicide-Resistant Corn Varieties

Some corn hybrids have been genetically enhanced to withstand herbicide applications that previously would have injured or killed corn. Genetically enhanced varieties allow herbicides to be used that provide a broader spectrum of control than would otherwise be available. Herbicide programs for genetically enhanced varieties also reduce the risk of crop injury associated with herbicide programs for conventional varieties. More varieties that contain multiple or "stacked" traits, such as both Roundup Ready and LibertyLink, and insect-resistant traits are becoming available.

LibertyLink corn is GMO to allow over-the-top applications of Liberty (glufosinate) herbicide. This program should provide broad-spectrum control of annual broadleaves and grasses of low to moderate pressure. Sequential applications or tank mixtures may be required for new weed flushes and perennials. This herbicide is becoming more important for the management of glyphosate-resistant weeds such as horseweed and Palmer amaranth.

Roundup Ready corn was developed using genetic engineering techniques. It has an altered target site not sensitive to glyphosate and allows for postemergence applications of glyphosate directly to corn. Glyphosate-resistant weeds are becoming an increasing issue in Roundup Ready crops.

Enlist corn was developed using GMO to tolerate glyphosate and improve 2,4-D tolerance. It also provides tolerance to "fop" herbicides such as Assure II, but is sensitive to "dim" herbicides such as clethodim.

Transgenic Insect-Resistant Corn Varieties

Most seed companies offer transgenic corn hybrids that include a gene or genes from a soil bacterium called *Bacillus thuringiensis* (Bt). Depending on the subspecies of the bacterium and the protein toxin it produces, the hybrid will provide protection against either European corn borer (ECB) and other caterpillar species or corn rootworms. Companies have also put both genes into the same hybrid to protect against both pests, calling these stacked-gene hybrids. They have also combined these same genes with the gene for Roundup Ready resistance. The Bt subspecies that produces toxins against European corn borer and several other Lepidoptera (moth and butterfly larvae) is *kurstaki*. Several types of crystalline protein toxins are produced by strains of this subspecies, including *Cry1Ab* (YieldGard and Agrisure Corn Borer) and *Cry1F* (Herculex I). With the exception of the Herculex material, these hybrids provide protection against first- and second-generation European corn borer and suppression against fall armyworm and stalk borer, but protect poorly against corn earworm, which has evolved resistance to *Cry1Ab*. Herculex also provides some protection against fall armyworm and black cutworm, but it is no longer reliable for controlling western bean cutworm. In fact, western bean cutworm appears to have evolved resistance against this trait, rendering it ineffective, particularly in the Great Lakes Region, including Michigan, New York, Ohio, and Ontario. Other subspecies of Bt that produce toxins that are active against corn rootworm larvae include *Cry3Bb1* (YieldGard Rootworm), *Cry34/35Ab1* (Herculex RW), *mCry3A* (Agrisure RW), and *eCry3.1Ab* (Duracade). The stacked-gene hybrids that provide protection against a suite of caterpillar species above ground and corn rootworms below ground are widely available. Growers now also have access to products containing "Vip" genes, insecticidal genes that were also isolated from *Bacillus thuringiensis*; however, Vip genes produce a toxin different from the Cry proteins. The Vip3A protein is claimed to control a complex of caterpillars, including corn earworm, black cutworm, western bean cutworm, dingy cutworm, and stalk borers, and is likely to be stacked with Agrisure traits to provide a spectrum of control that includes ECB and rootworms. A listing of the various Bt traits and trait packages is available in a summary compiled by Dr. Christina Difonzo (Michigan State University). The most recent version available at the time of printing this guide (January 2021) is included as Table 2.2-25 at the end of this chapter.

It is important to note that suspected resistance of western corn rootworm to *Cry3Bb1*, *mCry3A*, and/or *Cry34/35Ab1* has emerged in the past few years in at least 12 states, including New York and Pennsylvania. This widespread evolution of suspected resistance appears to have hastened the end of single-toxin varieties of corn targeting western corn rootworm, and companies are transitioning to providing only hybrids with two transgenes targeting rootworms.

Prior to widespread adoption of Bt varieties, research conducted in Pennsylvania and Maryland suggests that, on average, European corn borer feeding caused about a 5.5 percent reduction in yield. When infestation levels are high, yield losses can reach as high as 30 percent, but this situation is rare.

In 2020, 82 percent of field corn planted in the United States was transgenic for Bt traits. Adoption rates for individual states have been even higher. These high adoption rates have suppressed populations of ECB, the pest against which Bt varieties were first deployed. In fact, in many parts of the country ECB populations have reached historic lows. Moreover, similar trends in populations of corn rootworms

may also be developing. Therefore, growers need to understand their local pest populations to determine whether the Bt technology is necessary and vital for their profitability. We strongly suggest that growers consider evaluating the pest populations annually in their non-Bt refuge acreage or plant a specific non-Bt test strip to track ECB or rootworm populations. For rootworms, remember that this pest is problematic in Pennsylvania only for continuous corn production. If you are in Pennsylvania and not growing corn year after year, you do not need to purchase seeds with this trait.

Because not all fields experience a yield loss from ECB, a key issue is identifying fields that will benefit most from the Bt traits. Planting some non-Bt corn annually is an obvious way to understand your local populations, but the following criteria can help determine if you are likely to gain an economic benefit from a Bt corn hybrid:

- A history of significant ECB damage in your area indicates that conditions can be conducive to the pest.
- Early planted long-season hybrids that pollinate during early to mid-August will be attractive to both first- and second-generation ECB.
- Fields planted in low areas along streams and rivers are more susceptible to ECB.
- Fields managed for high yield or at higher population levels will benefit more from the technology than those with a low yield potential (for example, 3 percent of 150-bushel-per-acre corn is greater than the same percentage of 100-bushel-per-acre corn).
- Corn fields grown for grain will benefit more than those grown for silage. Silage tended to be harvested before ECB causes ear drop and stalk breakage, which are a significant component of losses caused by the pest.

As mentioned above, a key aspect of assessing the need for Bt corn is to assess the level of ECB and corn rootworm damage in the previous year. Bt corn hybrids vary in other agronomic traits such as yield, moisture, drought tolerance, and disease resistance, so you should consider these factors as well in the hybrid selection process. As is the case with normal hybrids, the use of Bt hybrids also should be based on performance data.

A concern with the use of Bt hybrids is the potential development of resistance by the corn borer or corn rootworm. Because of this, seed companies have been mandated to develop resistance management plans for the use of Bt hybrids. Resistance management plans vary among companies, but when they were first introduced farmers were required to plant a "structured" or "block" refuge by leaving some areas in a Bt-planted field—at least 5–20 percent of the field, depending on the hybrid—or in a nearby field planted to non-Bt corn hybrids to allow susceptible genetic types of ECB or corn rootworms to survive and mate with resistant individuals that survive on Bt corn. This structured refuge option is still available to growers, but now growers also have the option of planting an "integrated" refuge by purchasing mixtures of Bt and non-Bt corn, often referred to as "refuge-in-the-bag" (RIB). In these RIB products, the non-Bt seed accounts for 5–10 percent of the seed in the bag, and the lower refuge required is partially attributable to the Bt seed in these products having two transgenes targeting the different pest guilds. Growers who use this technology should check with their seed dealers on the insect resistance management (IRM) options that are available and how to implement them properly.

The corn rootworm Bt hybrids provide protection for the root system against the pest's feeding. Field evaluations suggest that under moderate to heavy corn rootworm pressure, corn plant height is significantly reduced over the protected Bt hybrids and protection of the rootworm system significantly reduced the frequency of stalk lodging. The corn rootworm hybrids only provide protection for the root system from larval feeding and do not reduce adult feeding activity in the field. Therefore, the Bt corn rootworm hybrids should be considered as alternatives to at-planting-time insecticide applications for protection against larval feeding and not as an adult control alternative. As mentioned above, some Pennsylvania growers appear to have suffered from populations of western corn rootworms that have evolved some resistance to some of the Bt toxins—this issue of course complicates rootworm management. The national recommendation is to rotate crops as much as possible to avoid rootworms. Alternatively, farmers should strive to grow no more than two to three years of corn in each field, and when rootworms need to be managed use pyramided Bt varieties, which contain at least two Bt genes targeting rootworms. All hybrids that have the Bt rootworm gene will have their seeds treated with neonicotinoid seed treatments, either Cruiser or Poncho, for control of secondary soil pests, though the evidence that these seed-applied insecticides are vital for productivity remains thin.

As with the Bt hybrids for European corn borer protection, all fields will not necessarily benefit from the rootworm-resistant technology. In Pennsylvania, rootworm damage can easily be managed with crop rotation. In the Midwest, many states have experienced heavier-than-expected damage from western corn rootworm larvae in their continuous corn acreage despite using Bt varieties targeting this pest species. As mentioned above, these populations are resistant to some of the rootworm traits, particularly the YieldGard trait (the *Cry3Bb1* protein), *mCry3A* (Agrisure RW), and *Cry34/35* (Herculex RW); therefore, continued use of these products in continuous corn acreage may threaten their viability. To avoid difficulty from resistant populations of rootworms, we strongly recommend rotating corn with other crops (e.g., soybeans, sorghum, alfalfa) to avoid long-term selection pressures for resistant rootworm populations. If continuous corn is necessary for particular growers, consider limiting

corn to two years of production in any one field. Alternatively, consider using Bt varieties with different Cry proteins to avoid continual pressure with a single trait. In potentially problematic fields, continuous corn growers also might consider the option of foregoing Bt varieties targeting rootworms and plant with a soil insecticide. In the Midwest there is also a variant of western corn rootworm that lays its eggs in soybean fields so that larvae emerge in corn fields in the typical two-crop corn-soybean rotation. Moreover, a variant of northern corn rootworm has developed an extended two-year diapause, allowing it to similarly overcome the corn-soybean rotation. These two variants do not occur in Pennsylvania and are unlikely to develop here given the more complex rotations typically employed by Pennsylvania farmers. If growers are committed to growing continuous corn, determining the likelihood of economic gain from the Bt technology against corn rootworms can be accomplished by using an IPM approach. During late July and August, fields should be scouted to determine whether rootworm adult populations exceed the economic threshold. Fields exceeding the economic threshold of one beetle per plant are good candidates for the technology; however, keep in mind that extended use of the same tactic year after year may favor localized resistance to particular tactics.

Weeds

Integrated Weed Management

An integrated approach to managing weeds in corn includes using cultural weed control, mechanical controls where applicable, and the judicious use of herbicides. Corn fields that are weed free for the first four to six weeks after planting will often yield the same as fields that are weed free for the entire growing season. This approach relies on starting with a clean seedbed and using residual soil-applied herbicides or mechanical control. Weeds that germinate with the crop but are controlled in a timely fashion (four to five weeks after planting) will also not impact final yields. This POST herbicide approach relies on effective and timely postemergence weed control. Also, it is not necessary to control all weeds in a field to achieve maximum yield. However, certain weeds can still be problematic at harvest even at low levels (e.g., burcucumber). Weed populations of one to two weeds per 10 square feet are sufficient to cause severe yield loss depending on the species. However, weed populations at one plant per 100 square feet will have no impact on final yield. The impact of weed populations between one and 10 per 100 square feet is difficult to predict. The decision to treat the field depends on the weed species present, crop vigor, weather conditions, and herbicide cost. For more comprehensive discussion of integrated weed management see the *Integrated Weed Management Guide for Mid-Atlantic Grain Crops*.

Chemical Weed Control

Herbicides are useful tools in most weed management programs. This chapter will focus on herbicides available for use in corn. They should be used to supplement, not replace, other methods or tools available. The following are definitions of terms you will find in this and similar publications on herbicides:

- Early preplant (EPP): The herbicide is applied at least 14 days before planting. EPP applications are generally
- used in no-till systems to control existing vegetation and provide residual control of early emerging weed species.
- Preplant: The herbicide is applied from zero to 14 days before planting. Preplant applications are generally used in no-till systems to control emerged weed species.
- Preplant incorporated (PPI): The herbicide is applied to the soil after primary tillage, but before planting, and mechanically mixed with the top 1 to 3 inches of soil with one of a variety of secondary tillage implements.
- Preemergence (PRE): The herbicide is applied to the soil after the crop is planted but before emergence. Rainfall or irrigation is needed to move the herbicide into the zone of weed seed germination before weed emergence for maximum effectiveness. If adequate rainfall for herbicide activation does not occur, a shallow cultivation or rotary hoeing should be done to control weeds that have germinated.
- Postemergence (POST): The herbicide is applied to the foliage of the crop and weeds after they have emerged.
- POST-directed (or directed): Refers to use of special spray equipment to direct the spray at the weeds but avoid it coming in contact with as much of the crop as possible.
- Residual activity: Herbicides that can be taken up by a plant's roots and shoots and injure or kill the plant. All soil-applied herbicides, as well as many postemergence herbicides, have residual activity. Length of residual activity ranges from a few weeks to the entire growing season.
- Translocated herbicide: These herbicides move throughout the plant and can cause injury to parts of the plants that do not come in direct contact with the herbicide spray.
- Contact herbicide: These herbicides do not move throughout the plant. They cause injury only to those parts of the plant that come in contact with the spray. Spray coverage is more critical for contact than translocated herbicides.
- Nonselective herbicide: This refers to herbicides that control a broad spectrum of plant species, including most crops and weeds. These herbicides are generally used with no-tillage production and sprayed prior to planting when control of all plants is required.

Herbicide-Resistant Weeds in Corn

Herbicide-resistant weeds are common in corn in the Mid-Atlantic region. Populations of herbicide-resistant weeds are selected for by repeated use of the same or similar herbicide over a period of time. Resistance is most likely to occur with residual herbicides having one specific mode of action. Weed species with a very high amount of seed production and a variable genetic pool are more likely to develop resistant populations—for example, common lambsquarters and pigweed species. Resistance management requires using herbicides with multiple modes of action and integrating mechanical (tillage and cultivation) and cultural weed control (cover crops, narrow row spacing, proper crop fertility, etc.) with chemical weed control.

Triazine Resistance

Weeds resistant to the Group 5 herbicides in the Mid-Atlantic region include common lambsquarters, Palmer amaranth, redroot and smooth pigweed, horseweed, scattered populations of barnyardgrass, giant foxtail, goosegrass, and suspected populations of common ragweed and velvetleaf. Atrazine and simazine are the primary products that are problematic in corn. A number of POST products can provide good control of triazine-resistant (TR) weeds on corn.

For TR pigweed control, include a Group 15 herbicide for residual control (acetochlor, dimethenamid, metolachlor, or pyroxasulfone) at planting. The Group 15 herbicides will suppress initial TR pigweed, but in most years a postemergence application of a non-triazine herbicide will be needed for full-season control.

For TR lambsquarters, some of the Group 15 herbicides will help suppress emergence (acetochlor and pyroxasulfone), but they are not as active on lambsquarters as they are on pigweed. The Group 3 herbicide pendimethalin can provide good control of TR lambsquarters when applied prior to emergence. In addition, residual control can be obtained with products such as mesotrione or isoxaflutole.

ALS Resistance

Weeds resistant to the Group 2 herbicides in the Mid-Atlantic region include several pigweed species, common and giant ragweed, common chickweed, horseweed, Italian ryegrass, giant foxtail, Johnsongrass, and shattercane. The principal issue with most ALS-resistant weeds in corn is lack of efficacy with POST ALS inhibitor products. For example, do not rely on nicosulfuron or rimsulfuron for POST control of resistant foxtail, Johnsongrass, or shattercane. ALS-resistant Johnsongrass and shattercane are a particular concern as only glyphosate and glufosinate are available for POST control in corn. Also, ALS-resistant broadleaves will not be controlled with halosulfuron or other Group 2 herbicides.

Glyphosate Resistance

Weeds resistant to the Group 9 herbicide glyphosate in the Mid-Atlantic region include Palmer amaranth and waterhemp, common and giant ragweed, and horseweed. In corn, all of these can be managed with alternative herbicides, including the Group 4 growth regulators, the triazines if they are not Group 5 resistant, and several others, including the Group 27 herbicides such as mesotrione and isoxaflutole.

Control of Roundup Ready Corn: Volunteers or Replanting

There are times when corn has to be removed from a field with the intention of replanting a corn crop. Tillage is one effective method, but it is not appropriate in no-tillage situations. Use of glyphosate is highly effective for non–Roundup Ready corn. However, the challenge is in removing Roundup Ready hybrids. There are limited herbicides to consistently kill small corn plants. Gramoxone SL, Liberty, and Select are three products that have shown the most activity. Research conducted in this region with Gramoxone and Select demonstrated that Select was the most effective for corn 2 to 3 inches tall. For taller corn (4 to 6 inches tall), Gramoxone in combination with a photosystem II–inhibiting herbicide (metribuzin, Lorox, or atrazine) was the most effective. Liberty is a third option, but it will not control LibertyLink hybrids.

- Select Max: up to 6 ounces of Select Max with a nonionic surfactant at 0.25 percent v/v plus AMS at 2.5 to 4 pounds per acre. Do not use a COC or MSO. Wait a minimum of six days from time of application until planting corn due to risk of crop injury. (Select Max will also control corn hybrids containing Roundup Ready and LibertyLink stacked traits.)
- Gramoxone SL 2.0: 3 to 4.5 pints per acre (2 to 2.7 pints of 3.0 SL formulation) in combination with metribuzin (4 to 6 ounces per acre), Lorox (1 pint per acre), or atrazine (1 pound per acre). These photosystem II inhibitors are not added to control the corn but used to slow down the Gramoxone activity, which helps provide more consistent control.
- Liberty 280: 22 to 29 ounces of Liberty has not been as consistent for control corn as Gramoxone and will not control varieties that contain the LibertyLink trait.

Insects

Insect pest populations, greatly influenced by weather conditions and other natural phenomena, cause variable crop losses from year to year. Since losses from insects may be high one year and of little consequence the next, growers should use a system for monitoring fields and making control decisions.

Table 2.2-1. Corn herbicides and their restrictions.

Trade Name	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide[1]	Water Quality Advisory[2]	Worker Reentry (Hours)[3]
2,4-D amine 4S	2,4-D amine	4	several	—	—	48
2,4-D LVE 4E	2,4-D LVE	4	several	—	—	12
Aatrex, Atrazine 4L/90DF	atrazine	5	Syngenta, others	Yes	Yes	12
Accent Q 54.5WG	nicosulfuron + safener	2	Corteva	—	—	4
Acuron 3.44SC	*S*-metolachlor + atrazine + mesotrione + bicyclopyrone	15/5/27/27	Syngenta	Yes	Yes	24
Acuron Flexi 3.26SC	*S*-metolachlor + mesotrione + bicyclopyrone	15/27/27	Syngenta	Yes	Yes	24
Acuron GT 4.295SC	*S*-metolachlor + mesotrione + bicyclopyrone + glyphosate[4]	15/27/27/9	Syngenta	—	Yes	24
Aim 2EC	carfentrazone-ethyl	14	FMC	—	—	12
Anthem Maxx 4.3SC	pyroxasulfone + fluthiacet	15/14	FMC	—	Yes	12
Anthem Flex 4SE	pyroxasulfone + carfentrazone	15/14	FMC	—	Yes	12
Armezon 2.8SC	topramezone	27	BASF	—	—	12
Armezon PRO 5.35EC	topramezone + dimethenamid-P	27/15	BASF	—	Yes	12
Assure II 0.88E/Targa	quizalofop	1	AMVAC/Gowan	—	—	12
Autumn Super 51WDG	iodosulfuron + thiencarbazone	2/2	Bayer CropScience	—	—	12
Axiom 68DF	flufenacet + metribuzin	15/5	Bayer CropScience	—	Yes	12
Balance Flexx 2SC	isoxaflutole + safener	27	Bayer CropScience	Yes	Yes	12
Basagran 4S	bentazon	6	several	—	Yes	12
Basis Blend 30DF	rimsulfuron + thifensulfuron	2/2	Corteva	—	—	4
Bicep II Magnum 5.5L/Cinch ATZ	*S*-metolachlor + atrazine + safener	15/5	Syngenta/Corteva	Yes	Yes	24
Bicep Lite II Magnum 6L/Cinch ATZ Lite	*S*-metolachlor + atrazine + safener	15/5	Syngenta/Corteva	Yes	Yes	24
Cadet 0.91EC	fluthiacet	14	FMC	—	Yes	12
Calibra 3.1ZC	*S*-metolachlor + mesotrione	15/27	Syngenta	—	Yes	24
Callisto 4SC	mesotrione	27	Syngenta	—	—	12
Callisto Xtra 3.7SC	mesotrione + atrazine	27/5	Syngenta	Yes	Yes	12
Capreno 3.45SC	tembotrione + thiencarbazone + safener	27/2	Bayer CropScience	—	Yes	12
Clarity 4S	dicamba	4	BASF	—	Yes	24
Corvus 2.63SC	isoxaflutole + thiencarbazone + safener	27/2	Bayer CropScience	Yes	Yes	12
Coyote 3.67EC	s-metolachlor + mesotrione	15/27	UPL	—	Yes	24
Curtail 2.38L	clopyralid + 2,4-D	4/4	Corteva	—	—	48
Defol 5L	sodium chlorate	not classified	Drexel	—	—	12
Degree Xtra 4.04ME	acetochlor + atrazine	15	Bayer CropScience	Yes	Yes	12
DiFlexx 4SC	dicamba + safener	4	Bayer CropScience	—	Yes	24
DiFlexx Duo 1.53SC	dicamba + tembotrione + safener	4/27	Bayer CropScience	—	Yes	24
Distinct 70DF	dicamba + diflufenzopyr	4/19	BASF	—	Yes	12
Dual Magnum 7.62E	*S*-metolachlor	15	Syngenta	—	Yes	24
Dual II Magnum 7.64E	*S*-metolachlor + safener	15	Syngenta	—	Yes	24

Table 2.2-1. Corn herbicides and their restrictions (continued).

Trade Name	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide[1]	Water Quality Advisory[2]	Worker Reentry (Hours)[3]
Durango DMA/Duramax 4S	glyphosate	9	Corteva	—	—	4
Elevore 0.57L	halauxifen	4	Corteva	—	Yes	12
Enlist Duo 3.3SL	2,4-D choline + glyphosate	4/9	Corteva	—	—	48
Enlist One 3.8SL	2,4-D choline	4	Corteva	—	—	48
Empyros 3.82EC	*S*-metolachlor + tolpyralate	15/27	Helena	—	Yes	12
EverpreX 7.62E	*S*-metolachlor	15	Corteva	—	Yes	24
Evik 80W	ametryn	5	Syngenta	—	—	12
Expert 4.88L	atrazine + *S*-metolachlor + glyphosate	5/15/9	Syngenta	Yes	Yes	12
Fierce 76WDG/Fierce EZ 3.04SC	pyroxasulfone + flumioxazin	15/14	Valent	—	Yes	12
FirstShot 50WDG	thifensulfuron + tribenuron	2/2	FMC	—	—	12
FulTime NXT 4.04EC	acetochlor + atrazine	15/5	Corteva	Yes	Yes	12
Gramoxone SL 2S/3S	paraquat	22	Syngenta	Yes	—	12–24
Halex GT 4.39EC	*S*-metolachlor + mesotrione + glyphosate[4]	15/27/9	Syngenta	—	Yes	24
Harmony Extra SG 50WDG/ Audit 1:1	thifensulfuron + tribenuron	2/2	FMC/UPL	—	—	12
Harmony SG 50WDG	thifensulfuron	2	FMC	—	—	4
Harness 7E	acetochlor + safener	15	Bayer CropScience	—	Yes	12
Harness MAX 3.85L	acetochlor + mesotrione	15/27	Bayer CropScience	—	Yes	12
Harness Xtra 5.6/6L	acetochlor + atrazine	15/5	Bayer CropScience	Yes	Yes	12
Hornet 78.5WDG	flumetsulam + clopyralid	2/4	AMVAC	—	Yes	48
Impact 2.8SC/Armezon	topramezone	27	AMVAC/BASF	—	—	12
Impact Core 7.15SC	topramezone + acetochlor	27/15	AMVAC	—	Yes	12
ImpactZ 4.26SC	topramezone + atrazine	5/27	AMVAC	Yes	Yes	12
Katagon 2OD	tolpyralate + nicosulfuron	27/2	Helm	—	Yes	12
Keystone LA NXT 6SE	acetochlor + atrazine	15/5	Corteva	Yes	Yes	12
Keystone NXT 5.6SE	acetochlor + atrazine	15/5	Corteva	Yes	Yes	12
Laudis 3.5SC	tembotrione	27	Bayer CropScience	—	Yes	12
Liberty 280 2.34L[5]/Rely 280	glufosinate	10	BASF	—	—	12
Lightning 70DG[6]	imazethapyr + imazapyr	2/2	BASF	—	Yes	12
Lorox 50DF/Linex 4L	linuron	5	Nova Source	—	—	24
Lumax EZ 3.67 SC/Lexar EZ 3.7SC	*S*-metolachlor + mesotrione + atrazine	15/27/5	Syngenta	Yes	Yes	24
Maestro 2E/Moxy (Buctril)	bromoxynil	6	Nufarm/WinField	—	—	24
Maverick 2.04SC	pyroxasulfone + mesotrione + clopyralid	15/27/4	Valent	—	Yes	12
Metribuzin 75DF/4L	metribuzin	5	various	—	Yes	12
Outlook 6EC	dimethenamid-P	15	BASF	—	Yes	12
Panoflex 50WDG	thifensulfuron + tribenuron	2/2	FMC	—	—	12
Peak 57WG	prosulfuron	2	Gowan	—	Yes	12
Permit 75WG	halosulfuron	2	Gowan	—	—	12

Table 2.2-1. Corn herbicides and their restrictions (continued).

Trade Name	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide[1]	Water Quality Advisory[2]	Worker Reentry (Hours)[3]
Permit Plus 74WDG	halosulfuron + thifensulfuron	2/2	Gowan	—	—	12
Perpetuo 2.3SC	pyroxasulfone + flumiclorac	15/14	Valent	—	Yes	12
Princep 4L/Simazine 90DF	simazine	5	Syngenta, others	—	Yes	12
Prowl 3.3E	pendimethalin	3	BASF	—	—	24
Prowl H2O 3.8CS	pendimethalin	3	BASF	—	—	24
Python 80WDG	flumetsulam	2	AMVAC	—	Yes	12
Realm Q 39WDG	rimsulfuron + mesotrione + safener	2/27	Corteva	—	Yes	12
Resicore 3.29SE/Resicore XL 3.26CS	acetochlor + mesotrione + clopyralid + safener	15/27/4	Corteva	—	Yes	12
Resolve 25DF	rimsulfuron	2	Corteva	—	—	4
Resolve Q 22.4WDG	rimsulfuron + thifensulfuron + safener	2/2	Corteva	—	—	4
Resource 0.86EC	flumiclorac	14	Valent	—	—	12
Restraint 6.5EC	acetochlor + tolpyralate	15/27	Summit Agro	—	Yes	12
Reviton 2.83SC	tiafenacil	14	Helm	—	Yes	12
Revulin Q 51.2WDG	nicosulfuron + mesotrione	2/27	Corteva	—	—	12
Roundup WeatherMAX 4.5S/ PowerMAX 4.5S/ PowerMAX3 4.8S	glyphosate	9	Bayer CropScience	—	—	4
Sequence 5.25EW	glyphosate + *S*-metolachlor	9/15	Syngenta	—	Yes	24
Sharpen 2.85SC	saflufenacil	14	BASF	—	Yes	12
Shieldex 400SC (3.33SC)	tolpyralate	27	Summit Agro	—	Yes	12
Sinate 2.57L	topramezone + glufosinate	27/10	AMVAC	—	Yes	12
Starane Ultra 2.8L	fluroxypyr	4	Corteva	—	—	12
Status 56WG	dicamba + diflufenzopyr + isoxadifen	4/19	BASF	—	Yes	12
Steadfast Q 37.7WG	nicosulfuron + rimsulfuron + safener	2/2	Corteva	—	—	4
Stinger 3S	clopyralid	4	Corteva	—	Yes	12
Stout 72.5WDG	nicosulfuron + thifensulfuron	2/2	Corteva	—	—	4
SureStart II 4.25SE/TripleFLEX II	acetochlor + flumetsulam + clopyralid	15/2/4	Corteva/Bayer CropScience	—	Yes	12
Surpass NXT 7E	acetochlor + safener	15	Corteva	—	Yes	12
TopNotch 3.2ME	acetochlor + safener	15	Corteva	—	Yes	12
Tough 5EC	pyridate	6	Belchim	—	—	12
TriVolt 3.65SC	isoxaflutole + flufenacet + thiencarbazone	27/15/2	Bayer CropScience	Yes	Yes	23 days
ValorSX 51WDG/Valor EZ 4SC	flumioxazin	14	Valent	—	—	12
Verdict 5.57EC	saflufenacil + dimethenamid-P	14/15	BASF	No	Yes	12
Warrant 3CS	acetochlor	15	Bayer CropScience	—	Yes	12
Yukon 67.5WDG	halosulfuron + dicamba	2/4	Gowan	—	—	12
Zidua SC 4.17L	pyroxasulfone	15	BASF	—	Yes	12

Table 2.2-1. Corn herbicides and their restrictions (continued).

Trade Name	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide[1]	Water Quality Advisory[2]	Worker Reentry (Hours)[3]

[1] Only licensed applicators may purchase and apply restricted-use pesticides. To become licensed, contact your state Department of Agriculture.
[2] These herbicides have properties that may result in groundwater or surface water contamination. Do not apply them in areas where soils are permeable or coarse and groundwater is near the surface. Practices should be followed to minimize the potential for dissolved runoff and/or runoff erosion. See the herbicide label for specific restrictions.
[3] If soil-applied products are injected or incorporated at application time, under certain circumstances the Worker Protection Standard allows workers to enter the treated area if they will have no contact with anything that has been treated. Personal protective equipment is required for early entry to treated areas if contact with treated soil, plants, or water is involved.
[4] For use on glyphosate-resistant corn hybrids only (Roundup Ready).
[5] For use on glufosinate-resistant corn hybrids only (LibertyLink).
[6] For use only on IMI (IR/IT) or Clearfield (CL) corn hybrids.

Table 2.2-2. Corn herbicide prepackaged mixes, or co-packs, and equivalents.

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae)	An Equivalent Tank Mixture of
Acuron 3.44SC	2.14 lb S-metolachlor	15	2.5 qt	1.34 lb S-metolachlor	1.4 pt Dual II Magnum 7.64E
	0.24 lb mesotrione	27		0.15 lb mesotrione	4.8 fl oz Callisto 4SC
	0.06 lb bicyclopyrone	27		0.038 lb bicyclopyrone	0.038 lb bicyclopyrone
	1 lb atrazine	5		0.625 lb atrazine	0.625 qt atrazine 4L
Acuron Flexi 3.26SC	2.86 lb S-metolachlor	15	2 qt	1.43 lb S-metolachlor	1.5 pt Dual II Magnum 7.64E
	0.32 lb mesotrione	27		0.16 lb mesotrione	5.12 fl oz Callisto 4SC
	0.08 lb bicyclopyrone	27		0.04 lb bicyclopyrone	0.04 lb bicyclopyrone
Anthem Flex 4SE	3.733 lb pyroxasulfone	15	3.5 fl oz	0.102 lb pyroxasulfone	3.1 fl oz Zidua 4.17SC
	0.267 lb carfentrazone	14		0.007 lb carfentrazone	0.47 fl oz Aim 2EC
Acuron GT 4.29SC	2 lb S-metolachlor	15	3.75 pt	0.94 lb S-metolachlor	1 pt Dual Magnum 7.62E
	0.2 lb mesotrione	27		0.09 lb mesotrione	3 fl oz Callisto 4SC
	0.095 lb bicyclopyrone	27		0.044 lb bicyclopyrone	0.044 lb bicyclopyrone
	2 lb glyphosate	9		0.94 lb glyphosate (ae)	27 fl oz glyphosate 4.5S
Anthem Maxx 4.3SC	4.174 lb pyroxasulfone	15	4 fl oz	0.133 lb pyroxasulfone	4.1 oz Zidua 4.17SC
	0.126 lb fluthiacet	14		0.004 lb fluthiacet	0.56 oz Cadet 0.91EC
Armezon PRO 5.35EC	0.1 lb topramezone	27	24 fl oz	0.017 lb topramezon	0.76 fl oz Armezon 2.8SC
	5.25 lb dimethenamid-P	15		0.84 lb dimethenamid-P	18 fl oz Outlook 6EC
Autumn Super 51WDG	0.06 lb iodosulfuron	2	0.4 oz	0.002 lb iodosulfuron	0.024 oz ai iodosulfuron
	0.45 lb thiencarbazone	2		0.011 lb thiencarbazone	0.18 oz ai thiencarbazone
Axiom 68DF	0.544 lb flufenacet	15	16 oz	0.544 lb flufenacet	17 oz Define 4SC
	0.136 lb metribuzin	5		0.136 lb metribuzin	2.9 oz Metribuzin 75DF
Basis Blend 30DF	0.20 lb rimsulfuron	2	0.825 oz	0.01 lb rimsulfuron	0.64 oz Resolve 25DF
	0.10 lb thifensulfuron	2		0.005 lb thifensulfuron	0.16 oz Harmony SG 50DF
Bicep II Magnum 5.5L/ Cinch ATZ	2.4 lb S-metolachlor	15	2.1 qt	1.26 lb S-metolachlor	1.33 pt Dual II Magnum 7.64E
	3.1 lb atrazine	5		1.63 lb atrazine	1.63 qt atrazine 4L
Bicep Lite II Magnum 6L/ Cinch ATZ Lite	3.33 lb S-metolachlor	15	1.3 qt	1.08 lb S-metolachlor	1.13 pt Dual II Magnum 7.64E
	2.67 lb atrazine	5		0.87 lb atrazine	0.87 qt atrazine 4L
Callisto GT	0.38 lb mesotrione	27	2 pt	0.095 lb mesotrione	3.04 fl oz Callisto 4SC
	3.8 lb glyphosate	9		0.95 lb glyphosate	27 fl oz glyphosate 4.5S
Callisto Xtra 3.7SC	0.5 lb mesotrione	27	24 fl oz	0.09 lb mesotrione	3.04 fl oz Callisto 4SC
	3.2 lb atrazine	5		0.6 lb atrazine	1.2 pt atrazine 4L
Capreno 3.45SC	2.88 lb tembotrione	27	3 fl oz	0.068 lb tembotrione	2.5 fl oz Laudis 3.5SC
	0.57 lb thiencarbazone	2		0.013 lb ai thiencarbazone	0.21 oz ai thiencarbazone
Corvus 2.63SC	1.88 lb isoxaflutole	27	5.6 fl oz	0.083 lb isoxaflutole	5.3 fl oz Balance Flexx 2SC
	0.75 lb thiencarbazone	2		0.033 lb thiencarbazone	0.52 oz ai thiencarbazone
Coyote 3.67SC	0.33 mesotrione	27	2 qt	0.168 lb mesotrione	5.36 fl oz Callisto 4SC
	3.34 S-metolachlor	15		1.67 lb S-metolachlor	1.75 pt Dual II Magnum 7.64 EC
Curtail 2.38L	0.38 lb clopyralid	4	2 pt	0.095 lb clopyralid	0.25 pt Stinger 3S
	2 lb 2,4-D	4		0.5 lb 2,4D	1.0 pt 2,4-D 4S

Table 2.2-2. Corn herbicide prepackaged mixes, or co-packs, and equivalents (continued).

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae)	An Equivalent Tank Mixture of
Degree Xtra 4.04ME	2.7 lb acetochlor	15	3 qt	2.03 lb acetochlor	2.3 pt Harness 7E
	1.34 lb atrazine	5		1 lb atrazine	1 qt atrazine 4L
DiFlexx Duo 1.53SC	1.26 lb dicamba	4	32 fl oz	0.32 lb dicamba	10.25 oz DiFlexx 4SC
	0.27 lb tembotrione	27		0.068 lb tembotrione	2.5 fl oz Laudis 3.5SC
Enlist Duo 3.3SL	1.6 lb 2,4-D choline salt	4	4.75 pt	0.95 lb ae 2,4-D	30 fl oz Enlist One 3.8SL
	1.7 lb glyphosate	9		1.0 lb ae glyphosate	32 fl oz Durango DMA
Expert 4.88L	1.74 lb S-metolachlor	15	3 qt	1.3 lb S-metolachlor	1.4 pt Dual II Magnum 7.64E
	2.14 lb atrazine	5		1.6 lb atrazine	1.6 qt atrazine 4L
	0.75 lb ae glyphosate	9		0.75 lb glyphosate	1.5 pt glyphosate 4S
Fierce 76WDG	0.335 lb flumioxazin	14	3 oz	0.063 lb flumioxazin	2 oz Valor SX 51WG
	0.425 lb pyroxasulfone	15		0.08 lb pyroxasulfone	1.5 oz Zidua 85WG
Fierce EZ 3.04SC	1.34 lb flumioxazin	14	6 fl oz	0.063 lb flumioxazin	2 oz Valor SX 51WDG
	1.70 lb pyroxasulfone	15		0.08 lb pyroxasulfone	2.46 fl oz Zidua 4.17SC
FulTime NXT 4.04CS	2.7 lb acetochlor	15	3 qt	2 lb acetochlor	2.5 qt TopNotch 3.2ME
	1.34 lb atrazine	5		1 lb atrazine	1 qt atrazine 4L
Halex GT 4.39EC	2.09 lb S-metolachlor	15	3.6 pt	0.94 lb S-metolachlor	1 pt Dual Magnum 7.62E
	0.209 lb mesotrione	27		0.09 lb mesotrione	3 fl oz Callisto 4SC
	2.09 lb glyphosate	9		0.94 lb glyphosate (ae)	27 fl oz glyphosate 4.5S
Harness MAX 3.85L	3.52 lb acetochlor	15	2 qt	1.76 lb acetochlor	2 pt Harness 7E
	0.33 lb mesotrione	27		0.165 lb mesotrione	5.3 fl oz Callisto 4SC
Harness Xtra 6.0L	4.3 lb acetochlor	15	2 qt	2.15 lb acetochlor	2.46 pt Harness 7E
	1.7 lb atrazine	5		0.85 lb atrazine	0.85 qt atrazine 4L
Harness Xtra 5.6L	3.1 lb acetochlor	15	2.5 qt	1.94 lb acetochlor	2.21 pt Harness 7E
	2.5 lb atrazine	5		1.56 lb atrazine	1.56 qt atrazine 4L
Hornet 78.5WDG	0.185 lb flumetsulam	2	5 oz	0.058 lb flumetsulam	1.15 oz Python 80WDG
	0.5 lb clopyrald	4		0.195 lb clopyralid	6.7 fl oz Stinger 3S
Impact Core 7.15SC	7.08 lb acetochlor	15	30 fl oz	1.66 lb acetochlor	1.9 pt Harness 7E
	0.071 lb topramezone	27		0.017 lb topramezone	0.77 fl oz Impact 2.8SC
ImpactZ 4.26SC	4 lb atrazine	5	10.7 fl oz	0.33 lb atrazine	10.6 fl oz atrazine 4L
	0.26 lb topramezone	27		0.02 lb topramezone	1 fl oz Impact 2.8SC
Keystone LA NXT 6SE	4.3 lb acetochlor	15	2.3 qt	2.47 lb acetochlor	2.7 pt Surpass NXT 7EC
	1.5 lb atrazine	5		1.43 lb atrazine	1.95 pt atrazine 4L
Keystone NXT 5.6SE	3.1 lb acetochlor	15	2.5 qt	1.94 lb acetochlor	2.22 pt Surpass/Breakfree NXT
	2.5 lb atrazine	5		1.57 lb atrazine	3.15 pt atrazine 4L
Lexar EZ 3.7SC	1.74 lb S-metolachlor	15	3 qt	1.3 lb S-metolachlor	1.36 pt Dual II Magnum 7.64E
	0.224 lb mesotrione	27		0.168 lb mesotrione	5.36 oz Callisto 4SC
	1.74 lb atrazine	5		1.3 lb atrazine	1.3 qt atrazine 4L
Lumax EZ 3.67SC	2.49 lb S-metolachlor	15	2.7 qt	1.67 lb S-metolachlor	1.75 pt Dual II Magnum 7.64E
	0.249 lb mesotrione	27		0.168 lb mesotrione	5.36 oz Callisto 4SC
	0.935 lb atrazine	5		0.625 lb atrazine	0.625 qt atrazine 4L

Table 2.2-2. Corn herbicide prepackaged mixes, or co-packs, and equivalents (continued).

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae)	An Equivalent Tank Mixture of
Maverick 2.04SC	0.693 lb pyroxasulfone	15	32 fl oz	0.173 lb pyroxasulfone	5.3 fl oz Zidua 4.17SC
	0.829 lb mesotrione	27		0.207 lb mesotrione	6.6 fl oz Callisto 4SC
	0.525 lb clopyralid	4		0.131 lb clopyralid	5.6 fl oz Stinger 3S
Permit Plus 74WDG	0.662 lb halosulfuron	2	0.75 oz	0.031 lb halosulfuron	0.67 oz Permit 75WG
	0.078 lb thifensulfuron	2		0.004 lb thifensulfuron	0.12 oz Harmony 50SG
Perpetuo 2.3SC	0.59 lb flumiclorac	14	8 fl oz	0.037 lb flumiclorac	5.5 fl oz Resource 0.86EC
	1.71 lb pyroxasulfone	15		0.107 lb pyroxasulfone	3.28 fl oz Zidua 4.17SC
Realm Q 38.75WDG	0.075 lb rimsulfuron	2	4 oz	0.019 lb rimsulfuron	1.2 oz Resolve 25WG
	0.313 lb mesotrione	27		0.078 lb mesotrione	2.5 fl oz Callisto 4SC
Resicore 3.29SE	2.8 lb acetochlor	15	2.5 qt	1.75 lb acetochlor	2 pt Surpass NXT 7E
	0.3 lb mesotrione	27		0.18 lb mesotrione	5.76 fl oz Callisto 4SC
	0.19 lb clopyralid	4		0.119 lb clopyralid	0.3 pt Stinger 3S
Resolve Q 22.4WDG	0.184 lb rimsulfuron	2	1.25 oz	0.014 lb rimsulfuron	0.9 oz Resolve 25DF
	0.04 lb thifensulfuron	2		0.003 lb thifensulfuron	0.1 oz Harmony 50SG
Revulin Q 51.2WDG	0.144 lb nicosulfuron	2	4 oz	0.036 lb nicosulfuron	1.1 oz Accent Q 54.5WG
	0.368 lb mesotrione	27		0.094 lb mesotrione	3 fl oz Callisto 4SC
Sinate 2.57L	0.1 lb topramezone	27	28 fl oz	0.022 lb topramezone	1 fl oz Impact 2.8SC
	2.47 lb glufosinate	10		0.54 lb glufosinate	29.5 fl oz Liberty 2.34L
Status 56WG	0.4 lb dicamba	4	5 oz	0.125 lb dicamba	4 fl oz Clarity 4S
	0.16 lb diflufenzopyr	19		0.05 lb diflufenzopyr	0.05 lb diflufenzopyr
Steadfast Q 37.7WG	0.125 lb rimsulfuron	2	1.5 oz	0.012 lb rimsulfuron	0.76 oz Resolve 25WG
	0.252 lb nicosulfuron	2		0.02 lb nicosulfuron	0.7 oz Accent Q 54.5WG
Stout 72.5WDG	0.675 lb nicosulfuron	2	0.75 oz	0.031 lb nicosulfuron	0.67 oz Accent 75DF
	0.05 lb thifensulfuron	2		0.002 lb thifensulfuron	0.05 oz Harmony 75DF
SureStart II 4.25SE or TripleFLEX II	3.75 lb acetochlor	15	2 pt	0.94 lb acetochlor	1.1 pt Surpass NXT 7E
	0.29 lb clopyralid	4		0.075 lb clopyralid	3.2 fl oz Stinger 3S
	0.12 lb flumetsulam	2		0.03 lb flumetsulam	0.6 oz Python 80WDG
TriVolt 3.65SC	0.57 lb isoxaflutole	27	20 fl oz	0.09 lb isoxaflutole	5.76 fl oz Balance Flexx 2SC
	2.85 lb flufenacet	15		0.45 lb flufenacet	0.45 lb flufenacet
	0.23 lb thiencarbazone	2		0.04 lb thiencarbazone	0.04 lb thiencarbazone
Verdict 5.57EC	5 lb dimethenamid-P	15	13 fl oz	0.5 lb dimethenamid-P	11 fl oz Outlook 6EC
	0.57 lb saflufenacil	14		0.058 lb saflufenacil	2.6 fl oz Sharpen 2.85L
Yukon 67.5WDG	0.125 lb halosulfuron	2	4 oz	0.03 lb halosulfuron	0.67 oz Permit 75WG
	0.55 lb dicamba	4		0.125 lb dicamba	4 fl oz Clarity 4S

Table 2.2-3. Relative effectiveness of burndown treatments for control of weeds in no-till corn.

Herbicide[1]	Site of Action Number	Brome, Downy	Burdock, Common	Chickweed[2]	Dandelion	Dock, Curly	Dogbane, Hemp; Dewberry; Milkweed; etc.	Evening Primrose, Cutleaf	Fleabanes, Annual	Foxtail spp.	Garlic, Wild	Geranium, Carolina	Groundsel, Common[3]	Henbit/Deadnettle	Horseweed/Marestail[2,4]	Lambsquarters	Mustard spp.	Quackgrass Sod	Ragweed, Common	Smartweed	Thistle, Canada	Violet, Field/Pansy
2,4-D (spring-applied) (1 qt)	4	N	7	6	8	7	N	**9**	6	N	7	—	6	N	**8+**	**9**	**9**	N	**9**	7	8	6
2,4-D + dicamba (spring-applied)	4/4	N	8	8	8	7+	6	**9**	8	N	7	7+	7	6	**9**	**9**	**9**	N	**9**	**9**	**8+**	7
Atrazine	5	7	6	8	N	6	N	7	7+	7	N	**9**	**9**	8	8	N	8	8	**9**	**9**	6	8
Atrazine + 2,4-D	5/4	7	7+	8	**9**	7	N	**9**	7+	7	7	**9**	**9**	8	**9**	**9**	**9**	7	**9**	**9**	**8+**	8
Autumn Super + 2,4-D (fall-applied)	2/4	N	**9**	**9**[2]	**9**	7	N	**9**	8	N	—	—	8	**9**	**9**	—	**9**	N	—	—	6	6
Balance/Corvus	27/(2)	N	7	8	6	N	N	—	7	6	—	—	8	7+	7	7	8	N	7	6	6	6
Glyphosate (fall-applied)[5]	9	**9**	**8+**	**9**	**9**	7	**8+**	7	8	—	**9**	8	**9**	8	N	—	**9**	**9**	—	—	**9**	7
Glyphosate (spring-applied)[5]	9	**9**	7	9	6	6	7	6	7+	**9+**	8	7	**9**	6	N	**9**	**9**	8	**9**	7	8	6
Glyphosate + 2,4-D or dicamba (fall-applied)	9/4	**9**	**9+**	**9**	**9**	7	**9**	**9+**	**9**[6]	—	**9**	8	**9**	**8+**[6]	**9**[6]	—	**9**[6]	**9**	—	—	**9+**	7
Glyphosate + 2,4-D or dicamba (spring-applied)	9/4	**9**	7+	**9**	8	7	7+	9	8	**9+**	8	7	**9**	**8+**	**9**	**9**	**9**	**9**	**9**	**8+**	**8+**	8
Glyphosate + atrazine	9/5	**9**	7+	**9**	7	6	N	6	7+	**9**	8	7	**9**	**9**	8	**9**	**9**	**9**	**9**	**9**	8	8
Glyphosate + metribuzin	9/5	**9**	7	**9**	6	6	7	6	8	**9**	8	7	**9**	**8+**	N	**9**	**9**	9	**9**	**9**	8	8
Gramoxone	22	7	N	**8+**	N	N	6	7	6	**9**	6	8	**8+**	7	7	8	8	6	8	7	6	8
Gramoxone + 2,4-D or dicamba[5]	22/4	7	7	**9**	7	7	6	**9**	7	**9**	7	8	**8+**	8	**8+**	**9**	**9**	6	**9**	**8+**	8	**8+**
Gramoxone + atrazine	22/5	8	6	**9**	N	6	6	7	7	**9**	6	8	**8+**	**9**	**8+**	8	**8+**	8	**9**	**9**	7	8
Gramoxone + metribuzin	22/5	7	6	**9**	N	N	6	7	6	**9**	6	8	**8+**	8	8	8	**8+**	6	**9**	**9**	6	8
Harmony Extra/FirstShot/ Audit	2/2	N	6	**9**	6	8	6	—	N	N	**8+**	—	**9**	8	7+[2]	**9**	**9**	N	6	**9**	8	N
Harmony Extra/FirstShot/ Audit + 2,4-D	2/4	N	7	**9**	**9**	**9**	6+	**9**	6	N	**8+**	—	**9**	**9**	**8+**	**9**	**9**	N	**9**	**9**	**8+**	7
Liberty	10	6	6	8	6	—	N	—	8	8	—	—	7	6	8	8	8	6	8	8	6	N

Table 2.2-3. Relative effectiveness of burndown treatments for control of weeds in no-till corn (continued).

Herbicide[1]	Site of Action Number	Brome, Downy	Burdock, Common	Chickweed[2]	Dandelion	Dock, Curly	Dogbane, Hemp; Dewberry; Milkweed; etc.	Evening Primrose, Cutleaf	Fleabanes, Annual	Foxtail spp.	Garlic, Wild	Geranium, Carolina	Groundsel, Common[3]	Henbit/Deadnettle	Horseweed/Marestail[2,4]	Lambsquarters	Mustard spp.	Quackgrass Sod	Ragweed, Common	Smartweed	Thistle, Canada	Violet, Field/Pansy
Lumax	15/5/27	N	8	**9**	8	8	N	—	8	6	N	**8+**	**9**	8	8	9	8	N	**8+**	**9**	7	7
Reviton (2 fl oz)	14	6	—	8	6+	—	—	8	7+	6	—	—	—	8	7	8	8	—	8	—	—	8
Sharpen[7] (1 fl oz)	14	N	N	6	7	—	N	N	7+	N	—	—	8	6	8	8	8	N	8	8	6	N
Sharpen + glyphosate	14/9	**9**	7	**9**	8	6	7	6	8	**9+**	—	—	**9**	6	**9**	**9**	**9**	8	**9**	**9**	8	6
Valor SX/Fierce	14/(15)	8	N	**9**	7[8]	N	N	6	N	N	—	—	7	7	6	**9**	8	N	7	7	N	N

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale.
This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage. Treatments are rated only for control of vegetation existing at the time of application.

[1] See Table 2.1-10 for additional formulations or trade names containing some of these same active ingredients.
[2] Group 2 herbicides will not control ALS-resistant biotypes.
[3] Certain populations of common groundsel in the northeastern U.S. are resistant to triazine herbicides. Herbicide programs that contain bromoxynil (Maestro, Moxy) or clopyralid (Stinger) provide good control of groundsel in crop.
[4] Roundup, Touchdown, and other glyphosate products are not effective on glyphosate-resistant horseweed biotypes.
[5] Activity is reduced if applied in certain tank-mixes; glyphosate with photosynthesis inhibitors such as triazine herbicides; 2,4-D and Clarity with Gramoxone. May still be tank-mixed for convenience, but burndown is improved if applied separately.
[6] Based on control in early spring. Emergence of seedlings in the spring will reduce effectiveness.
[7] Use rate of 1.5 fl oz/A has been more consistent for horseweed/marestail control than 1.0 fl oz/A.
[8] Valor provides control of germinating dandelion seedling; however, it is weak on dandelion when applied POST.

Table 2.2-4. Effectiveness of herbicides for control of common cash or cover crops in spring before corn establishment.

Herbicide	Rate (lb ai or ae/ acre)[1]	Alfalfa[2]	Austrian Winter Pea	Bluegrass/ Timothy[2]	Bromegrass/ Orchardgrass/ Fescue[2]	Clover, Crimson	Clover, Red[2]	Clover, White[2]	Mustards/ Radish/ Rapeseed	Ryegrass, Annual[4]	Rye, Cereal	Triticale	Wheat, Winter	Vetch, Hairy
2,4-D ester	0.5	7+	N	N	N	7	8	6	8	N	N	N	N	**9**
	1	8	N	N	N	8	**9**	7	**9**	N	N	N	N	**10**
2,4-D ester + dicamba	0.5 + 0.5	**9+**	7	N	N	**8+**	**9**	**9**	8	N	N	N	N	**10**
Atrazine	1	N	—	6	6	6	6	6	6	6	6	6	6	7
	2	6	—	7	7	7	7	7	7	7	7	7	7	8
Clopyralid	0.25	**8+**	8	N	N	8	**9**	**9**	N	N	N	N	N	**9**
Dicamba	0.5	**9**	7	N	N	8	**9**	**9**	6	N	N	N	N	**9**
Elevore	0.004	—	7	N	N	N	—	—	N	N	N	N	N	8
Glyphosate	0.75	6	7	**9**	8	8	7	6	7+	8	**9**	**9**	**9**	7
	1.5	7	8	**9+**	**8+**	**8+**	7+	7	**8+**	**9**	**9**	**9**	**9**	8
Glyphosate + 2,4-D ester or dicamba	0.75 + 0.5	**8+**	**9**	**9**	8	**9**	8	8	**9**	8	**9**	**9**	**9**	**10**
		9	**9**	**9**	8	**9**	**9**	**9**	8	8	**9**	**9**	**9**	**10**
Glyphosate + Liberty, Interline, Scout, others[3]	0.75 + 0.59	—	**9**	—	—	**9**	—	—	6	9	8	**9**	**9**	**9**
Glyphosate + Sharpen	0.75 + 0.022	—	**9**	—	—	8	—	—	7	**9**	**8+**	**9**	**9**	8
Mesotrione + atrazine	0.168 + 1	7	—	6	6	8	7+	7+	8	6	6	6	6	7
Paraquat	0.5	N	7	7	6	8	7	7	8	6	7	7	8	7
	0.75	N	8	7+	7	**9**	8	7	**8+**	6	8	7+	**8+**	8
Paraquat + atrazine or	0.5 + 1	7	**8+**	**9**	8	**10**	**8+**	7	**9**	7	**8+**	8	**8+**	**9**
metribuzin	or 0.25		**8+**									8		
Paraquat + 2,4-D or dicamba	0.75 + 0.5	7+	8	7	6	**9**	**8+**	8	**9**	6	8	7	**8+**	**10**
Liberty, Interline, Scout, others[3]	0.59	—	**8+**	—	—	**9**	L	—	6	7	6	7	7	**9**
Liberty, Interline, Scout, others[3] + 2,4-D	0.59 + 0.5	—	**9**	—	—	**9**	—	—	8	7	6	6	7	**9+**
Reviton (2 fl oz)	0.044	—	—	N	N	8	—	—	—	N	N	N	N	N
Sharpen (1 fl oz)	0.022	—	6	N	N	N	—	—	N	N	N	N	N	N

Table 2.2-4. Effectiveness of herbicides for control of common cash or cover crops in spring before corn establishment (continued).

Herbicide	Rate (lb ai or ae/ acre)[1]	Alfalfa[2]	Austrian Winter Pea	Bluegrass/ Timothy[2]	Bromegrass/ Orchardgrass/ Fescue[2]	Clover, Crimson	Clover, Red[2]	Clover, White[2]	Mustards/ Radish/ Rapeseed	Ryegrass, Annual[4]	Rye, Cereal	Triticale	Wheat, Winter	Vetch, Hairy

Control ratings: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55%; L= listed as controlled on herbicide label, but local data are limited; + = upper end of rating scale; — = not applicable or no local data available.

[1] 0.75 lb glyphosate = 32 fl oz of a 41% glyphosate; 0.5 lb paraquat = 2 pt Gramoxone SL2.0 or 1.33 pt Gramoxone SL 3.0. Clopyralid is a component of Stinger and SureStart/TripleFLEX.

[2] Application in the fall can improve control with some herbicides.

[3] Warm temperatures, high humidity, and bright sunlight improve the performance of Liberty. Weed control may be reduced when applications are made to weeds under stress from drought or cool temperatures.

[4] Tank mixing clethodim (Select, etc.) or rimsulfuron (Resolve, Basis Blend) with glyphosate has shown improved burndown activity on annual ryegrass cover crop control in university field trials. Consult herbicide label for use guidelines.

Table 2.2-5. Comments on burndown herbicides for no-till corn.

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
2,4-D LVE 4E	2,4-D ester	4	1–2 qt	1–2

• Apply 7–14 days before planting or 3–5 days after planting for greater crop safety.
• Plant corn at least 1.5 inches deep.
• This product is poor on chickweed, henbit, and red deadnettle, and ineffective on all grasses.
• Add Clarity (dicamba) to increase efficacy on legume sods. A combination of 2,4-D + dicamba controls most annual broadleaf weeds and alfalfa. Emerged perennial broadleaves are partially controlled. This combination is fair on chickweed, henbit, and red deadnettle, and ineffective on all grasses.
• Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary to limit spray drift. Comply with guidelines for drift management (see label for details).

Atrazine 90DF	atrazine	5	1.8–2.2 lb	1.6–2

• Apply 1.6–2 qt atrazine 4L prior to planting.
• Controls small emerged annual broadleaves and some grasses.
• Can be applied in liquid nitrogen as the carrier to improve burndown characteristics.
Atrazine Use Restrictions
Preplant or preemergence:
• On highly erodible soils (as defined by the U.S. Natural Resources Conservation Service):
• Fields where more than 30% of the soil surface is covered with plant residue at planting, apply a maximum of 2 lb ai/A as a broadcast spray.
• Fields where less than 30%of the soil surface is covered with plant residue at planting, apply a maximum of 1.6 lb ai/A as a broadcast spray.
• Apply a maximum of 2 lb ai/A as a broadcast spray.
Postemergence:
• If no atrazine was applied prior to crop emergence, use a maximum rate of 2 lb ai/A.
• If a soil-applied application was made in the same calendar year, the combined preplant or preemergence and postemergence applications may not exceed 2.5 lb ai/A.
Safety Precautions for Using Atrazine
• Do not mix, load, or apply within 50 feet of drinking water wells, livestock wells, agricultural drainage wells, irrigation wells, abandoned wells, or sinkholes.
• Do not mix or load within 50 feet of intermittent streams, perennial streams, rivers, lakes, or reservoirs.
• Do not apply within 200 feet of lakes or reservoirs.
• Do not apply within 66 feet of the points where surface water runoff enters intermittent streams, perennial streams, or rivers. The 66-foot buffers should be planted to a crop or seeded with grass on highly erodible land.
• *Restricted-use pesticide and water quality advisory.*

Autumn Super 51WDG	iodosulfuron	2	0.3–0.5 oz	0.001–0.002
	thiencarbazone	2		0.01–0.014

• Autumn Super may be applied after fall harvest and up to 30 days prior to corn planting.
• Do not apply to frozen ground. Apply to actively growing weeds.
• Autumn Super will provide short-term residual control of small-seeded broadleaves but will not provide season-long PRE control of annual grasses and broadleaf weeds.
• Apply Autumn Super at 0.3–0.5 oz/A plus necessary adjuvants.
• For enhanced burndown activity, tank-mix with 2,4-D, glyphosate, paraquat, simazine, or metribuzin.
• Be cautious of crop rotation restrictions.

Clarity 4S	dicamba (DGA salt)	4	0.5–1 pt	0.25–0.5 lb ae

• Apply 7–14 days before planting or 3–5 days after planting for greater crop safety.
• Plant corn at least 1.5 inches deep.
• A combination of 2,4-D + dicamba controls most annual broadleaf weeds and alfalfa. Emerged perennial broadleaves are partially controlled. This combination is fair on chickweed, henbit, and red deadnettle, and ineffective on all grasses. Applications should be made while annual weeds are small (4 inches) and actively growing.
• Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary to limit spray drift. Comply with guidelines for drift management (see label for details).
• Dicamba can be difficult to completely remove from spray equipment and residue is capable of injuring sensitive plants. Follow label instructions concerning sprayer cleanout.

Table 2.2-5. Comments on burndown herbicides for no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Enlist Duo 3.3SL	2,4-D choline +	4	3.5–4.75 pt	0.7–0.95 ae
	glyphosate	9		0.74–1 ae
• Can be used as a burndown application to corn with or without the Enlist trait to control broadleaves and grasses. • Apply 7–14 days before planting for greater crop safety. • Do not apply less than 10 GPA total spray solution and do not use nitrogen solutions as a carrier. • Comply with guidelines for drift management (see label for details). • For best results do not apply to light sandy soils as a PRE application. • Can be tank-mixed with residual herbicides.				
Enlist One 3.8SL	2,4-D choline	4	1.5–2 pt	0.71–0.95
See comments under 2,4-D LVE and Enlist Duo for more details.				
Expert 4.88L	*S*-metolachlor +	15	2.5–3.75 qt	1.09–1.63
	atrazine +	5		1.33–2
	glyphosate	9		0.63–0.94 ae
• Expert is a premix of metolachlor (Dual II Magnum), atrazine, and glyphosate. • The 3 qt rate contains 1.3 lb *S*-metolachlor, 1.6 lb atrazine, and 0.75 lb ae glyphosate. • Expert can be used as a burndown/PRE program in corn or as an early POST application in Roundup Ready hybrids. • See Expert label for additional information. • *Restricted-use pesticide and water quality advisory.*				
Glyphosate**	glyphosate	9	See Table 2.1-8	
• Fall applications of glyphosate are better than spring applications for control of orchardgrass sods and quackgrass. • If controlling orchardgrass sod in spring, it is best to spray when sod is 6 to 10 inches tall. • Use at least 1.13 lb ae glyphosate or higher, especially if tank-mixing with pre-residual herbicide and nitrogen carriers. • Spring applications may be used for control of annual weeds. • Using low-volume sprays may allow for a reduced rate. • For control of small annual weeds or volunteer small grains, glyphosate may be used at reduced rates. • Can be tank-mixed with residual herbicides such as atrazine. When tank-mixing glyphosate with residual herbicides, apply in 10–20 gal water/A or 10–60 gal liquid fertilizer nitrogen/A. • Adding 2,4-D or dicamba improves control of large annual broadleaf weeds, dandelion, and alfalfa. • Glyphosate may be applied in clear liquid nitrogen fertilizers and clear liquid complete-analysis fertilizers, but it may be less effective on certain annual grasses and perennials. • Do not use glyphosate with suspension-type liquid fertilizers.				
Gramoxone SL 2.0	paraquat	22	2–4 pt	0.5–1
Gramoxone SL 3.0			1.3–2.7 pt	
• Apply in 20–60 gal/A for control of emerged annual weeds. • Add 16–32 oz non-ionic surfactant/100 gal of spray. • Adding 2,4-D or dicamba improves control of large annual broadleaf weeds and alfalfa. Alfalfa control is improved by applying 2,4-D or dicamba separately at least one day ahead of paraquat. • Can be tank-mixed with residual herbicides; adding atrazine to paraquat can improve control of fescue and certain other perennial sods. • Phosphate-containing liquid fertilizer solutions diminish paraquat activity if used as a carrier. • Use appropriate precautions when handling paraquat to minimize exposure to the herbicide. • Do not use flood jet tips larger than size 20 or spacing greater than 40 inches.· • Other labeled formulations of paraquat are available; see Table 2.1-10 for options. *Paraquat Use Restrictions* • Only certified applicators who successfully complete the paraquat-specific training can mix, load, or apply paraquat. • Application of paraquat "under the direct supervision" of a certified applicator is no longer allowed; registered technicians cannot apply. • Required training at http://usparaquattraining.com; certified applicators must repeat training every three years. • *Gramoxone is a restricted-use pesticide.*				
Harmony Extra SG 50DF	thifensulfuron +	2	0.45–0.9 oz	0.009–0.018
	tribenuron	2		0.005–0.009
• Adding Harmony Extra to glyphosate or 2,4-D can improve control of certain winter annual broadleaves and perennials. • Must be applied in fall or early spring at least 14 days ahead of planting. • Other products that contain thifensulfuron and tribenuron include FirstShot and Panoflex.				

Table 2.2-5. Comments on burndown herbicides for no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Liberty 2.34SL	glufosinate	10	32–43 fl oz	0.59–0.79
• Liberty may be applied as a burndown treatment prior to the planting or emergence of any corn variety. • However, early season burndown activity may be reduced since warm temperatures, high humidity, and bright sunlight are necessary to improve the performance of Liberty. Weed control may be reduced when applications are made to weeds under stress from drought or cool temperatures. • Liberty performs better as a POST herbicide as compared to burndown applications in April. • Apply a minimum of 32 fl oz/A to young, actively growing weeds; burndown and in-crop applications may not exceed 87 fl oz/A per season. • Applications should be made from dawn until 2 hours prior to sunset to avoid the possibility of reduced weed control. • Liberty must be applied with ammonium sulfate, and the recommended use rate is3 lb/A. • Uniform, thorough spray coverage (20 gal/A is recommended) is necessary to achieve consistent weed control; do not use nozzles that produce large droplets.				
Metribuzin 75DF/4L	metribuzin	5	2–4 oz DF	0.094–0.19
• Include metribuzin as part of an herbicide program for burndown of existing vegetation prior to crop emergence. • Metribuzin may be tank-mixed with 2,4-D LVE, Gramoxone, or glyphosate. • Use a maximum of 4 oz DF if applying less than 10 days before planting or on soils with less than 2% organic matter. • Do not use on coarse soils with less than 1.5% organic matter or on soils having pH 7.0 or greater. • Plant corn at least 1.5 inches deep to avoid injury. • *Water quality advisory.*				
Reviton 2.83SC	tiafenacil	14	1–3 fl oz	0.022–0.066
• Reviton may be applied as an early preplant/burndown treatment through preemergence timings; it will injure emerged corn. There are no plant-back restrictions between application and corn planting. • It is best to apply before weeds are taller than 5 inches, and complete spray coverage is important for adequate weed control. • Reviton can be applied with glyphosate (or other herbicides) to enhance the speed of burndown and increase weed spectrum. • Include necessary additives MSO plus nitrogen solution or AMS to the spray mixture. • Burndown activity may be decreased or slowed under cloudy, foggy, or cooler weather or when weeds are drought stressed. • Reviton is similar to Sharpen but less active on marestail; however, it has better grass, field pansy/violet, and primrose activity.				
Sharpen 2.85SC	saflufenacil	14	1–3 fl oz	0.022–0.067
• Sharpen may be applied as a preplant/burndown treatment from 14 days early preplant through preemergence timings; do not apply to emerged corn. • Apply Sharpen in a typical glyphosate burndown herbicide program to enhance the speed of burndown and increase weed spectrum, including glyphosate-resistant horseweed. • Depending on the rate, Sharpen can provide some short-term residual control of certain annual broadleaf weeds. Include necessary additives MSO plus nitrogen solution or AMS to the spray mixture. • Do not apply more than 1 fl oz/A where at-planting OP or carbamate insecticides are being used. • Sharpen is a Group 14 herbicide, and due to concerns for long-term viability of this herbicide mode of action, extension specialists in the Mid-Atlantic region recommend not using it every year. • This mode of action has greater utility in soybeans than corn, especially for control of glyphosate-resistant horseweed (marestail). As such, we suggest that Sharpen and other saflufenacil-containing products (e.g., Verdict, Optill) be used in soybean first and only in alternate years. • The use of Sharpen in continuous corn should also be limited to every other year (alternating years with HPPD-containing herbicide [Group 27]) and avoided if Sharpen is used in soybean in a corn-soybean rotation.				
Valor SX 51WDG	flumioxazin	14	1–2 oz	0.51–1.02 oz
• Valor may be included in a typical no-till burndown herbicide program to enhance the speed of burndown and increase weed spectrum. • Corn can be planted seven days after application if there is at least 25% soil residue cover and 1/4 inch of rainfall. • On coarse-textured soils: stunting is often observed with Valor; corn must be planted between 14 and 30 days after application; and only use where last year's crop residue has not been incorporated into the soil. • Fierce 76WDG contains the active ingredients in Valor and Zidua and can be used in burndown programs; see Table 2.2-8 for additional details. • Valor is a Group 14 herbicide, and due to concerns for long-term viability of this herbicide mode of action, extension specialists in the Mid-Atlantic region recommend not using it every year. This mode of action has greater utility in soybeans than corn, especially for control of glyphosate-resistant horseweed (marestail). As such, we suggest that Valor and other flumioxazin-containing products (e.g., Fierce, Valor XLT, Envive) be used in soybean first and only in alternate years. • The use of Valor in continuous corn should also be limited to every other year (alternating years with HPPD-containing herbicide [Group 27]) and avoided if Valor is used in soybean in a corn-soybean rotation.				

See Table 2.2-3 for relative effectiveness of these treatments. May need to combine with residual treatment or postemergence program (Tables 2.2-8 and 2.2-13) for complete no-till weed control program.

*See Table 2.2-1 for additional formulations or trade names containing some of these same active ingredients.

**Refer to current product label for active ingredient concentration and application rate (e.g., 1 qt/A glyphosate 4S = 22 fl oz/A Roundup WeatherMAX).

Table 2.2-6. Water solubility and longevity of soil-applied herbicides.

Relative Moisture to Activate	ppm	Estimated Water to Activate*
Low	>500 ppm (very soluble)	0.33 inch
Medium	250–500 ppm	0.33–0.5 inch
High	100–250 ppm	0.5–0.75 inch
Very high	<100 ppm	>0.75 inch

*More water (additional irrigation) may be necessary if soil is dry at time of application, for soils with higher clay content, or if high plant residues are present.
Solubility (parts per million; ppm) refers to how many microliters of the herbicide will dissolve in 1 liter of water. The less soluble the herbicide, the more moisture (rain or irrigation) is needed to activate the herbicide and move it into the root zone. Solubility is used as a guideline for rainfall or irrigation required within a short time after application. Moisture needed also depends on the soil moisture at time of application.

Trade Name	Solubility (ppm)	Relative Moisture to Activate	Duration of Residual Weed Control
Atrazine	33	Very high	4–5 weeks
Balance Flexx	7	Very high	2–4 weeks
Callisto	1,500	Low	2–4 weeks
Dual II Magnum/Cinch	488	Medium	4–5 weeks
Flufenacet	56	Very high	2-4 weeks
Harmony SG	pH 5: 223	High	1–2 weeks
	pH 7: 2,240	Low	
Harness/Breakfree/Surpass	223	High	2–4 weeks
Intrro	242	High	2–4 weeks
Metribuzin	1,200	Low	2–4 weeks
Outlook	1,174	Low	2–4 weeks
Princep	5	Very high	4–5 weeks
Prowl/Other Pendimethalin Formulations	1	Very high	4–5 weeks
Python	5,600	Low	4–6 weeks
Resolve SG	pH 7: 7,300	Low	1–2 weeks
Sharpen	pH 5: 30 pH 7: 2,100	Very high Low	1–3 weeks
Stinger	1,000	Low	1–3 weeks
Thiencarbazone-methyl	436	Medium	2–4 weeks
Topnotch	223	High	2–4 weeks
Valor SX	2	Very high	4–5 weeks
Zidua	3.49	Very high	4–5 weeks

Relative duration of residual control is for comparison only based on herbicide half-life (length of time it takes for half the herbicide to break down). Herbicide breakdown results from chemical and/or microbial activity. Since the speed of breakdown is affected by a number of factors, including soil pH, soil temperature, and soil moisture, duration can vary for herbicides based on the specific conditions. Residual activity is not the same as herbicide carryover. Duration of residual control assumes (1) good activation, (2) no excessive rain or irrigation, and (3) that weed species are sensitive to the herbicide(s) applied.

Table 2.2-6. Water solubility and longevity of soil-applied herbicides (continued).

Premixes	Constituents
Acuron	Dual II Magnum, Callisto, atrazine, bicyclopyrone
Acuron Flexi	Dual II Magnum, Callisto, bicyclopyrone
Anthem ATZ	Zidua, Cadet, atrazine
Anthem Flex	Zidua, Aim
Anthem Maxx	Zidua, Cadet
Bicep II Magnum/Cinch ATZ	Dual II Magnum (or Cinch), atrazine
Bicep Lite II Magnum	Dual II Magnum, atrazine
Corvus	Balance Flexx, thiencarbazone
Coyote	Dual Magnum, Callisto
Fierce	Valor SX, Zidua
FulTime/Keystone/Breakfree ATZ	Topnotch (or Surpass), atrazine
Harness MAX	Harness, Callisto
Harness Xtra/Degree Xtra	Harness (or Degree), atrazine
Lumax EZ/Lexar EZ	Dual II Magnum, Callisto, atrazine
Maverick	Zidua, Callisto, Stinger
Resicore	Surpass, Callisto, Stinger
Resolve Q/Basis Blend	Resolve SG, Harmony SG
SureStart II/TripleFLEX II	Harness, Python, Stinger
TriVolt	Balance Flexx, thiencarbazone, flufenacet

Table 2.2-7. Relative effectiveness of soil-applied (preemergence) corn herbicides.

Grasses

Trade Name[1]	Site of Action Number	Barnyardgrass	Bermudagrass	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wire-stem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Atrazine	5	7	N	7	6+	7	N	N	6	6	6	N	7+	6	N
Balance Flexx[2]	27	8	N	7	8[3]	N	6	7+	N	N	8	N	N	7+	N
Dual products	15	**9**	N	**9**	**9**	**9+**	N	6	N	8	8	N	N	6	8
Harness, Surpass NXT, or TopNotch	15	**9**	N	**8+**	**9**	**9+**	N	7	N	7+	8	N	N	6	8
Outlook	15	**9**	N	8	**9**	**9**	N	6	N	7+	8	N	N	6	7
Princep	5	**8+**	N	8	8	8	N	6	8	6	**8+**	N	7	6	N
Prowl	3	**8+**	N	**8+**	8	8	N	7	N	6	**8+**	7	N	7	8
Zidua	15	**8+**	N	**9**	**8+**	**9+**	N	6	N	6	8	N	N	6	8
Mixtures															
Acuron	5/15/27	**9**	N	**9**	**9**	**9+**	N	6	6	**8+**	8	N	6	6	8
Acuron Flexi	15/27/27	**9**	N	**9**	**9**	**9+**	N	6	N	**8+**	8	N	N	6	8
Anthem Maxx or Flexx	14/15	**8+**	N	**9**	**8+**	**9+**	N	6	N	6	8	N	N	6	8
Atrazine + Princep	5/5	**8+**	N	**8+**	**8+**	8	N	6	8	**8+**	**8+**	N	**8+**	6	N
Axiom	5/15	**9**	N	**9**	**9**	8	N	6	N	6	8	N	N	6	N
Bicep, Cinch ATZ	5/15	**9**	N	**9**	**9**	**9+**	N	6	6	**8+**	8	N	6	6	8
Corvus	2/27	8	N	8	**8+**	N	7	7+	N	7	8	N	N	7+	N
Fierce	14/15	**8+**	N	**9**	**9**	**9+**	N	6	N	6	8	N	N	6	—
Harness MAX, Coyote	15/27	**9**	N	**8+**	**9**	**9+**	N	7	N	7+	8	N	N	6	8
Harness Xtra, Degree Xtra, FulTime NXT, or Keystone NXT	5/15	**9**	N	**9**	**9**	**9+**	N	7	6	**8+**	8	N	6	6	8
Lumax/Lexar	5/15/27	**9**	N	**9**	**9**	**9+**	N	6	6	**8+**	8	N	6	6	8
Maverick	15/27/4	**8+**	N	**9**	**8+**	**9+**	N	6	N	6	8	N	N	6	8
Resicore/Resicore XL	15/27/4	**9**	N	**8+**	**9**	**9+**	N	7	N	7+	8	N	N	6	8
SureStart II/TripleFLEX II	2/4/15	8	N	8	8	**9+**	N	6	N	6	8	N	N	6	8
TriVolt	27/15/2	**9**	N	**9**	**9**	**9**	7	7+	N	7	8	N	N	7+	8
Verdict	14/15	8	N	8	8	**9**	N	N	N	7+	8	N	N	N	N

Table 2.2-7. Relative effectiveness of soil-applied (preemergence) corn herbicides (continued).

Grasses

Trade Name[1]	Site of Action Number	Barnyardgrass	Bermudagrass	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wire-stem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale.
Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).
[1] See Table 2.1-10 and Table 2.2-1 for additional products that contain these active ingredients.
[2] Performance ratings based on full labeled rates.
[3] Herbicide is less effective on yellow foxtail: Balance (6) and Liberty (7).

Broadleaves

Trade Name[1]	Site of Action Number	Amaranth, Palmer/ Waterhemp[2]	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters[3]	Marestail/ Horseweed[4]	Morningglory, Annual	Nightshade, Eastern Black	Pigweed[3]	Ragweed, Common[5]	Ragweed, Giant[5]	Sida, Prickly	Smartweed	Velvetleaf	Corn Tolerance, Medium Soils	Corn Tolerance, Coarse Soils
Atrazine	5	**9+**	8	6	**8+**	**9**	N	**9**	**8+**	**9**	N	**9**	8	**9**	**9+**	8	E	E
Balance Flexx	27	8	—	7	N	8	**9**	**8+**	N	**9**	8	8	7	7	7+	**9**	F–G[6]	G
Dual products	15	**8+**	N	N	N	N	6	N	N	7+	8	6	N	N	N	N	G	G
Harness, Surpass NTX, or TopNotch	15	8	N	N	N	N	7	N	N	**8+**	**9**	7+	N	N	7	6	G	G
Lorox	7	7	—	N	7+	7	**8+**	7	N	6	8	7	N	N	**9**	7	F–G	F
Outlook	15	8	N	N	N	N	6	N	N	7+	8	6	N	N	6	N	G	G
Princep	5	**9+**	8	6	8	**9**	N	**9**	**9**	**9**	N	**9+**	7	**9**	**9**	8	E	E
Prowl	3	8	N	N	N	6	**9**	N	N	N	8	N	N	N	8	8	G[6]	F–G
Python	2	N	7	6	8	8	**8+**	N	N	7	**9**	7+	6	8	**8+**	8	F–G[6]	F
Zidua	15	**9**	N	N	N	7	8	N	N	8	**9**	7+	6	6	7	7	G	G
Mixtures																		
Acuron	5/15/27	**9+**	**9**	7	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**8+**	**9**	**9**	**9**	G	G
Acuron Flexi	15/27/27	**8+**	—	N	6	8	**9**	**8+**	6	**8+**	**8+**	7	7	N	**8+**	**9**	G	G
Anthem ATZ	5/14/15	**9+**	8	6	**9**	**9**	8	**9**	**8+**	**9**	**9**	**8+**	8	**9**	**9**	8	G	G
Anthem Maxx or Flex/Perpetuo	14/15	**9**	N	N	N	7	8	N	N	8	**9**	7+	6	6	7	7	G	G

Table 2.2-7. Relative effectiveness of soil-applied (preemergence) corn herbicides (continued).

Broadleaves

Trade Name[1]	Site of Action Number	Amaranth, Palmer/ Waterhemp[2]	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters[3]	Marestail/ Horseweed[4]	Morningglory, Annual	Nightshade, Eastern Black	Pigweed[3]	Ragweed, Common[5]	Ragweed, Giant[5]	Sida, Prickly	Smartweed	Velvetleaf	Corn Tolerance, Medium Soils	Corn Tolerance, Coarse Soils
Atrazine + Princep	5/5	**9+**	8	7	**9**	**9+**	N	**9**	**9**	**9**	N	**9**	**8+**	**9**	**9**	**8+**	E	E
Axiom	5/15	7	—	N	N	6	N	6	N	N	N	N	N	6+	6	N	G	F–G
Basis Blend/Resolve[7]	2/2	N	—	N	6	6	**8+**	N	N	N	**9**	N	N	N	6	6	F–G	F[7]
Bicep, Cinch ATZ	5/15	**9+**	**9**	6	**8+**	**9**	7	**9**	**8+**	**9**	**8+**	**8+**	8	**9**	**9**	**8+**	G	G
Corvus	2/27	8	—	7	8	8	**9**	**8+**	7	**9**	**9**	7+	7+	7	**8+**	**9**	G	F
Fierce	14/15	**9**	8	N	6	8	**9**	**8+**	7+	**9**	**9**	7+	6	8	7	8	G	F
Harness MAX, Coyote	15/27	**8+**	—	N	6	8	**9**	8	6	**8+**	**8+**	7	7	N	**8+**	**9**	G	G
Harness Xtra, Degree Xtra8, FulTime NXT, or Keystone NXT	5/15	**9+**	**9**	6	**8+**	**9**	7+	**9**	**8+**	**9**	**9**	**8+**	8	**9**	**9**	**8+**	G	G
Lexar	5/15/27	**9**	**9**	7	**9**	**9**	**9**	**9**	**9**	**9**	**8+**	**8+**	**8+**	**9**	**9**	**9**	G	G
Lumax	5/15/27	**9**	**9**	6	**8+**	**9**	**9**	**9**	**8+**	**9**	**8+**	**9**	8	7+	**9**	**9**	G	G
Maverick	15/27/4	**9**	—	N	6	8	**9**	**9**	6	**8+**	**8+**	7	7	N	**8+**	**9**	G	G
Prowl + atrazine	3/5	**9+**	8	6	**8+**	**9**	**9**	**9**	**8+**	**9**	**9**	**8+**	8	**9**	**9+**	**9+**	G[6]	FG
Resicore/Resicore XL	15/27/4	**8+**	—	N	6	8	**9**	**9**	6	**8+**	**8+**	7	7	N	**8+**	**9**	G	G
SureStart II/TripleFLEX II	2/4/15	**8+**	—	N	7	7	8	**9**	6	8	**8+**	8	7+	7	8	8	G	F
TriVolt	27/15/2	8	—	7	8	8	**9**	**8+**	7	**9**	**9**	7+	7+	7	**8+**	**9**	G	F
Verdict	14/15	**9**	—	6	8	8	**9**	7+	8	**9**	**9**	8	8	7	**9**	8	G	G

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale.
Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

[1] See Table 2.1-10 and Table 2.2-1 for additional products that contain these active ingredients.
[2] Biotypes resistant to Groups 2 and 9 herbicides are common in the region; do not rely on Groups 2 or 9 herbicides to provide effective control.
[3] Triazine-resistant (TR) biotypes of common lambsquarters and redroot/smooth pigweed are widespread in the region and thus triazine (Group 5) herbicides are not effective against these populations.
[4] ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations.
[5] Biotypes resistant to Groups 2 and 9 herbicides are found in the region; Groups 2 or 9 herbicides may not provide effective control.
[6] See remarks in Table 2.2-8 and the herbicide label for specific management guidelines to maximize crop tolerance.
[7] Corn stunting is likely with products that contain rimsulfuron if (1) used on coarse-textured soils, (2) applied within 7 days of planting, and (3) growing conditions are less than ideal.
[8] Degree Xtra may be less consistent on lambsquarters control compared to other acetochlor products.

Table 2.2-8. Comments on preplant or preemergence herbicides for conventional, min-, or no-till corn.

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Anthem Flex	pyroxasulfone +	15	EPP, PRE, or EPOST	3.5–6 fl oz	0.102–0.175
	carfentrazone	14			0.007–0.012
Anthem Maxx 4.3SE	pyroxasulfone +	15	EPP, PRE, or EPOST	3–6 fl oz	0.1–0.2
	fluthiacet	14			0.003–0.006
• Fluthiacet (Cadet) and carfentrazone (Aim) do not provide any residual weed control. • See Zidua (pyroxasulfone) entry for more details.					
Atrazine 4L	atrazine	5	EPP or PRE	1–2 qt	1–2
• Atrazine may be used at 1–2 qt/A. Most commonly used in combination with other herbicides at 1–1.5 qt. • On highly erodible ground with less than 30% surface residue, no more than 1.6 qt may be applied prior to crop emergence. *Atrazine Use Restrictions* Preplant or preemergence: • On highly erodible soils (as defined by the U.S. Natural Resources Conservation Service): • Fields where more than 30% of the soil surface is covered with plant residue at planting, apply a maximum of 2 lb ai/A as a broadcast spray. • Fields where less than 30% of the soil surface is covered with plant residue at planting, apply a maximum of 1.6 lb ai/A as a broadcast spray. • Apply a maximum of 2 lb ai/A as a broadcast spray. Postemergence: • If no atrazine was applied prior to crop emergence, use a maximum rate of 2 lb ai/A. • If a soil-applied application was made in the same calendar year, the combined preplant or preemergence and postemergence applications may not exceed 2.5 lb ai/A. *Safety Precautions for Using Atrazine* • Do not mix, load, or apply within 50 feet of drinking water wells, livestock wells, agricultural drainage wells, irrigation wells, abandoned wells, or sinkholes. • Do not mix or load within 50 feet of intermittent streams, perennial streams, rivers, lakes, or reservoirs. • Do not apply within 200 feet of lakes or reservoirs. • Do not apply within 66 feet of the points where surface water runoff enters intermittent streams, perennial streams, or rivers. The 66-foot buffers should be planted to a crop or seeded with grass on highly erodible land. • *Restricted-use pesticide and water quality advisory.*					
Balance Flexx 2SC	isoxaflutole + corn safener	27	EPP, PRE, or EPOST	3–6 fl oz	0.047–0.094
• Balance Flexx contains isoxaflutole plus a corn safener (cyprosulfamide) and can be applied from preplant through early postemergence (up to V2 corn). • The medium soil texture rate is 5 fl oz/A. • Tank-mix with pregrass products (Define, Dual, Harness, TopNotch, Outlook, etc.) to improve residual grass control. Balance Flexx can be mixed with atrazine, 2,4-D, Gramoxone, or glyphosate plus COC or MSO to improve burndown activity on emerged weeds in a no-till setting. • Early postemergence applications of Balance Flexx will likely not control weeds that are larger than one-leaf stage, but the addition of atrazine can improve control. • Balance Flexx also can be used as a foundation herbicide in a planned preherbicide followed by POST herbicide system. • Do not apply with adjuvants, tank-mix with other herbicides or OP or carbamate insecticides, or use fluid fertilizer carriers after corn has emerged. • To improve crop safety, it is best to plant corn at least 1.5 inches deep and make sure seed is completely covered and seed slit is firmed. • Do not apply more than 6 fl oz/A/year Balance Flexx (0.094 lb ai isoxaflutole). • When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • *Restricted-use pesticide and water quality advisory.*					
Basis Blend 30WDG	rimsulfuron +	2	PRE	0.825–1.25 oz	0.01–0.015
	thifensulfuron	2			0.005–0.008
• Basis Blend is a mixture of rimsulfuron (Resolve) and thifensulfuron (Harmony SG). • Soil application of Basis Blend is permitted in the Mid-Atlantic region, including Pennsylvania. • Soil-applied Basis Blend is effective on triazine-resistant lambsquarters and pigweed. • Corn stunting is commonly observed when Basis Blend is used on coarse-textured soils. • Tank-mix with other products to broaden the spectrum of control. • For additional remarks, see Basis Blend remarks in the postemergence herbicide for corn section.					

Table 2.2-8. Comments on preplant or preemergence herbicides for conventional, min-, or no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Bicep II Magnum 5.5L/ Cinch ATZ	*S*-metolachlor + atrazine	15/5	EPP, PRE, or EPOST	1.3–2.6 qt	See Table 2.2-2 for ai rates
Bicep Lite II Magnum 6L/Cinch ATZ Lite				0.9–2.2 qt	
Degree Xtra 4.04ME or	acetochlor + atrazine	15/5	EPP, PRE, or EPOST	2.9–3.7 qt	
FulTime NXT 4.04CS				2.9–4.4 qt	
Harness Xtra 6L or	acetochlor + atrazine	15/5	EPP, PRE, or EPOST	1.8–2.3 qt	
Harness Xtra 5.6L				1.4–3 qt	
Keystone LA NXT 6SE or				1.8–2.7 qt	
Keystone NXT 5.6SE				1.4–3 qt	

• These mixtures contain one of the chloroacetamide herbicides plus atrazine.
• Bicep Lite II Magnum, Cinch ATZ Lite, Harness Xtra 6L, and Keystone LA NXT are premixes of reduced-atrazine-rate ratios.
• The application rates based on soil texture for each of these products are listed in Table 2.2-9.
• These products may be applied to emerged corn in a water carrier; refer to Table 2.2-10 for maximum corn and weed size restrictions.
• Degree Xtra can be applied early POST in a UAN carrier if the temperature is below 85°F. Some corn leaf burn should be expected. Refer to label for more details. Do not include surfactants, crop oils, or other additives.
• See individual component sections in this table and atrazine use restrictions under that entry for additional information.
• *Restricted-use pesticides and water quality advisory.*

Corvus 2.63SC	isoxaflutole +	27	EPP, PRE, or EPOST	3.33–5.6 fl oz	0.049–0.083
	thiencarbazone +	2			0.02–0.033
	corn safener				

• Corvus is a premix of isoxaflutole, cyprosulfamide (Balance Flexx), and thiencarbazone (AL*S*-inhibitor herbicide that improves control of annual weeds) and can be applied from preplant through early postemergence (up to V2 corn) to provide residual control of annual broadleaves and grasses, especially when tank-mixed with atrazine.
• The typical use rate is 5.6 fl oz/A.
• Corvus can provide some control of small, emerged annual weeds (<6 inches) in no-till.
• To improve burndown activity on emerged weeds in a no-till setting, mix with atrazine, 2,4-D, Gramoxone, or glyphosate plus COC or MSO.
• Early postemergence applications of Corvus will control small, emerged weeds, but the addition of atrazine can improve control.
• Corvus also can be used as a foundation herbicide in a planned preherbicide followed by postherbicide system.
• Do not apply with adjuvants (COC or MSO), tank-mix with other herbicides or OP or carbamate insecticides, or use fluid fertilizer carriers after corn has emerged.
• To improve crop safety, it is best to plant corn at least 1.5 inches deep and make sure seed is completely covered and seed slit is firmed.
• Do not apply more than 0.094 lb ai isoxaflutole per acre per year.
• When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds.
• *Restricted-use pesticide and water quality advisory.*

Dicamba-containing products	dicamba	4	PRE or EPOST	varies	0.5 lb ae

• Dicamba may be applied after planting on medium- to fine-textured soils.
• Do not apply preemergence to soil containing less than 2% organic matter or to coarse-textured soils.
• Preemergence applications have a greater potential to injure corn under conditions of excessive moisture and cool temperatures.
• Crop tolerance is greatest to dicamba, and weeds are generally most susceptible when corn is from the spike to five-leaf stage of growth.

Dual II Magnum 7.64E	*S*-metolachlor	15	EPP or PRE	1–2 pt	0.96–1.9

• Dual II Magnum are similar in activity to Harness, Outlook, Surpass, and Zidua.
• Dual II Magnum contains a crop-safening agent, benoxacor.
• These may be applied broadcast on up to 40-inch-tall corn prior to weed emergence.
• The medium soil texture rate is 1.67 pt for Dual II Magnum.
• For early preplant applications or fields with heavy surface plant residue, the Dual II Magnum rate may need to be increased by up to 20%.
• Incorporation improves control of yellow nutsedge.
• *Water quality advisory.*

Table 2.2-8. Comments on preplant or preemergence herbicides for conventional, min-, or no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Fierce 76WDG	pyroxasulfone +	15	EPP or PRE	3 oz	0.08
	flumioxazin	14			0.063

• Fierce contains pyroxasulfone (Zidua) and flumioxazin (Valor) and can be used only in no-till or minimum-tilled fields where crop residue has not been incorporated into the soil and corn will be planted directly into a stale seedbed, cover crop, or previous crop residue.
• Apply Fierce at 3 oz/A to field corn early preplant.
• Corn must be planted between 7 and 30 days after application.
• When applied as part of a burndown program, Fierce must be tank-mixed with appropriate herbicides and adjuvants to control emerged weeds.
• In addition, Fierce provides residual control of several annual grass and broadleaf weeds, but other herbicides can be tank-mixed to improve control spectrum.
• Do not use on soils with less than 1% organic matter unless an activation rainfall (0.5 inch or more) has occurred between application and planting.
• Fierce also can be used as part of a fall burndown program.
• *Water quality advisory.*

Harness 7E	acetochlor	15	EPP or PRE	1.25–3 pt	1–2.6
Surpass NXT 7E				1.25–3 pt	1.09–2.6
TopNotch 3.2CS				2–3.75 qt	1.6–3

• Harness, Surpass NXT, and TopNotch contain acetochlor.
• Acetochlor is similar in activity to Dual, Outlook, and Zidua, but it is more active on certain broadleaf weeds.
• Acetochlor may be applied on up to 11-inch-tall corn depending on the tank-mix partner.
• The medium soil texture rate is about 2 pt/A for Harness, 2.25 pt for Surpass NXT, and 2.25 qt for TopNotch.
• For early preplant applications or fields with heavy surface plant residue, the rate of acetochlor may need to be increased by up to 20%.
• Incorporation improves control of yellow nutsedge.
• *Restricted-use pesticide and water quality advisory.*

Harness MAX 3.85L	acetochlor +	15	EPP or PRE	1.7–2.75 qt	1.5–2.42
	mesotrione	27			0.14–0.227

• Controls many annual broadleaf and grass weeds but will not provide consistent control if grasses have already emerged.
• Can be applied PRE thru POST; when applied in a planned PRE followed by POST programs better weed control usually can be expected and more modes of action can be incorporated for better resistance management.
• Typical medium soil rate is 64 fl oz/A Harness MAX.
• It does not contain atrazine, so it provides a non-atrazine alternative for triazine-sensitive areas. However, other herbicides can be tank-mixed to broaden the weed control spectrum.
• Harness MAX can be applied to corn that is no more than 11 inches tall; use rates might need to be reduced for POST applications and include necessary adjuvants.
• Do not apply more than 0.24 lb ai mesotrione/A/year from any product or combination of products containing mesotrione.
• When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds.
• See label for additional application guidelines.
• Coyote is a similar premix but contains *S*-metolachlor and mesotrione.

Lexar EZ 3.7SC or	*S*-metolachlor + mesotrione + atrazine	15/27/5	EPP, PRE, or EPOST	3–3.5 qt	See Table 2.2-2 for ai rates
Lumax EZ 3.67SC				2.7–3.25 qt	
Acuron 3.44SC	*S*-metolachlor + mesotrione + atrazine + bicyclopyrone	15/27/5	EPP, PRE, or EPOST	2.5–3 qt	
Acuron Flexi 3.26SC	*S*-metolachlor + mesotrione + bicyclopyrone	15/27	EPP, PRE, or EPOST	2–2.25 qt	

• Lexar EZ and Lumax EZ are mixtures of *S*-metolachlor (Dual II Magnum), mesotrione (Callisto), and atrazine.
• Acuron contains the same active ingredients as Lumax/Lexar with the addition of another Group 27 herbicide, bicyclopyrone. In general, it controls a broader weed spectrum and is better on ragweed, cocklebur, and annual morningglory, and effective on many annual broadleaves and some grasses compared to Lumax/Lexar.
• The typical use rates in all tillage systems are 3 qt/A Lexar EZ, 2.7 qt/A Lumax EZ, and 2.5 qt/A Acuron.
• These products may be applied broadcast on up to 12-inch-tall corn, but prior to annual grass emergence.
• Do not apply more than 3.5 qt/A Lexar EZ, 3.25 qt/A Lumax EZ, or 3 qt/A Acuron per growing season.
• Do not apply more than 0.24 lb ai mesotrione/A/year from any product or combination of products containing mesotrione.
• When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds.

Table 2.2-8. Comments on preplant or preemergence herbicides for conventional, min-, or no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
• Do not apply Lexar, Lumax, or Acuron early POST if the corn was treated with Counter insecticide. Do not tank-mix Lexar, Lumax, or Acuron with organophosphate (OP) or carbamate insecticides and apply as a foliar POST application. Do not make a foliar POST application of any OP or carbamate insecticide within 7 days before or 7 days after a Lexar EZ, Lumax EZ, or Acuron application, or severe corn injury may occur. • Corn, soybeans, small grains, and sorghum may be planted the spring following Lexar EZ, Lumax EZ, or Acuron application. • *Restricted-use pesticide and water quality advisory.*					
Lorox 50DF	linuron	7	PRE	0.7–1 lb	0.3–0.5
• Lorox applied at 0.7 to 1 lb/A will help control TR lambsquarters. • Do not incorporate. • Plant corn at least 1.5 inches deep to minimize risk of crop injury. • May cause crop injury under adverse conditions.					
Outlook 6.0E	dimethenamid-P	15	EPP or PRE	10–21 fl oz	0.47–0.98
• Outlook is similar in activity to Dual, Harness, and Zidua. • Outlook (dimethenamid-P) may be applied preemergence on up to 12-inch-tall corn prior to weed emergence. • The medium soil texture rate is 16 fl oz/A for Outlook. • For early preplant applications or fields with heavy surface plant residue, increase the Outlook rate by 1–2 fl oz/A. • Lower use rates, 6–16 fl oz/A, may be used in situations where partial control or reduced length of residue control is required, such as early postemergence applications or preemergence applications followed by postemergence herbicides. • Incorporation improves control of yellow nutsedge. • *Water quality advisory.*					
Princep 90DF	simazine	5	EPP or PRE	1.1–3.3 lb	1–3
• Princep is similar to atrazine but has better grass activity and less broadleaf control. • Like atrazine, Princep can persist in soil and leave carryover residues. • Use in combination with other herbicides to lower the necessary rate and broaden the weed spectrum. • If using Princep in combination with atrazine, follow recrop restrictions. • *Water quality advisory.*					
Princep 90DF +	simazine	5	EPP or PRE	1.1–1.7 lb	1–1.5
Atrazine 90DF	atrazine	5			
• Both simazine and atrazine have long soil residuals. • Plant corn, sorghum, or sudangrass the following year. • Simazine improves annual grass control; use 2:1 ratio of simazine to atrazine in fields with heavy grass pressure. • See comments under atrazine. • When tank-mixing or sequentially applying simazine and/or atrazine or products containing either active ingredient to corn, the total pounds of simazine and/or atrazine applied must not exceed 2.5 lb ai/acre per calendar year. • *Atrazine is a restricted-use pesticide, and both atrazine and simazine have a water quality advisory.*					
Prowl 3.3E or	pendimethalin	3	PRE or EPOST	1.8–4 pt	0.75–1.65
Prowl H2O 3.8CS				2–4 pt	0.95–1.9
• Plant corn at least 1.5 inches deep to avoid Prowl injury. • Do not incorporate. • Must be applied after planting up until corn reaches 30 inches tall or V8 growth stage (whichever is most restrictive). • Preemergence applications can injure corn. • Delaying application until spike stage helps maximize crop safety. • Prowl H2O is a water-based capsule suspension formulation that provides similar weed control as the older 3.3E product but causes less staining and odor.					
Prowl 3.3E or	pendimethalin	3	PRE or EPOST	1.8–3.6 pt	0.75–1.5
H2O 3.8CS +				2–4 pt	0.95–1.9
Atrazine 90DF	atrazine	5		1.1–2.2 lb	1–2
• Plant corn at least 1.5 inches deep to avoid Prowl injury. • Do not incorporate. • Must be applied after planting up until corn reaches 12 inches tall. • Preemergence applications can injure corn. • Delaying application until spike stage helps maximize crop safety. • See remarks under atrazine. • *Atrazine is a restricted-use pesticide and has a water quality advisory.*					

Table 2.2-8. Comments on preplant or preemergence herbicides for conventional, min-, or no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Python 80WDG	flumetsulam	2	EPP or PRE	0.8–1.14 oz	0.04–0.057

• Apply before crop or weed emergence.
• Plant corn at least 1.5 inches deep.
• Do not use where soil pH is greater than 7.8, where organic matter is less than 1.5%, or when extended cool, wet conditions exist.
• Apply all insecticides in a T-band or a band to avoid serious crop injury.
• Do not use if Counter insecticide was applied.
• See Table 2.1-11 for recrop restrictions.
• To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.
• *Water quality advisory.*

Resicore 3.29SE Resicore XL 3.26CS	acetochlor +	15	EPP, PRE, or POST	2.255–3 qt	1.58–2.1
	mesotrione +	27			0.162–0.216
	clopyralid + corn safener	4			0.107–0.143

• Resicore can be used with any field or silage corn hybrids.
• Controls many annual broadleaf and grass weeds but will not provide consistent control if grasses have already emerged.
• Can be applied PRE thru POST; when applied in a planned PRE followed by POST programs better weed control usually can be expected and more modes of action can be incorporated for better resistance management.
• Typical medium soil rate is 2.5 qt/A Resicore.
• Resicore does not contain atrazine, so it provides a non-atrazine alternative for triazine-sensitive areas. However, atrazine, glyphosate, 2,4-D, and other herbicides can be tank-mixed with Resicore to broaden the weed control spectrum.
• Contains acetachlor, so be sure to follow acetachlor use restrictions for soil type, organic matter, and depth to water table.
• Do not apply more than 0.24 lb ai mesotrione/A/year from any product or combination of products containing mesotrione.
• When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds.
• Adequate soil moisture is required for optimum herbicidal activity. If adequate soil moisture is not received within 7–10 days after a surface-applied treatment, a shallow cultivation is recommended.
• Observe the rotation restrictions on the label.
• If corn has received an at-plant phorate or terbufos insecticide application, POST applications of Resicore may cause severe injury. Refer to label for additional restrictions with insecticides.
• Do not make POST applications of Resicore using liquid fertilizer carriers or tank-mixed with OP insecticides otherwise severe crop injury will occur.
• Resicore can be applied to corn that is no more than 11 inches tall. Resicore XL can be applied to corn up to 24 inches tall.

Resolve 25DF	rimsulfuron	2	PRE	0.5–2 oz	0.0078–0.03

• Resolve can be applied PRE and may be tank-mixed with full or reduced rates of other soil-applied corn herbicides.
• Crop injury may occur following an application of Resolve if there is a prolonged period of cold weather and/or in conjunction with wet soil.
• Corn stunting is commonly observed when Resolve is used on coarse-textured soils.
• See additional comments about Resolve in Table 2.2-13.

SureStart II 4.25SE or TripleFLEX II	acetochlor +	15	EPP, PRE, or EPOST	1.5–3 pt	0.71–1.41
	flumetsulam +	2			0.056–0.113
	clopyralid	4			0.022–0.045

• SureStart II or TripleFLEX II is intended to be used with Roundup Ready or LibertyLink field or silage corn hybrids.
• When applied PRE, it is designed to provide early season control of common annual grasses and broadleaf weeds to allow better timing of the in-crop application of glyphosate or glufosinate.
• The typical medium soil rate is 1.75 pt/A SureStart II/TripleFLEX II. For longer residual control, use up to 3 pt/A.
• SureStart II/TripleFLEX II does not contain atrazine, so it provides a non-atrazine alternative for triazine-sensitive areas. However, atrazine, glyphosate, 2,4-D, and other herbicides can be tank-mixed with SureStart II/TripleFLEX II to broaden the weed control spectrum.
• Contains acetachlor, so be sure to follow acetachlor use restrictions for soil type, organic matter, and depth to water table.
• Adequate soil moisture is required for optimum herbicidal activity. If adequate soil moisture is not received within 7–10 days after a surface-applied treatment, a shallow cultivation is recommended.
• Observe the rotation restrictions on the label.
• Injury to corn has been observed when cool, wet soil conditions follow application.
• Apply soil insecticides in furrow, a T-band, or a band. To avoid serious crop injury if using OP insecticides, apply in a T-band or a band. Do not use if Counter or Thimet insecticide was applied. Refer to label for additional restrictions with soil insecticides.
• Corn must be planted at least 1.5 inches deep.
• Do not use as a soil treatment in fields with less than 1.5% organic matter unless the risk of crop injury is acceptable.

Table 2.2-8. Comments on preplant or preemergence herbicides for conventional, min-, or no-till corn (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Verdict 5.57EC	saflufenacil +	14	EPP or PRE	10–16 fl oz	0.058–0.071
	dimethenamid-P	15			0.384–0.615
• Verdict can be used in a burndown program or in a planned PRE followed by POST herbicide system. In a burndown program it is best to include glyphosate and atrazine in addition to the necessary adjuvants (MSO plus AMS; substituting COC can result in reduced weed control) to improve control of emerged weeds including horseweed. • The medium soil texture rate is 13 fl oz/A and will provide some initial residual weed control, but it will likely need to be followed by a POST application of glyphosate (RR-corn), glufosinate (LL-corn), or conventional herbicides as needed. • The use of Verdict can follow a burndown application of Sharpen (1 fl oz/A). • Do not apply Verdict to emerged corn or if OP or carbamate insecticides are being used.					
Zidua SC 4.17L or	pyroxasulfone	15	EPP or PRE	1.75–6.5 fl oz	0.05–0.21
Zidua 85WDG				1.5–4 oz	
• Zidua contains the single active ingredient pyroxasulfone. • Zidua has annual grass activity similar to Dual, Harness, Outlook, Surpass, etc., but also provides good control of several annual broadleaves. • Zidua can be applied preplant (surface or incorporated) up to 45 days before planting or preemergence. • The typical use rate is 4 fl oz/A SC (2.5 oz WDG) on medium-textured soils. Rates can be adjusted for soil type or two-pass application programs. • Corn must be planted at least 1 inch deep. • Zidua does not control existing weeds and must be activated by at least 0.5 inch of rainfall prior to weed germination; otherwise, effectiveness may be reduced. • Zidua can be tank-mixed with atrazine or other corn herbicides to broaden weed control spectrum. • Zidua may be applied in a carrier of water (5 gal/A or more) or liquid nitrogen fertilizer solution (20 gal/A or more). Also, it may be impregnated and applied on certain dry bulk fertilizers. • Zidua may be applied up to V8 corn stage, but tank-mix if weeds are emerged. • Zidua may be applied in the fall. • Other pyroxasulfone-containing products include Anthem Flex, Anthem Maxx, Fierce, Maverick, and Perpetuo. • Maverick is a premix of pyroxasulfone, mesotrione (Callisto), and clopyralid (Stinger). Perpetuo is a premix of flumiclorac (Resource) plus pyroxasulfone and must be applied post. • *Water quality advisory.*					

*See Tables 2.1-10 and 2.2-1 for additional formulations or trade names containing some of these same active ingredients.
**Application: EPP = early preplant (application prior to plant; in most cases, 7–14 days before planting); PPI = applied to conventionally tilled soil then mechanically incorporated; PRE = preemergence (applied before the crop has emerged); EPOST = early postemergence (during the early stages of crop and weed growth).
See specific product label to determine correct rate for soil type and weed species found in each field. These treatments may be used in conventional, reduced-till, and no-till systems. Treatments may be applied preplant-incorporated or preemergence, unless stated otherwise. Incorporation reduces the need for timely rainfall after application and may improve control of certain weeds. The higher rates for a given soil may be required for no-till. In no-till situations, burndown herbicides may be required to control weeds or cover crops present at time of application. Tables 2.2-3, 2.2-4, and 2.2-5 list characteristics of burndown herbicides.

Table 2.2-9. Corn herbicide preplant or preemergence rates per acre based on soil texture and organic matter.

Trade Name	Site of Action Number	Unit	<1.5–3% Organic Matter			>3% Organic Matter			Inc. for No-till	Max Rate Unit on HEL, Less Than 30% Residue
			Coarse	Medium[1]	Fine	Coarse	Medium	Fine		
Acuron 3.44SC	5/15/27/27	qt	2.5	2.5	2.5	3.0	3.0	3.0	no	N/A
Acuron Flexi 3.26SC	15/27/27	qt	2.0	2.0	2.0	2.25	2.25	2.25	no	—
Anthem Flex 4SC	14/15	fl oz	3.5	4.5	5.5	4.5	5.5	6.5	no	—
Anthem Maxx 4.3SC	14/15	fl oz	3.0	4.0	5.0	4.0	5.0	6.0	no	—
Atrazine 4L[2]	5	qt	1.25	1.5	1.5	1.25	1.5	2.04	no	1.6
Atrazine 90DF[2]	5	lb	1.4	1.67	1.67	1.4	1.67	2.24	no	1.8
Axiom 68DF	5/15	oz	13.0	16.0	20.0	15.0	18.0	22.0	1–2 oz	—
Balance Flexx 2SC	27	fl oz	3.0	6.0	6.0	4.0	6.0	6.0	no	—
Basis 75DF	2/2	oz	0.33	0.33	0.33	0.33	0.33	0.33	no	—
Basis Blend 30DF	2/2	oz	0.825	0.825	0.825	0.825	0.825	0.825	no	—
Bicep II Magnum 5.5L/Cinch ATZ	5/15	qt	1.8	2.1	2.1	2.1	2.4	2.6	up to 25%	2.1
Bicep Lite II Magnum 6L/Cinch ATZ Lite	5/15	qt	1.5	1.5	1.5	1.3	1.9	1.9	up to 20%	N/A
Bullet 4L	5/15	qt	2.5	3.0	3.75	3.0	3.75	4.0	20%	N/A
Corvus 2.63SC	2/27	fl oz	3.3[3]	5.6	5.6	5.6	5.6	5.6	no	—
Degree Xtra 4.04 ME	5/15	qt	2.0	3.0	3.2	2.0	3.2	3.7	up to 25%	N/A
Dual II Magnum 7.64E	15	pt	1.33	1.67	1.67	1.33	2.0	2.0	up to 20%	—
Fierce 76WDG	14/15	oz	3.0	3.0	3.0	3.0	3.0	3.0	no	—
FulTime 4.04CS	5/15	qt	2.5	2.9	3.1	2.5	3.0	4.0	no	4.0
Harness 7E	15	pt	1.5	2.0	2.0	1.75	2.0	2.25	up to 25%	—
Harness MAX	15/27	fl oz	55	64	64	60	64	75	no	—
Harness Xtra 6.0L	5/15	qt	1.8	2.0	2.3	2.0	2.3	2.3	up to 25%	N/A
Harness Xtra 5.6L	5/15	qt	1.8	2.0	2.3	1.8	2.3	2.6	up to 25%	2.5
Keystone LA NXT 6SE	5/15	qt	1.8	2.0	2.1	1.8	2.1	2.4	no	N/A
Keystone NXT 5.6 SE	5/15	qt	1.4	2.0	2.5	2.0	2.5	2.5	up to 20%	2.5
Lexar EZ 3.7SC	5/15/27	qt	3.0	3.0	3.0	3.5	3.5	3.5	no	N/A
Lumax EZ 3.67SC	5/15/27	qt	2.7	2.7	2.7	3.25	3.25	3.25	no	N/A
Maverick 2.04SC	4/15/27	fl oz	18	18-24	18-32	18	18-24	18-32	no	—
Outlook 6.0E	15	fl oz	14.0	16.0	18.0	16.0	16.0	18.0	add 1–2 oz	—
Princep 4L	5	qt	1.0	2.5	2.7	1.0	2.7	3.0		

Table 2.2-9. Corn herbicide preplant or preemergence rates per acre based on soil texture and organic matter (continued).

Trade Name	Site of Action Number	Unit	<1.5–3% Organic Matter			>3% Organic Matter			Inc. for No-till	Max Rate Unit on HEL, Less Than 30% Residue
			Coarse	Medium[1]	Fine	Coarse	Medium	Fine		
Princep 90DF	5	lb	1.1	2.6	3.0	1.1	3.0	3.3	no	—
Prowl 3.3E	3	pt	2.0	3.6	4.0	3.6	4.0	4.2	no	—
Prowl H2O 3.8CS	3	pt	2.5	3.0	3.0	3.0	4.0	4.0	no	—
Python 80WDG	2	oz	0.8	0.89	1.0	0.89	1.0	1.1	no	—
Resicore 3.29SE/Resicore XL 3.26CS	4/15/27	qt	2.25	2.5	2.75	2.5	2.75	3.0	up to 0.25 qt/A	—
Sharpen 2.85SC	14	fl oz	2.0	2.5	3.0	2.0	2.5	3.0	no	—
SureStart II 4.25SE/TripleFLEX II	2/4/15	pt	1.5	1.75	2.0	1.75	1.75	2.0	no	—
Surpass NXT 7E	15	pt	1.5	2.0	2.25	2.0	2.5	2.5	up to 25%	—
TopNotch 3.2ME	15	qt	2.0	2.25	2.5	2.0	2.5	3.0	no	—
TriVolt 3.65SC	2/15/27	fl oz	10.75	20	20	10.75	20	20	no	—
Verdict 5.57EC	14/15	fl oz	10.0	13.0	16.0	11.0	13.0	16.0	no	—
Zidua 85WDG	15	oz	2.0	2.5	2.5	2.5	2.5	3.0	no	—
Zidua SC 4.17L	15	fl oz	3.5	4.0	4.0	4.0	4.0	5.0	no	—

This table shows application rates for products applied alone. Rates may vary if tank-mixed with other products, weed infestations are heavy, or if used in conservation tillage situations. See specific product label for additional information on application rates and use.

[1] Average soil type in most Mid-Atlantic areas.

[2] On highly erodible ground with less than 30% residue, apply no more than 1.6 qt/A or 1.8 lb/A of 90 DF (i.e., 1.6 lb ai).

[3] Reduce Corvus rate to 3.33 fl oz/A if soils are coarse and have < 2% O.M.

Table 2.2-10. Maximum corn size, weed sizes, and recommended adjuvants for delayed preemergence/early postemergence herbicide applications.

Trade Name	Maximum Corn Size	Maximum Weed Size
Acuron	12 inches	3-inch broadleaves; inconsistent on emerged grasses
Acuron Flexi	30 inches	3-inch broadleaves
Anthem Maxx	4 collars (V4)	2-inch broadleaves, before grass emergence
Atrazine	12 inches	1.5 inches
Axiom	Before emergence	Before emergence
Balance Flexx	2-leaf (V2)	1 true leaf stage
Bicep II Magnum	12 inches	1- to 2-leaf
Bicep Lite II Magnum, Cinch ATZ Lite	5 inches	2-leaf
Corvus	2-leaf (V2)	<2 inches (in general)
Dual, Dual II Magnum	40 inches	Before emergence
Fierce	Before emergence	2-inch broadleaves; by tank-mix partner for grasses
Halex GT/Acuron GT	30 inches (V8)	4 inches
Harness, Harness MAX, Harness Xtra[1], or Degree Xtra	11 inches or by tank-mix partner	Before broadleaf emergence, 2-leaf grasses or by tank-mix partner
Lexar EZ	12 inches	3-inch broadleaves; before grass emergence
Lumax EZ	12 inches	3-inch broadleaves; inconsistent on emerged grasses
Maverick	18 inches (V6)	3-inch broadleaves; before grass emergence
Outlook	12 inches	Before emergence or by tank-mix partner
Princep	Before emergence	Before emergence
Prowl H2O	30 inches (V8)	Before weed emergence
Python WDG	20 inches (V6)	Before weed emergence
Resicore/Resicore XL	11 inches/ 24 inches	3-inch broadleaves
Resolve Q	20 inches	2-inch grasses; 3-inch broadleaves (in general)
SureStart II/TripleFLEX II	11 inches	Limited activity on 1-inch broadleaves; before grass emergence
Surpass NXT, FulTime NXT, TopNotch, or Keystone NXT[2]	11 inches or by tank-mix partner	Before emergence or by tank-mix partner
TriVolt	2-leaf (V2)	<2 inches (in general)
Verdict	Before emergence	Before emergence
Zidua SC	Postemergence up to V8	Before emergence or by tank-mix partner

See specific herbicide label(s) for additional information on application. This type of application generally is used when weather conditions preclude the use of a standard preemergence program. For most products, do not apply in liquid fertilizer if corn has emerged. Poor control from residual herbicides may result if annual grasses such as foxtail and panicum have emerged at the time of application; tank-mix with product that controls emerged grasses. Delayed preemergence/early postemergence programs can work well with herbicide-resistant corn hybrids now available (e.g., Roundup Ready and LibertyLink). When tank-mixing with other pesticides, follow the most restrictive product label.

[1] May be tank-mixed with Accent Q, Atrazine (Harness), dicamba or Clarity, Permit, or Roundup (Roundup Ready corn).

[2] May be tank-mixed with a number of different products, including Accent Q, dicamba or Clarity, Prowl, etc. See an herbicide label for specific information.

Table 2.2-10. Maximum corn size, weed sizes, and recommended adjuvants for delayed preemergence/early postemergence herbicide applications (continued).

Trade Name	Recommended If Corn Has Emerged and Weeds Are Present	Optional
Acuron[1,2]	NIS (0.25% v/v) or	AMS 8.5 lb/100 gal
	COC[3] (1% v/v)	
Acuron Flexi	NIS (0.25% v/v) or	
	COC[3] (1% v/v)	
Anthem ATZ/Anthem Flex/Anthem Maxx	NIS (0.25% v/v) or	
	COC (1–2 pt/A) or	
	MSO (1–2 pt/A)	
Atrazine	Label only mentions COC	
Balance Flexx	Label states: "Do not use COC or MSO or fully loaded glyphosate formulation"	
Bicep II Magnum	Label mentions only NIS when tank-mixed with specific herbicides	
Corvus	Label states: "Do not use COC or MSO"	
FulTime NXT, TopNotch[1], or Keystone NXT[1]	Not addressed on label	
Halex GT/Acuron GT	NIS (1–2 qt/100 gal)	AMS (8.75–17 lb/100 gal) (required)
Harness MAX[1,4]	NIS (1 qt/100 gal) or	UAN (rate not specified)
	COC (1 gal/100 gal)	AMS (rate not specified)
Harness Xtra or Degree Xtra	Not addressed on label	
Lexar EZ[1,2]	NIS (0.25% v/v) or	UAN (2.5% v/v) or
	COC (1% v/v)	AMS (8.5 lb/100 gal)
Lumax EZ[1,2]	NIS (0.25% v/v) or	UAN (2.5% v/v) or
	COC (1% v/v)	AMS (8.5 lb/100 gal)
Maverick	NIS (1 qt/100 gal) or COC[3] (1 gal/100 gal)	AMS only allowed with glyphosate or glufosinate herbicides
Python WDG	NIS (1 qt/100 gal) or	UAN (2.5 gal/100 gal)
	COC (1 gal/100 gal)	AMS (2–4 lb/A)
Resicore/Resicore XL	NIS (1 qt/100 gal) or	AMS only allowed with glyphosate or glufosinate herbicides
	COC[3] (1 gal/100 gal)	
TriVolt	Label states: "Do not use COC or MSO"	

[1] Do not use either NIS or COC if tank-mixed with Liberty (AMS is allowed).
[2] Do not use either NIS or COC if tank-mixed with a fully loaded glyphosate (AMS is allowed); if glyphosate label recommends an adjuvant, add NIS and AMS.
[3] Label cautions about crop injury.
[4] Do not use either NIS or COC if tank-mixed with glyphosate (AMS is allowed).

Table 2.2-11. Relative effectiveness of postemergence corn herbicides.

Grasses

Trade Name (rate/A)[1]	Site of Action Number	Barnyardgrass	Bermudagrass	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wire-stem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Accent Q (0.9 oz)	2	**8+**	N	7	**9**	N	**8+**	**9**	7	6	**9**	**9**	**8+**	**9**	**9+**
Atrazine (1 qt)	5	8	N	6	7+	**9**	N	N	6	7	6	N	7	6	7
Basagran (1.5 pt)	6	N	N	N	N	N	N	N	N	8	N	N	N	N	N
Callisto (3 fl oz)	27	N	N	8[2]	N	N	N	N	N	8	N	N	N	N	N
Glyphosate (0.75 lb ae)[3,4]	9	**9+**	**9**	**9+**	**9+**	**10**	**9**	**9+**	**9**	7	**9+**	**9**	**9**	**9**	**10**
Impact/Armezon (0.75 fl oz)/Impact Core	27/(15)	7	N	8	**8+**	7	N	N	6	7	8	8	N	7	N
Laudis (3 fl oz)/DiFlexx Duo (32 fl oz)	27/(4)	8	N	8	**8+**	7	N	6	6	7	N	8	N	7+	8
Liberty (32 fl oz)[5]	10	8	N	8	**9**[6]	N	6	8	7	6	7+	8	6	8	7
Permit/Sandea (1 oz)	2	N	N	N	N	N	N	N	N	**9+**	N	N	N	N	N
Shieldex (1 fl oz)/Restraint	27/(15)	7	N	8	8	7	N	6	6	6	6	6	N	6	6
Mixtures															
Basis Blend (0.83 oz)/Resolve Q (1.25 oz)	2/2	8	N	6	**8+**	N	7	**8+**	6	6	**8+**	7	7+	**8+**	8
Capreno (3 fl oz)	2/27	8	N	8	**8+**	7	7	8	6	7	8	**9**	6	8	6
Halex GT (3.6 pt)/Acuron GT (3.75 pt)	9/15/27	**9+**	N	**9+**	**9+**	**10**	**9**	**9+**	**9**	8	**9+**	**9**	**9**	**9**	**10**
Realm Q (4 oz)	2/27	8	N	8	**8+**	N	7	**8+**	6	8	**8+**	7	7+	**8+**	8
Revulin Q (4 oz)	2/27	**8+**	N	8	**9**	N	**8+**	**9**	7	8	**9**	**9**	**8+**	**9**	**9**
Sinate (28 fl oz)	10/27	8	N	8	**9**	7	6	8	7	7	8	8	6	8	7
Steadfast Q (1.5 oz)	2/2	**8+**	N	7	**9**	N	8	**9**	6+	6	**9**	**9**	**9**	**9**	**9+**
Stout (0.75 oz)	2/2	**8+**	N	7	**9**	N	**8+**	**9**	7	6	**9**	**9**	**8+**	**9**	**9+**
Yukon (4 oz)/Permit Plus (0.75 oz)	2	N	N	N	N	N	N	N	N	**9+**	N	N	N	N	N

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale.
Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good; on rare occasion is crop injury observed; G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

[1] See Table 2.1-10 and Table 2.2-1 for additional products that contain these active ingredients.
[2] Large crabgrass only.
[3] For use on Roundup Ready corn varieties only.
[4] Glyphosate-containing products include Roundup, Durango, and many others; see Table 2.1-8.
[5] For use on LibertyLink or glufosinate-resistant corn varieties only.
[6] Herbicide is less effective on yellow foxtail: Balance (6) and Liberty (7).

Table 2.2-11. Relative effectiveness of postemergence corn herbicides (continued).

Grasses

Control of Roundup Ready Corn—Volunteers or Replanting: There are times when corn has to be removed from a field with the intention of replanting a corn crop. Tillage is one effective method, but it is not appropriate in no-tillage situations. Use of glyphosate is highly effective for non–Roundup Ready corn. But the challenge is in removing Roundup Ready hybrids. There are limited herbicides to consistently kill small corn plants. Gramoxone SL, Liberty, and Select are three products that have shown the most activity. Research conducted in this region with Gramoxone and Select demonstrated that Select was the most effective for corn 2 to 3 inches tall. For taller corn (4 to 6 inches tall), Gramoxone in combination with a photosystem II–inhibiting herbicide (metribuzin, Lorox, or atrazine) was the most effective. Liberty is a third option, but it will not control LibertyLink hybrids.
Select Max/clethodim: up to 6 fl oz of Select Max or 3 fl oz clethodim 2EC with a non-ionic surfactant at 0.25% v/v plus AMS at 2.5 to 4 lb/A. Do not use a COC or MSO. Wait a minimum of 6 days from time of application until planting corn due to risk of crop injury. (Select Max/clethodim will also control corn hybrids containing Roundup Ready and LibertyLink stacked traits.)
Gramoxone SL 2.0: 3 to 4.5 pt/A (2 to 2.7 pints of 3.0 SL formulation) in combination with metribuzin (4 to 6 oz/A), Lorox (1 pt/A), or atrazine (1 lb/A). These photosystem II inhibitors are not added to control the corn but used to slow down the Gramoxone activity, which helps provide more consistent control.
Liberty 280: 22 to 29 oz Liberty has not been as consistent for control of corn as Gramoxone and will not control varieties with LibertyLink traits.

Broadleaves

Trade Name (rate/A)[1]	Site of Action Number	Amaranth, Palmer/ Waterhemp[2,3]	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters[4]	Marestail/ Horse-weed[5]	Morningglory, Annual	Nightshade, East-ern Black	Pigweed[4]	Ragweed, Com-mon[2,3]	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf	Corn Tolerance
2,4-D (1 pt)	4	8	—	6	**9**	8	**9**	7+	8	7	**9**	**8+**	7+	**9**	7	8	F[6]
Accent Q (0.9 oz)	2	N	—	7	7	7	6	N	7	N	**9**	6	N	N	8	7	F–G
Aim (0.8 oz)/Cadet (0.9 oz)	14	N	—	N	N	N	**9**	N	**8+**	**9**	**9**	N	N	7	N	**9+**	G
Atrazine (1 qt)	5	**9+**	—	8	**9**	**9**	N	N	**9**	**9**	N	**9**	8	**8+**	**10**	8	VG
Basagran (1.5 pt)	6	N	7	N	**9**	**9**	8	6	N	N	6+	8	7	8	**9**	**8+**	G
Basis Blend (0.83 oz)	2/2	N	—	N	7	7	**8+**	N	6	N	**9**	7[3]	N	N	**9**	**9**	F–G
Callisto (3 fl oz)	27	**8+**	N	7+	**8+**	**9**	**9**	6	7+	**9**	**8+**	8	8	6	**9**	**9**	G
Capreno (3 fl oz)	2/27	**8+**	—	7	**8+**	**9**	**9**	6	7	**9**	**9**	8	8	6	**9**	**9**	G
Curtail	4/4	**9**	—	6	**9**	8	**9**	7+	**9**	7	**9**	**9**	**9+**	**9**	7	8	F
Dicamba (0.25 lb ae)	4	**8+**	—	7	**9**	**9**	**9**	**8+**	8	8	**9**	**8+**	7+	8	**9**	8	F–G[6]
DiFlexx (8 fl oz)/DiFlexx Duo (32 fl oz)	4	**8+**	—	7	**9**	**9**	**9**	**8+**	**9**	8	**9**	**9**	**9**	8	**9**	8	G
Glyphosate (0.75 lb ae)[7,8]	9	N	8	**8+**	**9**	**9**	**8+**	N	7	8	**9**	**8+**[2]	8	7	**8+**	8	E
Halex GT (3.6 pt)	9/15/27	**8+**	—	**8+**	**9**	**9**	**9+**	6	7+	**9+**	**9**	**8+**	8	7	**9**	**9**	G
Harmony SG (0.125 oz)	2	N	N	7	7+	7	**9**	N	N	N	**9**	6	N	N	**9**	**8+**	G
Impact/Armezon (0.75 fl oz)/Impact Core	27/(15)	**8+**	—	7+	**8+**	**9**	**9**	6	7+	**9**	**8+**	8	8	6	**9**	**9**	VG
Laudis (3 fl oz)	27	**8+**	—	7	**8+**	**9**	**9**	6	7	**9**	**8+**	8	8	N	**9**	**9**	VG

Table 2.2-11. Relative effectiveness of postemergence corn herbicides (continued).

Liberty (32 fl oz)[9]	10	**9**	—	8	**9**	**9**	**8+**	**9**	8	8	**9**	**9**	**8+**	8	**8+**	8	E
Maestro/Moxy (1 pt)	6	N	—	8	**9**	**9**	**9**	6	8	**9**	7	7+	8	N	**9**	**8+**	F–G[6]
Peak (0.5 oz)	2	N	—	**8+**	**8+**	8	8	N	7	N	**8+**	**9**	6	6	7	8	G
Permit/Sandea (1 oz)	2	N	—	6	**9**	N	N	N	6	6	**9**	**9**[3]	82	7	8	**9**	G
Realm Q (4 oz)	2/27	**8+**	8	7+	**8+**	**9**	**9**	6	7+	**9**	**9**	8	8	6	**9**	**9**	G
Resolve Q (1.25 oz)	2/2	N	—	N	7	7	**8+**	N	6	N	**9**	*73*	N	N	**9**	**9**	G
Resource (6 fl oz)/ Perpetuo	14	7	—	7	6	7	7	N	N	8	7+	8	6	7	6	**9+**	G
Revulin Q (4 oz)	2/27	**8+**	—	7+	**8+**	**9**	**9**	N	7+	**9**	**9**	8	8	6	**9**	**9**	G
Shieldex (1 fl oz)/Restraint	27/(15)	**8+**	—	—	7	—	**9**	8	7	7	**9**	**8+**	8	—	7	**9**	VG
Sinate (28 fl oz)	10/27	**9**	—	8	**9**	**9**	**9**	**9**	8	**9**	**9**	**9**	**8+**	8	**9**	**9**	VG
Status (5–8 oz)	4/19	**8+**	—	7	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	8	**9**	**9**	G
Steadfast Q (1.5 oz)	2/2	N	—	7	7	7	6	N	7	N	**9**	6	N	N	8	**8+**	F–G
Stinger (0.5 pt)	4	N	—	N	**9**	8	6	7	N	7	6	**9+**	**9**	7	7	6	VG
Stout (0.5 oz)	2/2	N	—	7	7	7	**9**	N	7	N	**9**	6	N	N	**8+**	8	F–G
Tough 5EC (24 fl oz)	6	**8+**	—	6	8	8	**9**	—	N	**9**	**9**	7	7	—	**7**	6	F–G
Yukon (4–8 oz)	2/4	7	—	6	**9**	**9**	**9**	6	**9**	8	**9**	**9**	8	8	**9+**	**9**	F–G

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale.
Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good; on rare occasion is crop injury observed; G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); F–G = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

[1] See Tables 2.1-10 and 2.2-1 for additional products that contain these active ingredients.
[2] Glyphosate resistance has been confirmed for this species and is widespread in the region.
[3] Group 2 (ALS) resistance is confirmed for this species and is widespread in the region.
[4] Triazine-resistant (TR) biotypes of common lambsquarters and redroot/smooth pigweed are widespread in the region and thus triazine (Group 5) herbicides are not effective against these populations.
[5] Most marestail populations in the region are resistant to glyphosate (Group 9); some populations are also resistant to ALS (Group 2) herbicides. For best management of marestail, control in the fall or with an effective burndown program before planting. There are several herbicides that provide effective residual activity. However, in-crop control of marestail can be challenging since there are only a few herbicides that are effective postemergence. Make sure to apply herbicide before marestail reaches 6 inches tall.
[6] See remarks in Table 2.2-8 and the herbicide label for specific management guidelines to maximize crop tolerance.
[7] For use on Roundup Ready corn varieties only.
[8] Glyphosate-containing products include Roundup, Durango, and many others; see Table 2.1-8.
[9] For use on glufosinate-resistant or LibertyLink corn varieties only.

Table 2.2-12. Effectiveness of postemergence herbicides on perennial broadleaf weeds.

Trade Name	Site of Action Number	Artichoke, Jerusalem	Bindweed, Hedge	Dandelion	Dewberry spp.	Dock spp.	Dogbane, Hemp	Horsenettle	Ivy, Poison	Milkweed	Mugwort	Pokeweed	Thistle, Canada	Corn Tolerance
2,4-D	4	7	8	8	6	7+	7	6	7	6	6	7	7+	F
Accent Q	2	6	7	N	8	N	6	6	—	6	N	7	6	F–G
Atrazine[1]	5	N	7+	6	6	7	6	6	6	N	N	6	6	VG
Callisto	27	—	—	7+	N	—	7	7+	—	7	—	7	8	G
Clarity/DiFlexx	4	8	**8+**	7+	6	8	7	7	7+	6	7+	7	8	F–G
Glyphosate[2]	9	8	7+	7	8	8	8	7	8	8	7	8	**8+**	E
Liberty (36 fl oz)[3]	10	—	N	7	—	6	6	7	—	6	—	6	6	E
Starane Ultra	4	N	8	N	N	N	**8+**	N	N	N	N	N	N	VG
Stinger	4	**9**	N	7	N	**8+**	N	6	7	N	8	N	**9**	VG
Mixtures														
Curtail	4/4	**9**	8	8	6	**8+**	7	6	7	6	8	7	**9**	F
Status	4/19	8	**8+**	**8+**	6	8	7	7	7+	7	7+	8	**8+**	G
Yukon	2/4	7	8	8	6	7	7	7+	—	8	7+	8	**8+**	F–G

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale. Performance ratings are based on seasonal control from early season application in corn.

Crop tolerance: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); F–G = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

[1] Ratings based on 1.6–2 lb/A rate.

[2] For use on Roundup Ready corn varieties only. Glyphosate-containing products include Roundup, Durango, and many others; see Table 2.1-8.

[3] For use on glufosinate-tolerant or LibertyLink corn varieties only.

Table 2.2-13. Comments on postemergence herbicides for corn.

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
2,4-D amine 4S	2,4-D amine	4	0.5–1 pt	0.2–0.5
• Use from time corn emerges until approximately 36 inches. • Risk of 2,4-D injury increases as corn increases in size. • Use 0.5 pt rate with drop nozzles after corn exceeds 8 inches in height. • Corn is most susceptible to injury when growing rapidly. • Adjust sprayer to minimize drift in order to prevent injury to nontarget plants.				
Acuron GT 4.29SC	*S*-metolachlor +	15	3.75 pt	0.94
	mesotrione +	27		0.09
	bicyclopyrone	27		0.044
	glyphosate	9		0.94 ae
• Acuron GT is very similar to Halex GT, has a similar utility, and can only be applied to glyphosate-resistant (RR) corn hybrids from emergence to 30 inches tall (8-leaf stage). • For best results, apply to weeds before they are 4 inches tall. • Include NIS and AMS in the spray mixture. • Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Acuron GT and atrazine to corn greater than 12 inches tall. • Do not apply another HPPD-inhibitor herbicide (Callisto, Capreno, Impact/Armezon, Laudis) postemergence in the same season. • See label for additional use restrictions.				
Accent Q 54.4WG	nicosulfuron + safener	2	0.9 oz	0.031
• Accent Q contains nicosulfuron plus isoxadifen (corn safener). • The typical use rate of Accent Q is 0.9 oz/A and it controls many annual grasses and some broadleaves. Accent Q is weak on crabgrass. • Apply to corn broadcast or directed up to 20 inches tall (V6) or directed up to 36 inches tall (V10). • Include appropriate adjuvant in spray tank (see Table 2.2-16). • Accent Q may be tank-mixed with certain herbicides. Do not tank-mix with Basagran, 2,4-D, or certain OP insecticides such as Lorsban, malathion, etc. Do not use Counter 15G. Do not use Counter 20CR in furrow or over the row at cultivation; may be banded, but may cause injury, especially on soils with less than 4% organic matter. The use of Dyfonate, Lorsban, Thimet may result in temporary injury. There are no precautions for non-OP insecticides. • Revulin Q is a premix that contains nicosulfuron + mesotrione. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.				
Aim 2EC	carfentrazone	14	0.5–1 fl oz	0.008–0.016
• Apply to corn up to 8-leaf collar stage and when weeds generally are 1–4 inches tall. • Include a non-ionic surfactant (2 pt/100 gal). • Tank-mix with other herbicides to increase weed control spectrum.				
Armezon 2.8SC	topramezone	27	0.5–1 fl oz	0.011–0.022
• See Impact entry for more details • Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Armezon and atrazine to corn greater than 12 inches tall. • Armezon PRO is a premix containing topramazone plus dimethenamid-P (Outlook) and can be applied over the top of corn for additional residual weed control.				
Atrazine 4L	atrazine	5	1–2 qt	1–2
• Apply before weeds are 1.5 inches tall and before corn reaches 12 inches in height. • Add 1 qt crop oil concentrate/A to spray solution. Do not include oil if corn is under stress from prolonged cold, wet weather or other factors. • Provides good to excellent residual control of susceptible broadleaf weeds. *Atrazine Use Restrictions* Postemergence: • If no atrazine was applied prior to crop emergence, use a maximum rate of 2 lb ai/A. • If a soil-applied application was made in the same calendar year, the combined preplant or preemergence and postemergence applications may not exceed 2.5 lb ai/A. Safety precautions for using atrazine: • Do not mix, load, or apply within 50 feet of drinking water wells, livestock wells, agricultural drainage wells, irrigation wells, abandoned wells, or sinkholes. • Do not mix or load within 50 feet of intermittent streams, perennial streams, rivers, lakes, or reservoirs. • Do not apply within 200 feet of lakes or reservoirs. • Do not apply within 66 feet of the points where surface water runoff enters intermittent streams, perennial streams, or rivers. The 66-foot buffers should be planted to a crop or seeded with grass on highly erodible land. • *Restricted-use pesticide and water quality advisory.*				

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Basagran 4S	bentazon	6	1.5–2 pt	0.75–1

• Apply when weeds are small and actively growing.
• Split treatments may be required for yellow nutsedge and Canada thistle.
• Include the appropriate adjuvant in the spray tank (see Table 2.2-16).
• Basagran poses less threat to off-target plants from drift than 2,4-D or Clarity/Banvel.
• Basagran is weak on pigweed and the addition of atrazine improves control.

Basis Blend 30WDG	rimsulfuron +	2	0.825 oz	0.01
	thifensulfuron	2		0.005

• Basis Blend is a mixture of rimsulfuron (Resolve) and thifensulfuron (Harmony) (SG); however, its formulation is different from Basis 75DF; thus, the application rate has changed.
• Apply 0.825 oz/A Basis Blend to corn from spike stage through 2 collars (about 6 inches tall). Do not apply to corn having 3 fully emerged collars or corn over 6 inches tall.
• Basis Blend controls some small annual grasses and broadleaves. Will provide residual control of susceptible species.
• Basis Blend must include an adjuvant including an ammonium nitrogen fertilizer.
• Crop injury may occur following an application of Basis Blend if there is a prolonged period of cold weather and/or in conjunction with wet soil.
• Do not tank-mix with Basagran.
• Regardless of PRE and/or POST applications, do not apply more than a total of 1 oz/A/season active ingredient rimsulfuron.
• Do not tank-mix Basis Blend with foliar-applied organophosphate insecticides such as Lorsban, malathion, parathion, etc., as severe crop injury may occur. To avoid crop injury or antagonism, apply these products at least 7 days before or 3 days after the application of Basis Blend. Do not apply Counter within 60 days of a preemergence or preplant application of Basis Blend since crop injury may result. Do not apply Basis Blend within 45 days of crop emergence where Counter was applied as a treatment since crop injury may occur. There are no precautions for Force and Fortress.
• To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.

Cadet 0.91EC	fluthiacet	14	0.4–0.9 fl oz	0.0028–0.006

• Application timing to corn ranges from 2 visible collars (V2) until the corn is 48 inches tall (or prior to tasseling).
• Apply 0.4 to 0.6 fl oz/A with glyphosate (RR corn) or glufosinate (LL corn) or 0.5 to 0.9 fl oz when applied alone.
• Include the necessary spray additives (NIS or COC plus AMS or nitrogen solution).
• Applications should be made when susceptible broadleaf weeds are small.
• Cadet is very effective on velvetleaf (up to 36 inches tall), but other broadleaf weeds must be small to achieve control/suppression.
• Cadet does not provide residual weed control.
• Cadet can cause burning/speckling on the corn leaves.
• Cadet is similar to Aim herbicide.

Callisto 4SC	mesotrione	27	3 fl oz	0.094

• Callisto can be applied postemergence at 3 fl oz/A to corn up to 30 inches tall (8-leaf stage).
• Always include crop oil concentrate and UAN or AMS in the spray mixture. Do not use methylated seed oil (MSO).
• Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Callisto and atrazine to corn greater than 12 inches tall. (Callisto Xtra is a premix of Callisto + atrazine.)
• Callisto will provide residual control of susceptible weed species.
• Do not apply more than a total of 7.7 oz/A of Callisto/A/season (i.e., 0.24 lb ai/A mesotrione)from any product or combination of products containing mesotrione.
• When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds.
• Do not apply Callisto postemergence in a tank mixture with emulsifiable concentrate grass herbicides.
• Do not apply Callisto postemergence:
(1) if the crop was previously treated with Counter or Lorsban insecticide
(2) with any OP or carbamate insecticide
(3) 7 days before or after an OP or carbamate insecticide was applied
• Small grains may be planted 4 months after application. Corn, soybeans, and sorghum can be planted the year after application, 10-month restriction for alfalfa, and 18-month restriction for clover. See Table 2.1-11 for additional rotational crops.
• Other postemergence premixes that contain mesotrione include:
- Callisto GT (mesotrione + glyphosate)
- Callisto Xtra (mesotrione + atrazine)
- Halex GT (mesotrione + S-metolachlor + glyphosate)
- Harness MAX (mesotrione + acetochlor)
- Realm Q (mesotrione + rimuslfuron)
- Revulin Q (mesotrione + nicosulfuron)

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Capreno 3.45SC	tembotrione +	27	3 fl oz	0.068
	thiencarbazone +	2		0.013
	corn safener			
• Capreno is a premix of tembotrione (Laudis), thiencarbazone (ALS-inhibitor herbicide that improves control of annual weeds), and cyprosulfamide (corn safener) and can be applied postemergence up to V7 corn stage to provide control of annual broadleaves and grasses, especially when tank-mixed with atrazine. • The use rate is 3 fl oz/A in addition to COC and UAN or AMS in the spray mixture. (Do not use NIS or MSO.) • For best results, apply Capreno when broadleaf weeds are less than 4 to 6 inches tall and grasses are less than 3 inches tall and not tillering. • Do not apply more than 0.164 lb ai tembotrione/A/year (6 fl oz/A total Capreno) • Temporary stunting is occasionally observed with Capreno, corn recovers in 7 to 10 days and does not affect yield. • When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Capreno and atrazine to corn greater than 12 inches tall. • Capreno can be tank-mixed with glyphosate, or glufosinate to broaden control spectrum. • Capreno will provide residual control of susceptible weed species. • Do not use Capreno in the same season as OP insecticides such as Lorsban, Counter, Dyfonate, or Thimet.				
Clarity 4S	dicamba (DGA salt)	4	8–16 fl oz	0.25–0.5 lb ae
• May apply dicamba up to 0.5 lb ae/A before corn is 8 inches tall (5-leaf stage). Use 0.25 lb ae/A on corn between 8 and 36 inches. • Take precautions to prevent drift of dicamba off the target site. • Early postemergence applications are preferable for lambsquarters control. • Applications should be made while annual weeds are small (4 inches) and actively growing. • Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary to limit spray drift. Comply with guidelines for drift management (see label for details). • Dicamba can be difficult to completely remove from spray equipment and residue is capable of injuring sensitive plants. Follow label instructions concerning sprayer cleanout.				
Curtail 2.38L	clopyralid +	4	2 pt	0.095
	2,4-D	4		0.5 ae
• Curtail contains clopyralid (Stinger) and 2,4-D. • Apply to corn less than 8 inches tall (V4). • For increased control of Canada thistle, tank-mix Curtail with Stinger (2–6 fl oz).				
DiFlexx 4SC	dicamba + safener	4	8–32 fl oz	0.25–1
• This safened dicamba product contains cyprosulfamide, which is the same safener used in Balance Flexx and Corvus. • Can be applied to field corn from spike stage to V6 (36 inches tall). • The lower use rates (8–16 fl oz) are recommended for annual broadleaf weeds that are small and actively growing, while the mid and higher rates are recommended for larger annual weeds and established biennial and perennial species. • The addition of UAN or AMS plus NIS or COC/MSO is recommended to improve control. • See label for additional use details and restrictions.				
DiFlexx Duo 1.53SC	dicamba + safener +	4	24–40 fl oz	0.24–0.4
	tembotrione	27		0.051–0.085
• DiFlexx Duo contains the active ingredients in DiFlexx (dicamba) and Laudis (tembotrione) and has activity on both broadleaf and grassy weeds. • DiFlexx Duo can be applied from corn emergence to 36 inches tall or before V7 stage, whichever comes first. • For best results, apply before annual broadleaf weeds reach 6 inches tall and grasses reach 3 inches tall. • The addition of UAN or AMS plus MSO or COC is recommended to improve control. • Do not apply more than 0.164 lb ai tembotrione per acre per year. • When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • See label for additional use details and restrictions.				
Enlist One 3.8SL	2,4-D chloline	4	1.5–2 pt	0.71–0.95 ae
Enlist Duo 3.3SL	2,4-D choline +	4	3.5–4.75 pt	0.7–0.95 ae
	glyphosate	9		0.74–1.0 ae

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
• Enlist Duo and Enlist One can only be applied POST to corn with the Enlist trait and has activity on both broadleaf and grassy weeds. • Apply broadcast from corn emergence to 30 inches tall or before V8 stage, whichever comes first; use drop nozzles for corn heights 30 to 48 inches tall. • Make one or two applications with a minimum of 12 days between applications. • Apply in a broadcast spray volume from 10 to 15 GPA for best results and do not use nitrogen solutions as a carrier. • Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary to limit spray drift. Comply with guidelines for drift management (see label for details). • See label for additional use details and restrictions.				
Halex GT 4.39EC	*S*-metolachlor +	15	3.6–4 pt	0.94–1.04
	mesotrione +	27		0.09–0.1
	glyphosate	9		0.9–1.04 ae
• Halex GT contains *S*-metolachlor (Dual Magnum) plus mesotrione (Callisto) plus glyphosate and can only be applied to glyphosate-resistant (RR) corn hybrids from emergence to 30 inches tall (8-leaf stage). • For best results, apply to weeds before they are 4 inches tall. • Include NIS and AMS in the spray mixture. • Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Halex GT and atrazine to corn greater than 12 inches tall. • Do not apply another HPPD-inhibitor herbicide (Callisto, Capreno, Impact/Armezon, Laudis) postemergence in the same season. • Do not apply more than 4 pt/A Halex GT per season (0.0105 lb mesotrione, 1.05 lb *S*-metolachlor, and 1.05 lb glyphosate) or make more than one application per year. • Do not apply more than 0.24 lb ai mesotrione/A/year from any product or combination of products containing mesotrione. • When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • Halex GT will provide effective residual control of susceptible weed species. • Halex GT is not recommended for use as a preplant or PRE application. • Halex GT can be used in a planned PRE followed by POST herbicide program. • Use caution if applying OP or carbamate insecticides 7 days before or after Halex GT application. • See label for additional use restrictions.				
Harmony SG 50WDG	thifensulfuron	2	0.125 oz (1/8 oz)	0.063 oz
• Harmony SG can be applied to 2- to 6-leaf corn (1–4 collars, up to 12 inches tall) at a rate of 1/8 oz/A. • Harmony SG can be used in a tank-mix to control velvetleaf, pigweed, smartweed, wild mustard, and lambsquarters (including triazine-resistant species). • Include the necessary adjuvants in the spray solution. • Do not apply Harmony SG to normal or IT corn previously treated with Counter 15G or 20CR, Thimet, Dyfonate, Lorsban, or other OP insecticides, otherwise crop injury will result. No insecticide herbicide restriction with IR corn hybrids. There are no precautions for Fortress or Force insecticides. • Harmony SG is an ALS (Group 2) inhibitor herbicide. To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.				
Impact 2.8SC or Armezon 2.8SC	topramezone	27	0.5–2 fl oz	0.011–0.044
• Impact/Armezon is similar to Callisto but has more annual grass activity. • Apply postemergence to corn up to V8 growth stage or 45 days prior to corn harvest, whichever is more restrictive (use drop nozzles when necessary). • Always include methylated seed oil (MSO) or crop oil concentrate (COC) and UAN or AMS in the spray mixture. • Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture with atrazine to corn greater than 12 inches tall. • Impact is often used at 1 fl oz/A but the rate can be increased to 2 fl oz/A for larger or harder-to-control weeds such as fall panicum, yellow foxtail, or seedling Johnsongrass. • Impact/Armezon can be used in sequence after herbicides such as Balance, Lumax, Lexar, etc., but be cautious of rate restrictions. Impact/Armezon may be used after or in combination with all soil or foliar-applied insecticides registered for use in corn. • Do not apply more than 0.022 lb ai topramezone/A/year. • When HPPD-containing (Group 27) herbicides are used in both preemergence and postemergence (sequential applications), Impact must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • Corn can be planted any time after Impact/Armezon application; 3-month restriction for small grains; 9-month restriction for alfalfa, potato, soybean, and sorghum; and 18 months for other crops. See Table 2.1-11for other rotational crops. • ImpactZ is a premix containing topramazone plus atrazine. • Impact Core is a premix of topramezone plus acetochlor (Harness) and can be applied post. • Sinate is a premix of topramezone plus glufosinate (Liberty). • Armezon PRO is a premix containing topramazone plus dimethenamid-P (Outlook) and can be applied over the top of corn for additional residual weed control.				

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Laudis 3.5SC	tembotrione	27	3 fl oz	0.082
• For best results apply Laudis at 3 fl oz/A when weeds are small (i.e., 1 to 3 inches tall). • Methylated seed oil (MSO) or crop oil concentrate (COC) adjuvants are recommended by manufacturer. In addition, nitrogen fertilizer is required (UAN or AMS). • Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Laudis and atrazine to corn greater than 12 inches tall. Laudis can be tank-mixed with other herbicides to improve weed control spectrum. • Laudis will control/suppress crabgrass, foxtails, and other grass species, but it will not control fall panicum. • Do not make more than 2 applications of Laudis in a growing season. • Do not apply more than 0.164 lb ai tembotrione per acre per year • When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • Be cautious of crop rotation restrictions; see Table 2.1-11. • See label for additional use details.				
Liberty 2.34L	glufosinate	10	22–32 fl oz	0.40–0.59
• Liberty controls most annual grasses and broadleaves. • Apply over-the-top to glufosinate-resistant (e.g., LibertyLink) corn only. • Up to three Liberty applications can occur during the growing season (one at burndown and two in-crop) • Two postemergence applications of Liberty can be applied at least 7 days apart. • Broadcast applications may be made from corn emergence until corn is in the V-6 stage of growth, whichever comes first. • For best results, apply 22 to 32 fl oz of Liberty when weeds are 2 to 6 inches tall. • Do not apply more than 87 fl oz per acre per year. • Liberty herbicide should generally follow a soil residual herbicide program and/or be tank-mixed with an appropriate postemergence product to broaden the spectrum of control. • Applications should be made between dawn and 2 hours before sunset to avoid the possibility of reduced lambsquarters or velvetleaf control. • Weed control can be reduced if application is made when heavy dew, fog, or mist are present or when weeds are under environmental stress. • Liberty provides no soil residual activity. • See Table 2.2-16 for adjuvant information. Include ammonium sulfate (AMS) at 3 lb/A (17 lb/100 gal), but a lower rate is recommended if temperatures exceed 85 degrees (8.5 lb/100 gal) to reduce risk of leaf burn. Do not add any surfactants or crop oils. • Sinate is a premix of topramezone plus glufosinate (Liberty).				
Maestro/Moxy 2E	bromoxynil	6	1–1.5 pt	0.25–0.375
• Apply to small actively growing weeds. • Maestro or Moxy pose less threat to off-target plants from drift than 2,4-D or Clarity/Dicamba. • Bromoxynil is weak on pigweed.				
Metribuzin 75DF	metribuzin	5	2 oz	0.094
• Metribuzin may be applied postemergence at the 2 oz rate in tank-mix combination with atrazine, Dicamba, Clarity, Basagran, Buctril, Marksman, and 2,4-D for improved control of certain broadleaf weeds (e.g., velvetleaf). • Observe precautions and limitations of tank-mix partners. • *Water quality advisory.*				
Peak 57WG	prosulfuron	2	0.25–1 oz	0.009–0.036
• Peak is an ALS (Group 2) herbicide and can be applied in field corn to control broadleaf weeds. • Include necessary adjuvants in the spray mixture. • Peak can be applied when corn is 4 to 30 inches tall; use drop nozzles when corn is >20 inches tall. • In university field trials, Peak at 0.5 oz/A provided season-long control of burcucumber, especially when applied to 25-30 inch tall corn. • Be cautious of interactions with certain OP insecticides. • Be cautious of long crop rotational intervals for many crops; see label for details. • Refer to label for additional information on use and restrictions.				
Permit 75WG or Sandea	halosulfuron	2	0.67–1.33 oz	0.032–0.063
• Apply to corn from spike through layby (last cultivation). • The 0.67 oz rate is the standard rate for annual weed control. • Permit/Sandea is excellent on yellow nutsedge but weak on common lambsquarters. • Tank-mix with products such as Clarity/Banvel or 2,4-D to increase the weed control spectrum. • Permit/Sandea will provide residual control of susceptible weed species. • Permit/Sandea has no insecticide use restrictions. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides. • Yukon is a prepackaged product containing halosulfuron (Permit) plus the sodium salt of dicamba.				

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Permit Plus 74WDG	halosulfuron +	2	0.75 oz	0.031
	thifensulfuron	2		0.004
• The addition of thifensulfuron (Harmony SG) to halosulfuron (Permit) allows for a broader spectrum of control, especially on lambsquarters postemergence. • Apply 0.75 oz/A plus necessary adjuvants to corn with 2–6 leaves (but with no more than 5 collars). • Tank-mix to broaden control spectrum. • Permit Plus contains two ALS-type (Group 2) herbicides. To prevent herbicide resistance, avoid repeated annual applications of ALS herbicides.				
Realm Q 38.8WDG	rimsulfuron +	2	4 oz	0.019
	mesotrione +	27		0.078
	corn safener			
• Realm Q contains the active ingredients in Resolve and Callisto and the postemergence corn safener isoxadifen. • For best results, apply Realm Q at 4 oz/A in a two-pass program and when weeds are small and prior to corn reaching 12 inches tall. • Realm Q requires use of nitrogen fertilizer (AMS or UAN) in addition to COC or NIS. • Make only one application per season. • The addition of atrazine will improve postemergence weed control and is strongly recommended. • Realm Q can be used alone, in combination with glyphosate on Roundup Ready corn or glufosinate on LibertyLink corn, or included in other POST herbicide programs to improve weed control spectrum. • Realm Q will provide some residual as well as foliar control. • Regardless of PRE and/or POST applications, do not apply more than a total of 1 oz per acre per season active ingredient rimsulfuron and 3.85 oz per acre per season active ingredient mesotrione. • Do not apply more than 0.24 lb ai mesotrione/A/year from any product or combination of products containing mesotrione. • When HPPD-containing (Group 27) herbicides are used in both pre and post sequential applications, the post HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds. • Do not tank-mix with an organophosphate insecticide. Do not apply to corn previously treated with Counter or Lorsban.				
Resolve 25DF	rimsulfuron	2	0.5–2 oz	0.0078–0.03
• Resolve contains the single active ingredient rimsulfuron. • Resolve can be applied PRE or POST in corn at 0.5–2 oz/A. Use the higher rate when applying as a tank-mix partner in a PRE program. The typical use rate for POST applications is 1 oz/A, plus the necessary adjuvants. • Resolve alone will control small seedling weeds, grasses less than 2 inches and broadleaves less than 3 inches. Resolve will control crabgrass less than 0.5 inch tall. • Resolve can be tank-mixed with glyphosate to provide residual control of broadleaf and grass weed species emerging after the application. Resolve may be tank-mixed with full or reduced rates of other corn herbicides as well. • Do not apply Resolve to corn under stress due to crop injury. • Refer to the Resolve label for all restrictions concerning increased injury when tank-mixed with organophosphate insecticides (Counter, Lorsban, or Thimet). • Do not tank-mix with Basagran due to crop injury concern. • Apply Resolve up to 12-inch-tall corn or before the appearance of 6 or more collars, whichever is more restrictive. • Resolve must be applied with a non-ionic surfactant (NIS) and nitrogen fertilizer. Crop oil concentrate (COC) may be used in place of non-ionic surfactant. When applying Resolve in a tank mixture with a glyphosate product that contains a "built-in" adjuvant system, the Resolve label does not recommend the use of extra adjuvants. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.				
Resolve Q	rimsulfuron +	2	1.25 oz	0.014
	thifensulfuron	2		0.003
• Do not confuse Resolve with Resolve Q. Resolve Q contains rimsulfuron (Resolve) plus thifensulfuron (Harmony SG) and a postemergence corn safener. • Apply 1.25 oz/A postemergence to corn up to 20 inches tall. • Applications made after weed emergence will provide contact control of labeled weeds and limited residual control of later emergence. • For control of emerged weeds, include a nonionic surfactant and an ammonium nitrogen fertilizer. If applied in combination with a glyphosate or glufosinate herbicide that contains a built-in adjuvant system, no additional surfactant needs to be added. • Resolve Q may be tank-mixed with glyphosate or glufosinate herbicides if applications are made to corn hybrids containing appropriate herbicide tolerance genes, and can be tank-mixed with full or reduced rates of other products registered for use in corn. • Resolve Q may be tank-mixed with full or reduced rates of preemergence grass and broadleaf herbicides to provide added residual activity. Do not tank-mix Resolve Q with Basagran. • Resolve Q may negatively interact with certain OP insecticides, see label for specific details. To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.				

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Resource 0.86EC	flumiclorac	14	4–6 fl oz	0.027–0.04

• Apply to corn from 2-leaf to 10-leaf stage.
• Good on velvetleaf up to 30 inches tall.
• Tank-mix with other products such as Clarity or atrazine to increase the weed control spectrum.
• Perpetuo is a premix of flumiclorac plus pyroxasulfone (Zidua) and must be applied POST.

Roundup PowerMax 4.5S or Power-Max3 4.8S	glyphosate	9	22 to 32 fl oz 20 to 30 fl oz	0.75 lb ae to 1.12 lb ae
Durango DMA			24 to 36 fl oz	
Other glyphosate products				

• Apply over-the-top to Roundup Ready corn hybrids only.
• Apply from corn emergence through 48-inch-tall corn in a 10–20 GPA spray solution.
• Do not apply more than 1.13 lb ae/A of glyphosate (Roundup PowerMax at 32 fl oz or PowerMax3 at 30 fl oz/A) in a single in-crop application. (Refer to current product label for other use restrictions.)
• For corn grain and silage corn, two in-crop applications of Roundup can be made; allow 10 days between applications.
• For best results, apply a PRE residual herbicide followed by glyphosate when weeds are 4–6 inches tall (for best results tank-mix with other POST herbicides to improve weed control spectrum and prevent glyphosate-resistant weed species.)
• Early postemergence programs that include glyphosate plus a residual herbicide also are an option, but they may not be as consistent as the preemergence followed by the postemergence program.
• Be cautious of corn height restrictions for residual herbicides.
• Roundup WeatherMAX does not require additional adjuvants in the spray tank under most conditions.
• Do not harvest silage for 50 days or grain for 7 days after last application.
• Refer to Table 2.1-8 for various glyphosate products and see specific product label for additional application information and restrictions.

Shieldex 400 3.33SC	tolpyralate	27	1–1.35 fl oz	0.026–0.035

• For best results, apply Shieldex before weeds reach 5 inches tall.
• Methylated seed oil (MSO) or crop oil concentrate (COC) adjuvants are recommended by manufacturer. In addition, nitrogen fertilizer is required (UAN or AMS).
• Tank-mix with 0.25 to 1 lb ai/A of atrazine for much improved control and to broaden the spectrum of control. Local university data supports at least 0.5 lb ai/A of atrazine. Do not apply the tank mixture of Shieldex and atrazine to corn greater than 12 inches tall. Shieldex can be tank-mixed with other herbicides to improve weed control spectrum.
• Shieldex will control/suppress crabgrass, foxtails, and other grass species, but it will not control fall panicum. It will also provide control of several common annual broadleaf weeds found in our region.
• Do not make more than two applications of Shieldex in a growing season.
• Do not apply more than 0.07 lb ai (2.7 fl oz) tolpyralate per acre per year.
• When HPPD-containing (Group 27) herbicides are used in both PRE and POST sequential applications, the POST HPPD product must be tank-mixed with another herbicide that has a different and effective site of action on the target weeds.
• Be cautious of crop rotation restrictions; see Table 2.1-11.
• See label for additional use details.
• Other products that contain tolpyralate include the Empyros product line, Katagon, and Restraint.

Status 56WDG	dicamba +	4	2.5–10 oz	0.09–0.34
	diflufenzopyr +	19		0.025–0.1
	safener			

• Status contains dicamba (Clarity) plus another plant growth regulator (diflufenzopyr) and the postemergence corn safener isoxadifen.
• Apply Status at 5 oz/A to 4- to 36-inch-tall corn (V2–V8).
• Status can be tank-mixed with glyphosate at 2.5 oz/A. Use higher rates for more difficult to control weeds. Do not exceed a total of 12.5 oz/A per season.
• Include a non-ionic surfactant at 1 qt plus 5 qt of UAN (28–34% nitrogen) per 100 gallons of water (COC or MSO may be used instead of NIS).
• Status is effective on many broadleaf weeds.
• Do not tank-mix with products that contain 2,4-D, dicamba, or clopyralid.
• Refer to product label for additional precautions.
• *Water quality advisory.*

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Steadfast Q 37.7WG	nicosulfuron +	2	1.5 oz	0.02
	rimsulfuron +	2		0.012
	corn safener			
• Steadfast Q also contains a 2:1 ratio of nicosulfuron to rimsulfuron in addition to the postemergence corn safener isoxadifen. • Apply Steadfast Q at 1.5 oz/A to corn up to 20 inches tall (6 collars) and while weeds are young and actively growing. • Steadfast Q is weak on crabgrass, especially if >1 inch tall. Always include the necessary adjuvants in the spring mixture. • Steadfast Q can be tank-mixed to improve control and increase weed spectrum. • Do not tank-mix with Basagran, 2,4-D, or certain OP insecticides such as Lorsban, malathion, etc. Do not use Counter 15G. Do not use Counter 20CR in furrow or over the row at cultivation; may be banded, but may cause injury, especially on soils with less than 4% organic matter. The use of Dyfonate, Lorsban, or Thimet may result in temporary injury. There are no precautions for non-OP insecticides. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides. • See Table 2.1-11 for crop rotation restrictions.				
Stinger 3S	clopyralid	4	0.25–0.66 pt	0.093–0.25
• Apply to corn up to 24 inches tall. Use 0.25–0.5 pt/A for ragweed, cocklebur, and Jerusalem artichoke, and 0.33–0.66 pt/A for Canada thistle. • Delay planting soybeans for 18 months following Stinger application. • *Water quality advisory.*				
Stout 72.5WDG	nicosulfuron +	2	0.5–0.75 oz	0.031
	thifensulfuron	2		0.002
• Stout contains nicosulfuron (Accent) and thifensulfuron (Harmony SG). • The typical use rate for Stout is 0.75 oz/A and must include a crop oil concentrate (COC) or a non-ionic surfactant (NIS) in the spray mixture as well as a nitrogen fertilizer (UAN or AMS). • Stout can be applied up to 16-inch-tall corn or to corn with less than 6 collars, whichever is more restrictive. • Stout will not control crabgrass species. • Do not tank-mix Stout with Basagran due to crop safety concerns. Do not tank-mix with 2,4-D due to reduced grass control. • Refer to Stout label for restrictions regarding OP insecticides such as Counter, Lorsban, Malathion, and Thimet. Do not tank-mix with other ALS-inhibitor herbicides unless stated on herbicide label. • Refer to product label for additional use restrictions. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.				
SureStart II 4.25SE or TripleFLEX II	acetochlor +	15	1.5–3 pt	0.71–1.41
	flumetsulam +	2		0.056–0.113
	clopyralid	4		0.023–0.045
• SureStart II/TripleFLEX II can be applied up to the early POST stage (11-inch-tall corn) and is intended to be used with Roundup Ready or LibertyLink field or silage corn hybrids. • When applied PRE, it is designed to provide early season control of common annual grasses and broadleaf weeds to allow better timing of the in-crop application of glyphosate or glufosinate. • The use rate on medium-textured soils ranges from 1.5 to 1.75 pt/A, but for longer residual control, use up to 3 pt/A. • SureStart II/TripleFLEX II does not contain atrazine, so it provides a non-atrazine alternative for triazine-sensitive areas. However, atrazine and other herbicides can be tank-mixed with SureStart II/TripleFLEX II to broaden the weed control spectrum. • SureStart II/TripleFLEX II can be tank-mixed with glyphosate (in Roundup Ready corn) or glufosinate (LibertyLink corn) to provide broader spectrum of POST weed control. • Applications should be made to weeds 2 inches or less in height. • Make sure to plant corn 1.5 inches deep and be cautious of interactions with certain OP insecticides that may cause crop injury. • See label for additional details.				
Tough 5EC	pyridate	6	24 fl oz	0.94
• Tough is good on common lambsquarters and pigweeds but should generally be tank-mixed with atrazine or another suitable foliar-applied product to broaden the control spectrum. • Apply when broadleaves are in the one- to four-leaf stage of growth and before corn reaches V8 growth stage. • Include NIS, COC, or MSO plus AMS or nitrogen fertilizer to improve weed control. • Thorough spray coverage (15 to 20 gal/A) is necessary for optimal weed control. • See label for additional use restrictions.				

Table 2.2-13. Comments on postemergence herbicides for corn (continued).

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
Warrant 3CS	acetochlor	15	1.5–3 qt	1.13–2.25
• Warrant can be tank-mixed with glyphosate and POST applied to emerged corn to provide residual control of annual weeds. • Warrant does not control emerged weeds. • The typical use rate is 1.5 qt/A. • *Water quality advisory.*				
Yukon 67.5WDG	halosulfuron +	2	4–8 oz	0.03
	dicamba	4		0.125
• Yukon is a premix of halosulfuron (Permit) plus the sodium salt of dicamba. • Yukon can be applied at 4–8 oz/A to corn from spike to 36 inches tall; use drop nozzles when necessary. (The 4 oz/A Yukon rate equals 0.67 oz/A Permit plus 4 fl oz/A Clarity.) • Include necessary adjuvants in the spray solution (see Table 2.2-16). • Yukon has no insecticide use restrictions. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides.				

The treatments in this table are applied after corn emergence to control established weeds. See specific product label to determine correct rate for soil type and weed species found in individual fields.
*See Table 2.1-10 and Table 2.2-1 for additional formulations or trade names containing some of these same active ingredients.

Table 2.2-14. Weed sizes for postemergence corn herbicides.

Grasses

Trade Name (rate/A)	Barnyardgrass	Bermudagrass	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wirestem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
	Height Range (inches) at Application													
Accent Q (0.9 oz)	<4	—	—	<4	—	<18	<12	<8*	—	<4	≤3	<10*	<12	≤2
Basis Blend (0.825 oz)	1–2	—	—	1–2	—	—	—	—	—	1–2	—	—	—	—
Callisto (3 fl oz)	—	—	≤2	—	—	—	—	—	—	—	—	—	—	—
Capreno (3 fl oz)	<5	—	<3	<3	—	—	<5	—	—	<5	≤3	—	<12	≤5
Glyphosate (0.75 ae)	4–6	L*	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6
Halex GT (3.6 pt)/Acuron GT (3.75 pt)	<4	—	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Impact/Armezon (0.75 fl oz)/Impact Core	≤4	—	≤3	3–4[1]	≤3	—	4*	—	—	≤3*	≤3*	—	—	≤3*
Laudis (3 fl oz)/DiFlexx Duo (32 fl oz)	1–5	—	1–3	1–3	1–3	—	1–5	—	—	—	1–3	—	1–6	1–4
Liberty (32 fl oz)[2]	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3
Permit (1 oz)	—	—	—	—	—	—	—	—	4–12	—	—	—	—	≤2*
Realm Q (4 oz)	1–2	—	≤0.5	1–2	—	—	1–2*	—	1–2*	1–2	—	1–2*	1–4	≤2*
Require Q (4 oz)	1–2	—	0.5	1–2		—	*	—	*	1–2		*	1–4	
Resolve (1 oz)	1–2	—	≤0.5	1–2	—	—	1–2*	—	1–2*	1–2	—	1–2*	1–4	1–2*
Resolve Q (1.25 oz)	1–2	—	0.5	1–2	—	—	*	—	*	1–2	—	*	1–4	1–2*
Revulin Q (4 oz)	1–4	—	≤2	≤4	—	<18	<12	<6*	—	<4	<3	<10*	<12	≤2
Roundup PowerMAX (22 fl oz)[3]	4–6	L*	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6	4–6
Shieldex (1 fl oz)/Restraint	<5	—	<5	<5	<5	—	—	—	—	—	—	—	<5	<5
Sinate (28 fl oz)	≤4	—	≤4	≤4	—	—	≤4	*	*	≤4	≤4	—	≤4	≤4
Steadfast Q (1.5 oz)	<4	—	<1*	<4	≤2	<12	<12	<4*	—	<4	≤4	<8*	<6	≤2
Stout (0.75 oz)	≤4	—	—	≤4	—	≤18	≤12	≤8*	—	≤3	≤3	≤10*	≤12	≤2
Yukon (6–8 oz)	—	—	—	—	—	—	—	—	1–12	—	—	—	—	—

*Suppression only; additional control measures may be necessary.
[1] Yellow foxtail suppression only.
[2] For use on LibertyLink/GR corn hybrids only.
[3] For use on Roundup Ready corn hybrids only.

Table 2.2-14. Weed sizes for postemergence corn herbicides (continued).

Broadleaves

	Amaranth, Palmer/ Waterhemp	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters	Marestail/ Horseweed	Morningglory, Annual	Nightshade, Eastern Black	Pigweed	Ragweed, Common	Ragweed, Giant	Smartweed	Velvetleaf
Trade Name (rate/A)	**Maximum Height (inches) at Application**													
2,4–D[1]	4	—	—	6	3	4	4	6	2	4	6	6	—	2
Accent Q (0.9 oz)	—	—	3	—	3	—	—	2	—	4	—	—	4	—
Aim (0.5 oz)	—	—	—	—	—	4	—	2–3 lvs	4	4	—	—	—	36
Atrazine (2 qt)[1]	4	—	4	4	4	—	4*	4	4	—	4	4	4	2
Basagran (2 pt)	—	4	—	10	10	2*	—	—	—	—	3	6	10	5
Basis Blend (0.825 oz)	3	—	—	—	—	3	—	—	—	3	—	—	3	3
Cadet (0.9 fl oz)	2*	4*	3	—	2	3*	—	3	2	4	—	—	2	36
Callisto (3 fl oz)	3*	—	—	5	5	5	3*	5*	5	5	5*	5	5	5
Capreno (3 fl oz)	<6	—	<6*	<6	<6	<6	—	<6*	<6	<6	<6	<6	<6	<6
Clarity dicamba[1]	4	—	4	4	4	4	4	4	4	4	4	4	6	2
DiFlexx (8 fl oz)	3	3	3	3	3	3	3	3	3	3	3	3	3	3
DiFlexx Duo (32 fl oz)	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Glyphosate (0.75 ae)	6	3	6	6	6	6	6*	6	6	6	6	6	6	6
Halex GT (3.6 pt)/Acuron GT (3.75 pt)	<4*	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Harmony SG (0.125 oz)	4	—	—	—	—	4	—	—	—	12	—	—	6	6
Impact/Armezon (0.75 fl oz)/Impact Core	6*	—	—	8	6	6	—	6*	6	6	6	8	3	8
Laudis (3 fl oz)	<6	—	<6*	<6	<6	<6	—	<6*	<6	<6	<6	<6	<6	<6
Liberty (32 fl oz)[2]	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3	≤3
Maestro, Moxy (1.5–2 pt)	—	—	4	10	6	8	4*	4	6	2	6	6	6	5
Peak (0.5 oz)	3	—	3	6	4	3	3	3	—	3	6	3	3	4
Permit/Sandea (0.67 oz)	—	—	3*	9	—	2*	—	—	—	3	9	3	2	9
Permit/Sandea (1–1.33 oz)	—	—	12*	14	—	2*	—	3*	—	6	12	6	2	12
Permit Plus (0.75 oz)	4	—	3*	9	4*	4	—	3*	—	12	9	3	6	9
Perpetuo (8 fl oz)	4 lvs	—	—	4 lvs	4 lvs	3 lvs	—	—	—	3 lvs	3 lvs	—	—	6 lvs

Table 2.2-14. Weed sizes for postemergence corn herbicides (continued).

Broadleaves

	Amaranth, Palmer/ Waterhemp	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters	Marestail/ Horseweed	Morningglory, Annual	Nightshade, Eastern Black	Pigweed	Ragweed, Common	Ragweed, Giant	Smartweed	Velvetleaf
Realm Q (4 oz)	5	—	5	5	5	5	5*	5*	5	5	5	5	5	5
Resolve (1 oz)	—	—	—	3*	—	3*	—	3*	—	3	3*	—	3*	3*
Resolve Q (1.25 oz)	—	—	—	1–3*	—	1–3*	—	1–3*	—	1–3	1–3*	—	1–3*	1–3
Resource (6 oz)[3]	3 lvs	—	—	—	—	3 lvs	—	—	—	3 lvs	3 lvs	—	—	6 lvs
Revulin Q (4 oz)	<5	—	<2	<5	<5	<5	—	<5	<5	<5	<5	<5	<5	<5
Roundup PowerMAX (22 fl oz)[4]	6	3	6	6	6	6	6*	6	6	6	6	6	6	6
Shieldex (1 fl oz)/Restraint	<5	—	—	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sinate (28 fl oz)	6	—	6	6	6	6	6	4	6	4-6	6	6	4	6
Status (5 oz)[1]	4	—	4	4	4	4	4	4	4	4	4	4	4	4
Steadfast Q (1.5 oz)	—	—	4	4*	4	4*	—	4	—	4	—	—	4*	4*
Stout (0.75 oz)	—	—	3	—	3	4	—	2–3	—	4	—	—	4	4
Tough (24 fl oz)	4 lvs	—	4 lvs	4 lvs	4 lvs	4 lvs	—	—	4 lvs	4 lvs	—	—	—	—
Yukon (4–8 oz)	3	—	12*	14	4	6	4	6	6	12	12	6	3	12

*Suppression only, additional control measures may be necessary.
[1] No sizes given on label; sizes listed above are best estimates.
[2] For use on glufosinate-resistant or LibertyLink corn hybrids only.
[3] Resource label refers to weed size by number of leaves (lvs).
[4] For use on Roundup Ready corn hybrids only.

Table 2.2-15. Postemergence herbicide application restrictions for corn.

Trade Name	Over-the-Top Application	Use of Drop Nozzles	Comments
2,4-D	<8 inches tall	0.5 pt: 8–36 inches tall	Some 2,4-D formulations allow application up to tasseling
Accent Q	20 inches tall (free-standing) or <6 collars (V6 stage)	20–36 inches tall or V6 to V10 stage	—
Aim	Up to 8-leaf collar stage (V8)	Up to 14-leaf collar stage	Use drop nozzles or directed sprayers that target weeds but spray away from the corn whorl
Armezon PRO	Up to 30 inches tall (or 8-corn leaf stage)	When necessary	Do not make application within 45 days of corn harvest or after V8 corn growth stage
Atrazine	12 inches tall	—	—
Clarity	1 pt: 8 inches tall or 5 leaves; 0.5 pt: 8–36 inches tall or 15 days before tassel emergence	—	Do not apply dicamba near soybeans if corn is >24 inches tall, or if soybeans are >10 inches tall or have begun to bloom
Basagran	No restrictions	—	—
Basis Blend	Spike to 4 leaves (2 collars) or 0.5–6 inches tall	—	Do not apply to corn >6 inches tall or having 3 collars
Cadet	Up to 48 inches tall	When necessary	Apply before tasseling
Callisto, Callisto GT	Up to 30 inches tall (or 8-corn leaf stage)	—	—
Callisto Xtra	12 inches tall	—	—
Capreno	Up to V6 (6 collars)	To V7 (7 collars)	—
Curtail	<8 inches tall	—	—
DiFlexx/DiFlexx Duo	Spike to V6 or 36 inches tall	V7–V10	Apply 15 days prior to tasseling
Enlist Duo/Enlist One	Up to 30 inches tall (V8)	30–48 inches tall	Apply to Enlist corn hybrids only
Glyphosate products	Up to 30 inches tall (V8 stage)	30–48 inches tall	Apply to Roundup Ready hybrids only
Halex GT/Acuron GT	Emergence to 30 inches tall (8-leaf stage)	—	—
Harmony SG	2–6 leaves up to 12 inches tall (1 to 4 collars)	—	Do not apply to corn >12 inches tall or having 4 collars
Harness MAX	Up to 11 inches tall	—	—
Impact/Armezon	Up to V8 or 45 days prior to corn harvest (whichever is most restrictive)	When necessary	—
Impact Core	Up to 11 inches tall	—	—
Laudis	Emergence up to V8 stage	—	—
Liberty	Emergence to V6	When necessary up to 36 inches tall	Apply to LibertyLink or GR corn hybrids only
Maestro, Moxy	1 pt: emergence to tassel; 1.5 pt: 4 leaves to tassel	—	Postemergence application before 3-leaf stage may result in corn leaf burn
Metribuzin	Emergence to pretassel	When necessary	See tank-mix partner
Peak	4–20 inches tall	20-30 inches tall (V6)	—
Permit	Spike to 48 inches tall	When necessary	If tank-mixed: with 2,4-D, apply to corn up to 8 inches tall; with dicamba or Clarity, apply to corn up to 36 inches tall
Permit Plus	2- to 6-leaf corn (1 to 5 collars)	—	Do not apply to corn with more than 6 leaves (5 collars)
Perpetuo	2-leaf through V6 stage	—	—
Realm Q	Up to 20 inches tall but with no more than 6 collars	—	—

Table 2.2-15. Postemergence herbicide application restrictions for corn (continued).

Trade Name	Over-the-Top Application	Use of Drop Nozzles	Comments
Resicore Resicore XL	Up to 11 inches tall Up to 24 inches tall	—	—
Resolve	Up to 12 inches tall (<6 collars)	—	—
Resolve Q	Up to 20 inches tall (<6 collars)	—	—
Resource	2-leaf to 10-leaf stage (collars must be visible)	When necessary, to direct below corn leaves	—
Revulin Q	Up to 20 inches tall (<6 collars)	—	—
Roundup products	Up to 48 inches tall	—	Apply to Roundup Ready hybrids only
Shieldex	Up to V6 or 20 inches tall	—	—
Sinate	Up to 24 inches tall (7 collars)	24–36 inches tall	Apply to LibertyLink or GR corn hybrids only
Status	4 to 36 inches tall (V2 to V8)	—	Do not apply within 15 days before tassel emergence
Steadfast Q	Up to 20 inches tall (6 collars)	—	Best if applied when corn is <12 inches tall
Stout	Up to 16 inches tall (<6 collars)	—	—
SureStart II/TripleFLEX II	Up to 11 inches tall	—	—
Tough	Up to V8 growth stage	—	—
Warrant	Emergence to 30 inches tall	When necessary	Does not control emerged weeds; tank-mix with glyphosate in Roundup Ready corn
Yukon	Spike to 36 inches tall	When necessary	—

Table 2.2-16. Spray additives and rainfastness for burndown and postemergence corn herbicides.

Trade Name	Adjuvant(s)[1]	Rate	Rainfastness (hours)
2,4-D amine/2,4-D LVE	none, except in certain tank-mixes	—	6–8
Accent Q	crop oil concentrate or	1 gal/100 gal	4
	non-ionic surfactant	1–2 qt/100 gal	
	plus nitrogen solution or ammonium sulfate	2–4 qt/A	
Aim/Cadet	non-ionic surfactant or	2 pt/100 gal	1
	crop oil concentrate	1 gal/100 gal	
	plus ammonium sulfate or	2–4 lb/A	
	nitrogen solution (optional)	2–4 gal/100 gal	
Atrazine	crop oil concentrate	1 gal/100 gal	1–2
Basagran[2]	crop oil concentrate	2 pt/A	8
	plus nitrogen solution or	1 gal/A	
	ammonium sulfate	2.5 lb/A	
Basis Blend	crop oil concentrate or	1–2 gal/100 gal	4
	non-ionic surfactant	1–2 qt/100 gal	
	plus nitrogen solution or ammonium sulfate	2–4 qt/A	
Callisto[3], Callisto Xtra[3]	crop oil concentrate	1 gal/100 gal	1
	plus nitrogen solution or	2.5 gal/100 gal	
	ammonium sulfate	8.5 lb/100 gal	
Callisto GT	non-ionic surfactant plus	1–2 qt/100 gal	1
	ammonium sulfate (optional)	8.5–17 lb/100 gal	
Capreno[3]	crop oil concentrate	1 gal/100 gal	1
	plus nitrogen solution or	1.5 qt/A	
	ammonium sulfate	1.5 lb/A or 8.5 lb/100 gal	
Clarity[4]	non-ionic surfactant or	1 qt/100 gal	4
	crop oil concentrate plus	1 gal/100 gal	
	nitrogen solution	2–4 qt/A	
DiFlexx[3]	non-ionic surfactant or	1 qt/100 gal	4
	crop oil concentrate or	1–2 pt/A	
	methylated seed oil	1–2 pt/A	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate	8.5–17 lb/100 gal	
DiFlexx Duo[3]	methylated seed oil or	1 gal/100 gal	4
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	1.5 qt/A	
	ammonium sulfate	8.5–17 lb/100 gal	
Durango/Duramax DMA	no NIS/COC required ammonium sulfate (optional)	8.5–17 lb/100 gal	1
Enlist Duo, Enlist One	see label for details		1–4
Glyphosate (if not fully loaded with formulation adjuvants)	non-ionic surfactant	2 qt/100 gal	6
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	

Table 2.2-16. Spray additives and rainfastness for burndown and postemergence corn herbicides (continued).

Trade Name	Adjuvant(s)[1]	Rate	Rainfastness (hours)
Gramoxone SL	non-ionic surfactant or	2 pt/100 gal	0.5
	crop oil concentrate or MSO	1 gal/100 gal	
Halex GT/Acuron GT	non-ionic surfactant	1–2 qt/100 gal	1–6
	plus ammonium sulfate	8.5–17 lb/100 gal	
Harness MAX	non-ionic surfactant or	1 pt/100 gal	1–6
	crop oil concentrate	1 gal/100 gal	
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Harmony SG	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate	2–4 lb/A	
Impact/Armezon	methylated seed oil or	1–1.5 gal/100 gal	1
	crop oil concentrate	1–1.5 gal/100 gal	
	plus nitrogen solution or	1.25–2.5 gal/100 gal	
	ammonium sulfate	8.5 lb/100 gal	
Impact Core	methylated seed oil	1–2 qt/100 gal	1–4
	plus nitrogen solution or	1.25–2.5 gal/100 gal	
	ammonium sulfate	1.5–2.5 lb/100 gal	
Laudis[3]	methylated seed oil (MSO) or	1 gal/100 gal	1
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	1–5 qt/A	
	ammonium sulfate	1.5 lb/A	
Liberty	ammonium sulfate	3 lb/A	4
Maestro, Moxy[5]	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate or	1 gal/100 gal	
	nitrogen solution	1–4 gal/100 gal	
Peak	crop oil concentrate or	1 gal/100 gal	4
	non-ionic surfactant	1 qt/100 gal	
Permit/Permit Plus	non-ionic surfactant or	1–2 qt/100 gal	4
	crop oil concentrate	1 gal/100 gal	
Perpetuo	crop oil concentrate or	1 gal/100 gal	1
	methylated seed oil or	1 gal/100 gal	
	nonionic surfactant	1 qt/100 gal	
	plus nitrogen solution or	1.25–2.5 gal/100 gal	
	ammonium sulfate (optional)	1.5–2.5 lb/100 gal	
Realm Q	crop oil or modified seed oil	1 gal/100 gal	4
	concentrate or non-ionic surfactant	1 qt/100 gal	
	plus nitrogen solution or	2 qt/A	
	ammonium sulfate	2 lb/A	

Table 2.2-16. Spray additives and rainfastness for burndown and postemergence corn herbicides (continued).

Trade Name	Adjuvant(s)[1]	Rate	Rainfastness (hours)
Resolve/Resolve Q	crop oil or modified seed oil	1 gal/100 gal	4
	concentrate or non-ionic surfactant	1 qt/100 gal	
	plus nitrogen solution or	2 qt/A	
	ammonium sulfate	2 lb/A	
Resource	crop oil concentrate	1 pt/A	1
	plus nitrogen solution (optional)	1–2 qt/A	
Revulin Q	crop oil concentrate	1 gal/100 gal	4
	plus nitrogen solution or	2 qt/A	
	ammonium sulfate	2 lb/A	
Roundup/Glyphosate	non-ionic surfactant	2 qt/100 gal	4
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Roundup PowerMAX/Roundup WeatherMAX	no NIS/COC required	—	4
	ammonium sulfate (optional)	8.5–17 lb/100 gal	
Shieldex	methylated seed oil (MSO) or	0.5–1 gal/100 gal	1
	crop oil concentrate	0.5–1 gal/100 gal	
	plus nitrogen solution or	2.5 gal/100 gal	
	ammonium sulfate	8.5 lb/100 gal	
Sinate	methylated seed oil or	1 gal/100 gal	4
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	1.25–2.5 gal/100 gal	
	ammonium sulfate	1.5–2.5 lb/100 gal	
Status	non-ionic surfactant or	1 qt/100 gal	4
	crop oil concentrate or	1–2 pt/A	
	methylated seed oil	1–2 pt/A	
	plus nitrogen solution or	5 qt/100 gal	
	ammonium sulfate	5–17 lb/100 gal	
Steadfast Q	crop oil concentrate or	1 gal/100 gal	4
	non-ionic surfactant	1–2 qt/100 gal	
	plus nitrogen solution or	2 qt/A	
	ammonium sulfate	2 lb/A	
Stinger	none	—	6–8
Stout	crop oil or modified seed oil	1 gal/100 gal	4
	concentrate or non-ionic surfactant	1 qt/100 gal	
	plus nitrogen solution or	2 qt/A	
	ammonium sulfate	2 lb/A	
Tough	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate or	1–2 pt/A	
	methylated seed oil	1–2 pt/A	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate	2–4 lb/A	

Table 2.2-16. Spray additives and rainfastness for burndown and postemergence corn herbicides (continued).

Trade Name	Adjuvant(s)[1]	Rate	Rainfastness (hours)
Yukon	non-ionic surfactant or	1–2 qt/100 gal	4
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate (optional)	2–4 lb/A	

[1] In general, non-ionic surfactants should contain at least 80% surface active agent; crop or vegetable oil concentrates should be nonphytotoxic, containing at least 15% approved emulsifier; nitrogen solution is an ammonium-based fertilizer such as 28%, 30%, or 32% N; and ammonium sulfate should be spray-grade dry ammonium sulfate (21-0-0) or other equivalent liquid formulation of AMS (refer to product label for use rate information). 10-34-0 also may be used with some products.
[2] Use crop oil concentrate if lambsquarters, common ragweed, Canada thistle, yellow nutsedge, or field bindweed are present. Include nitrogen solution if velvetleaf is the primary target.
[3] Refer to the label if tank-mixing with glyphosate (Roundup Ready corn) or glufosinate (LibertyLink corn) for additional adjuvant precautions.
[4] Do not use COC after corn exceeds 5 inches tall. Adjuvant addition depends on tank-mix partner.
[5] When Maestro or Moxy is applied alone, spray additives generally are not needed and may cause excessive leaf burn.

Spray Additives When Tank-Mixed with Liberty (LibertyLink Corn [LL]) or Glyphosate (Roundup Ready Corn [RR])

Trade Name	Specific Adjuvant Comments
2,4-D	n/a*
Accent Q	n/a
Aim/Cadet	n/a
Atrazine	n/a
Basagran	n/a
Callisto/Callisto Xtra	LL: Do not use COC
	RR: Add AMS; if glyphosate calls for an adjuvant, add NIS (do not use UAN, COC or MSO)
DiFlexx/DiFlexx Duo	LL: Do not use MSO or COC; only add AMS at 8.5 lb/100 gal
	RR: Label allows for additional adjuvant if resistant weeds are present
Harmony SG	LL: n/a
	RR: Add AMS; if glyphosate calls for an adjuvant, add NIS (1–2 pt/100 gal) (do not use UAN, COC, or MSO)
Impact/Armezon	n/a
Laudis	LL: Do not use MSO or COC; only add AMS at 8.5 lb/100 gal
	RR: Label recommends additional adjuvant if fully loaded glyphosate is used; label requires additional adjuvant if partially loaded glyphosate is used
Maestro/Moxy	n/a
Permit/Sandea	n/a
Resource	n/a
Stinger	n/a
Mixtures	
Basis Blend	n/a
Capreno	LL: Do not use MSO or COC; only add AMS at 8.5 lb/100 gal
	RR: Use of glyphosate compatible high surfactant oil concentrate (HSOC) is recommended with fully loaded glyphosate and required with partially loaded glyphosate; AMS is required; do not use COC or MSO
Curtail	n/a
Halex GT	LL: Not allowed
Permit Plus	n/a
Realm Q	LL: n/a
	RR: When tank-mixed with glyphosate, ensure total adjuvant load is equivalent to the label recommendation

Table 2.2-16. Spray additives and rainfastness for burndown and postemergence corn herbicides (continued).

Spray Additives When Tank-Mixed with Liberty (LibertyLink Corn [LL]) or Glyphosate (Roundup Ready Corn [RR])

Trade Name	Specific Adjuvant Comments
Resolve Q	When tank-mixed with glyphosate or glufosinate, ensure total adjuvant load is equivalent to the label recommendation
Revulin Q	LL: n/a
	RR: When tank-mixed with glyphosate, ensure total adjuvant load is equivalent to the label recommendation
Status	n/a
Steadfast Q	n/a
Stout	n/a
Yukon	n/a

*n/a = adjuvants for LibertyLink or glyphosate not addressed.

Table 2.2-17. Comments on harvest aid herbicides for corn.

Trade Name*	Common Name	Site of Action Number	Product/A	lb ai/A
2,4-D LV4	2,4-D ester	4	1–2 pt	0.5–1
• Apply 1–2 pt/A after the hard dough or dent stage to suppress large weeds that may interfere with harvest and to decrease production of weed seeds. • Use higher rate on larger weeds and those under stress. • Do not forage or feed corn fodder for 7 days after application.				
Aim 2EC	carfentrazone	14	2 fl oz	0.031
• May be applied 3 days before harvest. • Use as a harvest aid to desiccate certain broadleaf weeds. • Apply in 10 gal/A water. • Include necessary adjuvants (MSO or COC plus AMS) and make sure spray coverage is sufficient (≥15 GPA), otherwise poor control will result. • Aim tends to be less injurious to surrounding crops compared to Gramoxone. • See label for additional details.				
Defol 5L	sodium chlorate	not classified	4.8 qt	6
• Defol products are labeled for preharvest applications to desiccate problem weeds in early maturing corn. • Apply at least 14 days before anticipated harvest date. • Apply in 10 to 20 gal/A water with an appropriate adjuvant (NIS or COC). • Desiccation of morningglory and other vine weeds may be erratic. • Some universities recommend tank mixing Defol with Aim or Gramoxone for improved activity. • Do not graze treated fields or feed fodder, forage, or residual grain within 14 days of application. • Refer to product label for additional details.				
Glyphosate	glyphosate	9	see Table 2.1-8	up to 0.75 lb ae
• Glyphosate products are labeled for preharvest applications in corn. • They can be applied from a week or more prior to harvest. • Apply when grain has 35% or less moisture and after maximum kernel fill is complete and corn is physiologically mature. • Adjuvants (NIS or COC plus AMS) can be added to the spray solution to improve performance. • Do not apply to corn for seed. • 0.75 lb glyphosate = 32 fl oz of a 3 lb ae/gal formulation or 22 fl oz of a 4.5 lb ae formulation • Refer to product label for application restrictions.				
Gramoxone SL 2.0	paraquat	22	1.2–2 pt	0.3–0.5
Gramoxone SL 3.0			0.8–1.3 pt	
• Apply after corn is mature and black layer has formed. • Make application at least 7 days before harvest. • Use lower rates in most cases as a harvest aid, otherwise the 0.5 lb ai/A rate can be used to desiccate mature broadleaves and grasses over 18 inches tall. • Include a non-ionic surfactant (1 qt/100 gal) in the spray solution.				

*See Table 2.2-1 for additional formulations or trade names containing some of these same active ingredients.

The treatments listed in the table are applied prior to harvest to control and help desiccate green weed tissue in established weeds in order to aid in the harvesting process. Contact herbicides are usually better at this process; however, it can vary by weed species and usually will require at least a week or more to desiccate weeds or make them more brittle. Some of these herbicides are not that effective on large weeds or certain species. Harvest aids are not intended to (and usually do not) help speed up crop maturity. If applied too early, they can interfere with the natural crop maturation process. Illegal herbicide residues in grain can result if specific application timing and other label guidelines are not followed. See specific product label to determine correct rate, timing, weed species controlled, and other restrictions with this type of application.

Table 2.2-18. Grazing and forage restrictions for corn herbicides.

Trade Name	Graze	Silage/Grain
	(days after treatment)	
2,4-D	7	7
Accent Q	30	30
Acuron	45	60
Acuron Flexi	45	60
Anthem Maxx	30	70
Atrazine	60	60
Basagran	12	12
Basis Blend	30	30
Cadet	30	90
Callisto Xtra	60	60
Capreno	45	45
Clarity	After milk stage	After milk stage
Corvus	45	45
Curtail	40	40
DiFlexx/DiFlexx Duo	45	45
Enlist Duo	50	50
Enlist One	Not specified	30
Glyphosate*	50	50/7
Glyphosate (spot treatment)	14	14
Gramoxone (POST directed)	Do not graze	Do not feed
Halex GT/Acuron GT	45	45
Harmony SG	30	30
Harness MAX	60	60
Impact/Armezon	45	45
Impact Core	45	45
Laudis	45	45
Lexar	45	60
Liberty**	70	70
Maestro, Moxy	30	30
Maverick	30	45
Metribuzin	60	60
Outlook	40	40
Peak	60	40
Permit/Sandea/Permit Plus/Yukon	30	30
Prowl H2O	21	21
Python	45	45
Realm Q	45	45/70
Resicore/Resicore XL	45	45
Resolve/Resolve Q	30	30
Resource/Perpetuo	28	28

Table 2.2-18. Grazing and forage restrictions for corn herbicides (continued).

Trade Name	Graze	Silage/Grain
	(days after treatment)	
Revulin Q	45	45
Sharpen	80	80
Shieldex	21	21
Sinate**	60	60
Status	72	32/72
Steadfast Q	30	30
Stinger	40	40
Stout	30	30
SureStart II/TripleFLEX II	45	45/85
TriVolt	45	45
Tough	—	—
Verdict	80	80
Warrant	40	40
Zidua	—	—

Products listed restrict grazing and/or foraging (silage) following their use in corn.
*For use only with Roundup Ready corn hybrids.
**For use only with LibertyLink corn hybrids.

Table 2.2-19. Corn herbicide half-lives and their potential to injure fall-established cover crops.

Trade Name	Common Name	Normal Rate per Acre	Half-Life (days)*	Fall-Established Cover Crops	Considerations/ OK to Plant	Other Concerns/Comments
2,4-D 4S	2,4-D	1–2 pt	7	All	Wait 30 days before planting sensitive broad-leaves	Amine formulations more water soluble and can leach into seed zone
Accent 75DF/Steadfast75DF	Nicosulfuron/nicosulfuron + rimsulfuron	0.66 oz/0.75 oz	21	Fall cereal grains, ryegrass	Small-seeded legumes (alfalfa, clovers, and hairy vetch), mustards, sorghum	More persistent in high pH soils (>7)
Armezon/Impact 2.8SC	Topramezone	0.75 fl oz	14	Wheat, barley, oats, and rye are allowed after 3 months; ryegrass should also be OK	Although many broad-leaves are restricted, Impact does not have much soil activity	We have not seen this herbicide carry over in the Mid-Atlantic region. Clovers might be slightly suppressed.
Atrazine 4L	Atrazine	1–2 qt	15–90	Sorghum species	Cereals, ryegrass, legumes, and mustards	More persistent in high pH soils (>7); rates < 1 lb/A can allow more flexibility; half-life in the Mid-Atlantic probably closer to 30
Balance Flexx 2L	Isoxaflutole	6 fl oz	50–120	Fall cereals grains	Ryegrass, legumes, and mustards	15 inches of cumulative precipitation required from application to planting rotation crops except soybean, barely, wheat, sorghum, and sunflower
Callisto 4L (includes Acuron, Acuron Flexi, Halex GT, Harness Max, Lexar, Lumax, Resicore, Revulin, Solstice, , etc.)	Mesotrione	3–6 fl oz	10–50	All grasses	Small-seeded legumes, mustards	Sequential applications (PRE fb POST) increase the potential for injury
Capreno 3.45SC	Tembotrione + thiencarba-zone	3 fl oz	15	Wheat, triticale, rye	Small-seeded legumes, mustards, sorghum	15 inches of cumulative precipitation required from application to planting rotation crops except wheat
Clarity 4S (DiFlexx, Distinct, Status)	Dicamba	16–24 fl oz	5–14	All	Only at high rates or less than 120 days after application	Anything can be planted after 120 days with 24 fl oz/A or less
Corvus 2.63SC	Isoxaflutole + thiencarbazone	5.6 fl oz	50–120	Wheat, triticale, rye	Small-seeded legumes, mustards, sorghum	15 to 30 inches of cumulative precip-itation from application to planting for sensitive crops
Dual II Mag 7.62E	Metolachlor	1.67 pt	15–50	Cereal grains, legumes	Annual ryegrass or other small-seeded grasses	Higher rates and later applications more of a potential problem
Glyphosate 4L	Glyphosate	0.75–1.25 lb ae	473	All	None	Glyphosate does not have soil activity at normal use rates
Gramoxone 2S/3S	Paraquat	2 pt/1.3 pt	1,000	All	None	Paraquat does not have soil activity at normal application rates.

Table 2.2-19. Corn herbicide half-lives and their potential to injure fall-established cover crops (continued).

Trade Name	Common Name	Normal Rate per Acre	Half-Life (days)*	Fall-Established Cover Crops	Considerations/ OK to Plant	Other Concerns/Comments
Harmony 50WDG	Thifensulfuron	1/8 oz	12	No restrictions for wheat, barley, and oats	None with 45-day waiting interval	Harmony Extra also contains tribenuron
Harness 7E (Degree, Surpass, Warrant)	Acetochlor	2 pt	10–20	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops are allowed after corn harvest
Laudis 3.5SC (DiFlexx Duo)	Tembotrione	3 fl oz	14	Cereal grains after 4 months	Unknown; small-seeded legumes, mustards could be a problem	Other crops may be seeded after a successful field bioassay
Liberty 2.34L	Glufosinate	22–36 fl oz	73	All	Food or feed residues rather than crop injury may be a concern	Glufosinate does not have soil activity at normal use rates
Metribuzin 75DF (Sencor)	Metribuzin	0.33 lb ai	14–60	Cereal grains and ryegrass	Slight risk for small-seed-ed legumes and mus-tards	Nonfood/feed winter cover crops allowed
Outlook 6E (Armezon Pro)	Dimethenamid-P	16 fl oz	20	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops should be OK after corn harvest
Peak 57WG	Prosulfuron	1 oz	9–152	Cereal grains and sorghum are labeled, other grasses	Small-seeded legumes, mustards	More persistent in high pH soils (>7)
Permit/Sandea 75DF	Halosulfuron	2⁄3 oz	9–27	Cereal grains and sor-ghum after 2 months and other grasses	Small-seeded legumes, mustards	Halosulfuron also an ingredient in Yukon
Prowl H2O 3.8CS	Pendimethalin	3 pt	44	Cereal grains	Small-seeded legumes and annual ryegrass	We have not seen this herbicide carry over in the Mid-Atlantic; nonfood/feed winter cover crops should be OK
Python 80WDG (Hornet and SureStart)	Flumetsulam	1 oz	14–120	Cereal grains	Small-seeded legumes, mustards, and annual ryegrass	Cover crops and forage grasses are restricted for 9 months
Resolve 25DF (Resolve Q)	Rimsulfuron	2 oz	2–4	Based on the short half-life, most fall cov-er crops should be OK in the Mid-Atlantic	None	More persistent in drought conditions
Sharpen 2.85SC (Verdict)	Saflufenacil	3 fl oz	7–35	All	None	Label has 30-day wait for cover crops; more persistent in western Canada

Table 2.2-19. Corn herbicide half-lives and their potential to injure fall-established cover crops (continued).

Trade Name	Common Name	Normal Rate per Acre	Half-Life (days)*	Fall-Established Cover Crops	Considerations/ OK to Plant	Other Concerns/Comments
Shieldex 400 3.33SC	Tolpyralate	1 – 1.35	1-2	Wheat, barley, oats, and rye are allowed after 3 months; ryegrass should also be OK	Although many broad-leaves are restricted, Shieldex does not have much soil activity	Clovers might be slightly suppressed
Simazine 4L (Princep)	Simazine	1–2 qt	60	Sorghum species	Cereals, ryegrass, legumes, and mustards	Soil pH >7
Stinger 3S (Hornet, Resicore, SureStart)	Clopyralid	5 oz	40	All grasses	Small-seeded legumes	
Zidua (Anthem)	Pyroxasulfone	2.5 oz	20	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops should be OK after corn harvest

This table does not directly address preharvest establishment of cover crops such as interseeding or aerial seeding, which may be more restrictive.
*The time it takes for 50 percent of the herbicide active ingredient to dissipate. See the "Managing Herbicides" section for additional information. Herbicide half-life estimates are derived for the *WSSA Herbicide Handbook* and other scientific literature.

Crop rotation provides effective control of corn rootworms and helps reduce several other corn pests. In fact, recent research at Penn State supports the idea that more diverse rotations that include cover crops have fewer insect pest and slug problems. Although the Midwest has seen new variants of the western and northern corn rootworms that defeat the corn and soybean rotation by laying their eggs in soybean fields or diapausing for two years, respectively, these variants have yet to reach Pennsylvania and are unlikely to do so given that our rotations are more complex than the two-year cycle predominant in the Midwest. Minimum-till and no-till systems and poor weed control can increase the incidence of true armyworm, black cutworm, and stalk borer, but these pest species can easily be targeted and defeated using IPM (scouting and applying rescue treatments if necessary). In some cases, eliminating grassy weeds at least two weeks before planting reduces the possibility of these problems. Moreover, ongoing research at Penn State is suggesting that planting corn or soybeans directly into green cover crops (i.e., planting green) can also mitigate some of this potential early season insect and slug damage; however, this method of farming should only be pursued after consulting with farmers who have experience with it. True armyworms also can be serious problems in fields where corn is planted into wheat stubble or rye mulch. It must be noted that the true armyworm population that arrived in Pennsylvania during spring 2012 was so large that many fields were overwhelmed even when growers used proper management strategies. These types of outbreak populations are only manageable via rescue treatments as they do not occur annually and are very difficult to predict. Insecticides can be applied to reduce pest populations, but unless the predicted losses are greater than the cost of application, such applications are not profitable.

Biologically engineered corn hybrids that produce an insecticidal toxin from the bacterium *Bacillus thuringiensis* (Bt) provide a modern method for managing European corn borer, some other caterpillar species, and corn rootworm. This technology offers yield protection that could not be obtained by using conventional insecticides. Because of its high degree of effectiveness, Bt corn has rapidly gained popularity; however, this technology is not immune to the threat of insects developing resistance to the toxin, particularly if Bt varieties are overused—as evidenced by populations of western corn rootworm that are resistant to some Bt varieties. Growers who choose Bt corn hybrids will be required to implement a resistance management program to minimize the rate of resistance development. For more information on using Bt corn hybrids, see the discussion on insect-resistant (Bt) corn varieties earlier in this chapter.

Another option for managing insect pests in corn uses seed treatments. Although hopperbox treatments have been available for a long time, commercially applied seed treatments using a newer class of chemical have become popular.

Figure 2.2-1. Key periods of corn insect pests.

This newer insecticide class, neonicotinoids, has two main compounds that are available for corn. The first material available as a commercially applied seed treatment, imadicloprid (Gaucho), was the initial compound that growers could use. However, with the introduction of two newer compounds, thiamethoxam (Cruiser) and clothianidin (Poncho), imadicloprid has been relegated to a hopperbox treatment now known as Concur or Latitude. The two products now commercially applied, Cruiser and Poncho, are available each at multiple rates, often 0.25, 0.50, and 1.25 milligrams of active ingredient (ai) per kernel, among others. All rates provide some protection against soil insect pests for two to three weeks (not 45 to 60 days, as some companies claim). At the higher rate, both seed treatments add corn rootworm larvae and billbugs to their labels; however, studies have shown that they only work well against low to moderate populations of rootworm larvae; they do not work well under intense rootworm pressure. Also, it is important to know that these neonicotinoid seed treatments are soluble in water; therefore, excessive rain around planting and early season seedling growth has the potential to carry the insecticides away from the root zone, where it is typically absorbed by plants' roots. Researchers have also raised some concerns about the influence of neonicotinoid seed treatments on water quality and pollinator health, particularly around the time of corn planting. These issues remain to be resolved, but it is clear that these insecticides are getting into surface water and groundwater with unknown consequences, and some pollinator populations and species can suffer from neonicotinoid exposure.

The first step in managing corn pests is to know when the pest species is present in your area. Figure 2.2-1 illustrates

Conversion of row-applied (T-band or in-furrow) soil insecticides expressed in ounces per 1,000 feet of row to pounds per acre of formulated material for any row spacing.

Rate (oz per 1,000 linear feet of row)	Row Spacing	15	20	30	32	34	36	38	40
	Fraction of Acre	**34.85**	**26.14**	**17.42**	**16.34**	**15.37**	**14.52**	**13.76**	**13.07**
	Conversion Factors	**2.178**	**1.6335**	**1.089**	**1.021**	**0.961**	**0.908**	**0.86**	**0.817**
0.1		0.22	0.16	0.11	0.10	0.10	0.09	0.09	0.08
0.2		0.44	0.33	0.22	0.20	0.19	0.18	0.17	0.16
0.3		0.65	0.49	0.33	0.31	0.29	0.27	0.26	0.25
0.4		0.87	0.65	0.44	0.41	0.38	0.36	0.34	0.33
0.5		1.09	0.82	0.54	0.51	0.48	0.45	0.43	0.41
1		2.18	1.63	1.09	1.02	0.96	0.91	0.86	0.82
2		4.36	3.27	2.18	2.04	1.92	1.82	1.72	1.63
3		6.53	4.90	3.27	3.06	2.88	2.72	2.58	2.45
4		8.71	6.53	4.36	4.08	3.84	3.63	3.44	3.27
5		10.89	8.17	5.45	5.11	4.81	4.54	4.30	4.09
6		13.07	9.80	6.53	6.13	5.77	5.45	5.16	4.90
7		15.25	11.43	7.62	7.15	6.73	6.36	6.02	5.72
8		17.42	13.07	8.71	8.17	7.69	7.26	6.88	6.54
9		19.60	14.70	9.80	9.19	8.65	8.17	7.74	7.35
10		21.78	16.34	10.89	10.21	9.61	9.08	8.60	8.17
11		23.96	17.97	11.98	11.23	10.57	9.99	9.46	8.99
12		26.14	19.60	13.07	12.25	11.53	10.90	10.32	9.80

the approximate timing of corn pest occurrences in Pennsylvania. The presence of a pest can vary within the presented range, depending on the location in the state and on local weather conditions.

See Table 2.2-20 for a quick reference to insecticides recommended for corn insect control, and Table 2.2-21 for specific rates, restrictions, and other information. Table 2.2-22 lists herbicides that are compatible with selected corn insecticides.

To determine the appropriate per-acre amount of product needed, find a product (in the sections of Table 2.2-21) and the listed rate in ounces per 1,000 feet of linear row. In the table below, find the rate in ounces per 1,000 linear feet of row in the first column. Find the appropriate row spacing for the field to which you will be applying the soil insecticide and follow it down to the rate per 1,000 feet of linear row that you want to apply. The value in the box where you follow the row for ounces per 1,000 feet of row over to the column with the desired row space is the rate of product you will be applying to your field. To calculate pounds of material needed per acre for rates not included in the table, simply multiply the rate per 1,000 feet of linear row by the conversion factor listed in the table below for the row spacing in the field. If you would like to determine the amount of active ingredient per acre being applied, divide the percentage of active ingredient value of the formulation by 100 and then multiply the pounds of product being applied per acre:

> pounds of active ingredient per acre = (percent of active ingredient in formulation ÷ 100) × (pounds of material)

For example, Force is to be applied at 4 ounces per 1,000 feet of row to a field planted in 30-inch rows. Based on the table below, the amount of product will be 4.36 pounds. Since Force is a 3G formulation, it contains 3 percent active ingredient, so total active ingredient per acre is (3 ÷ 100) × (4.36) = 0.13 pound. This method will work for all formulations that are based on a percentage of material and ounces applied per 1,000 linear feet per row.

Nonpesticide Methods of Insect Management in Corn

Insecticides should be used only as a last defense against insects, when all other methods of keeping their numbers below economic thresholds have failed and when no other control tactic exists. Corn growers have numerous strategies other than insecticides to manage insect populations, including rotating crops to break insect life cycles; using resistant varieties (including genetically modified hybrids); eliminating

Table 2.2-20. Summary of suggested insecticides and seed treatments for corn insect control.

Insecticides

Corn Pest	AC	Bt	BI1	BI2	CB	CF	CH	CL	CN	DI	DM	ES	ET	EZ	GC	LC	LCC	ME	MF	MT	PE1	PE2	PE3	PO	RYN	SP	ST	SU	TC	TE	TF	ZE	ZEB
Armyworm responsive	▲		▲	▲	▲	▲		▲		▲	▲					▲	▲		▲		▲	▲	▲			▲	▲						▲
Billbug	▲																▲													▲			
Black cutworm responsive	▲	▲	▲	▲	▲	▲			▲		▲	▲			▲	▲	▲				▲	▲	▲				▲					▲	▲
Brown marmorated stink bug	▲		▲			▲																											▲
Corn earworm	▲		▲	▲	▲	▲		▲	▲		▲	▲			▲	▲	▲	▲			▲	▲			▲	▲	▲						
Corn leaf aphid	▲								▲	▲	▲				▲		▲		▲				▲					▲					▲
Corn rootworm beetle	▲		▲		▲				▲	▲	▲	▲			▲	▲	▲	▲			▲	▲										▲	▲
Larva			▲	▲			▲						▲		▲	▲								▲					▲	▲	▲		
European corn borer, first generation	▲	▲	▲	▲	▲	▲		▲	▲		▲	▲			▲	▲	▲		▲		▲	▲	▲	▲	▲	▲	▲					▲	▲
Second generation		▲	▲		▲	▲		▲	▲		▲	▲			▲	▲	▲		▲		▲	▲	▲		▲	▲	▲					▲	▲
Fall armyworm		▲	▲	▲	▲	▲		▲	▲		▲				▲	▲		▲				▲			▲	▲	▲					▲	▲
Flea beetle			▲	▲	▲	▲			▲		▲	▲			▲	▲	▲	▲			▲	▲		▲						▲		▲	▲
Garden symphylan							▲																							▲			
Grasshoppers	▲			▲		▲		▲	▲	▲	▲				▲		▲		▲														
Hop vine borer	▲														▲		▲				▲												▲
Japanese beetle (adult)	▲		▲	▲	▲	▲			▲		▲	▲			▲	▲	▲															▲	▲
Seedcorn maggot			▲	▲			▲		▲						▲	▲						▲	▲	▲					▲	▲	▲		
Slugs																				▲													
Sod webworm	▲	▲				▲			▲		▲				▲	▲					▲	▲	▲									▲	
Stalk borer	▲		▲			▲			▲		▲	▲			▲	▲					▲	▲	▲									▲	▲
Two-spotted spider mite				▲		▲							▲																				

Table 2.2-20. Summary of suggested insecticides and seed treatments for corn insect control (continued).

Insecticides

Corn Pest	AC	Bt	BI1	BI2	CB	CF	CH	CL	CN	DI	DM	ES	ET	EZ	GC	LC	LCC	ME	MF	MT	PE1	PE2	PE3	PO	RYN	SP	ST	SU	TC	TE	TF	ZE	ZEB
Western bean cutworm	▲	▲	▲	▲	▲	▲		▲	▲			▲			▲	▲	▲						▲	▲		▲	▲					▲	▲
White grubs			▲	▲			▲		▲				▲		▲	▲								▲					▲	▲	▲		
Wireworm			▲	▲			▲		▲				▲		▲	▲						▲	▲	▲					▲	▲	▲		

AC = alpha-cypermethrin (Fastac), Bt = *Bacillus thuringiensis**, BI1 = bifenthrin (Bifenture, Brigade, Discipline), BI2 = bifenthrin (Capture, Empower, Ethos XB), CB = carbaryl (Sevin), CF = chlorantraniliprole + bifenthrin (Elevest), CH = chlorethoxyfos + bifenthrin (SmartChoice, Index), CL = chlorantraniliprole (Vantacor), CN = cyfluthrin (Baythroid), DI = dimethoate, DM = deltamethrin (Delta Gold), ES = esfenvalerate (Asana XL), ET = ethoprop (Mocap), EX = etoxazole (Zeal), GC = gamma-cyhalothrin (Proaxis), LC = lambda-cyhalothrin (Ballista, Lambda Cy, Taiga, Warrior), LCC = lambda-cyhalothrin + chlorantraniliprole (Besiege), ME = methomyl (Lannate), MF = methoxyfenozide (Intrepid), MT = metaldehyde (Deadline MPs, Metarex), PE1 = permethrin (Ambush), PE2 = permethrin (Arctic, Pounce), PE3 = permethrin (Pounce), PO = phorate (Phorate, Thimet), RYN = rynaxypyr (Coragen, Prevathon), SP = spinosad (Blackhawk, Entrust), ST = spinetoram (Radiant), SU = sulfoxaflor (Transform), TC = tebupirimphos + cyfluthrin (Aztec, Defcon), TE = terbufos (Counter), TF = tefluthrin (Force), ZE = zeta-cypermethrin (Mustang Max), ZEB = zeta-cypermethrin + bifenthrin (Hero). *Transgenic lines of corn containing insecticidal Bt toxins have activity against a limited range of pests. Consult each variety for details.

Neonicotinoid Seed Treatments. Pests not listed here are not controlled well by seed-applied insecticides. Note that, even for the pests listed, seed treatments tend to provide inconsistent control.

Corn Pest	CL1	CL2	IM	TH1	TH2
Billbug		▲			▲
Corn rootworm larvae		▲			▲
Flea beetle	▲	▲	▲	▲	▲
Seedcorn maggot	▲	▲	▲	▲	▲
Slugs (Note: neonicotinoid seed treatments tend to make slug populations worse)					
White grubs	▲	▲	▲	▲	▲
Wireworm	▲	▲	▲	▲	▲

CL1 = clothianidin (Poncho, 0.25 mg ai per seed), CL2 = clothianidin (Poncho, 1.25 mg ai per seed), IM = imidacloprid (Concur, planter box), TH1 = thiamethoxam (Cruiser, 0.25 mg ai per seed), TH2 = thiamethoxam (Cruiser, 1.25 mg ai per seed).

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects.

- "**R**" after the insecticide name indicates that the compound has a restricted-use label.
- "**O**" indicates that the pesticide is labeled for organic use. However, check with your organic certifier to be sure that the material is allowed for your organic system.
- Reentry intervals are in hours unless indicated otherwise. For all reentry intervals of 0, do not enter the field without protective clothing until the spray has dried.
- "N/A" under harvest restrictions indicates that the harvest interval is not applicable at the time the compound is being applied. However, the user should be aware that the harvest restrictions exist.
- For certified organic insect control materials, refer to the Organic Materials Review Institute materials list at https://www.omri.org/, call 514-343-7600, or check with your local certifier and see https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program.
- Pesticide use can many times be avoided by using a combination of pest management methods. See Part I, Section 11: Organic Crop Production and Part II, Section 1: Pest Management to learn about IPM programs and methods for organic production.
- Each year there is an increase in the number of products offering mixtures of two active ingredients. If growers are faced with an outbreak of a pest complex, the two-ingredient mixtures may be of value; however, these products tend to be more expensive, and single ingredients can be just as effective. In general, we feel that the value of these two-ingredient mixtures is questionable for managing above-threshold populations of a single pest species.
- Insurance treatments are not necessarily economical or effective parts of IPM programs.
- **Most of these products are highly toxic to bees and many other beneficial insect species.**

See labels for details.

Suggested insecticides, rates, and restrictions for ARMYWORM (OR TRUE ARMYWORM).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Insurance Treatments (Note: this approach is recommended only if labor and time are constraints and a field has had a history of problems with this pest while armyworm populations are spotty and tend not to be problematic annually.)					
Bifenthrin **R** (Brigade 2EC) (Discipline 2EC)	0.15 to 0.3 oz per 1,000 feet of row	0.0023 to 0.0046 lb per 1,000 feet of row	30	12	Do not apply more than 0.3 lb ai per acre per season for all applications. Do not apply to soil with more than 30% cover of crop residue remaining. Can also apply at a PRE or PPI application; see label for rates and information.
(Capture LFR)	3.4 to 5.3 oz	0.04 to 0.062 lb		12	For mixing directly with liquid fertilizer to control soil insect pests. Can be preplant incorporated or used preemergence. See label for specific rates.
Chlorantraniliprole (Vantacor)	1.7 – 2.5 oz	0.066 - 0.098 lb	14	4	In-furrow spray at planting. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Pounce 25WP)	Many formulations available; see label for rates and restrictions				Can be used preplant, preemergent, or as a foliar postemergence application. Use higher rate if incorporating into the soil. Maximum of 0.6 lb ai per acre per season.
(Pounce 1.5G)	8 to 16 oz per 1,000 feet of row	0.15 lb per 1,000 feet of row	30	24	Applied in-furrow or as a band. Maximum of 0.6 lb ai per acre per season. See label for details.
Responsive Treatments (Threshold: 25% of plants are damaged or some plants are being killed.)					
Alpha-cypermethrin (Fastac)	3.2 to 3.8 fl oz	0.02 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application. Do not apply more than 0.3 lb ai per acre per season for all applications.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for ARMYWORM (OR TRUE ARMYWORM); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
(Capture 1.15G)	3.5 to 8.7 lb	0.04 to 0.1 lb	30	24	Do not apply more than 0.3 lb ai per acre per season, including at-plant plus foliar applications.
(Empower 2)					
Carbaryl	1 to 2 qt		48	24	
(Sevin)					
Chlorantraniliprole + bifenthrin **R**	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
(Elevest)					
Cyfluthrin **R**	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Maximum of four applications per acre per season and 11.2 oz per acre.
(Baythroid XL)					
Deltamethrin **R**	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
(Delta Gold)					
Esfenvalerate **R**	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Apply as necessary to maintain control. However, more than one application is not cost effective in most situations. Do not apply more than 0.25 lb ai per acre per season.
(Asana XL)					
Gamma-cyhalothrin **R**	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
(Proaxis)					
Lambda-cyhalothrin **R**	1.28 to 3.84 oz	0.02 to 0.03 lb	21	24	See label for details and restrictions. Use higher rates for larger larvae. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Methomyl **R**		0.23 to 0.45 lb	21	48	Do not apply more than 2.25 lb ai per crop per season. Apply when insects first appear in significant numbers. Highly toxic to humans. Lower rates help conserve beneficial arthropods.
(Lannate 90SP)	0.25 to 0.5 lb				
(Lannate LV)	0.75 to 1.5 pt				
Methoxyfenozide	4 to 16 oz	0.06 to 0.25 lb	21	4	Controls only lepidopteran larvae (caterpillars). Does not have significant negative impact on beneficial arthropods. Not registered in NY.
(Intrepid 2F)					
Permethrin **R**	Many formulations available; see label for rates and restrictions				Apply before the brown silk stage. Pounce 1.5G may be applied as a preplant-incorporated preemergence treatment or at planting time.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 1.5G)					
(Pounce 25WP)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for ARMYWORM (OR TRUE ARMYWORM); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Spinetoram (Radiant)	3 to 6 fl oz	0.023 to 0.047 lb	28 (grain); 3 (silage)	4	No more than three applications and 16 fl oz (0.125 lb ai) per year
Spinosad **O**			28	4	Do not apply more than 8.3 oz of Blackhawk or 12 oz of Entrust SC per acre per year.
(Blackhawk)	2.4 to 6 oz	0.023 to 0.094 lb			
(Entrust SC)	1.67 to 3.3 oz	0.023 to 0.074 lb			
Zeta-cypermethrin **R** (Mustang Max)	3.2 to 4 oz	0.02 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Suggested insecticides, rates, and restrictions for BILLBUGS.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: none established; rescue treatment is warranted when damage is widespread and adults can be found.					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Tefluthrin **R** (Force 10G)	1.25 to 1.5 oz per 1,000 feet of row	0.125 to 0.15 lb	Not applicable	48	For suppression only. At-planting applications can be placed in a 7-inch band over the row in front of or behind the press wheel, or in-furrow.
Terbufos **R** (Counter 20G)	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	30	48	In-furrow applications reduce the potential for insecticide runoff resulting from excessive rain. Do not exceed 6.5 lb ai per acre.
Seed Treatments					
Clothianidin (Poncho)	1.25 mg per kernel	0.75 to 1 lb			Not for hopperbox treatment.
Thiamethoxam (Cruiser)	1.25 mg per kernel				Not for hopperbox treatment.

Suggested insecticides, rates, and restrictions for BLACK CUTWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Insurance Treatments (Note: this approach is recommended only if labor and time are constraints and a field has had a history of problems with this pest while cutworm populations are spotty and tend not to be problematic annually.)					
Azadirachtin **O** (Neemix 4.5)	0.25 to 1 pt	N/A		4	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and may repel or deter insect feeding. May require multiple applications to provide adequate control. Little data is available on effectiveness on these pests, but it is a natural product.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for BLACK CUTWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Bifenthrin **R**	0.15 to 0.3 oz per 1,000 feet of row	0.0023 to 0.0046 lb per 1,000 feet of row	30	12	Do not apply more than 0.1 lb ai per acre per season as an at-plant application. See label for other manners of application.
(Brigade 2EC)					
(Discipline 2EC)					
(Capture 1.15G)	3.2 to 8 oz per 1,000 feet of row	0.002 to 0.006 lb per 1,000 feet of row	30	7	Do not apply more than 0.3 lb ai per acre per season, including at-plant plus foliar applications. Highly toxic to bees.
(Empower 2EC)					
(Capture LFR)	3.4 to 5.3 oz	0.04 to 0.062 lb		12	For mixing directly with liquid fertilizer to control soil insect pests. Can be preplant incorporated or used preemergence. See label for specific rates.
Chlorethoxyfos **R**	3 to 7.5 oz per 1,000 feet of row	0.12 to 0.18 lb	30	48	Recommended as a T-band application.
(SmartChoice HC, Index)					
Esfenvalerate **R**	0.45 oz per 1,000 feet of row	0.0023 lb per 1,000 feet of row	21	12	Apply in-furrow or as a band. Do not apply more than 0.25 lb ai per acre per season.
(Asana XL)					
Ethoprop **R**	8 oz per 1,000 feet of row	7 lb	See label	48	Apply as a band. Only one application per crop.
(Mocap 15G)					
Gamma-cyhalothrin **R**	0.66 oz per 1,000 feet of row	0.0025 lb per 1,000 feet of row	21	24	See label for application.
(Proaxis)					
Lambda-cyhalothrin **R**	0.33 to 0.66 oz per 1,000 feet of row	0.005 lb per 1,000 feet of row	21	24	See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Taiga Z)					
(Warrior and Warrior II)					
Permethrin **R**	Many formulations available; see label for rates and restrictions				See label for rates and restrictions. May be applied preplant, preemergent, or as foliar postemergence application.
(Ambush 25W)					
(Arctic 3.2EC)					
(Pounce 25WP)					
(Pounce 1.5G)	8 oz per 1,000 feet of row	0.1 to 0.2 lb	30	24	
Tebupirimphos **R** + cyfluthrin	3 to 6.7 oz per 1,000 feet of row	0.12 lb		48	Apply as a T-band. Incorporate into the soil surface. A maximum rate of 73 lb material per acre per season.
(Aztec 4.67G)					
(Defcon 2.1)					
Tefluthrin **R**	1.25 to 1.5 oz per 1,000 feet of row	0.125 to 0.15 lb	30	48	Good control when applied at planting. Good option when a field has a known history of cutworm or problems are anticipated.
(Force 10G)					
(Force 6.5G)	1.8 to 2.3 oz per 1,000 feet of row	0.1 to 0.12 lb			Application may be by in-furrow, band, or T-band; see label for details.
Terbufos **R**	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	30	48	Suppression only. Do not exceed 6.5 lb of Counter 20G per acre. One of the few compounds that can help reduce some nematode populations.
(Counter 20G)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for BLACK CUTWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Zeta-cypermethrin **R** (Mustang Max)	0.16 oz per 1,000 feet of row	0.001 lb per 1,000 ft	30 (grain); 60 (forage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
Responsive Treatments (Threshold: plants cut per 100: seedling, two; V2, three; V3, five; V4, seven; V5, seldom an economic problem.)					
Alpha-cypermethrin (Fastac)	1.3 to 2.8 fl oz	0.008 to 0.018 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	0.25 to 1 pt	N/A		12	Use a minimum of 30 gal of water per acre during application. Interferes with an insect's ability to molt and may repel or deter insect. May require multiple applications to provide adequate control. Little data on effectiveness on these pests is available, but it is a natural product.
Bacillus thuringiensis **O**	Many formulations available; see label for rates and restrictions				
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application. Do not apply more than 0.3 lb ai per acre per season.
(Capture LFR)	2.8 to 8.5 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application for field corn (grain and silage), popcorn, and field corn grown for seed.
Carbaryl (Sevin)	1 to 2 pt		48	24	
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 fl oz	0.084 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin **R** (Baythroid XL)	0.8 to 1.6 oz	0.013 to 0.025 lb	21	12	Maximum of four applications per acre per season and 11.2 oz per acre.
Deltamethrin **R** (Delta Gold)	1 to 1.5 oz	0.012 to 0.018 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz in a growing season.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Apply as necessary to maintain control. Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	1.92 to 3.2 oz	0.0075 to 0.0125 lb	21	24	See label for further restrictions and uses.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.92 to 3.2 oz	0.015 to 0.025 lb	21	24	See label for details and restrictions. Warrior II uses half the rate of Warrior.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for BLACK CUTWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Lambda-cyhalothrin + chlorantraniliprole	5 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Permethrin **R**	Many formulations available; see label for rates and restrictions				Very effective at controlling black cutworm larvae. Do not exceed a total of 0.6 lb ai per acre per season.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
(Pounce 1.5G)	6.7 to 13.3 lb	0.1 to 0.2 lb	30	24	
Zeta-cypermethrin **R**	2.6 to 6.1 oz	0.025 to 0.06 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.
(Mustang Max)					

Black cutworm notes: Insurance treatments for black cutworm are effective only if the caterpillars are present soon after planting. Responsive treatments are not effective unless the insects come in contact with the insecticide. Under dry conditions, black cutworm tends to remain underground, not contacting surface-applied insecticide. It is advisable to apply most chemicals in the evening and when the soil is moist. Cultivation after an insecticide application will help under dry conditions.

Suggested insecticides, rates, and restrictions for CORN EARWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Corn earworm rarely causes economic damage to field corn in PA; check the math before treating to make sure the decision makes economic sense.					
Alpha-cypermethrin	1.8 to 3.8 fl oz	0.011 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
(Fastac)					
Bifenthrin **R**	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application. Do not apply more than 0.3 lb ai per acre per season.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					
(Capture LFR)	2.8 to 8.5 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application for field corn (grain and silage), popcorn, and field corn grown for seed.
Chlorantraniliprole (Vantacor)	1.2 – 2.5 oz	0.047 - 0.098 lb	14	4	Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.
Chlorantraniliprole + bifenthrin **R**	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
(Elevest)					
Cyfluthrin **R**	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Maximum of four applications per acre per season and 11.2 oz per acre.
(Baythroid XL)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for CORN EARWORM; continued.

Deltamethrin **R**	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not make more than five applications or apply more than 8.1 oz per acre per season.
(Delta Gold)					
Esfenvalerate **R**	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	First application should be at or before silking. Do not apply more than 0.25 lb ai per acre per season.
(Asana XL)					
Gamma-cyhalothrin **R**	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
(Proaxis)					
Lambda-cyhalothrin **R**	1.92 to 3.2 oz	0.015 to 0.025 lb	21	24	See label for details and restrictions. Use higher rates for larger larvae. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	5 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Methomyl **R**		0.23 to 0.45 lb	21	48	Do not apply more than 2.25 lb ai per crop per season. Apply when insects first appear in significant numbers. Highly toxic to humans. Lower rates help conserve beneficial arthropods.
(Lannate 90SP)	0.25 to 0.5 lb				
(Lannate LV)	0.75 to 1.5 pt				
Permethrin **R**	Many formulations available; see label for rates and restrictions				Do not exceed a total of 0.6 lb ai per acre per season.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
Spinetoram	3 to 6 fl oz	0.023 to 0.047 lb	28 (grain); 3 (silage)	4	No more than three applications and 16 fl oz (0.125 lb ai) per year
(Radiant)					
Spinosad **O**			28	4	Do not apply more than 8.3 oz of Blackhawk or 12 oz of Entrust SC per acre per year.
(Blackhawk)	2.2 to 3.3 oz	0.05 to 0.074 lb			
(Entrust SC)	3 to 6 oz	0.047 to 0.094 lb			
Zeta-cypermethrin **R**	1.76 to 4 oz	0.011 to 0.025 lb	30 (grain)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
(Mustang Max)					

Suggested insecticides, rates, and restrictions for CORN LEAF AND OAT BIRD CHERRY APHIDS.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 50% or more plants with colonies of 100 or more aphids, and 3% or more plants with heavily infested tassels and or upper leaves.					
Alpha-cypermethrin	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)		Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
(Fastac)					
Bifenthrin **R**	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Direct spray to cover foliage.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for CORN LEAF AND OAT BIRD CHERRY APHIDS; continued.

Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not make more than five applications or apply more than 8.1 oz per acre per season. Suppression only.
Dimethoate	Many formulations available; see label for rates and restrictions				See comments for corn rootworm beetles.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Direct spray at aphid population. Aphids not contacted by spray, such as in the whorls and leaf axis, may not be adequately controlled. Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	Suppression only. See label for details and restrictions. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole (Besiege)	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
Methomyl **R**		0.23 to 0.45 lb	21	48	Do not apply more than 2.25 lb ai per crop per season. Apply when insects first appear in significant numbers. Highly toxic to humans. Lower rates help conserve beneficial arthropods.
(Lannate LV)	0.75 to 1.5 pt				
(Lannate 90SP)	0.25 to 0.5 lb				
Phorate **R** (Phorate 20G)	5 lb	1 lb	30	48	Broadcast into whorls. See label for details.
Sulfoxaflor (Transform WG)	0.75 to 1.5 oz	0.023 to 0.047 lb	14 (grain); 7 (silage)	24	No more than two applications and 3.0 oz (0.09 lb) per year. Highly toxic to bees.
Zeta-cypermethrin **R** (Mustang Max)	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Suggested insecticides, rates, and restrictions for CORN ROOTWORM (BEETLES, not larvae).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: control usually not needed; treatments not suggested unless there is an average of five beetles per ear and corn is less than 50% brown silk.					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)		Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Direct spray over tassel and into ear zone. Do not apply more than 0.3 lb ai per acre per season.
Carbaryl	1 to 2 qt		48	24	

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for CORN ROOTWORM (BEETLES, not larvae); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Maximum of four applications per acre per season and 11.2 oz per acre.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz in a growing season.
Dimethoate	Many formulations available; see label for rates and restrictions				See label for rates and restrictions. Do not make more than three applications per year. Do not apply to corn during the pollen shedding period.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Control should be instigated only if an economic level of rootworm beetles is observed. Once the silks turn brown, control is no longer necessary. Apply at first sign of silk feeding. Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	For corn rootworm control as part of an aerial applied control program, use a minimum of 3.8 oz per acre (0.03 lb ai per acre). See label for details and restrictions. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole (Besiege)	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
Methomyl **R**		0.23 to 0.45 lb	21	48	No more than 2.25 lb ai per crop per season. Apply when insects first appear in significant numbers. Highly toxic to humans. Lower rates help conserve beneficial arthropods.
(Lannate 90SP)	0.25 to 0.5 lb				
(Lannate LV)	0.75 to 1.5 pt				
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Perm-up) (Pounce 25WP)	Many formulations available; see label for rates and restrictions				See label for further limitations.
Zeta-cypermethrin **R** (Mustang Max)	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Suggested insecticides, rates, and restrictions for CORN ROOTWORM (LARVA).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: number of beetles per plant in August: first year, one western corn rootworm and two northern corn rootworm; two or more years of corn, 1.5 western corn rootworm and three northern corn rootworm.					
Bifenthrin **R**	0.3 oz per 1,000 feet of row	0.0046 lb per 1,000 feet of row	30	12	Apply as a 5- to 7-inch T-band over an open seed furrow. Apply a minimum of 3 gal per acre by ground. Straw may not be used for food or feed.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					
(Capture 1.15G)	6.4 to 8 oz per 1,000 feet of row	0.005 to 0.006 lb per row foot	30	24	Apply as a 5- to 7-inch T-band treatment. Use high rate for heavy insect pressure. Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications. Highly toxic to bees.
(Empower 2EC)					
Chlorethoxyfos **R**	3 to 4.5 oz per 1,000 feet of row	0.12 to 0.18 lb per 1,000 feet of row	30	48	Recommended as a T-band application.
(SmartChoice HC, Index)					
Ethoprop **R**	8 oz per 1,000 feet of row	7 lb	See label	48	Apply at planting.
(Mocap 15G)					
Gamma-cyhalothrin **R**	0.66 oz per 1,000 feet of row	0.0025 lb per 1,000 feet of row	21	24	Apply as a band.
(Proaxis)					
Lambda-cyhalothrin **R**	11.5 fl oz per acre (0.66 fl oz per 1,000 feet of row)	0.005 lb ai per 1,000 feet of row	21	24	Compatible with liquid fertilizer. In-furrow and T-band applications possible; see label for details.
(Ballista)					
(Taiga Z)	0.66 oz per 1,000 feet of row	0.005 lb per 1,000 feet of row	21	24	Apply as a band. See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Warrior and Warrior II)					
Phorate **R**	6 oz per 1,000 feet of row	1 lb	30	48	Do not apply more than 6.5 lb of Phorate 20G per acre. Do not use in-furrow application. Apply in a 7-inch band over the row directly behind the planter shoe in front of or behind the press wheel and lightly incorporate. See label for details.
(Phorate 20G)					
Tebupirimphos + cyfluthrin **R**	3 to 6.7 oz per 1,000 feet of row	0.12 lb	30	48	Apply as a T-band or in-furrow. Incorporate into the soil surface. Do not apply more than 7.3 lb of material per acre per season.
(Aztec 4.67G)					
(Defcon 2.1G)					
Tefluthrin **R**	1.25 to 1.5 oz per 1,000 feet of row	0.125 to 0.15 lb	Not applicable	48	At-planting applications can be placed in a 7-inch band over the row in front or behind the press wheel, or in-furrow. When applied at cultivation, place at the base of plants on both sides of the plant (split boot). Cover the treated band with 2 to 3 inches of soil.
(Force 10G)					
(Force 6.5G)	1.8 to 2.3 oz per 1,000 feet of row	0.1 to 0.12 lb			Application may be by in-furrow, band, or T-band; see label for details.
Terbufos **R**	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	Not applicable	48	Do not exceed 6.5 lb per acre. Counter is one of the few compounds that can help reduce some nematode populations.
(Counter 20G)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for CORN ROOTWORM (LARVA); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Seed Treatments					
Clothianidin (Poncho)	1.25 mg per kernel				Not for hopperbox treatment. Research suggests only effective against low to moderate rootworm populations.
Thiamethoxam (Cruiser)	1.25 mg per kernel				Not for hopperbox treatment. Research suggests only effective against low to moderate rootworm populations.

Corn rootworm larva notes: Liquid formulations have advantages: they are cheaper and may be mixed with some herbicides and liquid fertilizers to reduce application cost; however, the relatively high content of active toxicant in liquid formulations makes them more hazardous to handle than granules. Use of an organophosphate insecticide, such as Counter, Lorsban, or Phorate, with a postemergence sulfonylurea herbicide can cause corn plant injury. Counter shows the greatest tendency for this because of its systemic properties, but the CR20 formulation has helped reduce this problem. For band application, the rate (ounces per 1,000 feet of row) is constant and independent of row spacing. Therefore, the pound of formulation per acre rate needed increases as row spacing decreases. Read the label to determine the proper rate for your row spacing. Research indicates that at-planting insecticide applications may have a reduced level of effectiveness when corn is planted before May 1. Larvae are believed to begin hatching between June 1 and 15 in central Pennsylvania. The total hatching period is 3 to 4 weeks long. Hatch may occur 7 to 10 days earlier in southern areas of the state and 7 to 10 days later in more northern and higher elevations. Under average conditions most rootworm insecticides remain effective for approximately 6 to 8 weeks. An alternative to at-planting application is at-cultivation or sidedress between June 1 and 10 (possibly a week earlier in southern areas).

Suggested insecticides, rates, and restrictions for EUROPEAN CORN BORER (FIRST GENERATION).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: see chart in the Field Crop IPM Reference and Training Manual to calculate economic threshold.					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bacillus thuringiensis **O**	Many formulations available; see label for rates and restrictions				Time applications to egg hatch. Small larvae are more susceptible to compounds. Treat when newly hatched larvae are present and the first feeding damage is observed. See label for further directions.
Bifenthrin **R** (Bifenture) (Capture 1.15G) (Empower 2EC)	3.5 to 8.7 lb per 1,000 feet of row	0.04 to 0.1 lb per 1,000 feet of row	30	7	Apply as a broadcast application when insect injury is first noticed or phenology models indicate the initiation of first instars. Do not apply more than 0.1 lb ai per acre per season as an at-plant application. Do not apply more than 0.3 lb ai per acre per season, including at-plant plus foliar applications. Highly toxic to bees.
(Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl (Sevin)	1.5 to 2 qt		48	24	
Chlorantraniliprole (Vantacor)	1.2 – 2.5 oz	0.047 - 0.098 lb	14	4	Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for EUROPEAN CORN BORER (FIRST GENERATION); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Chlorantraniliprole + bifenthrin **R**	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
(Elevest)					
Cyfluthrin **R**	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
(Baythroid XL)					
Deltamethrin **R**	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
(Delta Gold)					
Esfenvalerate **R**	7.8 to 9.6 oz	0.04 to 0.05 lb	21	12	Use higher rates for higher insect pressure. Do not apply more than 0.25 lb ai per acre per season.
(Asana)					
Gamma-cyhalothrin **R**	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for additional limitations and uses.
(Proaxis)					
Lambda-cyhalothrin **R**	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	For control before the larva bores into the plant stalk or ear. See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Methoxyfenozide	4 to 16 oz	0.06 to 0.25 lb	21	4	Controls only lepidopteran larvae (caterpillars). Does not have significant negative impact on beneficial arthropods. Not registered in NY.
(Intrepid 2F)					
Permethrin **R**	Many formulations available; see label for rates and restrictions		30	24	Apply every 5 days as needed.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
(Pounce 1.5G)	6.7 to 13.3 lb	0.1 to 0.2 lb	30	12	Apply in band over whorl stage corn plants.
Phorate **R**	5 lb	1 lb	30	48	Broadcast into whorl. See label for details.
(Phorate 20G)					
Spinetoram	3 to 6 fl oz	0.023 to 0.047 lb	28 (grain); 3 (silage)	4	No more than three applications and 16 fl oz (0.125 lb ai) per year
(Radiant)					
Spinosad **O**			28	4	Do not apply more than 8.3 oz of Blackhawk or 12 oz of Entrust SC per acre per year.
(Blackhawk)	1.67 to 3.3 oz	0.023 to 0.094 lb			
(Entrust SC)	2.4 to 6 oz	0.023 to 0.094 lb			
Zeta-cypermethrin **R**	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
(Mustang Max)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for EUROPEAN CORN BORER (FIRST GENERATION); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

First-generation European corn borer notes: The granular formulations are recommended for first-generation control because they stay in the whorl where small corn borer larvae are feeding. Liquid formulations stick to leaves and move out of the whorl region as the plant grows. Granulars should be directed into the whorl when applied.

Suggested insecticides, rates, and restrictions for EUROPEAN CORN BORER (SECOND GENERATION).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: variable; see the Field Crop IPM Training and Reference Manual. The PA-PIPE online system helps determine when the second generation is active.					
Bacillus thuringiensis **O**	Many formulations available; see label for rates and restrictions				Time applications to egg hatch. Small larvae are more susceptible to compounds.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Direct spray over tassel and into ear zone. Do not apply more than 0.3 lb ai per acre per season.
Carbaryl (Sevin)	1.5 to 2 qt		48	24	Suggested as an alternative because of their relatively low toxicity to humans. Handle all insecticides with care.
Chlorantraniliprole (Vantacor)	1.2 – 2.5 oz	0.047 - 0.098 lb	14	4	Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.
Chlorantraniliprole + bifenthrin **R** (Elevest)	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	12	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
Esfenvalerate **R** (Asana XL)	7.8 to 9.6 oz	0.04 to 0.05 lb	21	12	Use higher rates for higher insect pressure. Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for limitations and further uses.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for EUROPEAN CORN BORER (SECOND GENERATION); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Lambda-cyhalothrin **R**	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	For control before the larva bores into the plant stalk or ear. See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Methoxyfenozide	4 to 16 oz	0.06 to 0.25 lb	21	4	Controls only lepidopteran larvae (caterpillars). Does not have significant negative impact on beneficial arthropods. Not registered in NY.
(Intrepid 2F)					
Permethrin **R**	Many formulations available; see label for rates and restrictions				Apply 5 days as needed.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
(Pounce 1.5G)	6.7 to 13.3 lb	0.1 to 0.2 lb			Apply in band over whorl stage corn plants.
Spinosad **O**					Do not apply more than 8.3 oz of Blackhawk or 12 oz of Entrust SC per acre per year.
(Blackhawk)	1.67 to 3.3 oz	0.023 to 0.074 lb			
(Entrust SC)	2.4 to 6 oz	0.23 to 0.094 lb			
Zeta-cypermethrin **R**	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
(Mustang Max)					
Zeta-cypermethrin + bifenthrin **R**	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain) ; 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.
(Hero)					

Second-generation European corn borer notes: When treating for a second generation, use drop nozzles on ground application equipment. Direct spray into the ear zone since 90 percent of the small larvae will be in this area. Time sprays for when the majority of eggs are hatching or in the blackhead stage. Improperly timed sprays will be ineffective because newly hatched larvae soon reach sheltered areas of the plant.

Suggested insecticides, rates, and restrictions for FALL ARMYWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 75% of plants showing feeding in whorl, and live larvae.					
Alpha-cypermethrin	3.2 to 3.8 fl oz	0.02 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
(Fastac)					
Azadirachtin **O**	0.25 to 1 pt	N/A		4	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and may repel or deter insect feeding. May require multiple applications to provide adequate control. Little data on effectiveness on these pests is available, but it is a natural product.
(Neemix 4.5)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for FALL ARMYWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Bacillus thuringiensis **O**	Many formulations available; see label for rates and restrictions				
Bifenthrin **R**	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Direct spray over tassel and into ear zone. Do not apply more than 0.3 lb ai per acre per season.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					
(Capture LFR)	2.8 to 8.5 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application for field corn (grain and silage), popcorn, and field corn grown for seed.
Carbaryl	1 to 2 qt		48	24	
(Sevin)					
Chlorantraniliprole (Vantacor)	1.2 – 2.5 oz	0.047 - 0.098 lb	14	4	Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.
Chlorantraniliprole + bifenthrin **R**	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
(Elevest)					
Cyfluthrin **R**	1.6 to 2.8 oz	0.013 to 0.022 lb	21	24	Do not make more than four applications or apply more than 11.2 oz per acre per season. For use against first and second instars.
(Baythroid XL)					
Deltamethrin **R**	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not apply more than 8.1 oz in a growing season.
(Delta Gold)					
Gamma-cyhalothrin **R**	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for further limitations and uses.
(Proaxis)					
Lambda-cyhalothrin **R**	1.28 to 3.84 oz	0.02 to 0.03 lb	21	24	For control of first and second instars only. See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Methomyl **R**		0.23 to 0.45 lb	21	48	Do not apply more than 2.25 lb ai per crop per season. Apply when insects first appear in significant numbers. Highly toxic to humans. Lower rates help conserve beneficial arthropods.
(Lannate LV)	0.75 to 1.5 pt				
(Lannate 90SP)	0.25 to 0.5 lb				

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for FALL ARMYWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Permethrin **R**	Many formulations available; see label for rates and restrictions				See label for further limitations and uses.
(Ambush 25W)					
(Arctic 3.2)					
(Perm-up)					
(Pounce 25WP)					
Spinosad **O**			28	4	Do not apply more than 8.3 oz of Blackhawk or 12 oz of Entrust SC per acre per year.
(Blackhawk)	1.67 to 3.3 oz	0.023 to 0.074 lb			
(Entrust SC)	2.4 to 6 oz	0.023 to 0.094 lb			
Zeta-cypermethrin **R**	3.2 to 4 oz	0.02 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
(Mustang Max)					
Zeta-cypermethrin + bifenthrin **R**	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (silage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.
(Hero)					

Suggested insecticides, rates, and restrictions for FLEA BEETLE (ADULT).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: five or more beetles per plant prior to V4.					
Alpha-cypermethrin	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)		Do not apply more than 11.4 fl oz product (0.075 lb ai) per acre per season.
(Fastac)					
Azadirachtin **O**	0.25 to 1 pt	N/A		4	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and may repel or deter feeding by the insect. May require multiple applications to provide adequate control. Little data on effectiveness on these pests is available, but it is a natural product.
(Neemix 4.5)					
Bifenthrin **R**	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Spray in band over small plants. Do not apply more than 0.3 lb ai per acre per season.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					
(Capture LFR)	2.8 to 8.5 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application for field corn (grain and silage), popcorn, and field corn grown for seed.
Carbaryl (Sevin)	1 to 2 qt		48	24	

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for FLEA BEETLE (ADULT); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Chlorantraniliprole + bifenthrin **R**	4.8 to 9.6 fl oz	0.084 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
(Elevest)					
Cyfluthrin **R**	0.8 to 1.6 oz	0.013 to 0.025 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
(Baythroid XL)					
Deltamethrin **R**	1 to 1.5 oz	0.012 to 0.018 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
(Delta Gold)					
Esfenvalerate **R**	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Use no more than 0.25 lb ai per season.
(Asana XL)					
Gamma-cyhalothrin **R**	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for further limitations.
(Proaxis)					
Lambda-cyhalothrin **R**	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Methomyl **R**		0.23 to 0.45 lb	21	48	Do not apply more than 2.25 lb ai per crop per season. Apply when insects first appear in significant numbers. This chemical is highly toxic to humans. Lower rates help conserve beneficial arthropods.
(Lannate 90SP)	0.25 to 0.5 lb				
(Lannate LV)	0.75 to 1.5 pt				
Permethrin **R**	Many formulations available; see label for rates and restrictions				Apply when insect first appears in significant numbers.
(Ambush 25WP)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
Terbufos **R**	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	4.5 to 6 oz per 1,000 feet of row	48	See black cutworm insurance treatment.
(Counter 20G)					
Zeta-cypermethrin **R**	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.
(Mustang Max)					
Zeta-cypermethrin + bifenthrin **R**	2.6 to 6.1 oz	0.025 to 0.06 lb	30 (grain) ; 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.
(Hero)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for FLEA BEETLE (ADULT); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Seed Treatments					
Clothianidin (Poncho)	0.25 or 1.25 mg per kernel				Not for hopperbox treatment.
Imidacloprid (Concur) (Latitude)	1.8 oz per 50 lb of seed				Used as a planter box treatment. Also contains a fungicide.
Thiamethoxam (Cruiser)	0.25 or 1.25 mg per kernel				Not for hopperbox treatment.

Flea beetle notes: Treatment is recommended for flea beetles on a rescue basis because of the low probability of problems. Survival of overwintering corn flea beetles is closely tied to the temperature during the winter months. For this reason, they are seldom a problem in Pennsylvania except in a few of the southeastern counties. If flea beetle has been a continual problem on your farm or in a field, Counter 20G, Counter 20CR, Phorate 20G, or one of the listed seed treatments can be applied at planting as a preventive treatment. Read the label for specific recommendations and restrictions.

Suggested insecticides, rates, and restrictions for GARDEN SYMPHYLAN (CENTIPEDE).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: treat if a significant area of the field is affected.					
Chlorethoxyfos + bifentrin **R** (SmartChoice HC, Index)	3 to 3.75 oz per 1,000 feet of row	0.12 to 0.18 lb	30	48	Recommended as an in-furrow application.
Terbufos **R** (Counter 20G)	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	30	48	Place granules in a 7-inch band or, preferably, in-furrow directly behind or in front of planter shoe in front of the press wheel at planting. Do not exceed 6.5 lb ai per acre.

Suggested insecticides, rates, and restrictions for GRASSHOPPER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: seven or more per square yard in field margins.					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	0.25 to 1 pt	N/A		4	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and may repel or deter insect feeding. May require multiple applications to provide adequate control. Little data on effectiveness on these pests is available, but it is a natural product.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Direct spray to get through coverage of foliage. Do not apply more than 0.3 lb ai per acre per season.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for GRASSHOPPER; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Carbaryl (Sevin)	1 to 2 qt		48	24	
Chlorantraniliprole (Vantacor)	1.2 – 2.5 oz	0.047 - 0.098 lb	14	4	For best results treat when grasshoppers are 2nd or 3rd instar nymphs and add methylated seed oil (MSO) adjuvant at 1 gal per 100 gal spray volume. See label for more details.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 fl oz	0.084 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin **R** (Baythroid XL)	2.1 to 2.8 oz	0.033 to 0.044 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
Deltamethrin **R** (Delta Gold)	1 to 1.5 oz	0.012 to 0.018 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
Dimethoate	Many formulations available; see label for rates and restrictions				
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Broadcast over infested area. Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for further limitations.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	Timing and frequency of spray should be based on when insect populations reach economic thresholds. See label for details and restrictions. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole (Besiege)	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
Zeta-cypermethrin **R** (Mustang Max)	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.2 lb ai per acre per season, including at-plant plus foliar applications.
Zeta-cypermethrin + bifenthrin **R** (Hero)	2.6 to 6.1 oz	0.025 to 0.06 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Suggested insecticides, rates, and restrictions for HOP VINE BORER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for further limitations.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	See label for details and restrictions. For control before larvae bore into plant stalk or ear. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole (Besiege)	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Perm-up) (Pounce 25WP)	Many formulations available; see label for rates and restrictions				See label for further limitations.
Zeta-cypermethrin **R** (Mustang Max)	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	See label for further limitations.
Zeta-cypermethrin + bifenthrin **R** (Hero)	2.6 to 6.1 oz	0.025 to 0.06 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Suggested insecticides, rates, and restrictions for JAPANESE BEETLE (ADULT).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: three or more beetles per ear when silks are green.					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Direct spray through coverage of foliage. Do not apply more than 0.3 lb ai per acre per season.
(Capture LFR)	2.8 to 8.5 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application for field corn (grain and silage), popcorn, and field corn grown for seed.
Carbaryl (Sevin)	1 to 2 qt		48	24	See label for rates and restrictions. Do not apply when bees are foraging in the field.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for JAPANESE BEETLE (ADULT); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 fl oz	0.084 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Maximum of four applications per acre per season and 11.2 oz per acre.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not make more than 5 applications or apply more than 8.1 oz per acre in a growing season.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	See label for further limitations. Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	See label for further limitations.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	Do not apply more than 0.06 lb ai per acre after silk initiation. See label for details and restrictions. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole (Besiege)	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
Zeta-cypermethrin **R** (Mustang Max)	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Suggested insecticides, rates, and restrictions for SEEDCORN MAGGOT.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: none; follow replanting guidelines.					
Bifenthrin **R** (Capture LFR)	4 to 5.3 oz	0.047 to 0.062 lb		12	For mixing directly with liquid fertilizer to control soil insect pests. To be preplant incorporated. See label for specific rates.
Lambda-cyhalothrin **R** (Ballista)	11.5 fl oz per acre (0.66 fl oz per 1,000 feet of row)	0.005 lb ai per 1,000 feet of row	21	24	Compatible with liquid fertilizer. In-furrow and T-band applications possible; see label for details.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for SEEDCORN MAGGOT; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Tefluthrin **R** (Force 10G)	1.25 to 1.5 oz per 1,000 feet of row	0.125 to 0.15 lb	Not applicable	48	At-planting applications can be placed in a 7-inch band over the row in front or behind the press wheel, or in-furrow. When applied at cultivation, place at the base of plants on both sides of the plant (split boot). Cover the treated band with 2 to 3 inches of soil.
(Force 6.5G)	1.8 to 2.3 oz per 1,000 feet of row	0.1 to 0.12 lb			Application may be by in-furrow, band, or T-band; see label for details.
Seed Treatments					
Clothianidin (Poncho)	0.25 or 1.25 mg per kernel				Not for hopperbox treatment.
Imidacloprid (Concur) (Latitude)	1.8 oz per 50 lb of seed				Used as a planter box treatment. Also contains a fungicide.
Thiamethoxam (Cruiser)	0.25 or 1.25 mg per kernel				Not for hopperbox treatment

Seedcorn maggot notes: If one of the above soil insecticides is used at planting, there is no need to use a seed treatment: Aztec 4.67, Brigade 2EC, Counter 20G, Force 10G, SmartChoice HC, or Phorate 20G. For the soil insecticide to be effective at protecting the seed, part of the product must be applied in the furrow (T-band or in-furrow applications). Otherwise, a seed treatment can be used if needed (see Table 2.2-20). Seedcorn maggot can cause serious injury to both soybean and corn fields. Certain field conditions, such as tilling in a green cover crop, are more likely to lead to seedcorn maggot problems. If these conditions exist, a seed treatment is relatively inexpensive and may be a good investment. Fields with heavy applications of manure or high in organic matter are most likely to have serious maggot problems. Although more expensive, an at-planting granular treatment also will control this insect (see Table 2.2-24).

Suggested insecticides, rates, and restrictions for SLUGS.

	Rate per Acre		Restrictions		Comments
Molluscicide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 50% of leaf area missing on plants less than V6.					
Metaldehyde (Deadline M-Ps) (Metarex) (Orcal Snail and Slug Bait)	5 to 40 lb per acre	0.2 to 1.6 lb	0	12	Metaldehyde breaks down to carbon dioxide in water.
Sodium ferric EDTA (Ferroxx)	5 to 20 lb per acre or 0.11 to 0.44 lb per 1,000 sq ft	0.25 to 1lb	0	0	See label for more details.

Slug notes: Slug damage is most severe during cool, wet weather, especially in fields under reduced tillage with a fairly heavy cover of organic matter. Corn plants normally recover from slug feeding; however, extensive plant mortality may occur during periods of prolonged wet weather in May and June. Slug baits tend to be water soluble, so gaining effective control may be challenging when rain is frequent. Slug damage can be made worse when corn seed is coated with a neonicotinoid insecticide; these insecticides do not control slugs, which are molluscs rather than insects, and they kill insects that are natural enemies and can contribute to insect control.

Suggested insecticides, rates, and restrictions for SOD WEBWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: see thresholds for black cutworm.					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	0.25 to 1 pt	N/A		4	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and may repel or deter insect feeding. May require multiple applications to provide adequate control. Little data on effectiveness on these pests is available, but it is a natural product.
Bacillus thuringiensis **O**	Many formulations available; see label for rates and restrictions				These products perform best when larvae are still small and numbers are low to moderate.
Chlorantraniliprole + bifenthrin **R** (Elevest)	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
Permethrin **R** (Ambush 25WP) (Arctic 3.2EC) (Perm-up) (Pounce 25WP)	Many formulations available; see label for rates and restrictions				Use good IPM practices and apply based on need. Sod webworms are typically a problem only in corn planted in old sod. See comments for other corn insects.
(Pounce 1.5G)	6.7 to 13.3 lb	0.1 to 0.2 lb			
Zeta-cypermethrin **R** (Mustang Max)	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications

Suggested insecticides, rates, and restrictions for STALK BORER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: see the "Field Crop IPM Reference and Training Manual."					
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)		Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Preemergence application after planting. Read the label for other uses as a PRE or PPI application. Do not apply more than 0.3 lb ai per acre per season.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for STALK BORER; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
(Capture LFR)	3.4 oz	0.04 lb		12	For mixing directly with liquid fertilizer to control soil insect pests. To be used preemergence. See label for specific rates.
Chlorantraniliprole + bifenthrin **R**	5.6 to 9.6 fl oz	0.098 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
(Elevest)					
Cyfluthrin **R**	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
(Baythroid XL)					
Deltamethrin **R**	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Apply as necessary to maintain control. Do not make more than five applications or apply more than 8.1 oz per acre in a growing season.
(Delta Gold)					
Esfenvalerate **R**	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Application must be made early in migration from grassy areas to corn, before borers enter the plant. More than one application may be necessary. Do not apply more than 0.25 lb ai per acre per season.
(Asana XL)					
Gamma-cyhalothrin **R**	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
(Proaxis)					
Lambda-cyhalothrin **R**	2.56 to 3.84 oz	0.02 to 0.03 lb	21	24	Apply before larvae bore into the plant stalk. See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Lambda-cyhalothrin + chlorantraniliprole	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
(Besiege)					
Permethrin **R**	Many formulations available; see label for rates and restrictions		30	12	Use same application timing as for Asana. When treating for stalk borer, apply at or shortly before the larvae are moving into the corn from surrounding weeds and grasses. Mowing or using a burndown herbicide can initiate movement.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
(Pounce 1.5G)	6.7 to 13.3 lb	0.1 to 0.2 lb	30	24	
Zeta-cypermethrin **R**	2.72 to 4 oz	0.017 to 0.025 lb	30 (grain); 60 (silage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
(Mustang Max)					
Zeta-cypermethrin + bifenthrin **R**	2.6 to 6.1 oz	0.025 to 0.06 lb	30 (grain); 60 (forage)		Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.
(Hero)					

Suggested insecticides, rates, and restrictions for STINK BUG (including brown marmorated stink bug).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin (Fastac)	2.7 to 3.8 fl oz	0.017 to 0.025 lb	30 (grain); 60 (forage)		Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application. Do not apply more than 0.3 lb ai per acre per season for all applications.
Chlorantraniliprole + bifenthrin **R** (Elevest)	7.7 to 9.6 fl oz	0.134 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	30 (grain); 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Only for use as a foliar application.

Stink bug notes: No economic threshold exists for brown marmorated stink bug in corn. Brown marmorated stink bugs tend to accumulate on field edges; thus, treating just the edge can be an effective control option. Most of these insecticides are broadly active and claim to have activity on "stink bugs"; however, efficacy work has revealed that bifenthrin-based products work well against brown marmorated stink bug. It appears clear that most products provide little if any residual control; once treated, populations should be monitored closely for recovery.

Suggested insecticides, rates, and restrictions for TWO-SPOTTED SPIDER MITE.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Bifenthrin **R** (Bifenture) (Brigade 2EC)	5.12 to 6.4 oz	0.08 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Chlorantraniliprole + bifenthrin **R** (Elevest)	7.7 to 9.6 fl oz	0.134 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Etoxazole (Zeal SC)	2 to 6 fl oz	0.045 to 0.135 lb	21	12	Do not apply after R5 stage. Do not apply more than 0.27 lb ai per acre per calendar year. Do not graze treated soybean fields or feed treated forage or hay to livestock.
Hexythiazox (Onager)	10 to 24 oz		30	12	Do not make more than one application or apply more than 24 oz per year.
Spiromesifin (Oberon 2SC)	5.7 to 16 oz	0.9 to 0.25 lb	5 to 30 (see label)	12	Do not apply more than 17 oz per acre per season.

Suggested insecticides, rates, and restrictions for WESTERN BEAN CUTWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 8% of plants have egg masses or small larvae.					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for WESTERN BEAN CUTWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin (Fastac)	1.8 to 3.8 fl oz	0.011 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bacillus thuringiensis **O**	Many formulations available; see label for rates and restrictions				
Bifenthrin **R** (Bifenture) (Brigade 2EC) (Discipline 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	30	12	Do not apply more than 0.3 lb ai per acre per season for all applications.
(Capture LFR)	2.8 to 8.5 oz	0.033 to 0.1 lb	30	12	Do not graze livestock in treated areas or cut treated crops for feed within 30 days of the last application for field corn (grain and silage), popcorn, and field corn grown for seed.
Carbaryl	2 qt		48	24	
Chlorantraniliprole (Vantacor)	1.2 – 2.5 oz	0.047 - 0.098 lb	14	4	Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 fl oz	0.084 to 0.167 lb	30	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	21	12	Do not make more than four applications or apply more than 11.2 oz per acre per season.
Esfenvalerate **R** (Asana XL)	2.9 to 5.8 oz	0.015 to 0.03 lb	21	12	Do not apply more than 0.25 lb ai per acre per season.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Apply as necessary to maintain control.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.92 to 3.2 oz	0.015 to 0.025 lb	21	24	See label for details and restrictions. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole (Besiege)	6 to 9 oz		21	24	Do not exceed 31 oz of Besiege or 0.12 lb ai of lambda-cyhalothrin-containing products per acre per year.
Methoxyfenozide (Intrepid 2F)	4 to 16 oz	0.06 to 0.25 lb	21	4	Controls only lepidopteran larvae (caterpillars). Does not have significant negative impact on beneficial arthropods. Not registered in NY.

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for WESTERN BEAN CUTWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Permethrin **R**	Many formulations available; see label for rates and restrictions				Do not exceed a total of 0.6 lb ai per acre per season.
(Ambush 25W)					
(Arctic 3.2EC)					
(Perm-up)					
(Pounce 25WP)					
Spinetoram	3 to 6 fl oz	0.023 to 0.047 lb	28 (grain); 3 (silage)	4	No more than three applications and 16 fl oz (0.125 lb ai) per year
(Radiant)					
Spinosad **O**			28	4	Do not apply more than 8.3 oz of Blackhawk or 12 oz of Entrust SC per acre per year.
(Blackhawk)	2.2 to 3.3 oz	0.050 to 0.074 lb			
(Entrust SC)	3 to 6 oz	0.047 to 0.094 lb			
Zeta-cypermethrin **R**	1.76 to 4 oz	0.011 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 0.1 lb ai per acre per season, including at-plant plus foliar applications.
(Mustang Max)					
Zeta-cypermethrin + bifenthrin **R**	2.6 to 6.1 oz	0.025 to 0.06 lb	30 (grain) ; 60 (forage)	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season.
(Hero)					

Suggested insecticides, rates, and restrictions for WHITE GRUB.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: one or more white grubs per square foot.					
Bifenthrin **R**	0.15 to 0.3 oz per 1,000 feet of row	0.0023 to 0.0046 lb per 1,000 feet of row	30	12	Do not apply more than 0.3 lb ai per acre per season.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					
(Capture 1.15G)	3.2 to 8 oz per 1,000 feet of row	0.002 to 0.006 lb per feet of row	30	24	Apply as a 5- to 7-inch T-band treatment. Do not apply more than 0.1 lb ai per acre per season as an at-plant application. Do not apply more than 0.3 lb ai per acre per season, including at-plant plus foliar applications. Highly toxic to bees.
(Empower 2EC)					
(Capture LFR)	4 to 5.3 oz	0.047 to 0.062 lb		12	For mixing directly with liquid fertilizer to control soil insect pests. To be preplant incorporated. See label for specific rates.
Chlorethoxyfos **R**	3 to 7.5 oz per 1,000 feet of row	0.12 to 0.18 lb	30	48	Recommended as a T-band application.
(SmartChoice HC, Index)					
Ethoprop **R**	8 oz per 1,000 feet of row	7 lb	See label	48	Suppression only.
(Mocap 15G)					
Gamma-cyhalothrin **R**	0.66 oz per 1,000 feet of row	0.0025 lb per 1,000 feet of row	21	24	See label for other limitations and uses.
(Proaxis)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for WHITE GRUB; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Lambda-cyhalothrin **R**	0.66 oz per 1,000 feet of row	0.005 lb per 1,000 feet of row	21	24	See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Tebupirimphos **R**	3 to 6.7 oz per 1,000 feet of row	0.12 lb per 1,000 feet of row	30	48	Apply as a T-band or in-furrow. Incorporated into the soil surface.
(Aztec 4.67G)					
(Defcon 2.1G)					
Tefluthrin **R**	1.25 to 1.5 oz per 1,000 feet of row	0.125 to 0.15 lb	Not applicable	48	Apply the granules as an in-furrow treatment. Use 5 oz per 1,000 feet of row for severe infestations.
(Force 10G)					
(Force 6.5G)	1.8 to 2.3 oz per 1,000 feet of row	0.1 to 0.12 lb			Application may be by in-furrow, band, or T-band; see label for details.
Terbufos **R**	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	30	48	Do not exceed 6.5 lb per acre.
(Counter 20G)					
Seed Treatments					
Clothianidin	0.25 or 1.25 mg per kernel				Not for hopperbox treatment.
(Poncho)					
Imidacloprid	1.8 oz per 50 lb of seed				Used as a planter box treatment. Also contains a fungicide.
(Concur)					
(Latitude)					
Thiamethoxam	0.25 or 1.25 mg per kernel				Not for hopperbox treatment
(Cruiser)					

White grub notes: White grub is seldom a problem in Pennsylvania corn fields. The pest occurs primarily in corn planted into old bluegrass sod. Before treating specifically for this pest, it is best to scout the field. If other pests are a problem in the field, select a soil insecticide with activity against white grub and the other pest. See label for other uses.

Suggested insecticides, rates, and restrictions for WIREWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: two or more wireworms per 10 shovels of soil, or one or more per grain bait trap.					
Bifenthrin **R**	0.15 to 0.3 oz per 1,000 feet of row	0.0023 to 0.0046 lb per 1,000 feet of row	30	12	Do not apply more than 0.3 lb ai per acre per season.
(Bifenture)					
(Brigade 2EC)					
(Discipline 2EC)					
(Capture 1.15G)	3.2 to 8 oz per 1,000 feet of row	0.002 to 0.006 lb	30	24	Apply in furrow or as a 5- to 7-inch T-band treatment. Do not apply more than 0.1 lb ai per acre per season as an at-plant application. Do not apply more than 0.3 lb ai per acre per season, including at-plant plus foliar applications.
(Empower 2EC)					

Table 2.2-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for WIREWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
(Capture LFR)	4 to 5.3 oz	0.047 to 0.062 lb		12	For mixing directly with liquid fertilizer to control soil insect pests. To be preplant incorporated. See label for specific rates.
Chlorethoxyfos **R**	3 to 4.5 oz per 1,000 feet of row	0.12 to 0.18 lb	30	48	Recommended as a T-band application.
(SmartChoice HC, Index)					
Cyfluthrin **R**	0.12 to 0.16 oz per 1,000 feet of row		21	12	See label for other uses and limitations.
(Baythroid XL)					
Ethoprop **R**	8 oz per 1,000 feet of row	7 lb	See label	48	Apply in a band over a closed seed furrow at planting. Mix granules with top half inch of soil.
(Mocap)					
Gamma-cyhalothrin **R**	0.66 oz per 1,000 feet of row	0.0025 lb ai per 1,000 feet of row	21	24	Suppression only.
(Proaxis)					
Lambda-cyhalothrin **R**	0.66 oz per 1,000 feet of row	0.005 lb ai per 1,000 feet of row	21	24	Apply in-furrow or as T-bands. See label for details and restrictions. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Taiga Z)					
(Warrior and Warrior II)					
Permethrin **R**	0.3 oz per 1,000 feet of row		30	24	Apply in-furrow or as a band.
(Ambush 25W)					
(Arctic 3.2EC)					
(Pounce 1.5G)	8 oz per 1,000 feet of row	0.13 lb	30	24	Should only be considered if heavy infestations are present and corn rootworm is not a concern in the field.
Phorate **R**	6 oz per 1,000 feet of row	1 lb	30	48	Do not place phorate granules in direct contact with seed; use T-band or band application. See label for details.
(Phorate 20G)					
Tebupirimphos + cyfluthrin **R**	3 to 6.7 oz per 1,000 feet of row	0.12 lb	30	48	Apply as a T-band or in-furrow. Incorporate into the soil surface.
(Aztec 4.67G)					
(Defcon 2.1G)					
Tefluthrin **R**	1.25 to 1.5 oz per 1,000 feet of row	0.125 to 0.15 lb	Not applicable	48	Apply the granules as an in-furrow treatment. Use 5 oz per 1,000 feet of row for severe infestations.
(Force 10G)					
(Force 6.5G)	1.8 to 2.3 oz per 1,000 feet of row	0.1 to 0.12 lb			Application may be by in-furrow, band, or T-band; see label for details.
Terbufos **R**	4.5 to 6 oz per 1,000 feet of row	0.75 to 1 lb	30	48	Can be applied as 7-inch band, but better control can be achieved by placing the granules in the furrow directly behind the planter shoe. Do not exceed 6.5 lb ai per acre.
(Counter 20G)					
Seed Treatments					
Clothianidin	0.25 or 1.25 mg per kernel				Not for planter box treatment.
(Poncho)					

Table 2.2-22. Compatibility of selected insecticides and herbicides.

Ambush 2EC					
Gramoxone	Micro-Tech/atrazine premix	Bicep	Micro-Tech	2,4-D	Dual
Atrazine	Princep	Banvel	Princep Caliber 90	Roundup	
Asana XL					
2,4-D (use jar test for physical compatibility)	Classic				
Velpar	Velpar L				
Lorsban 4E (EPA has canceled Lorsban's registration and it is no longer legal to use on food crops)					
(Preplant incorporated treatments				(At-planting or preemergence treatments)	
Nonpressure fertilizer solutions and/or with:				Nonpressure fertilizer solutions and/or with:	
Dual	Eradicane			Paraquat	Roundup
Micro-Tech	Atrazine				

This table is for your convenience. Always check the label before using any product or combination of products to avoid incompatibility problems. The label is a legal document and must be followed.

insect-attracting weeds at least 10 days before planting; timely field preparations, adjusting planting dates to avoid key insects, adjusting harvest dates to minimize crop losses, and possibly even irrigating to help plants compensate for stresses caused by insect feeding; using good crop management techniques (fertilization, weed management, etc.), and selecting well-adapted hybrids. The specific combinations of these techniques farmers use depend on the set of key insect pests they must manage. Some of these insect management tactics are often implemented by farmers because they are good crop production practices regardless of their insect management benefits.

A farmer who is scouting or having his or her fields scouted on a regular basis has a pretty good idea which pests occur most frequently on his or her farm. Pest history and knowledge of the relationship between a pest and a field characteristic can be used to select the best set of nonpesticide practices. For example, a farmer might be having repeated problems with western corn rootworm, European corn borer, black cutworm, and slugs. Other insect pest species rarely cause problems. From field records and discussion with the farmer, we learn that a field has been in no-till corn for two years and has had an increasing problem with common chickweed. Before the field was in corn, it was in a grass-legume mixture for five years. Observation of the field tells us that it is in a low-lying area near a stream.

Through research and experience, insect management experts have learned that corn rootworm populations build up in continuous corn and that rootworm larvae can survive only on corn roots. These experts also have learned that black cutworm populations often are associated with common chickweed. Slug populations are known to increase in perennial crop systems. European corn borer moths prefer areas with high humidity and low wind speed, such as those typically found in lowlands along streams and rivers. By understanding the environmental requirement of each pest, the farmer can select tactics to manage it.

A possible long-term non-insecticide-based management program for this set of pests might include the following: (1) to minimize corn rootworm population buildup, implement a crop rotation that includes only one or two years of corn; (2) to manage European corn borer in years when corn is grown, select a Bt corn hybrid with good agronomic traits for the farm; (3) use pheromone traps in the spring to capture black cutworm moths to know when they arrive in order to accurately time scouting for larval cutting damage; and (4) to manage slugs, consider including a cover crop, like cereal rye, in the rotation to help build natural enemy populations that can contribute to slug control, and consider planting into a standing green cover crop (seek out mentorship from an experienced colleague prior to doing this), and use IPM to focus your insecticide use because Penn State research has shown that broadcast and seed-applied insecticides can limit populations of predaceous insects that can help control slugs.

This is one of a number of possible insect management programs that could be used to manage this complex of pests. The specific set of management tactics a farmer selects is controlled by a number of variables, such as the farmer's equipment, the crop needs, time constraints, etc. Regardless of the design, insect management programs rarely achieve 100 percent success; therefore, insecticides may be needed as a backup when other methods fail to keep insect populations under control.

Table 2.2-23. Summary of soil insecticide activity spectrum for soil insects.

Corn Pest	BI	CH	ET	PE	PO	TC	TE	TF
Billbug	NR	NR	NR	NR	NR	NR	C	C
Black cutworm	C	C	C	C	NR	C	S	C
Corn rootworm	C	C	C	NR	C	C	C	C
Flea beetle	C	NR	NR	NR	C	NR	C	NR
Seedcorn beetle	C	NR	NR	NR	C	C	C	C
Seedcorn maggot	C	C	NR	NR	C	C	C	C
Symphylan	NR	C	NR	NR	NR	NR	C	NR
White grub	C	C	C	NR	C	C	C	C
Wireworm	C	C	C	NR	C	C	C	C

BI = bifenthrin (Capture), CH = chlorethoxyfos + bifenthrin (SmartChoice, Index), ET = ethoprop (Mocap), PE = permethrin (Pounce), PO = phorate (Phorate), TC = tebupirimphos + cyfluthrin (Aztec, Defcon), TE = terbufos (Counter), TF = tefluthrin (Force).
C = control, M = moderate control, S = suppression, NR = not registered.
Products with the same active ingredients are available in different formulations. Check the labels of products for specific pest species controlled. This table is provided for convenience, and should be checked against labels.

Selecting a Soil Insecticide

In Pennsylvania field corn, the primary reason for using a soil insecticide is to protect the crop from corn rootworm injury. Other pests occur much less frequently and under specific cropping patterns, but controlling these species with a broad-spectrum soil insecticide is unlikely to be profitable. Targeting these other, secondary pests with insecticidal seed coating might make more sense (see the next section). When selecting an insecticide to be used in the soil, whether in-furrow or as a seed treatment, you first must know which insects, if any, are likely to attack your crop in the coming year. Field history will be an important part of this decision, but new information from scouting will be vital. See Table 2.1-6 for field characteristics that increase the likelihood of a corn insect species. Table 2.2-23 shows the spectrum of soil insecticide activity on soil insects. Choose the soil insecticide that controls the pests likely to occur in your field.

Selecting a Commercially Applied Seed Treatment

Rather than a broad-spectrum soil insecticide, in some situations a commercially applied seed treatment may be preferred. Unfortunately, many seed companies are not giving growers much of a choice in whether or not they receive seed treatment because the great majority of field corn seed, particularly transgenic seed, is available only with a seed-applied insecticide and fungicide (see Table 2.2-24 for ranges of activity for seed treatments against seed-feeding insects). A seed treatment may be a good choice in first-year corn fields that were in pasture or hay the previous year. In these conditions, wireworm can cause stand reductions. Some seed treatment products can provide control of this pest species at a low cost per acre. Keep in mind, however, that recent research indicates that no-till fields planted with neonicotinoid seed treatments tend to have fewer natural enemies and worse slug problems (recall that slugs are mollusks, which often are not killed by insecticides), so manage your no-till fields for the most relevant pest that you have—perhaps not including seed treatments will help bring your slug populations under better control by natural enemies.

Foliar feeding insects such as black cutworm, true armyworm, stalk borer, sod webworm, flea beetle, and billbugs are best controlled with rescue applications of a foliar insecticide.

Corn Insect Pests

Below are descriptions of common insect pests of corn. More information on these and other insect pests is available on the Penn State Extension website or through your county extension office.

Armyworm

Armyworms (also known as true armyworm) do not appear to overwinter in Pennsylvania. They overwinter in southern states and upon emergence move northward on storm fronts from early May to early June. Eggs are deposited on the leaves of grasses and corn plants. Larvae hatch about a week later and develop over a period of approximately three weeks. Damage is observed most frequently in no-till fields that were sod the previous year or in fields where small grains cover crops (rye or wheat) were planted.

The first symptom of damage is ragged feeding on the top leaves, with wet, brown pellets in the area. True armyworm caterpillars hide inside the whorl during the day and are easily found by unrolling the innermost leaves. At night,

Table 2.2-24. Summary of the newer planter box and commercial seed treatment options for field corn.

	Active Ingredient		Insect Spectrum						
Trade Name	**Insecticide**	**Fungicide**	**BB**	**BCW**	**CRW**	**FB**	**SCM**	**SCB**	**WW**
Planter Box Options									
Concur, Latitude	imidacloprid					▲	▲	▲	▲
Commercial Seed Treatments. (Note that these products tend to make slug populations worse.)									
Acceleron 250	clothianidin	ipconazole, trifloxystrobin, and metalaxyl				▲	▲		▲
Acceleron 1250	clothianidin	ipconazole, trifloxystrobin, and metalaxyl	▲		▲	▲	▲		▲
Cruiser 5FS	thiamethoxam	Maxim XL		▲		▲	▲	▲	▲
Cruiser CRW	thiamethoxam	Maxim XL	▲	▲	▲	▲	▲	▲	▲
Poncho 250	clothianidin					▲	▲		▲
Poncho 1250	clothianidin		▲		▲	▲	▲		▲
Votivo*	clothianidin	—		▲			▲		▲

BB = billbug, BCW = black cutworm, CRW = corn rootworm, FB = flea beetle, SCB = seedcorn beetle, SCM = seedcorn maggot, WW = wireworm.
*Includes *Bacillus firmus* for control of soilborne plant-pathogenic nematodes.

they emerge to feed on leaf tissue. As feeding progresses, it becomes evident that caterpillars are avoiding the midrib. Heavily infested fields can have a caterpillar in the whorl of every plant, and heavily damaged plants have little leaf tissue left beyond the midribs. Corn fields likely to be attacked should be checked every few days during the first two weeks of June. In some years, like 2012, such heavy populations migrate into Pennsylvania that nearly every corn field is at risk. It is important to note that at this time, no Bt varieties offer protection against true armyworm caterpillars. Field treatments are not usually profitable unless 7 percent or more of plants are infested or showing damage symptoms. For more information on armyworms, consult the fact sheet "Armyworm as a Pest of Field Corn" available online at https://extension.psu.edu/armyworm-as-a-pest-of-field-corn or from your county extension office.

Corn Rootworm

Two species of corn rootworm (northern and western) are present in Pennsylvania. These species have similar life cycles, except that the western corn rootworm tends to hatch about three to five days earlier in the spring, and northern corn rootworm tends to be more common in northern states and likely northern parts of Pennsylvania. Corn rootworm beetles emerge during late summer (mid-July to mid-August) in most areas of the state and can remain until the first killing frost in the fall. In some southern areas of the state, beetles emerge as early as early July. It is at this time that corn fields should be scouted and the need for control determined for the next season.

Rootworm beetles begin depositing eggs in corn fields approximately two weeks after they emerge. They deposit the eggs in soil around the base of corn plants, and the eggs remain there until the following spring. Larvae begin hatching about mid-June in most areas of the state but may begin hatching earlier in southern areas. The larval stage inflicts the most severe damage to corn plants, so most chemical control is aimed at this stage.

Research data collected from numerous sites over the past years indicate that soil insecticides applied at planting for corn rootworm control have not increased yields significantly except in a small percentage of the fields (about 25 percent). There is no need to treat for rootworm if the problem is not in the field. Rootworms will not be a problem in the field if any crop other than corn was grown the previous year. Fields in continuous corn may develop problems, but these can be predicted by what happens to the plants in July and August of the previous year. Plants that fell over in July should be checked for damage to the root system. Badly damaged roots at this time indicate a problem in the field. In mid-August, examine the ear tips for beetles. For the publication "Western and Northern Corn Rootworm Management," which provides economic thresholds and other information, visit the Penn State Extension website or your county office.

Populations of western corn rootworm have developed resistance to all of the Bt varieties that are currently available, and these populations have become quite problematic in Illinois, Iowa, Minnesota, Nebraska, and South Dakota, among other states. In Pennsylvania, we have encountered a handful of fields that appear to have been colonized by rootworm larvae that are somewhat resistant to some of the Bt varieties.

Table 2.2-25. Summary of Bt traits available for insect control in corn hybrids.

The Handy Bt Trait Table for U.S. Corn Production, updated February 2020

Trait packages in alphabetical order (acronym that may be used)	Bt protein(s) in the trait package	Marketed for control of: BCW	CEW	ECB	FAW	SB	SCB	SWB	TAW	WBC	CR	Resistance confirmed to the combination of Bts in package (check local situation)	Herbicide trait GR	LL	E	Non-Bt Refuge % (cornbelt)
AcreMax (AM)	Cry1Ab Cry1F	x	x	x	x	x	x	x				CEW FAW WBC	x	x		5% in bag
AcreMax CRW (AMRW)	Cry34/35Ab1										x	NCR WCR	x	x		10% in bag
AcreMax1 (AM1)	Cry1F Cry34/35Ab1	x		x	x	x	x	x			x	ECB FAW SWB WBC NCR WCR	x	x		10% in bag 20% ECB
AcreMax Leptra (AML)	Cry1Ab Cry1F Vip3A	x	x	x	x	x	x	x	x	x			x	x		5% in bag
AcreMax TRIsect (AMT)	Cry1Ab Cry1F mCry3A	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x	x		10% in bag
AcreMax Xtra (AMX)	Cry1Ab Cry1F Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW FAW WBC NCR WCR	x	x		10% in bag
AcreMax Xtreme (AMXT)	Cry1Ab Cry1F mCry3A Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x	x		5% in bag
Agrisure 3010 (BR)	Cry1Ab		x	x			x	x				CEW	x	x		20%
Agrisure 3000GT & 3011A	Cry1Ab mCry3A		x	x			x	x			x	CEW WCR	x	x		20%
Agrisure Viptera 3110 (VR)	Cry1Ab Vip3A	x	x	x	x	x	x	x	x	x			x	x		20%
Agrisure Viptera 3111 (A4)	Cry1Ab Vip3A mCry3A	x	x	x	x	x	x	x	x	x	x	WCR	x	x		20%
Agrisure 3120 E-Z Refuge (BZ)	Cry1Ab Cry1F	x	x	x	x	x	x	x				CEW FAW WBC	x	Same as Bag Refuge		5% in bag
Agrisure 3122 E-Z Refuge	Cry1Ab Cry1F mCry3A Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x			5% in bag
Agrisure Viptera 3220 E-Z (VZ)	Cry1Ab Cry1F Vip3A	x	x	x	x	x	x	x	x	x			x			5% in bag
Agrisure Viptera 3330 E-Z	Cry1Ab Vip3A Cry1A.105/Cry2Ab2	x	x	x	x	x	x	x	x	x			x	CD = no; E2 = yes		5% in bag
Agrisure Duracade 5122 E-Z (D1)	Cry1Ab Cry1F mCry3A eCry3.1Ab	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x			5% in bag
Agrisure Duracade 5222 E-Z (D2)	Cry1Ab Cry1F Vip3A mCry3A eCry3.1Ab	x	x	x	x	x	x	x	x	x	x	WCR	x			5% in bag
Herculex I (HXI)	Cry1F	x		x	x	x	x	x				ECB FAW SWB WBC	x	x		20%
Herculex RW (HXRW)	Cry34/35Ab1										x	NCR WCR	x	x		20%
Herculex XTRA (HXX)	Cry1F Cry34/35Ab1	x		x	x	x	x	x			x	ECB FAW SWB WBC NCR WCR	x	x		20%
Intrasect (YHR)	Cry1Ab Cry1F	x	x	x	x	x	x	x				CEW FAW WBC	x	x		5%
Intrasect TRIsect (CYHR)	Cry1Ab Cry1F mCry3A	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x	x		20%
Intrasect Xtra (YXR)	Cry1Ab Cry1F Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW FAW WBC NCR WCR	x	x		20%
Intrasect Xtreme (CYXR)	Cry1Ab Cry1F mCry3A Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x	x		5%
Leptra (VYHR)	Cry1Ab Cry1F Vip3A	x	x	x	x	x	x	x	x	x			x	x		5%
Powercore [a] (PW) PW Refuge Advanced [b] (PWRA)	Cry1A.105/Cry2Ab2 Cry1F	x	x	x	x	x	x	x				CEW WBC	x	x		[a] 5% [b] 5% in bag
Powercore Enlist (PWE)	Same as Powercore	x	x	x	x	x	x	x				Same as Powercore	x	x	x	5% in bag
QROME (Q)	Cry1Ab Cry1F mCry3A Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW FAW WBC WCR	x	x		5% in bag
SmartStax [a] (SX,STX or SS) STX Refuge Advanced [b] (SXRA) STX RIB Complete [b] (STXRIB)	Cry1A.105/Cry2Ab2 Cry1F Cry38b1 Cry34/35Ab1	x	x	x	x	x	x	x			x	CEW WBC NCR WCR	x	x		[a] 5% [b] 5% in bag
SmartStax Enlist (SXE)	Same as SmartStax	x	x	x	x	x	x	x			x	Same as SmartStax	x	x	x	5% in bag
Trecepta [a] (TRE) Trecepta RIB Complete [b] (TRERIB)	Cry1A.105/Cry2Ab2 Vip3A	x	x	x	x	x	x	x	x	x			x			[a] 5% [b] 5% in bag
TRIsect (CHR)	Cry1F mCry3A	x		x	x	x	x	x			x	ECB FAW SWB WBC WCR	x	x		20%
VT DoublePRO [a] (VT2P) VT2P RIB Complete[b] (VT2PRIB)	Cry1A.105/Cry2Ab2		x	x	x	x	x	x				CEW	x			[a] 5% [b] 5% in bag
VT TriplePRO [c] (VT3P) VT3P RIB Complete [d] (VT3PRIB)	Cry1A.105/Cry2Ab2 Cry38b1		x	x	x	x	x	x			x	CEW NCR WCR	x			[c] 20% [d] 10% in bag
Yieldgard Corn Borer (YGCB)	Cry1Ab		x	x			x	x				CEW	x			20%
Yieldgard Rootworm (YGRW)	Cry38b1										x	NCR WCR	x			20%
Yieldgard VT Triple (VT3)	Cry1Ab Cry38b1		x	x			x	x			x	CEW NCR WCR	x			20%

Table 2.2-25. Summary of Bt traits available for insect control in corn hybrids (continued).

This table is borrowed from a summary compiled by Dr. Christina DiFonzo from the Department of Entomology at Michigan State University. This table accounts for products available across the U.S. and as a result includes pest species that are not relevant for Pennsylvania, particularly sugarcane borer and southwestern corn borer.
To the best of our knowledge, this information is current as of March 2022 but may be out of date for subsequent field seasons. Nevertheless, we feel there is value in sharing a snapshot of this dynamic information with growers to provide a sense of the diversity available. Talk with your seed providers about new trait combinations and associated refuge requirements that may be available.
Purchasing the correct Bt hybrid for your pest situation is imperative for maximizing profitability when using Bt. Consider local pest populations and the threat they pose when making seed choices. For example, in Pennsylvania there has been no risk from rootworms in rotated fields; thus, we see no need in first-year corn fields for Bt toxins targeting rootworms. Similarly, if you have not seen any evidence of European corn borer in your refuge acreage for a few years, do you need Bt hybrids targeting corn borer?
Note the column listing the non-Bt refuge requirement for each trait combination. Obeying refuge requirements is critical for resistance management; several instances of resistance have been found to Bt hybrids and these have been linked to improper refuge management. Different Bt proteins are active against different pests: mCry3A, Cry3Bb1, and Cry45/35Ab1 are active against rootworms only, while Cry1Ab, Cry1F, Vip3A, Cry1A.105, and Cry2Ab2 are active only against lepidopteran pests. See the table for products containing the different proteins.
Insect targets controlled or suppressed (and abbreviations): black cutworm (BCW), corn earworm (CEW), corn rootworm (CRW), European corn borer (ECB), fall armyworm (FAW), stalk borer (SB), sugarcane borer (SCB), southwestern corn borer (SWCB), true armyworm (TAW), western bean cutworm (WBC).
Research indicates that western corn rootworm can evolve resistance to the proteins targeting it (mCry3A, Cry3Bb1, Cry45/35Ab1, and eCry3.1Ab), and we have seen some evidence of this resistance in Pennsylvania. Given the capacity of rootworms to evolve resistance and to avoid problems from potential resistance, we recommend that growers limit growing corn in the same field to two years. Alternatively, growers should use corn hybrids with two or more traits targeting CRW.
Recent evidence from Eastern states indicates that corn earworm is evolving resistance to some of the proteins targeting it. We recommend scouting corn ears at the end of the season to assess damage and, if the damage is too high, using a different Bt protein the next year. Other evidence from Great Lakes states strongly suggests that Cry1F can struggle to control western bean cutworm; therefore, to be cautious, here we list Cry1F as only suppressing WBC.
Abbreviations for herbicide activity: DI = dicamba tolerant; GT = glyphosate tolerant; LL = LibertyLink, glufosinate-tolerant; RR2 = Roundup Ready 2, glyphosate-tolerant.
Abbreviations for Refuge placement: RIB = refuge in the bag; w/in = refuge acres need to be within the Bt field; adj = refuge acres can be in adjacent field.
For the hybrids you purchase: understand the expected level of control for each trait and refuge requirements for that hybrid, confirm that the seed you ordered in the fall is the same seed delivered in the spring, keep good planting records and save a representative sample of bags or bag tags, and, most important, if you see unexpected damage or poor performance of a trait (especially rootworm damage), contact your seed dealer and extension educator immediately so that the field can be visited while the problem is still fresh and samples can be taken. This is critical to identify and manage resistance to Bt, particularly for rootworms, corn earworm, and western bean cutworm.

This issue warrants close attention and those fields should be rotated more regularly to soybeans, alfalfa, or even sorghum.

Billbugs

The only billbug species of concern in Pennsylvania is the clay-colored billbug. Billbug larvae cannot develop in corn; thus, damage is limited to fields where nutsedge was a problem the previous year. Billbugs overwinter as adults in the soil, emerging during May and feeding on various kinds of grasses. Most feeding and subsequent corn plant damage occurs during May. Upon emerging from the soil, adults chew small cavities in the stems. Numerous stem punctures can severely retard or even kill small plants. Eliminating nutsedge from the field is the best pest management option. See the "Billbugs as Pests of Field Corn" fact sheet available online at https://extension.psu.edu/billbugs-as-pests-of-field-corn or through your county extension office.

Black Cutworm

Black cutworm is among the most difficult insect pests of corn to control. The insects overwinter in states to the south of Pennsylvania as pupae in the soil and free-living adults. In early spring, adults migrate into Pennsylvania, mostly on spring storm fronts. Black cutworms deposit their eggs in April and May, usually before the crop has been planted. Adults tend to be attracted to trashy fields or those where green weeds are present, particularly winter annuals such as common chickweed. Population sizes and risk associated with black cutworm can be gauged by trapping adult moths using pheromone traps, which are available from many suppliers. Once a "significant" flight of moths (eight moths over the course of two nights) is detected, degree-day accumulations (base 50°F) can be used to predict when larval cutting damage and scouting should occur (300 degree days). Due to the patchy distribution of black cutworm populations, rescue treatments based on scouting—not preventative insecticide applications—are the most economic approach for controlling black cutworm damage.

Newly hatched larvae feed on the weeds until new corn seedlings emerge. When larvae are small, their feeding may go unnoticed. Damage to plants becomes noticeable when the larvae are about one-half to two-thirds grown. If the soil is moist, cutworms cut the plants off just above ground level. Under dry conditions, however, larvae stay below ground level and cut the plants off (plants appear wilted).

Black cutworm develops from egg to adult in approximately two months. If the majority of larvae are 1.5 to 2 inches long, control does not help because most of their feeding is complete. For more information, see the "Black Cutworm" fact sheet available online at https://extension.psu.edu/black-cutworm or through your county extension office.

Brown Marmorated Stink Bug

This new pest has only been problematic in field corn for a few years around 2010 when populations exploded. In subsequent years, populations of this exotic pest species have settled in states to the south of Pennsylvania, but it is still present across most of the Commonwealth and remains a pest to watch. The damage caused by brown marmorated stink bug is still not well understood, nor is its economic impact, but it is clear that stink bugs accumulate on corn ears while ears are growing and filling in during July and August. Typically, these populations accumulate in the border rows of fields and have rarely been reported from entire fields. Populations are often heaviest adjacent to woodlots. Stink bugs feed directly through the husk on individual developing kernels, removing moisture. Stink bugs may also cause early season damage by feeding on growing seedlings. Both these types of feeding would seem to cause yield reductions, but their cost and the benefits of controlling stink bugs remain to be determined.

Corn Leaf Aphid

The corn leaf aphid is a minor pest of field corn in Pennsylvania. In recent years, this pest species has only become problematic when farmers "flare" their populations by applying insecticides (usually unnecessarily) to mid-season corn; this insecticide is usually included in a tank mix because something else, like a fungicide, is being applied to the field and adding an insecticide is cheap and easy. These unnecessary insecticide applications kill the beneficial insects that were keeping aphid populations in check naturally, and aphids that are not killed by the insecticide are free to reproduce without checks. From early July until fall, small colonies of corn leaf aphid can be found on or near tassels or whorl leaves in most corn fields. Unless the insect is widespread across the field, there is no need to instigate control measures. If 50 percent or more of the plants are infested with colonies of over 75 aphids each during late whorl and pollen shed, treatment is warranted. If left uncontrolled, the honeydew produced from their feeding falls onto the silks and prevents pollination, resulting in some barren plants. Late in the season, this pest can be challenging to control because of the amount of foliage in the field that will intercept the insecticide before it reaches the aphids. For more information, see the "Corn Leaf Aphid on Field Corn" fact sheet available online at https://extension.psu.edu/corn-leaf-aphid-on-field-corn or through your county extension office.

European Corn Borer

Historically, European corn borer has been a very significant pest of field corn; in recent years, however, Penn State researchers have documented a significant drop in their population. The exact cause of this drop is unknown, but it may be related to widespread adoption of Bt varieties. Bt hybrids

are very effective for controlling this pest species. Treatment with an insecticide is suggested only when more than 75 percent of the plants show whorl feeding in mid-June for the first brood, and when 50 percent of the plants have an egg mass by peak flight in the second brood. Corn planted before May 20 seldom is hurt by the second generation. If corn is planted late and is to be harvested for silage, borer damage is of little significance. The big loss occurs with corn varieties that have a tendency to drop ears.

The European corn borer completes two generations per year in most areas of Pennsylvania; however, in the mountain-valley region a single-generation European corn borer type co-occurs with the two-generation type. First-generation eggs are laid between late May and late June. Larvae hatching from the eggs can be found feeding in the whorl from early June to mid-July. Second-generation eggs are deposited on corn leaves from late July to late August. Larvae can be found feeding in the corn stalk during August and September. For more information on this pest, see European Corn Borer: Ecology and Management, available through your county Penn State Extension office.

Fall Armyworm

Fall armyworm is a pest late in the growing season. Larvae can be found feeding in the whorl of late planted corn in late July and during August. Fall armyworms overwinter along the Gulf of Mexico and the moths migrate to Pennsylvania. On arrival, the moths deposit egg masses onto green plants. The eggs hatch in about five to seven days and the young larvae feed in the whorl. Infested plants appear ragged with wet, brown, sawdustlike pellets scattered throughout the whorl. See the "Fall Armyworm as a Pest of Field Corn" fact sheet available online at https://extension.psu.edu/fall-armyworm-as-a-pest-of-field-corn or through your county extension office.

Flea Beetle

Survival of overwintering flea beetle adults is closely tied to temperatures during the winter months. For this reason, they seldom are a problem in the state, except for a few of the southeastern counties. Flea beetles complete many generations during the growing season, but only those generations attacking seedling corn are considered of economic importance. Flea beetles causing problems occur from early May to late June. Damage is caused by adults feeding on the leaves and transmitting bacterial wilt disease (Stewart's wilt).

Garden Centipede (Symphylan)

The garden symphylan is an occasional pest of field crops, but it is difficult to diagnose because of the pests' mobility within the soil. Most problems occur in the eastern half of Pennsylvania and some researchers believe that symphylan infestations are a symptom of other problems in a field rather than the main cause of a problem, though this hypothesis remains to be established with certainty. These creatures are difficult to study given their ghostlike tendencies. Symphylans overwinter in the soil as adults. In the spring, they move up into the top 6 inches of soil when the soil temperature rises to about 45°F. Symphylans deposit eggs in late April, May, and June. The eggs hatch two to three weeks later into tiny, white nymphs that resemble the adults except that they have only six pairs of legs. Control of garden symphylans involves preventive treatment before or at the time of planting. No rescue treatment is effective while the crop is growing. For more specific information, see the "Garden Symphylan as a Pest of Field Crops" fact sheet available online at https://extension.psu.edu/garden-symphylan-as-a-pest-of-field-crops or through your county extension office.

Japanese Beetle (Adults)

The Japanese beetle is the adult of one species of white grub. Its larvae are soil-feeding insects. The adults begin emerging around July 4 and move to many species of plants to feed on the foliage. Corn fields that are silking can be extremely attractive to the beetles. When populations of the pest are extremely high, the number of beetles feeding on corn silks can reduce pollination, resulting in poor kernel set. In many cases, however, damage is restricted to the field margin. Consider control only if the feeding is spread throughout the field. See the "White Grubs in Home Lawns" fact sheet available online at https://extension.psu.edu/white-grubs-in-home-lawns or through your county extension office.

Seedcorn Maggot

The adult flies of the seedcorn maggot emerge during late April and early May. Eggs are deposited on or near the soil surface and hatch in a few days. Problems can be especially severe when a green, living cover crop such as a rye or wheat crop or an old alfalfa stand is incorporated into the soil and planting occurs within two weeks. The maggots work their way into the soil in search of food and complete their development in seven to ten days. Three to five generations emerge each year. Any cultural practice that speeds up germination and plant emergence helps to reduce crop losses from maggots. For more information, see the "Seedcorn Maggot as a Pest of Field Corn" fact sheet available online at https://extension.psu.edu/seedcorn-maggot-as-a-pest-of-field-corn or through your county extension office.

Slugs

Several slug species produce one, and possibly a partial second generation per year. Slugs overwinter in either the egg or the adult stage, depending on species. Juvenile slugs hatch from eggs in the spring, soon after the soil warms, and remain

in the field all summer, though they burrow deep into the soil during the hot, dry portion of the summer. Slugs prefer environments with high humidity, relatively cool temperatures, and debris such as crop litter or manure for shelter from the sun. Penn State research has revealed that more diverse rotations have fewer slug problems and that predators, like ground beetles and wolf spiders, are key allies in slug control. Conserving these natural enemies can make slug control possible. For more information, consult the "Slugs as Pests of Field Crops" fact sheet available online at https://extension.psu.edu/slugs-as-pests-of-field-crops or through your county extension office.

Sod Webworms

Several species of sod webworms may occasionally be serious pests of field corn in Pennsylvania. The corn root webworm and bluegrass webworm are the two most common species. Damage usually occurs in corn fields previously in sod and is seldom uniform throughout the field.

Sod webworms overwinter as partially grown larvae. They start feeding in April and complete their development in early June. Young corn plants are damaged near ground level. Some plants may be cut off and partly dragged into the silk-lined tunnels made by the larvae. The damage is similar to that caused by the black cutworm. See the "Sod Webworms as Occasional Pests of Field Corn" fact sheet available online at https://extension.psu.edu/sod-webworm-as-occasional-pests-of-field-corn or through your county extension office.

Stalk Borer

The importance of the stalk borer has grown with the increase in no-till corn production in Pennsylvania. One generation occurs per year. Moths are present from late August to mid-October, and most of the eggs are deposited from mid-September to early October. Eggs are laid singly or in groups in folded, dead grass and weed leaves. They also may be deposited on corn plants. Moths are very attracted to orchardgrass and rye for egg deposition.

The stalk borer overwinters in the egg stage, and then hatches over a relatively long period of four to five weeks, from mid-May to mid-June. The larval stage lasts approximately nine to 12 weeks, and most corn damage occurs from early to late June. For more information, see the "Stalk Borer" fact sheet available online at https://extension.psu.edu/stalk-borer or through your county extension office.

Western Bean Cutworm

This pest was first detected in Pennsylvania in 2009. It has one generation per year and is unlike a typical cutworm because adults are active in late June, July, and August. Larvae (i.e., caterpillars) do not cut plants; rather, they feed on reproductive tissue of corn, including pollen, tassel, silk, and, particularly, developing kernels. Complicating matters is that its feeding on ear facilitates fungal infections. It can be difficult to control once caterpillars get inside the ear husk, so timing of insecticide application is crucial. An accepted economic threshold is 8 percent of plants having egg masses. Varieties of transgenic Bt corn can be used to target western bean cutworm. These varieties include those that express the Cry1F protein and are marketed as the Herculex trait, but recent reports from the Great Lakes states appear to indicate that this trait is not providing expected levels of control. In some areas, this trait is not providing any noticeable control, and insecticide applications remain necessary. See https://extension.psu.edu/western-bean-cutworm for more information on this pest and details of its current distribution.

White Grubs

This complex of insect species is a problem in home lawns and in corn planted into an old grass sod, particularly in bluegrass sod fields. In heavily infested sod fields, grubs can be found feeding on the roots of grasses about 1 to 4 inches deep in the soil. If the soil is dry, the insects migrate deep into the soil profile. When corn is planted into a grass sod, the food source (grass roots) is eliminated, leaving only the corn roots as food.

Injury symptoms include small, stunted plants, dead plants, and plants with a purple coloration (caused by the roots' inability to acquire phosphorus in the soil). Grubs are dirty white, soft bodied, and robust, with a brown head and six well-developed legs. For more information, see the "White Grubs in Home Lawns" fact sheet available online at https://extension.psu.edu/white-grubs-in-home-lawns through your county extension office.

Wireworm

Wireworms overwinter mainly in the soil as partially grown larvae and adult beetles. The larvae feed on underground plant parts for one to three years before reaching maturity. This insect is a pest for only two to three years after a field has been in a grass sod. Preventing wireworm damage requires treatment before or at planting. There are no practical or effective ways to control the pest after the crop has been planted. See the "Wireworms as Pests of Field Crops" fact sheet available online at https://extension.psu.edu/wireworms-as-pests-of-field-crops or through your county extension office.

Diseases

Corn diseases are strongly influenced by weather conditions and are difficult to predict. Most diseases in Pennsylvania are best controlled by using resistant hybrids and a balanced fertility program. Since major corn pathogens can overwinter in

Pennsylvania, residue management through tillage and crop rotation are common cultural practices for reducing sources of disease-causing organisms, particularly if disease was a problem the previous year.

In no-till plantings of corn, extra care must be taken to select disease-resistant hybrids. A high incidence of leaf blight can cause early death of plants, increase stalk lodging, and move harvest dates ahead; the incidence of stalk rots increases in blighted fields. Delayed harvest leads to greater field losses by reducing grain quality and yield and increasing the incidence of lodging. Harvest dates should be determined by crop maturity and grain moisture. If a field is blighted with severe ear rots, it may be economical to harvest at higher grain moisture and dry the grain to halt the infection rather than waiting for natural dry down.

As with most agronomic crops, it is important to realize that not all diseases cause economic losses and the timing of occurrence is as important as the disease. In corn, the most important leaves to protect after tasseling are from the ear leaf and farther up the stalk. As lesions increase on these photosynthetically active leaves, the amount of carbohydrates produced and transferred to the grain decreases. In severe cases of gray leaf spot, lodging will increase because the plant has pulled nutrients out of the stalk to devote to grain fill.

Fortunately for Pennsylvania, these conditions rarely occur. The advancement of genetic resistance and the use of crop rotation have reduced many of the yield-limiting diseases that would benefit from fungicide applications. Disease prevention or control with fungicides, other than seed treatments, is usually not economical and should be considered only on an individual basis.

Disease Management

Disease management should start with planting resistant hybrids, maintaining good soil fertility, practicing crop rotation, and monitoring fields for disease. In order to choose the correct resistant hybrids, knowing what diseases have been present is necessary. Therefore, growers should monitor the occurrence of disease and positively identify the diseases. The best method to monitor disease pressure is periodically scouting fields from planting through harvest. This way you can note the diseases present and disease pressure to better select hybrids the following year. Collect specimens of diseased materials that exhibit symptoms and send them to your local extension office or the Plant Pathology Disease Clinic for identification.

Although the use of foliar fungicides on corn has increased in Pennsylvania, results on yield impact have been mixed. The two most commonly applied foliar fungicide families, the triazoles and strobilurins, are both very effective in controlling diseases and have been marketed as increasing yield. Both the triazole and strobilurin families of fungicides use very site-specific modes of action and multiple fungal pathogens have developed resistance to one or, in some cases, both fungicide families. The continued use of these chemicals without adequate disease pressure or as prophylactic treatments will further increase the likelihood of resistance occurring. Once pathogens become resistant, there will be few chemicals to control them if the diseases become an economic threat.

Foliar Fungicide Considerations

Foliar fungicides can be a great tool for protecting a corn crop under adverse conditions and high disease pressure. Research has found that during certain application periods—namely, late vegetative through tasseling (V8–VT)—fungicides should not be applied with a non-ionic surfactant (NIS) adjuvant. NIS is a typical adjuvant used to facilitate the wetting and uniform spreading of pesticides across the leaf surface, as well as to increase plant uptake of the chemical. The use of NIS during the V8–VT stage of corn growth has increased the likelihood of "Hollow Husk," or arrested ear development. Arrested ear development is where the corn cob is shortened, there are fewer kernels per cob, and a dried, stunted cob tip results. In some cases, silk does not emerge from arrested ears, so the husk covers a shortened, bare cob. Often the plants affected will display a red or purple-red coloration that starts in the leaves, and, eventually, the stalk may also appear red or purple. This is due to an accumulation of sugars produced to fill developing kernels. This color change indicates poor kernel set, not just arrested ear syndrome.

Seed and Seedling Diseases

Corn planted into cold, wet soils can be in the ground for several weeks before emergence. Under these conditions, seeds and newly emerged seedlings are quite susceptible to attack by soilborne pathogens. The use of conservation tillage practices, particularly no-till, also results in seed being placed into cooler soils. As growers move to earlier planting dates and increase no-till planting, the use of fungicide seed treatments on corn has increased. Most commercially sold corn seed is treated with a fungicide or mixture of fungicides to aid in the control of early season diseases. While seed treatments offered each season change frequently, it is important to realize that technology is driving the use of new protection products on corn seed. Multiple modes of action are important to protect against both diseases and insects that can lead to disease issues. This will be especially important to keep in mind in the case of ordering custom seed treatments.

Leaf and Stalk Diseases

Leaf and stalk diseases can affect corn from emergence through physical maturity and beyond. Many diseases can reduce yield by parasitizing the plant and reducing grain

quality. Stalk rots can further cause yield loss through reduced stalk strength leading to increasing lodging. The following list of diseases, symptoms, and possible control options should be used only as a guide, with diagnosis done either by a local extension educator or the Penn State Plant Disease Clinic, 218 Buckhout Lab, University Park, PA 16802.

Anthracnose

Anthracnose can occur as early season leaf blight, later season leaf blight, late season top dieback, and/or stalk rot. The early season leaf blight can be found on corn after emergence when exposed to long periods of rain. Depending on the duration of plant stress, favorable plant growth conditions will help the plants recover. Later season leaf blight is usually observed on older (lower) leaves under conditions of high humidity. Symptoms may resemble those of nitrogen deficiency—yellowish-orange leaves with necrotic lesions. Fall symptoms include yellow to brown leaf lesions with wavy margins that spread from bottom leaves to top leaves. Top dieback may be evident later in the season, with many of the tassels broken off. Stalk rot will appear as shiny, black, linear streaks and blotches above the brace roots, leading to increased lodging and harvesting problems. Crop rotation is the best method of control.

Bacterial Leaf Blight (Stewart's Wilt)

Bacterial leaf blight (Stewart's wilt) can be prominent in many areas of Pennsylvania. The disease starts as pale green streaks that enlarge and turn brown or necrotic. The lesions often have wavy margins. Many commercial hybrids are resistant, but the disease can be an issue in sweet corn and popcorn. The disease-causing organism overwinters in the corn flea beetle and is transmitted by this insect. To predict the severity of this disease, the sum total of the mean temperatures for the months of December, January, and February indicates how well the flea beetle will survive the winter. If this sum is greater than 85°F, severe levels of bacterial leaf blight may be expected on highly susceptible hybrids. The most practical control for this disease is to plant resistant hybrids. In certain situations, chemical control may be necessary and must be directed toward controlling the corn flea beetle early in the season. Suggested controls of the corn flea beetle are listed in Tables 2.2-23 and 2.2-24.

Eyespot

Eyespot is characterized by round or oval spots with a tan/brown center and a brown or purple margin. The disease has been associated with cooler growing regions and may be controlled by planting resistant hybrids. Localized outbreaks have been observed in Pennsylvania.

Gray Leaf Spot

Gray leaf spot can be severe in fields of continuous no-till corn where air drainage is poor. Along with northern corn leaf blight, this is the most common foliar disease on corn in Pennsylvania. Fields along streams and rivers are particularly vulnerable to gray leaf spot because of the extended dew periods and high humidity. Disease symptoms are gray, rectangular lesions restricted by the leaf veins. An individual lesion resembles a paper match. This disease produces a toxin that requires sunlight; therefore the disease usually begins on the field edges and moves in. Control measures include rotation, tillage, and planting resistant hybrids.

Northern Corn Blight

Northern corn leaf blight is found throughout Pennsylvania and is characterized by long (1- to 6-inch), boat- or cigar-shaped, grayish-green to tan lesions. Lesions first appear on the lower leaves, progressing to the upper leaves over time. A few years ago, the incidence and severity of this disease increased with the occurrence of a new race of the pathogen. Higher levels of genetic resistance to the new pathogen have been incorporated into many hybrids, so yield losses have been limited in the last several years. Potentially, however, this disease can result in yield losses. Avoiding inoculum by rotation and/or tillage along with planting resistant hybrids are the best methods of controlling this disease.

Northern Corn Leaf Spot

Northern corn leaf spot is characterized by long, linear, chain-like lesions. The disease is observed throughout the state and only rarely causes a significant yield loss. Resistant hybrids and crop rotations are the best methods of control. Localized outbreaks have been observed in Pennsylvania.

Stalk Rots

Stalk rots are some of the most frequently observed corn diseases in Pennsylvania and usually can be traced to stress occurring at some critical point in the growing season. Moisture stress, along with stresses from other diseases, insect damage, and unbalanced fertilization are the most common factors associated with increased levels of stalk rot. Growers should select hybrids that stand well and attempt to minimize as many stresses as possible. There have been mixed results on the reduction of stalk rots using corn with the Bt (*Bacillus thuringiensis*) gene to decrease insect damage.

Tar Spot

This disease is relatively new to North America. It is characterized by glossy black, raised lesions on leaves, which may be surrounded by dead tissue as the disease progresses. In severe cases, tar spot may cause poor test weight, kernel fill, reduced silage quality, and other issues. While yield loss has been

significant in the Midwestern United States in select years, this disease was only first described in Pennsylvania in late 2020, increasing in distribution over the past couple of years. Nonetheless, it is not yet known if it will be a persistent threat to the region causing significant yield losses. Information regarding the management of tar spot is still limited, but crop rotation, residue management, hybrid selection, and appropriate use of fungicides may help limit the impact.

Ear and Kernel Diseases

Ear and kernel diseases are important to diagnose mostly due to the possibility of mycotoxin production (see "Moldy Corn and Toxin Production" below). In addition to toxin production, ear and kernel diseases cause reduced test weight and lower grain quality. Many of these diseases are often associated with insect or other damage to the ear. The best method for halting fungal growth is proper drying of the grain to 15 percent moisture or less, but neither drying nor heat will reduce mycotoxin levels if present.

Research has shown that the presence of the Bt (*Bacillus thuringiensis*) gene in corn has reduced the likelihood of ear and kernel diseases when compared to conventional hybrids. The production of Bt throughout the corn plant reduces insect damage to the ear, therefore minimizing that method of entry for the fungal pathogens. This is especially important when fungal pathogens producing mycotoxins have been an issue in the past.

Aspergillus Ear Rot

Aspergillus ear rot can become an issue during periods of drought, extreme heat, and corn ear injury from insect feeding. Although this is usually not an economic disease due to the fact it only colonizes a few kernels and not an entire ear, the pathogens involved can produce aflatoxins, which are extremely toxic compounds. The signs of the disease vary depending on the age of the infection, usually yellow-green fungal masses that turn to dark green or brown. If a high portion of ears are affected, the grain should be analyzed for mycotoxin concentrations.

Diplodia Ear Rot

Diplodia ear rot infects the plant just after flowering. Typical signs of Diplodia on the ear are a white or grayish mass of mycelium with black specks, pycnidia (survival structures), produced on the husks, kernels, cobs, and even the stalks. Diplodia does not produce mycotoxins, but it will significantly reduce grain quality. This disease overwinters within infected debris and can be troublesome in continuous no-till planted corn. Crop rotation and fall tillage have been known to reduce inoculum levels.

Fusarium Kernel or Ear Rot

Fusarium kernel or ear rot is most severe when hot, dry weather occurs at or just after flowering. The sign of this disease is often a whitish-pink fungal growth on kernels. This disease can also be seen on the tip of the ear associated with insect damage from earworms or other pests. In severe cases, the entire ear may exhibit signs of the disease. The major concern of this disease is the likelihood of mycotoxins produced in the corn grain. The Fusarium family of pathogens is very good at overwintering on debris; therefore, crop rotation and tillage will reduce inoculum levels in severely infested fields.

Gibberella Ear Rot

Gibberella ear rot is characterized as a reddish mold that starts at the tip and grows down the ear. In severe cases the entire ear may be affected. This disease is also associated with Gibberella stalk rot of corn as well as Fusarium head blight (scab) of wheat. The stalk rot is also characterized by reddish-pink discoloration inside the stalk. This disease can affect silage, and corn not properly ensiled can lead to mycotoxin issues in the feed. The association of *Gibberella* with both corn and wheat has led to high levels of Fusarium head blight in wheat following corn silage that had high levels of stalk rot. In severely infected corn fields, crop rotation and tillage will help to reduce inoculum levels.

Penicillium Ear Rot

Penicillium ear rot is commonly found on ears with insect, bird, or other damage. The sign of this disease is powdery green or blue mold between kernels, usually near the tip of the ear. This disease is not often considered economically important in corn for grain, but it can pose problems in both high-moisture corn and corn silage.

Moldy Corn and Toxin Production

In recent years, there have been many reports of corn fields in which 30 to 50 percent (occasionally a greater percentage) of the ears are colonized by fungi to such an extent that the problem is readily apparent to growers. Several species of fungi are responsible for producing these "moldy ears," and they are present wherever corn is grown in the state. Corn that dies prematurely usually shows excessively high moisture content in the grain, which favors fungal growth. Wet weather during the drydown period also promotes mold growth.

Once the crop is harvested, the combination of high grain moisture levels and warm temperatures will favor fungal growth. A kernel grain moisture content of 15 percent is the critical point for mold growth. Grain falling below this moisture content percentage does not support mold development; moisture levels greater than 15 percent do support mold growth. Temperatures in the range of 40 to 50°F restrict most mold growth, while temperatures of 70°F or above promote it.

Table 2.2-26. Efficacy of fungicides for corn disease control based on appropriate application timing.

Class	Active Ingredient	Product	Rate per Acre (fl oz)	Anthracnose Leaf Blight	Common Rust	Eyespot	Gray Leaf Spot	Northern Leaf Blight	Southern Rust	Tar Spot[1]	Harvest Restriction[2]
Strobilurin (FRAC 11)	Azoxystrobin 22.9%	Quadris 2.08 SC; multiple generics	6–15.5	VG	E	VG	E	G	G	NL	7 days
	Picoxystrobin	Aproach 2.08 SC	3–12	VG	VG–E	VG	F–VG	VG	G	G[3]	7 days
	Pyraclostrobin 23.6%	Headline 2.09 EC/SC	6–12	VG	E	E	E	VG	VG	NL	7 days
Triazole (FRAC 3)	Flutriafol 20.9%	Xyway LFR 1.92 SC Xyway 3D 2.5 SC	LFR: 7.6–15.2 3D: 5.8–11.8	NL	U	NL	G	VG	NL	NL	N/A
	Propiconazole 41.8%	Tilt 3.6 EC; multiple generics	2–4	NL	VG	E	G	G	F	NL	30 days
	Prothioconazole 41.0%	Proline 480 SC2	5.7	U	VG	E	U	VG	G	NL	14 days
	Tebuconazole 38.7%	Folicur 3.6 F; multiple generics	4–6	NL	U	NL	U	VG	F	NL	36 days
	Tetraconazole 20.5%	Domark 230 ME	4–6	U	U	U	E	VG	G	G[3]	R3 (milk)
Mixed Modes of Action	Azoxystrobin 13.5%; Propiconazole 11.7%	Quilt Xcel 2.2 SE; multiple generics	10.5–14	VG	VG–E	VG–E	E	VG	VG	NL	30 days
	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro 2.21 SE	13.7	U	U	U	E	VG	E	G–VG	30 days
	Cyproconazole 7.17% Picoxystrobin 17.94%	Aproach Prima 2.34SC	3.4–6.8	U	U	U	E	VG	G	G–VG[3]	30 days
	Flutriafol 19.3% Fluoxastrobin 14.84%	Fortix 3.22SC Preemptor 3.22SC	4–6	U	U	U	E	VG	VG	G–VG[3]	R4 (dough)
	Flutriafol 26.47% Bixafen 15.55%	Lucento	3–5.5	U	U	U	VG–E	VG	VG	G	R4
	Prothioconazole 16.0% Trifloxystrobin 13.7%	Delaro 325 SC	8–12	VG	E	VG	E	VG	G–VG	G–VG	14 days
	Prothioconazole 14.9% Trifloxystrobin 13.1% Fluopyram 10.9%	Delaro Complete 3.83 SC	8.0–12.0	U	U	U	E	VG–E	G–VG	VG	14 days
	Pydiflumetofen 7.0% Azoxystrobin 9.3% Propiconazole 11.6%	Miravis Neo 2.5 SE	13.7	U	U	U	E	VG–E	VG	G–VG	30 days

Table 2.2-26. Efficacy of fungicides for corn disease control based on appropriate application timing, (continued).

Class	Active Ingredient	Product	Rate per Acre (fl oz)	Anthracnose Leaf Blight	Common Rust	Eyespot	Gray Leaf Spot	Northern Leaf Blight	Southern Rust	Tar Spot[1]	Harvest Restriction[2]
Mixed Modes of Action	Pyraclostrobin 28.58%	Priaxor 4.17 SC	4–8	U	VG	U	VG	VG–E	VG	U	21 days
	Fluxapyroxad 14.33%										
	Pyraclostrobin 13.6%	Headline AMP 1.68 SC	10–14.4	U	E	E	E	VG	G	G–VG	20 days
	Metconazole 5.1%										
	Tetraconazole 7.48%	Affiance 1.5SC	10–14	U	G–VG	U	G–VG	G–VG	G	G[3]	7 days
	Azoxystrobin 9.35%										
	Trifloxystrobin 32.3%	Stratego YLD 4.18 SC	4–5	VG	E	VG	E	VG	G	NL	14 days
	Prothioconazole 10.8%										
	Flutriafol 18.63%	TopGuard EQ	5–7	U	F	U	VG	G–VG	G–VG	G–VG[3]	45 days
	Azoxystrobin 25.30%										
	Mefentrifluconazole 17.56%	Veltyma	7–10	U	U	U	VG–E	VG–E	VG	VG	21 days
	Pyraclostrobin 17.56%										
	Mefentrifluconazole 11.61%	Revytek	8–15	U	U	U	VG–E	VG–E	VG	VG	21 days
	Pyraclostrobin 15.49%										
	Fluxapyroxad 7.74%										

Efficacy categories: NR = not recommended; P = poor; F = fair; G = good; VG = very good; E = excellent; NL = not labeled for use against this disease; U = insufficient data to make statement about efficacy of this product for this disease.

1 Fungicide application timing is extremely important and needs to be made near the onset of the tar spot symptoms. Efficacy ratings based on limited site locations from 2018 to 2021.

2 Harvest restrictions are listed for field corn harvested for grain. Restrictions may vary for other types of corn (sweet, seed or popcorn, etc.), and corn for other uses such as forage or fodder.

3 A 2ee label is available for several fungicides for control of tar spot; however, efficacy data are limited. Check 2ee labels carefully, as not all products have 2ee labels in all states.

The Corn Disease Working Group (CDWG) has developed the above information on fungicide efficacy for control of major corn diseases in the United States. Efficacy ratings for each fungicide listed in the table were determined by field testing the materials over multiple years and locations by the members of the committee. Efficacy ratings are based on level of disease control achieved by product and are not necessarily reflective of yield increases obtained from product application. Efficacy depends on proper application timing, rate, and application method to achieve optimum effectiveness of the fungicide as determined by labeled instructions and overall level of disease in the field at the time of application. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and are based on a single application of the labeled rate as listed in the table. Many products have specific use restrictions about the amount of active ingredient that can be applied within a period of time or the amount of sequential applications that can occur. This table includes systemic fungicides available that have been tested over multiple years and locations. It is not intended to be a list of all labeled products.

This information is provided only as a guide. It is the responsibility of the pesticide applicator by law to read and follow all current label directions. No endorsement is intended for products listed, nor is criticism meant for products not listed. Members or participants in the CDWG committee assume no liability resulting from the use of these products. This table was revised in January 2020. A more updated version may be available.

Therefore, once the crop has been harvested, proper storage is critical.

Ear corn continues to dry when placed in properly designed cribs. The grain moisture content, however, should be 21 percent or lower when the crop is placed in the crib. High-moisture (greater than 25 percent) ear or shelled corn will heat up and develop molds rapidly; this corn should be ensiled immediately after harvest. Failure to do so will result in moldy, low-quality feed with a high risk for mycotoxin contamination.

Bird and insect damage to the ear before harvest can contribute to an increase in the incidence of ear molds. Ears in contact with the ground remain moist, promoting fungal growth. Excessive numbers of cracked or broken kernels promote mold growth, so proper combine adjustment also is important.

The primary concern in moldy corn is the production of mycotoxins. These poisonous components are by-products of fungal growth on the grain and can cause problems when fed to livestock, including poultry and horses. Although these toxins may not adversely affect cattle, the mycotoxins can be secreted into the milk. The toxins produced depend on the species of fungi growing on the ear. The potential for toxin production on corn occurs throughout the state. If you have experienced more than trace amounts of ear rots (moldy corn), consider having your grain tested for toxins, and follow recommended feeding practices if the results are positive. Contact your county extension educator for the names of public and private laboratories that conduct toxin tests.

Part II, Section 3

Sorghum Pest Management

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A well-planned pest management program for sorghum involves using multiple strategies. These should include preventive techniques such as monitoring, cultural controls, mechanical or physical controls, biological controls, and chemical control tactics. Preventive techniques may start with planting weed-free crop seed or choosing an alternative field or planting date. Regularly monitoring for pests is an important predictive tool. Rotating crops to disrupt pest life cycles and planting adapted varieties are good examples of cultural controls. Mechanical or physical controls may include tillage and mowing to disrupt certain pests. Biological controls may include using insect or disease organisms or even grazing animals in pasture production systems. Finally, chemical controls are an important component of many IPM systems, but their use should be based on sound management decisions. See Part II, Section 1 of this guide for more information about designing an integrated pest management program.

This guide provides chemical control suggestions based on university research and manufacturer recommendations. Management information for common sorghum pest problems is outlined in the following pages under "Weeds" and "Insects and Diseases." For more information on sorghum management and variety selection, see Part I, Section 5.

This publication strives for accuracy; however, omissions, inaccuracies, or dated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Weeds

Integrated Weed Management

An integrated approach to managing weeds in sorghum includes using cultural weed control, mechanical controls where applicable, and the judicious use of herbicides. Sorghum fields that are weed free for the first four to six weeks after planting will often yield the same as fields that are weed free for the entire growing season. This approach relies on starting with a clean seedbed and using residual soil-applied herbicides or mechanical control. Weeds that germinate with the crop but are controlled in a timely fashion (four to five weeks after planting) will also not impact final yields. This POST herbicide approach relies on effective and timely postemergence weed control. Also, it is not necessary to control all weeds in a field to achieve maximum yield.

Plant sorghum in a timely fashion to ensure the crop emerges uniformly and achieves rapid early growth. Seeding sorghum in narrow (15-inch) rows will improve overall weed control since the crop canopy will close the rows sooner and help to outcompete smaller weeds.

Chemical Weed Control

Herbicides are useful tools in most weed management programs. This chapter will focus on herbicides available for use in sorghum. They should be used to supplement, not replace, other methods or tools available. Definitions of terms you will find in this and similar publications on herbicides are provided below.

- Early preplant (EPP): The herbicide is applied at least 14 days before planting. EPP applications are generally used in no-till systems to control existing vegetation and provide residual control of early emerging weed species.
- Preplant: The herbicide is applied from zero to 14 days before planting. Preplant applications are generally used in no-till systems to control emerged weed species.
- Preplant incorporated (PPI): The herbicide is applied to the soil after primary tillage, but before planting, and mechanically mixed with the top 1 to 3 inches of soil with one of a variety of secondary tillage implements.
- Preemergence (PRE): The herbicide is applied to the soil after the crop is planted but before emergence. Rainfall or irrigation is needed to move the herbicide into the zone of weed seed germination before weed emergence for maximum effectiveness. If adequate rainfall for herbicide activation does not occur, a shallow cultivation or rotary hoeing should be done to control weeds that have germinated.
- Postemergence (POST): The herbicide is applied to the foliage of the crop and weeds after they have emerged.
- POST-directed (or directed): Refers to use of special spray equipment to direct the spray at the weeds but avoid it coming in contact with as much of the crop as possible.
- Residual activity: Herbicides that can be taken up by a plant's roots and shoots and injure or kill the plant. All soil-applied herbicides, as well as many postemergence herbicides, have residual activity. Herbicide degradation (breakdown) is the result of chemical and/or microbial activity, which can be dependent on soil pH, soil temperature, and soil moisture levels. Since degradation is dependent on a number of factors, length of residual activity can vary for herbicides based on the specific environmental conditions. Length of residual activity ranges from a few weeks to the entire growing season.
- Translocated herbicide: These herbicides move throughout the plant and can cause injury to parts of the plants that do not come in direct contact with the herbicide spray.
- Contact herbicide: These herbicides do not move throughout the plant. They cause injury only to those parts of the plant that come in contact with the spray. Spray coverage is more critical for contact than translocated herbicides.

- Nonselective herbicide: This refers to herbicides that control a broad spectrum of plant species, including most crops and weeds. These herbicides are generally used with no-tillage production and sprayed prior to planting when control of all plants is required.
- Herbicide-resistant hybrids: This refers to grain sorghum varieties that have been developed to withstand herbicide application that previously would have injured or killed sorghum. These enhanced varieties have been obtained through traditional breeding methods and exclusively include Inzen hybrids.
- Inzen grain sorghum is non-GMO and tolerant to nicosulfuron. The companion nicosulfuron product is Zest, a sulfonylurea herbicide (Group 2). Weed biotypes resistant to Group 2 herbicides are widespread in the region. Zest is labeled for use in DE and VA only.
- Igrowth grain and forage sorghum is non-GMO and imidazolinone tolerant, which allows the companion herbicide, ImiFlex (imazamox), to be applied PRE or POST for weed control. ImiFlex is a sulfonylurea herbicide (Group 2). Weed biotypes resistant to Group 2 herbicides are widespread in the region. ImiFlex is not labeled for use in NJ. This technology has not been evaluated by universities in the mid-Atlantic region.
- Double Team grain sorghum is non-GMO and tolerant to quizalofop. The companion quizalofop product is FirstAct. This technology has not been evaluated by universities in the mid-Atlantic region.

Herbicide-Resistant Weeds in Sorghum

Herbicide-resistant weeds are common in sorghum in the Mid-Atlantic region. Populations of herbicide-resistant weeds are selected for by repeated use of the same or similar herbicide over a period of time. Resistance is most likely to occur with residual herbicides having one specific mode of action. Weed species with a very high amount of seed production and a variable genetic pool are more likely to develop resistant populations—for example, common lambsquarters and pigweed species. Resistance management requires using herbicides with multiple modes of action and integrating mechanical (tillage and cultivation) and cultural weed control (cover crops, narrow row spacing, proper crop fertility, etc.) with chemical weed control.

Triazine Resistance (TR)

Weeds resistant to the Group 5 herbicides in the Mid-Atlantic region include common lambsquarters, redroot and smooth pigweed, and scattered populations of barnyardgrass, giant foxtail, goosegrass, and suspected populations of common ragweed and velvetleaf. Atrazine is the primary product that is problematic in sorghum. Careful selection of soil-applied and/or POST herbicides can provide good control of triazine-resistant (TR) weeds in sorghum.

For TR pigweed control, include a Group 15 herbicide for residual control (acetochlor, dimethenamid, or metolachlor) at planting. The Group 15 herbicides will suppress initial TR pigweed, but in most years a postemergence application of a non-triazine herbicide will be needed for full-season control.

For TR lambsquarters, some of the Group 15 herbicides will help suppress emergence (acetochlor), but they are not as active on lambsquarters as they are on pigweed. In addition, residual control can be obtained with products such as mesotrione.

ALS Resistance

Weeds resistant to the Group 2 (ALS) herbicides in the Mid-Atlantic region include several pigweed species, common and giant ragweed, common chickweed, horseweed, Italian ryegrass, giant foxtail, Johnsongrass, and shattercane. The principal issue with most ALS-resistant weeds in sorghum is lack of efficacy with POST ALS-inhibitor products. ALS-resistant broadleaves will not be controlled with halosulfuron or prosulfuron, other Group 2 herbicides. Group 2 herbicides can be used in a wide range of crops and application timings. Be sure to consider all herbicide applications when developing an herbicide-resistance management strategy.

Glyphosate Resistance

Weeds resistant to the Group 9 herbicide glyphosate in the Mid-Atlantic region include Palmer amaranth and waterhemp, common and giant ragweed, and horseweed. In sorghum, this could pose a problem in no-till if these biotypes are present at the time of burndown applications. If they are, be sure to include an alternate herbicide group to ensure these species are controlled prior to planting.

No-Till Weed Management

Successful production of no-till sorghum requires control of existing vegetation (cover crops and weeds) at planting and summer annual weeds that emerge after planting. Existing vegetation is traditionally controlled by the nonselective herbicides, which are often tank-mixed with residual herbicides. However, in many fields the presence of winter annual weeds, such as horseweed, requires an application while these plants are small and more susceptible to nonselective herbicides; this may require an application three to five weeks prior to planting. Some residual herbicides, such as Lumax or Bicep, can enhance burndown weed control. However, when the products are applied 14 to 28 days before sorghum planting, they provide residual weed control for only a week or two after planting sorghum. In fields with weeds that are difficult to control, an application of a nonselective herbicide and 2,

4-D should be used early to control winter annual weeds, and a second application of the residual herbicides may be needed at the time of sorghum planting. This second application will improve overall weed control.

Management of Johnsongrass and Shattercane

Johnsongrass, shattercane, and sorghum are closely related, and there are no satisfactory broadcast treatments currently available for controlling either species in grain sorghum. The only alternative available for rhizome Johnsongrass control is spot spraying glyphosate. Grain sorghum should not be planted in fields infested with Johnsongrass or shattercane.

Insects and Diseases

Foliar insects and diseases have not been major problems for sorghum in Pennsylvania. To protect against soilborne diseases, purchase seed that has been treated with an approved fungicide. Nevertheless, some common corn pests, including true armyworm, European corn borer, and fall armyworm, can infest sorghum and be problematic. Scouting is the key to detecting and managing these pest species. Check fields every 10 days or so for signs of insect feeding. If populations seem high, use Part II, Section 2: Corn Pest Management of this guide as a starting point for control options and be sure to check insecticide labels for details. Common broad-spectrum insecticides like Baythroid XL and Mustang Max are labeled for some insect pests on sorghum.

Table 2.3-1. Sorghum herbicides and their restrictions.

Trade Name	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide[1]	Water Quality Advisory[2]	Worker Reentry (hours)[3]
2,4-D amine 4S	2,4-D amine	4	several	—	—	48
2,4-D LVE 4E	2,4-D LVE	4	several	—	—	12
Aatrex, Atrazine 4L/90DF	atrazine	5	Syngenta, others	Yes	Yes	12
Aim 2EC	carfentrazone-ethyl	14	FMC	—	—	12
Basagran 4S	bentazon	6	Arysta LifeScience	—	Yes	12
Bicep II Magnum 5.5SC Bicep Lite II Magnum 6SC	*S*-metolachlor + atrazine + safener	15/5	Syngenta/Corteva	Yes	Yes	24
Callisto 4SC	mesotrione	27	Syngenta	—	—	12
Clarity 4S	dicamba	4	BASF	—	Yes	24
Coyote 3.67SC[4]	*S*-metolachlor + mesotrione	15/27	UPL	—	Yes	24
Degree Xtra 4.04ME/FulTime NXT 4.04EC	acetochlor + atrazine	15/5	Bayer CropScience/ Corteva	Yes	Yes	12
Dual Magnum 7.62EC	*S*-metolachlor	15	Syngenta	—	Yes	24
Dual II Magnum 7.64EC	*S*-metolachlor + safener	15	Syngenta/Corteva	—	Yes	24
Durango DMA/Duramax 4S	glyphosate	9	Corteva	—	—	4
Facet L 1.5L	quinclorac	4	BASF	—	—	12
FirstAct 0.83EC[5]	quizalofop	1	ADAMA	—	—	12
Gramoxone SL 2.0/3.0	paraquat	22	Syngenta	Yes	—	12–24
Halex GT 4.39EC	*S*-metolachlor + mesotrione + glyphosate	15/27/9	Syngenta	—	Yes	24
Huskie 2.06EC	pyrasulfotole + bromoxynil	27/6	Bayer CropScience	—	Yes	24
ImiFlex 1SL[6]	imazamox	2	UPL	—	Yes	4
Lorox 50DF/Linex 4L	linuron	5	NovaSource	—	—	24
Lumax EZ 3.67SC/Lexar EZ 3.7SC	*S*-metolachlor + mesotrione + atrazine	15/27/5	Syngenta	Yes	Yes	24
Maestro 2EC	bromoxynil	6	Nufarm	—	—	24
Outlook 6EC	dimethenamid	15	BASF	—	Yes	12
Peak 57WG	prosulfuron	2	Syngenta	—	Yes	12
Permit 75WG	halosulfuron	2	Gowan	—	—	12
Prowl H2O 3.8CS/Prowl 3.3E	pendimethalin	3	BASF	—	—	24
Roundup WeatherMAX 4.5S/ PowerMAX 4.5S	glyphosate	9	Bayer CropScience	—	—	4
Sandea 75WG	halosulfuron	2	Gowan	—	—	12
Sequence 5.25EW	glyphosate + *S*-metolachlor	9/15	Syngenta	—	Yes	24
Sharpen 2.85SC	saflufenacil	14	BASF	—	Yes	12
Starane Ultra 2.8L	fluroxypyr	4	Corteva	—	—	24
Verdict 5.57EC	saflufenacil + dimethenamid	14/15	BASF	No	Yes	12
Warrant 3CS	acetochlor	15	Bayer CropScience	—	Yes	12

Table 2.3-1. Sorghum herbicides and their restrictions (continued).

Trade Name	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide[1]	Water Quality Advisory[2]	Worker Reentry (hours)[3]
Yukon 67.5WDG	halosulfuron + dicamba	2/4	Gowan	—	—	12
Zest 75WDG[7]	nicosulfuron	2	Corteva	—	Yes	4

[1] Only licensed applicators may purchase and apply restricted-use pesticides. To become licensed, contact your state Department of Agriculture.
[2] These herbicides have properties that may result in groundwater or surface water contamination. Do not apply them in areas where soils are permeable or coarse and groundwater is near the surface. Practices should be followed to minimize the potential for dissolved runoff and/or runoff erosion. See the herbicide label for specific restrictions.
[3] If soil-applied products are injected or incorporated at application time, under certain circumstances the Worker Protection Standard allows workers to enter the treated area if they will have no contact with anything that has been treated. Personal protective equipment is required for early entry to treated areas if contact with treated soil, plants, or water is involved.
[4] Not labeled in MD and NJ.
[5] For use on grain sorghum containing the Double Team herbicide tolerance trait only.
[6] For use on grain and forage sorghum containing the igrowth herbicide tolerance trait only. Not labeled in NJ.
[7] For use on grain sorghum containing the Inzen herbicide tolerance trait only. Labeled in DE and VA only.

Table 2.3-2. Sorghum herbicide prepackaged mixes, or co-packs, and equivalents.

Trade Name	Components (ai/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai)	An Equivalent Tank Mixture of
Bicep II Magnum 5.5SC	2.4 lb *S*-metolachlor	15	2.1 qt	1.26 lb *S*-metolachlor	1.33 pt Dual II Magnum 7.64EC
	3.1 lb atrazine	5		1.63 lb atrazine	1.63 qt atrazine 4L
Bicep Lite II Magnum 5.5SC	3.33 lb *S*-metolachlor	15	1.5 qt	1.25 lb *S*-metolachlor	1.31 pt Dual II Magnum 7.64EC
	2.67 lb atrazine	5		1 lb atrazine	1 qt atrazine 4L
Degree Xtra 4.04ME	2.7 lb acetochlor	15	2.5 qt	1.67 lb acetochlor	2.1 qt TopNotch 3.2ME
	1.34 lb atrazine	5		0.83 lb atrazine	0.8 qt atrazine 4L
Coyote 3.67SC	0.33 mesotrione	27	2 qt	0.168 lb mesotrione	5.36 fl oz Callisto 4SC
	3.34 *S*-metolachlor	15		1.67 lb *S*-metolachlor	1.75 pt Dual II Magnum 7.64 EC
FulTime NXT 4.04CS	2.7 lb acetochlor	15	2.5 qt	1.67 lb acetochlor	2.1 qt TopNotch 3.2ME
	1.34 lb atrazine	5		0.83 lb atrazine	0.8 qt atrazine 4L
Halex GT 4.39EC	2.09 lb *S*-metolachlor	15	4 pt	1.05 lb *S*-metolachlor	1.11 pt Dual II Magnum 7.64EC
	0.209 lb mesotrione	27		0.11 lb mesotrione	3.33 oz Callisto 4SC
	2.09 lb glyphosate	9		1.05 lb ae glyphosate	30 fl oz Roundup PowerMAX 4.5S
Huskie 2.06EC	0.31 lb pyrasulfotole	27	13 fl oz	0.031 lb pyrasulfotole	0.031 lb pyrasulfotole
	1.75 bromoxynil	6		0.178 bromoxynil	11.4 fl oz Maestro 2EC (Buctril)
Lexar EZ 3.7SC	1.74 lb *S*-metolachlor	15	3 qt	1.3 lb *S*-metolachlor	1.36 pt Dual II Magnum 7.64EC
	0.224 lb mesotrione	27		0.168 lb mesotrione	5.36 oz Callisto 4SC
	1.74 lb atrazine	5		1.3 lb atrazine	1.3 qt atrazine 4L
Lumax EZ 3.67SC	2.49 lb *S*-metolachlor	15	2.7 qt	1.67 lb *S*-metolachlor	1.75 pt Dual II Magnum 7.64EC
	0.249 lb mesotrione	27		0.168 lb mesotrione	5.36 oz Callisto 4SC
	0.935 lb atrazine	5		0.625 lb atrazine	0.625 qt atrazine 4L
Verdict 5.57EC	5 lb dimethenamid	15	10 fl oz	0.38 lb dimethenamid	8.5 fl oz Outlook 6EC
	0.57 lb saflufenacil	14		0.045 lb saflufenacil	2 fl oz Sharpen 2.85L
Yukon 67.2WDG	0.125 lb halosulfuron	2	4 oz	0.03 lb halosulfuron	0.67 Sandea 75WG
	0.55 lb dicamba	4		0.125 lb ae dicamba	4 fl oz Clarity 4S

Table 2.3-3. Relative effectiveness of burndown herbicides for no-till sorghum.

Trade Name[1]	Site of Action Number	Alfalfa	Brome, Downy	Burdock, Common	Chickweed	Dandelion	Dock, Curly	Dogbane, Hemp; Dewberry; Milkweed; etc.	Fleabanes, Annual	Foxtail spp.	Garlic, Wild	Geranium, Carolina	Groundsel, Common[2]	Henbit/Deadnettle	Horseweed/Marestail[3]	Lambsquarters	Mustard spp.	Quackgrass	Ragweed, Common	Smartweed	Thistle, Canada	Violet, Field/Pansy
Atrazine	5	6	7	6	8	N	6	N	7+	7	N	**8+**	**9**	8	8	**9**	8	8	**9**	**9**	6	8
Dicamba	4	**9**	N	7	6	8	6	N	6	N	7	7	6	N	**8+**	**9**	N	N	**9**	7	8	6
Glyphosate[4]	9	7	**9**	7	**9**	6	6	7	7+	**9+**	7	8	**9**	6	8	**9**	**9**	8	**9**	7	8	6
Glyphosate + atrazine	5/9	7+	**9**	7+	**9**	7	6	N	7+	**9**	6	**8+**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	8	8
Glyphosate + dicamba	9/4	**8+**	**9**	7+	**9**	8	7	7+	8	**9+**	8	7	**9**	**8+**	**9**	**9**	**9**	**9**	**9**	**9**	**8+**	8
Gramoxone	22	N	7	N	**8+**	N	N	6	6	**9**	6	8	**8+**	7	7	8	**9**	6	8	**9**	6	8
Gramoxone + atrazine	22/5	7	8	6	**9**	N	6	6	7	**9**	6	**9**	**8+**	**9**	**8+**	**9**	8	8	**9**	7	7	8
Lumax/Lexar	5/15/27	6	N	8	**9**	8	8	N	8	6	N	**8+**	**9**	8	8	**9**	**9**	N	**8+**	7	7	7
Sharpen	14	N	N	N	6	7	—	N	7+	N	—	—	8	6	8	8	**9**	N	8	**9**	6	N
Sharpen + glyphosate	14/9	7	**9**	7	**9**	8	6	7	8	**9+**	—	8	**9**	6	**9**	**9**	8	8	**9**	**9**	8	6

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage. Delaying applications, thus treating larger weeds, will result in reduced control. Treatments are rated only for control of vegetation existing at the time of application. Add preemergence herbicides as required for the specific situation.

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = no local data available.

[1] See table of generic herbicides for additional formulations or trade names containing some of these same active ingredients; see Table 2.1-8 (glyphosates) and Table 2.1-10 (generics).

[2] Certain populations of common groundsel in the northeastern U.S. are resistant to triazine herbicides. Herbicide programs that contain Maestro (Buctril) provide good control of groundsel in crop.

[3] Roundup and other glyphosate products are not effective on glyphosate-resistant horseweed biotypes.

[4] Activity is reduced if applied in certain tank-mixes, Roundup with photosynthesis inhibitors such as triazine herbicides, and dicamba with Gramoxone. May still be tank-mixed for convenience, but burndown is improved if applied separately.

Table 2.3-4. Comments on burndown herbicides for no-till sorghum.

Trade Name*	Common Name	Site of Action Number	Sorghum Type	Product/A	lb ai/A
Atrazine 90DF or	atrazine	5	grain, forage	1.8–2.2 lb	1.6–2
Atrazine 4L				1.6–2 qt	
• Labeled for grain and forage sorghum. • Sorghum is not as tolerant as corn to atrazine; labels do not recommend use on coarse-textured soils and have precautions for use on medium- and fine-textured soils with less than 1% organic matter. • Controls small emerged annual broadleaves and some grasses. • Can be applied in liquid nitrogen as the carrier to improve burndown characteristics. • Tank-mixing with paraquat improves burndown control; however, this can antagonize glyphosate activity on some species. • Premixes containing atrazine include Bicep II Magnum, Degree Xtra, Lumax, Lexar, and others; atrazine rates differ among these products; refer to their labels for amount of atrazine. • Observe atrazine use restrictions; see atrazine entry in the soil-applied comments table. • *Restricted-use pesticide and water quality advisory.*					
Gramoxone SL 2.0	paraquat	22	grain	2–4 pt	0.48–1.0
Gramoxone SL 3.0				1.3–2.7 pt	0.49–1.0
• Apply in 20 to 60 gal/A for control of emerged annual weeds. • Addition of atrazine will often improve paraquat performance. • Adding dicamba improves control of large annual broadleaf weeds and alfalfa. Alfalfa control is improved by applying dicamba separately at least one day ahead of paraquat. • Can be tank-mixed with residual herbicides; adding atrazine to paraquat can improve control of fescue and certain other perennial sods. • Phosphate-containing liquid fertilizer solutions diminish paraquat activity if used as a carrier. • Do not use flood jet tips larger than size 20 or spacing greater than 40 inches. Paraquat use restrictions: • Only certified applicators who successfully complete the paraquat-specific training can mix, load, or apply paraquat. • Application of paraquat "under the direct supervision" of a certified applicator is no longer allowed; registered technicians cannot apply. • Required training at http://usparaquattraining.com; certified applicators must repeat training every 3 years. • *Restricted-use pesticide.*					
Glyphosate**	glyphosate	9	grain, forage	varies with formulation	0.75–1.5 ae
• Use at least 1.13 lb ae glyphosate or higher, especially if tank-mixing with residual herbicide. • Spring applications may be used for control of annual weeds. • Using low-volume sprays may allow for a reduced rate. • Can be tank-mixed with residual herbicides such as atrazine. When tank-mixing glyphosate with residual herbicides, apply in 10 to 20 gal water/A or 10 to 60 gal liquid fertilizer nitrogen/A. • Adding dicamba improves control of large annual broadleaf weeds, dandelion, and alfalfa. • Glyphosate may be applied in clear liquid nitrogen fertilizers and clear liquid complete-analysis fertilizers, but they may be less effective on certain annual grasses and perennials. • Do not use glyphosate with suspension-type liquid fertilizers.					
Lexar EZ 3.67SC	mesotrione +	27	grain	3 qt	0.168
	S-metolachlor +	15			1.3
	atrazine	5			1.3
Lumax EZ 3.7SC	mesotrione +	27	grain	2.7 qt	0.168
	S-metolachlor +	15			1.68
	atrazine	5			0.63
• Labeled for grain sorghum only. • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Apply prior to sorghum emergence; application to emerged sorghum will result in severe injury. • Applying either product less than 7 days before sorghum planting will increase the risk of crop injury, especially if irrigation or rainfall is received following the application. • Injury symptoms include temporary bleaching of newly emerging sorghum leaves or, in extreme conditions, stunting or partial stand loss. • Lexar or Lumax will improve performance of paraquat but can antagonize glyphosate on some weed species. • *Restricted-use pesticides and water quality advisory.*					

Table 2.3-4. Comments on burndown herbicides for no-till sorghum (continued).

Trade Name*	Common Name	Site of Action Number	Sorghum Type	Product/A	lb ai/A
Sharpen 2.85SC	saflufenacil	14	grain	1–2 fl oz	0.022–0.044

• Labeled for grain sorghum only.
• Sharpen may be applied as a preplant/burndown treatment from 14 days early preplant through preemergence timings. Do not apply to emerged sorghum.
• Apply Sharpen in a typical glyphosate burndown herbicide program to increase the weed control spectrum, including glyphosate-resistant horseweed.
• Include necessary additives methylated seed oil (MSO) plus nitrogen solution or ammonium sulfate (AMS) to the spray mixture.
• Verdict is a prepackaged mixture containing Sharpen.
• Sharpen will provide very short residual activity at the rates labeled for sorghum.

May need to be combined with residual treatment or postemergence program for complete no-till weed control program.
*See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.
**Consult specific product label for active ingredient concentration and application rate; various formulations of this herbicide are available (e.g., 1 qt/A glyphosate = 22 fl oz/A WeatherMAX); see Table 2.1-8 (glyphosates).

Table 2.3-5. Water solubility and longevity of soil-applied herbicides.

Relative Moisture to Activate	ppm	Estimated Water to Activate*
Low	>500 ppm (very soluble)	0.33 inch
Medium	250–500 ppm	0.33–0.5 inch
High	100–250 ppm	0.5–0.75 inch
Very high	<100 ppm	>0.75 inch

*More water (additional irrigation) may be necessary if soil is dry at time of application, for soils with higher clay content, or if high plant residues are present.
Solubility (parts per million; ppm) refers to how many microliters of the herbicide will dissolve in 1 liter of water. The less soluble the herbicide, the more moisture (rain or irrigation) is needed to activate the herbicide and move it into the root zone. Solubility is used as a guideline for rainfall or irrigation required within a short time after application. Moisture needed also depends on the soil moisture at time of application.

Trade Name	Solubility (ppm)	Relative Moisture to Activate	Duration of Residual Weed Control
Atrazine	33	Very high	4–5 weeks
Callisto	1,500	Low	2–4 weeks
Dual II Magnum	488	Medium	4–5 weeks
ImiFlex	4,160	Low	2–4 weeks
Linex/Lorox	75	Very high	4–5 weeks
Outlook	1,174	Low	2–4 weeks
Sharpen	pH 5: 30	Very high	1–3 weeks
	pH 7: 2,100	Low	
Warrant/TopNotch	223	High	2–4 weeks

Relative duration of residual control is for comparison only based on herbicide half-life (length of time it takes for half the herbicide to break down). Herbicide breakdown results from chemical and/or microbial activity. Since the speed of breakdown is affected by a number of factors, including soil pH, soil temperature, and soil moisture, duration can vary for herbicides based on the specific conditions. Residual activity is not the same as herbicide carryover. Duration of residual control assumes (1) good activation, (2) no excessive rain or irrigation, and (3) that weed species are sensitive to the herbicide(s) applied.

Premixes	Constituents
Bicep II Magnum	Dual II Magnum, atrazine
Bicep Lite II Magnum	Dual II Magnum, atrazine
Coyote	Dual II Magnum, Callisto
FulTime NXT	Topnotch, atrazine
Halex GT	Dual II Magnum, Callisto, glyphosate
Lumax EZ/Lexar EZ	Dual II Magnum, Callisto, atrazine
Verdict	Outlook, Sharpen

Table 2.3-6. Relative effectiveness of soil-applied herbicides.

Grasses

Trade Name*	Site of Action Number	Barnyardgrass	Bermudagrass	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wirestem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Atrazine	5	7	N	7	6+	7	N	N	6	6	6	N	7+	6	N
Bicep products	5/15	**9**	N	**9**	**9**	**9+**	N	6	6	**8+**	**9**	N	6	6	8
Degree Xtra, FulTime NXT	5/15	**9**	N	**8+**	**9**	**9+**	N	7	6	**8+**	**9**	N	6	6	8
Dual products, Cinch	15	**9**	N	**9**	**9**	**9+**	N	6	N	8	**8+**	N	N	6	8
Halex GT	15/27/9	**9**	N	**9+**	**9+**	**10**	**9**	**9+**	**9**	8	**9+**	**9**	**9**	**9**	**10**
ImiFlex[1]	2	8	N	7	8	N	N	6	N	7	7	N	N	6	N
Linex/Lorox	7	6	N	6	6	6	N	N	N	N	6	N	N	N	N
Lumax/Lexar	5/15/27	**9**	N	**9**	**9**	**9+**	N	6	6	**8+**	**9**	N	6	6	8
Outlook	15	**9**	N	8	**9**	**9**	N	6	N	7+	**8+**	N	N	6	8
Verdict	14/15	8	N	8	8	**9**	N	N	N	6	8	N	N	N	N
Warrant	15	**9**	N	**8+**	**9**	**9+**	N	7	N	7+	**8+**	N	N	6	8

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = no local data available.

Crop tolerance: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

Ratings are based on labeled application rates for the soil type and timely rainfall or irrigation to incorporate the herbicides. Ratings are also based on control three to four weeks after application. Length of effective control (residual control) beyond 4 weeks after application often declines. Results may differ with variations in soil type, temperature, rainfall, soil moisture, soil organic matter, and soil pH. For ratings on herbicide combinations not listed, see the component parts.

*Performance ratings based on full labeled rates. See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.

[1]For use on grain and forage sorghum containing the igrowth herbicide tolerance trait only. Not labeled in NJ.

Broadleaves

Trade Name[1]	Site of Action Number	Amaranth, Palmer/ Waterhemp[2]	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters[3]	Marestail/ Horseweed	Morningglory, Annual	Nightshade, Eastern Black	Pigweed	Ragweed, Common[2]	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf	Sorghum Tolerance, Medium Soils	Sorghum Tolerance, Coarse Soils
Atrazine	5	**9+**	8	6	**8+**	**9**	**9+**	**9**	**8+**	**9**	N	**9**	8	**9**	**9+**	8	E	G
Bicep products	5/15	**9+**	**9**	6	**8+**	**9**	**9**	**8+**	**8+**	**9**	**8+**	**8+**	8	**9**	**9**	**8+**	G	G
Degree Xtra[4], FulTime NXT	5/15	**9+**	**9**	6	**8+**	**9**	**9**	N	**8+**	**9**	**9**	**8+**	8	**9**	**9**	**8+**	G	FG
Dual products, Cinch	15	**8+**	N	N	N	N	6	N	N	7+	8	6	N	N	N	N	G	G
Halex GT	15/27/9	**8+**	—	**8+**	**9**	**9**	**9**	**9**	7+	**9+**	**9**	**8+**	8	**9**	**9**	**9**	G	F
Imiflex	2	N	N	6	8	8	8	—	7	8	9	7+	6	8	**9**	8	—[5]	—[5]
Lexar	5/15/27	**9**	**9**	7	**9**	**9**	**9**	**9**	**9**	**9**	**8+**	**8+**	**8+**	**9**	**9**	**9**	G	F
Linex/Lorox	7	**9**	6	6	7	7	**8+**	—	6	6	**9**	7+	6	7+	8	7	G	G
Lumax	5/15/27	**9**	**9**	6	**8+**	**9**	**9**	**9**	**8+**	**9**	**8+**	**9**	8	7+	**9**	**9**	G	F
Outlook	15	8	N	N	N	N	6	N	N	7+	8	6	N	N	6	N	G	G
Verdict	14/15	**9**	—	6	8	8	**9**	7+	8	**9**	**9**	8	8	7	**9**	8	G	G
Warrant	15	8	N	N	N	N	7	N	N	**8+**	**9**	7+	N	N	7	6	G	FG

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = no local data available.
Crop tolerance: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).
[1] See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.
[2] Biotypes resistant to Group 2 herbicides are common in the region; do not rely on Group 2 herbicides to provide effective control.
[3] Triazine-resistant (TR) biotypes of common lambsquarters and redroot/smooth pigweed are widespread in the region, and thus triazine (Group 5) herbicides are not effective against these populations.
[4] Degree Xtra may be less consistent on TR lambsquarters control compared to other acetochlor products.
[5] For use on sorghum containing the igrowth herbicide tolerance trait only.

Table 2.3-7. Comments on preplant or preemergence herbicides for conventional, min-, or no-till sorghum.

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Atrazine 4L or	atrazine	5	EPP, PPI, PRE	1–2 qt	1–2
Atrazine 90DF				1.1–2.2 lb	

• Sorghum is not as tolerant to atrazine as corn.
• Labeled for grain and forage sorghum.
• Atrazine may be used at 1 to 2 qt/A. Usually used in combination with other herbicides at 1 to 1.5 qt.
• Can be applied to emerged sorghum up to 12 inches tall.
• On highly erodible ground with less than 30% surface residue, no more than 1.6 qt may be applied prior to crop emergence.
• Heavy rain immediately following application tends to cause excessive concentrations in seed furrow, resulting in higher risk of injury.
• Do not apply to coarse-textured soils (i.e., sand, loamy sand, and sandy loam), or injury may occur.
• Do not apply to medium- or fine-textured soils having less than 1% organic matter, or injury may occur.
• *Restricted-use pesticide and water quality advisory.*

Atrazine Use Restrictions

Preplant or preemergence:
• On highly erodible soils (as defined by the U.S. Natural Resources Conservation Service):
• Fields where more than 30 percent of the soil surface is covered with plant residue at planting, apply a maximum of 2 lb ai/A as a broadcast spray.
• Fields where less than 30 percent of the soil surface is covered with plant residue at planting, apply a maximum of 1.6 lb ai/A as a broadcast spray.
• Apply a maximum of 2 lb ai/A as a broadcast spray.

Safety precautions for using atrazine:
• Do not mix, load, or apply within 50 feet of drinking water wells, livestock wells, agricultural drainage wells, irrigation wells, abandoned wells, or sinkholes.
• Do not mix or load within 50 feet of intermittent streams, perennial streams, rivers, lakes, or reservoirs.
• Do not apply within 200 feet of lakes or reservoirs.
• Do not apply within 66 feet of the points where surface water runoff enters intermittent streams, perennial streams, or rivers. The 66-foot buffers should be planted to a crop or seeded with grass on highly erodible land.

Bicep II Magnum 5.5SC	*S*-metolachlor +	15	EPP, PPI, PRE, EPOST	1.3–2.1 qt	0.78–1.26
	atrazine	5			0.99–1.6
Bicep Lite II Magnum 6SC	*S*-metolachlor +	15	EPP, PPI, PRE	1.1–1.5 qt	0.92–1.25
	atrazine	5			0.73–1

• Labeled for grain or forage sorghum.
• Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15).
• Not labeled for use on coarse-textured soils with less than 1% organic matter.
• Bicep Lite II Magnum and Cinch ATZ Lite are premixes of reduced-atrazine-rate ratios.
• See individual component sections in this table and atrazine use restrictions for additional information.
• *Restricted-use pesticides and water quality advisory.*

Callisto 4SC	mesotrione	27	EPP, PRE	6–6.4 fl oz	0.188–0.2

• Labeled for grain sorghum only.
• Do not apply to sorghum grown on sand, loamy sand, or sandy loam soils due to risk of sorghum injury.
• Do not apply to emerged sorghum, or injury will occur.
• Applying Callisto less than 7 days before planting will increase risk of crop injury, especially if irrigation or rainfall is received following application. Applying more than 7 days prior to planting will reduce risk of injury.
• Do not apply more than 21 days prior to planting.
• If applied prior to planting, minimize disturbance of the herbicide-treated soil during planting process.

Coyote 3.67SC	*S*-metolachlor +	15	EPP, PRE	2 qt	1.67
	mesotrione	27			0.165

• Labeled for grain sorghum only.
• Do not apply to sorghum grown on sand, loamy sand, or sandy loam soils due to risk of sorghum injury.
• Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15).
• Do not apply to emerged sorghum, or injury will occur.
• Applying Coyote less than 7 days before planting will increase risk of crop injury, especially if irrigation or rainfall is received following application. Applying more than 7 days prior to planting will reduce risk of injury.
• Do not apply more than 21 days prior to planting.
• *Water quality advisory*.

Table 2.3-7. Comments on preplant or preemergence herbicides for conventional, min-, or no-till sorghum (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Degree Xtra 4.04ME/ FulTime NXT 4.04CS	acetochlor +	15	EPP, PPI, PRE	2–3.7 qt	1.3–2.4
	atrazine	5			0.67–1.23
• Labeled for grain sorghum only. • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Do not apply preplant incorporated on course- or medium-textured soils. • These products can be applied to emerged sorghum up to 11 inches in height. • See individual component sections in this table and atrazine use restrictions and acetochlor restrictions. • *Restricted-use pesticides and water quality advisory.*					
Dual II Magnum 7.64EC	*S*-metolachlor	15	EPP, PPI, PRE	1–1.67 pt	0.96–1.6
• Labeled for forage and grain sorghum. • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Dual II Magnum/Cinch are similar in activity to Outlook or Warrant. • Dual II Magnum/Cinch contains a crop-safening agent. • Incorporation improves control of yellow nutsedge. • A prepackaged mixture with glyphosate is available as Sequence; label mentions preplant or preemergence application only. • *Water quality advisory.*					
Halex GT 4.39EC	*S*-metolachlor +	15	EPP, PRE	4–6 pt	1.05–1.57
	mesotrione +	27			0.105–0.157
	glyphosate	9			1.05–1.57
• Labeled for grain sorghum only; do not use in production of forage sorghum, sudangrass, or sorghum-sudangrass hybrids • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • For best results, apply to weeds before they are 4 inches tall and from 21 days before planting up through planting but prior to crop emergence. • Include NIS and AMS in the spray mixture. • Atrazine can be tank-mixed with Halex GT. • Not labeled for use on coarse-textured soils. • Do not apply Halex GT to ground that has been or will be treated with Callisto in the same season. • Do not apply more than 6 pt/A Halex GT per season (0.0157 lb mesotrione, 1.57 lb *S*-metolachlor, and 1.57 lb glyphosate). • Use caution if applying OP or carbamate insecticides 7 days before or after Halex GT application. • See label for additional use restrictions. • *Water quality advisory.*					
ImiFlex 1SL	imazamox	2	PRE	6–9 fl oz	0.047–0.07
• Labeled on igrowth grain and forage sorghum only; conventional sorghum hybrids will be killed if treated with ImiFlex. • ImiFlex is not labeled for use in NJ. • Do not plant igrowth sorghum in fields known to have ALS-resistant johnsongrass or shattercane and do not replant igrowth sorghum in consecutive years. • For best results, apply to weeds before broadleaf weeds exceed a height of 3 inches and grass weeds exceed 4 to 5 leaves. • ImiFlex should be applied with non-ionic surfactant (NIS), or crop oil concentrate (COC) except when mixed with 2,4-D or dicamba. • Do not tank mix Huskie or Peak as significant injury can occur. • ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides. • Regional data suggest that utility of ImiFlex is primarily for postemergence weed control. • Refer to label for additional information on use and restrictions. • *Water quality advisory.*					
Lexar EZ 3.7SC	*S*-metolachlor +	15	EPP, PRE	3 qt	1.3
	mesotrione +	27			0.168
	atrazine	5			1.3
Lumax EZ 3.67SC	*S*-metolachlor +	15	EPP, PRE	2.7 qt	1.68
	mesotrione +	27			0.168
	atrazine	5			0.63

Table 2.3-7. Comments on preplant or preemergence herbicides for conventional, min-, or no-till sorghum (continued).

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
• Labeled for grain sorghum only; do not use in production of forage sorghum, sudangrass, or sorghum-sudangrass hybrids • Applying less than 7 days before sorghum planting will increase the risk of crop injury, especially if irrigation or rainfall is received shortly after application. • The label does not recommend application to sorghum grown on sandy soils (sand, sandy loam, or loamy sands). • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Do not apply to emerged sorghum, or severe injury will occur. See individual component sections in this table and atrazine use restrictions. • *Lexar and Lumax are restricted-use pesticides and have a water quality advisory.*					
Linex 4L or	linuron	7	PRE	0.625–2 pt	0.25–1
Lorox 50DF				0.5–2 lb	
• Label does not specify sorghum type. • Apply as tank mixture with other labeled herbicides. • Apply after planting but before crop emergence. • Plant seed at least 1 inch deep, or crop injury may occur.					
Outlook 6.0EC	dimethenamid	15	EPP, PPI or PRE	12–21 fl oz	0.56–0.98
• Labeled for grain sorghum only; sorghum forage may be grazed or fed to livestock 60 days after application • Outlook is similar in activity to Dual II Magnum. • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Outlook may be applied to sorghum up to 12 inches tall; Outlook will not control weeds that have emerged. • Outlook is not recommended for coarse-textured soils due to limited residual control. • For early preplant applications or fields with heavy surface plant residue, increase Outlook rate; see label. • Verdict contains dimethenamid but will need additional Outlook added to provide consistent residual control; see Verdict label. • Incorporation improves control of yellow nutsedge. • *Water quality advisory.*					
Verdict 5.57EC	saflufenacil +	14	EPP, PPI, or PRE	10 fl oz	0.38
	dimethenamid	15			0.045
• Labeled for grain sorghum only; sorghum forage can be harvested, fed or grazed 70 days after application • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Verdict can be used in a burndown program or as a preemergence treatment. If used in a burndown program, it is best to include glyphosate and atrazine in addition to the necessary adjuvants (methylated seed oil [MSO] plus ammonium sulfate [AMS] or nitrogen solution) to improve control of emerged weeds including horseweed. • Amount of dimethenamid in Verdict is low, additional Outlook can be included to improve residual control; refer to label for additional Outlook rates. • Do not apply Verdict to emerged sorghum, or severe injury will occur. • The use of Verdict can follow a burndown application of Sharpen (1 fl oz/A). • *Water quality advisory.*					
Warrant 3CS	acetochlor	15	EPP, PPI, or PRE	1.5–3 qt	1.125–2.25
• Labeled for forage and grain sorghum • Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Acetochlor is similar in activity to Dual II Magnum or Outlook, but it is more active on certain broadleaf weeds. • Warrant may be applied on up to 11-inch-tall sorghum, but Warrant alone will not control emerged weeds. • For early preplant applications or fields with heavy surface plant residue, the rate of acetochlor may need to be increased; refer to label. • *Water quality advisory.* Acetochlor use restrictions: • Do not apply within 50 feet of any well where depth to groundwater is 30 feet or less, sands with less than 3% organic matter, loamy sands with less than 2% organic matter, or sandy loams with less than 1% organic matter. • Do not mix or load within 50 feet of any wells, streams, rivers, lakes, or reservoirs. • Do not apply under conditions that favor runoff or wind erosion of soil containing this product to nontarget areas.					

*See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.

**Application timing: EPP = early preplant (application prior to planting; in most cases, 7 to 14 days before planting); PPI = applied to conventionally tilled soil, then mechanically incorporated; PRE = preemergence (applied before the crop has emerged); EPOST = early postemergence (during the early stages of crop and weed growth). See specific herbicide label to determine correct rate for soil type and weed species found in each field. These treatments may be used in conventional, reduced-till, and no-till systems; treatments may be applied preplant-incorporated or preemergence, unless stated otherwise. Incorporation reduces the need for timely rainfall after application and may improve control of certain weeds. Higher rates for a given soil may be required for no-till. In no-till situations, burndown herbicides may be required to control weeds or cover crops present at time of application.

Table 2.3-8. Sorghum herbicide preplant or preemergence rates per acre based on soil texture and organic matter.

Trade Name	Site of Action Number	Unit	< 3% Organic Matter			> 3% Organic Matter		
			Coarse	Medium	Fine	Coarse	Fine	Inc. for No-till
Atrazine 4L	5	qt	Not recommended	1.6	1.6	Not recommended	1.6	Yes
Atrazine 90DF	5	lb	Not recommended	1.8	1.8	Not recommended	1.8	Yes
Bicep II Lite Magnum 6SC	5/15	qt	Do not use	1.5	1.5	Do not use	1.5	Yes
Bicep II Magnum 5.5SC	5/15	qt	Do not use	2.1	2.1	Do not use	2.1	Yes
Callisto 4SC	27	fl oz	Do not use	6.0	6.0	Do not use	6.0	No
Coyote 3.67SC	15/27	qt	Do not use	2.0	2.0	Do not use	2.0	No
Degree Xtra 4.04ME	5/15	qt	2.0	2.5	2.75	2.3	3.7	No
Dual II Magnum 7.64EC	15	pt	1.33	1.67	1.67	1.3	1.67	Yes
FulTime 4.04CS	5/15	qt	2.0	2.5	2.9	2.5	3.2	No
Halex GT 4.39EC	15/27/9	pt	Do not use	4.0	4.0	Do not use	4.0	No
ImiFlex[1]	2	fl oz	9.0	9.0	9.0	9.0	9.0	No
Lexar EZ 3.7SC	5/15/27	qt	Do not use	3.0	3.0	Do not use	3.0	No
Linex 4L	7	pt	1.0	1.25	1.5	1.25	1.75	No
Lorox 50DF	7	lb	1.0	1.25	1.5	1.25	1.75	No
Lumax EZ 3.67SC	5/15/27	qt	Do not use	2.7	2.7	Do not use	2.7	No
Outlook 6.0EC	15	fl oz	14.0	18.0	18.0	16.0	20.0	Yes
Verdict 5.57EC	14/15	fl oz	10.0	10.0	10.0	10.0	10.0	Yes
Sequence 5.25EW	9/15	pt	3.5	3.75	3.75	3.5	4.0	No
Warrant 3CS	15	qt	1.5	1.75	3.0	2.0	2.75	No

This table shows application rates for products applied alone. Rates may vary if tank-mixed with other products, if weed infestations are heavy, or if used in conservation tillage situations. See specific product label for additional information on application rates and use.

[1] For use on sorghum containing the igrowth herbicide tolerance trait only. ImiFlex is not labeled for use in NJ.

Table 2.3-9. Relative effectiveness of postemergence herbicides.

Grasses

Trade Name (rate/A)*	Site of Action Number	Barnyardgrass	Bermudagrass	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wirestem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Atrazine (1 qt)	5	7+	N	6	7+	6	N	N	6	7	6	N	7	6	7
Basagran (1 qt)	6	N	N	N	N	N	N	N	N	8	N	N	N	N	N
Facet (>26 fl oz)	4	8	N	7	7	N	N	N	N	N	6	—	N	N	8
FirstAct (8 fl oz)[2]	1	**9**	**9**	**8+**	**9+**[1]	**9**	**9**	**9**	6	N	**9**	**8+**	**9**	**9+**	**9**
ImiFlex (6 fl oz)[3]	2	**8+**	N	7	**8+**	**N**	7	**8+**	N	6	**8+**	6	N	**8+**	8
Linex/Lorox (POST-directed)	7	7	—	8	8	**8+**	—	8	—	6	8	8	—	—	8
Permit (0.67 oz)	2	N	N	N	N	N	N	N	N	**9+**	N	N	N	N	N
Yukon (4 oz)	2	N	N	N	N	N	N	N	N	**9+**	N	N	N	N	N
Zest (1.33 oz)[4]	2	**8+**	N	7	**9**	N	**8+**	**9**	7	**6**	**9**	**9**	**8+**	**9**	**9+**

*See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.

[1] Herbicide is less effective on yellow foxtail compared to giant foxtail. FirstAct rating for yellow foxtail = 7.

[2] For use on sorghum containing the Double Team herbicide tolerance trait only.

[3] For use on sorghum containing the igrowth herbicide tolerance trait only. ImiFlex is not labeled for use in NJ.

[4] For use on sorghum containing the Inzen herbicide tolerance trait only. Zest is labeled for use in DE and VA only.

Table 2.3-9. Relative effectiveness of postemergence herbicides (continued).

Broadleaves

Trade Name (rate/A)*	Site of Action Number	Amaranth, Palmer/Waterhemp[1]	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters	Morniglory, Annual	Nightshade, Eastern Black	Pigweed[1]	Ragweed, Common[2]	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf	Sorghum Tolerance
2,4-D (1 pt)	4	9	—	6	9	8	9	9	7	9	9	9	9	7	8	F
Aim (0.5 oz)	14	7	—	N	N	N	6	6	8	7	N	N	6	N	9	FG
Atrazine (1 qt)	5	9+	—	8	9	9	9+	9	9	N	9	8	8+	9+	8	FG
Basagran (1 qt)	6	N	7	N	9	9	8	N	N	6+	8	7	8	9	8+	FG
Clarity (8 fl oz)	4	9	—	7	9	9	9	9	8	9	9	9	8	9+	8	F
Facet (>26 fl oz)	4	N	—	—	—	—	6**	7	—	N	6**	6**	—	N	6**	G
Huskie (12.8 fl oz)	6/27	8	—	—	8+	7+	9	8	8+	8	8	7	—	8+	8	G
Imiflex (6 fl oz)	2	N	7	6	**9**	8	**8+**	7	**8+**	**9**	8	8	6	8	9	—[3]
Linex/Lorox (POST-directed)	7	9	—	—	8+	8+	8+	8	—	9	9	—	8	7	8+	FG
Maestro (1.5 pt)	6	N	—	8	9	9	9	8	9	7	7+	8	N	9	8+	F
Peak (0.75 oz)	2	N	—	—	N	8	8	7	—	9	9	6	6	7	8+	G
Permit/Sandea (0.67 oz)	2	N	—	6	9	N	N	6	6	9	9	8	7	8	9	G
Starane Ultra (6.4 fl oz)	4	7+	—	—	8+	—	—	8+	6	7+	8+	8+	—	—	8+	G
Yukon (4 oz)	2/4	9	—	6	9	9	9	9	8	9	9	8	8	9+	9	FG
Zest (1.33 oz)	2	N	—	7	7	7	6	7	N	**9**	6	N	N	8	7	—[4]

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = no local data available.

Crop tolerance: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

Ratings are based on labeled application rates and weeds at 4 inches in height. Results may differ with variations in weed size, temperature, rainfall soil moisture, and good spray coverage. Ratings are based only on postemergence activity and do not reflect possible residual activity. For ratings on herbicide combinations not listed, see the component parts.

*See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.

**Facet is labeled for suppression of this species on weeds less than 2 inches tall.

[1] Group 2 resistance has been confirmed for this species and is widespread in the region.

[2] Common ragweed biotypes resistant to Groups 2 and 14 herbicides have been confirmed in the region. Group 14 resistance is limited to the DelMarVa region and NJ.

[3] For use on sorghum containing the igrowth herbicide tolerance trait only.

[4] For use on sorghum containing the Inzen herbicide tolerance trait only.

Table 2.3-10. Comments on postemergence herbicides for sorghum.

Trade Name*	Common Name	Site of Action Number	Sorghum Type	Application Timing	Product/A	lb ai/A
The following herbicides can be added with postemergence herbicides to improve residual weed control. They will not provide control of emerged weeds, so they should be applied to weed-free soil surface or with products that will provide postemergence control of weeds present at time of application. Consult labels when tank-mixing with any herbicide. Some pesticides or adjuvants used in combination with the following herbicides could increase the chance of soybean injury.						
Dual Magnum 7.62EC	*S*-metolachlor	15	grain, forage	POST	1–1.67 pt	0.95–1.59
• Application timing is not specified on label. • Do not make more than one application per year • Make applications at least 75 days before harvest. • *Water quality advisory*.						
Prowl 3.3EC	pendimethalin	3	grain only	4-inch growth stage up to layby	2.4–3.6 pt	1–1.5
Prowl H2O 3.8CS					1.5–3 pt	
• Do not apply preplant incorporated or preemergence. • Do not make more than one application per year. • Do not apply on sorghum planted in double-row beds. • Do not replant sorghum if crop loss occurs. • Do not apply in liquid fertilizer. • Use only where adequate tillage is practiced to provide good seed coverage and plant seeds at least 1 inch deep, or crop injury may occur. • Prior to application, crop must be cultivated in such a manner as to throw at least 1 inch of soil over the base of the crop plants to prevent direct contact of Prowl with the zone of brace root formation.						
Warrant 3CS	acetochlor	15	grain, forage	before 11 inches	1.5–3 qt	1.125–2.25
• Acetochlor is similar in activity to Dual, but it is more active on certain broadleaf weeds. • Do not apply POST using sprayable fluid fertilizer, or injury will occur. • *Water quality advisory*.						
The following treatments are applied after sorghum emergence to control established weeds. See specific product label to determine correct rate for soil type and weed species found in individual fields.						
2,4-D amine 4S	2,4-D amine	4	grain only	6 to 15 inches; over 8 inches, drops recommended	1 pt	0.5 ae
• Sorghum is not as tolerant to 2,4-D as corn. • Apply between 6- and 15-inch-tall sorghum; if sorghum is over 8 inches tall, consider drop nozzles to keep spray off the foliage; do not treat during the boot, flowering, or dough stages. • Do not apply during periods of rapid growth (high soil moisture, warm temperatures, recent nitrogen application) due to increased risk of crop injury. • Make only one application per season to emerged sorghum. • 2,4-D is volatile; be cautious of off-target movement. • Surfactants can increase risk of injury; be cautious of surfactant use when tank-mixing with other herbicides. • 2,4-D does not provide any residual weed control.						
Aim 2EC	carfentrazone	14	grain only	4 inches to boot stage	0.5 fl oz	0.008
• At rate labeled for Aim 2EC, control is limited to weeds less than 3 inches tall, or morningglory with no more than 3 leaves, and velvetleaf up to 4 inches. • Application timing is 4 inches tall to just prior to boot stage, but application should be based on small weeds. • Tank-mix with other herbicides to increase weed control spectrum. • Aim does not provide residual weed control. • Use a non-ionic surfactant (NIS); do not use crop oil concentrate (COC) on emerged sorghum with either formulation.						
Atrazine 4L or	atrazine	5	grain, forage	before 12 inches	0.75–2 qt	0.75–2
Atrazine 90DF					0.83–2.2 lb	
• Apply before sorghum exceeds 12 inches; apply before weeds are 1.5 inches tall. • Sorghum is not as tolerant as corn to atrazine. • If no atrazine was applied prior to sorghum emergence, maximum application rate is 2 qt/A. If POST application is following an earlier atrazine application, total atrazine amount cannot exceed 2.5 lb ai. • Length of residual control depends on rate applied. • Add 1 qt crop oil concentrate (COC)/A to spray solution. Do not include oil if sorghum is under stress from prolonged cold, wet weather or other factors.						

Table 2.3-10. Comments on postemergence herbicides for sorghum (continued).

Trade Name*	Common Name	Site of Action Number	Sorghum Type	Application Timing	Product/A	lb ai/A
Atrazine use restrictions: • Do not mix, load, or apply within 50 feet of drinking water wells, livestock wells, agricultural drainage wells, irrigation wells, abandoned wells, or sinkholes. • Do not mix or load within 50 feet of intermittent streams, perennial streams, rivers, lakes, or reservoirs. • Do not apply within 200 feet of lakes or reservoirs. • Do not apply within 66 feet of the points where surface water runoff enters intermittent streams, perennial streams, or rivers. The 66-foot buffers should be planted to a crop or seeded with grass on highly erodible land. • *Restricted-use pesticide and water quality advisory.*						
Clarity 4S	dicamba (DGA salt)	4	grain, forage	spike to 15 inches; over 8 inches, drops recommended	8 fl oz	0.25 ae
• May apply dicamba up to 0.25 lb ae/A from spike stage but before it is 15 inches tall; for best performance, apply when sorghum is in the 3- to 5-leaf stage; use drop nozzles if sorghum is taller than 8 inches to avoid spray getting into the whorl. • Applications during periods of rapid growth may increase the risk of injury. • Under most situations, dicamba does not provide acceptable levels of residual weed control.						
Basagran 4S	bentazon	6	grain, forage	before heading	1.5–2 pt	0.75–1
• Apply to sorghum before heading or blooming; however, Basagran needs to be applied when weeds are small and actively growing. • Basagran is weak on pigweed species, including Palmer amaranth. • Tank-mix with atrazine to broaden spectrum of control. • Label recommends use of crop oil concentrate. • Split treatments may be required for yellow nutsedge and Canada thistle. • Basagran does not provide residual weed control. • *Water quality advisory*.						
Bicep II Magnum 5.5SC	*S*-metolachlor	15	grain, forage	3-leaf growth stage up to 12 inches	1.3–2.1 qt	0.78–1.26
	atrazine	5				0.99–1.6
• Use sorghum seed treated with an approved seed safener for chloroacetamide herbicides (Group 15). • Do not apply more than a total of 2.58 qt of Bicep II Magnum/A/season (i.e., 1.55 lb ai/A *S*-metolachlor and 1.97 lb ai/A atrazine). • If other products containing *S*-metolachlor have been applied, the combined total amount of *S*-metolachlor resulting from all applications must not exceed 1.7 lb ai/A/calendar year. • See individual component sections in this table and atrazine use restrictions for additional information. • Tank-mix with other herbicides to increase weed control spectrum. • Make applications at least 75 days before harvest. • Add 1 qt crop oil concentrate (COC)/A to spray solution. The addition of UAN or AMS is recommended to improve control. • *Restricted-use pesticides and water quality advisory.*						
Facet 1.5L	quinclorac	4	grain only	before 12 inches tall	22–32 fl oz	0.25–0.375
• Sorghum stage is from emergence up to 12 inches tall. • For best activity apply with atrazine at 0.5 to 1 lb ai to weeds less than 2 inches tall. • Add 1 qt crop oil concentrate or methylated seed soil for better weed control. Ammonium sulfate (AMS) or urea ammonium nitrate (UAN) can also be added for improved efficacy. Non-ionic surfactant (NIS) plus a nitrogen source (AMS) may be used when Facet is tank-mixed with products that restrict use of crop oil concentrates. • Facet can provide residual control of susceptible weed species.						
FirstAct 0.83EC	quizalofop	1	grain only		6-10 fl oz	0.039–0.065
• Labeled on Double Team grain sorghum only; conventional sorghum hybrids will be killed if treated with FirstAct. • Do not replant Double Team grain sorghum in consecutive years. • Do not use crop oils manufactured from vegetable oils; when tank-mixing with a broadleaf herbicide, always read both labels to make sure the right surfactant and concentration are used. • Two applications of FirstAct can be applied POST, but there must be an interval greater than 7 days between FirstAct applications. • Apply when grasses are within the recommended growth stage specified on the label; perennial grasses may require a second application for complete control. • To avoid antagonism (reduced grass control) from broadleaf herbicides, spray 2 to 3 days before the broadleaf herbicide or wait 7 days after the broadleaf herbicide application. • FirstAct must be applied at least 45 days before harvest						

Table 2.3-10. Comments on postemergence herbicides for sorghum (continued).

Trade Name*	Common Name	Site of Action Number	Sorghum Type	Application Timing	Product/A	lb ai/A
Huskie 2.06EC	pyrasulfotole +	27	grain, forage	3 leaves to 30 inches tall (prior to flag leaf emergence)	12.8–16 fl oz	0.031–0.038
	bromoxynil	6				0.18–0.22
• Application timing for sorghum stage is 3-leaf up to 30 inches and/or prior to flag leaf emergence. • Huskie label does not require a surfactant. Non-ionic surfactant (NIS) and ammonium sulfate (AMS) can be included under challenging growing conditions, or if tank-mix partner requires an additive. • Huskie can be tank-mixed with atrazine at 0.25 to 1 lb ai to improve and broaden spectrum of control; see atrazine entry in this table for precautions. • Addition of atrazine with Huskie is recommended for most situations. • Two applications of Huskie can be applied POST, but there must be an interval of 11 days between Huskie applications. • Crop injury can occur if Huskie is applied to fields treated with mesotrione (Lumax or Lexar). • *Water quality advisory.*						
ImiFlex 1SL	imazamox	2	grain, forage	before 20 inches	6 fl oz	0.047
• Labeled on igrowth grain and forage sorghum only; conventional sorghum hybrids will be killed if treated with ImiFlex. • ImiFlex is not labeled for us in NJ. • Do not plant igrowth sorghum in fields known to have ALS-resistant johnsongrass or shattercane and do not replant igrowth sorghum in consecutive years. • Do not tank mix Huskie or Peak as significant injury can occur; Do not make more than one application per year. • When adequate moisture is present, ImiFlex will provide residual activity of susceptible germinating weeds. • ImiFlex should be applied with non-ionic surfactant (NIS), or crop oil concentrate (COC) except when mixed with 2,4-D or dicamba. • Risk of crop injury is higher with early POST application or when cool weather conditions prevail. ImiFlex may cause temporal yellowing and stunting to igrowth sorghum but will recover quickly. • ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides. • *Water quality advisory*.						
Maestro 2E	bromoxynil	6	grain, forage	4 leaves to preboot stage	1–1.5 pt	0.25–0.375
• Apply to sorghum between 4-leaf stage and up to preboot stage; however, Maestro needs to be applied when weeds are small and actively growing. • When applied alone, Maestro does not need any additional surfactant; when tank-mixing, it can be applied in combination with surfactants or crop oil concentrate. • Maestro is weak on pigweed species, including Palmer amaranth. • Maestro does not provide residual weed control.						
Peak 57WG	prosulfuron	2	grain, forage	5 to 30 inches tall; over 20 inches, drops are recommended	0.5–1 oz	0.018–0.036
• Application timing is between 5 and 30 inches tall, and prior to head emergence; use drop nozzles after sorghum is 20 inches tall. Application should focus on weed size rather than crop stage. • Tank-mix with other labeled POST herbicides to broaden spectrum of control. • Peak applications should include a non-ionic surfactant (NIS). Crop oil concentrate can be included if tank-mix partner recommends COC. • Refer to label for additional information on use and restrictions. • Peak will provide residual control of susceptible species. • ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides. • *Water quality advisory*.						
Permit 75WG or Sandea 75WG	halosulfuron	2	grain only	2 leaves to before head emergence	0.67–1 oz	0.031–0.047
• Apply from 2-leaf stage but before grain head emergence. • The 0.67 oz rate is the standard rate for annual weed control. • Permit/Sandea is excellent on yellow nutsedge but weak on common lambsquarters. • Tank-mix with other labeled POST herbicides to broaden spectrum of control. Yukon is a prepackaged product containing Permit + dicamba. • Permit/Sandea should be applied with non-ionic surfactant (NIS); use of crop oil concentrate (COC) increases risk of crop injury. • Permit/Sandea will provide residual control of susceptible species.						

Table 2.3-10. Comments on postemergence herbicides for sorghum (continued).

Trade Name*	Common Name	Site of Action Number	Sorghum Type	Application Timing	Product/A	lb ai/A
• Permit/Sandea is an ALS (Group 2) herbicide and there is widespread resistance to Group 2 herbicides in the region. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides. • ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides.						
Starane Ultra 2.8L	fluroxypyr	4	grain, forage	3- to 7-leaf stage; use drops for 8-leaf to boot stage	0.4 pt	0.14
• Timing for broadcast application 3-leaf of sorghum through 7-leaf stage, and drop nozzles from 8-leaf to boot stage. • Can be tank-mixed with other labeled herbicides to broaden spectrum of control. • Surfactants not needed; Starane Ultra is applied alone, but surfactants may be used when required by tank-mix partner. • Two applications of Starane Ultra can be made. • Starane Ultra will not provide residual weed control.						
Yukon 67.5WDG	halosulfuron +	2	grain only	2 to 15 inches tall; use drops after 8-leaf stage	4–6 oz	0.03–0.045
	dicamba	4				0.125–0.188
• Yukon is a premix of halosulfuron (Permit) plus the sodium salt of dicamba. • Yukon can be applied from 2-leaf through 15-inch-tall sorghum; use drop nozzles after sorghum is 8 inches tall. • Include non-ionic surfactant (NIS); crop oil concentrate (COC) can be used, but it increases the risk of injury. • See entry for each component of Yukon for more information. • To prevent herbicide resistance, avoid repeated annual applications of soil-persistent ALS (Group 2) herbicides. • ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides. • Yukon will provide residual control of susceptible species.						
Zest 75WDG	nicosulfuron	2	grain only	5- to flag-leaf stage	0.67–1.33 oz	0.031–0.062
• Labeled on Inzen grain sorghum only; conventional sorghum hybrids will be killed if treated with Zest. • Zest is labeled for use in DE and VA only. • Do not plant Inzen grain sorghum in fields known to have ALS-resistant johnsongrass or shattercane. • Do not tank-mix with Huskie, or injury will occur. • Two applications of Zest can be applied POST, but there must be an interval of 7 days between Zest applications. • Zest should be applied with non-ionic surfactant (NIS) or crop oil concentrate (COC) except when mixed with 2,4-D or dicamba. • Risk of crop injury is higher with early POST application or when cool weather conditions prevail. Zest may cause temporal yellowing to Inzen sorghum but will recover quickly. • Zest does not provide residual weed control. • ALS-resistant biotypes of marestail/horseweed are found in the region and thus Group 2 herbicides will not be effective against these populations. To prevent herbicide resistance, avoid repeated annual applications of ALS (Group 2) herbicides. • *Water quality advisory*.						
POST-Directed						
Linex 4L or	linuron	6	label does not specify		1–2 pt	0.5–1
Lorox 50DF					1–2 lb	
• POST-directed application only. Do not apply over the top of emerged sorghum. • Use only when there is sufficient differential between height of sorghum and weeds so that weeds are thoroughly covered and upper leaves of sorghum and whorl are not exposed to spray or drift. • Include a non-ionic surfactant (NIS). • Weeds should be treated prior to 2-inch-tall grass weeds and 6-inch broadleaf weeds. • Linex/Lorox will provide residual control of susceptible species.						

*See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.

Table 2.3-11. Weed sizes for postemergence sorghum herbicides.

Grasses	Barnyardgrass	Bermudagrass	Crabgrass spp.	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wirestem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Trade Name (rate/A)	Height Range (inches) at Application													
Atrazine (2 pt)	L-s*	—	L-s	L-s	—	—	—	—	—	—	—	—	—	—
Basagran (2 pt)	—	—	—	—	—	—	—	—	8	—	—	—	—	—
Facet (>26 fl oz)	2	—	2	2	—	—	—	—	—	—	—	—	—	2
FirstAct (> 6 fl oz)[1]	6	3	6	4	6	—	—	8	—	6	4	10	—	6
ImiFlex (6 fl oz)[2]	3	—	3	3	3**	—	—	—	3**	3	3**	3**	—	3
Linex/Lorox (directed)	2	—	2	2	2	—	—	—	—	2	2	—	—	2
Permit (0.67 oz)	—	—	—	—	—	—	—	—	6	—	—	—	—	—
Yukon (4 oz)	—	—	—	—	—	—	—	—	6	—	—	—	—	—
Zest (0.67 oz)[3]	4	—	2	4	—	—	—	—	—	4	3	—	—	2

This table lists postemergence sorghum herbicides, their rates, and height ranges of weed species that are controlled or suppressed. This table is for "quick reference" only; refer to the herbicide label for additional information on application and timing.

— = weed size is not on the herbicide label.

*L-s species are on the atrazine label as suppression.

**Suppression only; additional control measures may be necessary.

[1] For use on sorghum containing the Double Team herbicide tolerance trait only.

[2] For use on sorghum containing the igrowth herbicide tolerance trait only. ImiFlex is not labeled for use in NJ.

[3] For use on sorghum containing the Inzen herbicide tolerance trait only. Zest is labeled for use in DE and VA only.

Table 2.3-11. Weed sizes for postemergence sorghum herbicides (continued).

Broadleaves	Amaranth, Palmer/ Waterhemp	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters	Morningglory, Annual	Nightshade, Eastern Black	Pigweed spp.	Ragweed, Com-mon	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf
Trade Name (rate/A)	Maximum Height at Application (inches)													
2,4–D[1]	4	—	—	6	3	4	6	2	4	6	6	—	—	2
Aim (0.5 oz)	2	—	—	—	—	3	3 lvs	4	4	—	—	—	—	4
Atrazine (2 pt)[1]	4	—	4	4	4	6	4	4	—	4	4	4	4	2
Basagran (2 pt)	—	4	—	10	10	2*	—	—	—	3	6	4	10	5
Dicamba1	4	—	4	4	4	4	4	4	4	4	4	4	6	2
Facet (>26 fl oz)	—	—	—	—	—	—	2	—	—	2-s	2-s	—	—	2-s
ImiFlex (6 fl oz)[2]	4	—	—	8	6	5	4	5	8	5	5	4*	5	8
Huskie (12.8 fl oz)	4	—	4	4	—	4	4	4	4	4	4	—	—	4
Linex/Lorox (directed)	6	—	—	6	—	6	6	—	6	6	—	6	6	—
Maestro/Buctril (1.5–2 pt)	—	—	4	10	6	8	4	6	2	6	6	—	6	5
Peak (0.75 oz)	4	—	4-s*	10	6	4	4-s*	—	5	10	3	3-s*	4	6
Permit/Sandea (0.67 oz)	—	—	3*	9	—	2*	—	—	3	9	3	3	2	9
Starane Ultra[3]	—	—	—	8	8	—	8	8-s*	—	8	8	—	—	8
Yukon (4–8 oz)	6	–	5	14	4	4	6	4	3–6	12	6	4	4	12

This table lists postemergence sorghum herbicides, their rates, and height ranges of weed species that are controlled or suppressed. This table is for "quick reference" only; refer to the herbicide label for additional information on application and timing.

*Suppression only; additional control measures may be necessary.

[1] No sizes given on label; sizes listed above are best estimates.

[2] For use on sorghum containing the igrowth herbicide tolerance trait only. ImiFlex is not labeled for use in NJ.

[3] Starane Ultra label states that susceptible broadleaf species will be controlled if treated before they reach a height of 8 inches.

Table 2.3-12. Herbicide effectiveness on perennial broadleaf weeds.

Trade Name (rate/A)	Site of Action Number	Artichoke, Jerusalem	Bindweed, Hedge	Dandelion	Dewberry spp.	Dock spp.	Dogbane, Hemp	Horsenettle	Ivy, Poison	Milkweed	Mugwort	Pokeweed	Thistle, Canada
2,4-D (1 pt)	4	7	8	8	6	7+	6	6	7	6	6	7	7+
Atrazine (1.5 lb ai)	5	N	7+	6	6	7	6	6	6	N	N	6	6
Basagran + atrazine (1 qt + 1 qt)	5/6	6+	7+	7	N	7+	6	7	7	N	N	6	8
Clarity (8 fl oz)	4	8	**8+**	7+	6	8	7	7	7+	6	7+	6	8
Huskie + atrazine (12.8 fl oz + 0.75 lb ai)	27/6/5	L-s*	—	L-s	—	L-s	—	—	—	—	—	—	L-s
ImiFlex (6 fl oz)[1]	2	7	7+	7	6	7	7	7	—	6	—	6	6
Peak + Clarity (0.75 oz + 8 fl oz)	2/4	—	—	—	—	—	L-s	—	—	—	—	—	L-s
Starane Ultra (0.4 pt)	4	N	8	N	N	N	**8+**	N	N	N	N	N	N
Yukon (6 oz)	2/4	7	8	8	6	7	7	7+	—	8	7+	8	**8+**
Zest (0.67 oz)[2]	2	6	7	N	8	N	6	6	—	6	N	7	6

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = no local data available. Performance ratings are based on seasonal control from a postemergence application in sorghum.

*Herbicide label lists this species for partial control.

[1] For use on sorghum containing the igrowth herbicide tolerance trait only. ImiFlex is not labeled for use in NJ

[2] For use on sorghum containing the Inzen herbicide tolerance trait only. Zest is labeled for use in DE and VA only.

Table 2.3-13. Spray additives and rainfastness for burndown and postemergence sorghum herbicides.

Trade Name	Adjuvant(s)[1]	Rate	Rainfastness (hours)
2,4-D amine	none, except in certain tank mixes	—	6–8
Aim/Cadet	non-ionic surfactant or	2 pt/100 gal	1
	crop oil concentrate	1 gal/100 gal	
	plus ammonium sulfate or	2–4 lb/A	
	nitrogen solution (optional)	2–4 gal/100 gal	
Atrazine	crop oil concentrate	1 gal/100 gal	1–2
Basagran[2]	crop oil concentrate	2 pt/A	8
	plus nitrogen solution or	1 gal/A	
	ammonium sulfate	2.5 lb/A	
Clarity[3]	non-ionic surfactant or	1 qt/100 gal	4
	crop oil concentrate plus	1 gal/100 gal	
	nitrogen solution	2–4 qt/A	
Facet	crop oil concentrate or	1 gal/100 gal	6
	methylated seed oil	1–2 pt/A	
	plus nitrogen solution or	2.5 gal/100 gal	
	ammonium sulfate	8.5 lb/100 gal	
FirstAct	crop oil concentrate or	1 gal/100 gal	1
	non-ionic surfactant	1 qt/100 gal	
	plus ammonium sulfate (optional)	2 lb/A	
Glyphosate (if not fully loaded with formulation adjuvants)	non-ionic surfactant	2 qt/100 gal	6
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Gramoxone SL	non-ionic surfactant or	1 pt/100 gal	0.5
	crop oil concentrate	1 gal/100 gal	
Huskie	non-ionic surfactant	1–2 qt/100 gal	1–6
	plus nitrogen solution or	1–2 qt/A	
	ammonium sulfate (optional)	0.5–1 lb/A	
ImiFlex	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate or	1–2 gal/100 gal	
	methylated seed oil	1–2 gal/100 gal	
	plus ammonium sulfate (optional)	12–15 lb/100 gal	
Maestro[4]	crop oil concentrate or	1 gal/100 gal	1
	nitrogen solution	1–4 gal/100 gal	
Peak	crop oil concentrate	1 gal/100 gal	4
Permit	non-ionic surfactant or	1–2 qt/100 gal	4
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate (optional)	2–4 lb/A	
+ 2,4-D, Clarity, or Maestro	non-ionic surfactant	1–2 qt/100 gal	
+ atrazine	crop oil concentrate	1 gal/100 gal	

Table 2.3-13. Spray additives and rainfastness for burndown and postemergence sorghum herbicides (continued).

Trade Name	Adjuvant(s)[1]	Rate	Rainfastness (hours)
Roundup/Glyphosate	non-ionic surfactant	2 qt/100 gal	6
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Roundup PowerMAX/Roundup WeatherMAX	no NIS/COC required	—	<1
	ammonium sulfate (optional)	8.5–17 lb/100 gal	
Sharpen	methylated seed oil	1 gal/100 gal	4
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate	8.5–17 lb/100 gal	
Yukon	non-ionic surfactant or	1–2 qt/100 gal	4
	crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate (optional)	2–4 lb/A	
Zest	non-ionic surfactant or	1 qt/100 gal	4
	crop oil concentrate	1 gal/100 gal	
	plus ammonium sulfate (optional)	2 lb/A	

[1] In general, non-ionic surfactants should contain at least 80% surface active agent; crop or vegetable oil concentrates should be nonphytotoxic, containing at least 15% approved emulsifier; nitrogen solution is an ammonium-based fertilizer such as 28%, 30%, or 32% N; and ammonium sulfate should be spray-grade dry ammonium sulfate (21-0-0). 10-34-0 also may be used with some products.
[2] Use crop oil concentrate if lambsquarters, common ragweed, Canada thistle, yellow nutsedge, or field bindweed are present. Include nitrogen solution if velvetleaf is the primary target.
[3] Do not use COC after sorghum exceeds 5 inches tall. Adjuvant addition depends on tank-mix partner.
[4] When Maestro is applied alone, spray additives generally are not needed and may cause excessive leaf burn.

Table 2.3-14. Grain harvest and forage restrictions for sorghum herbicides.

Trade Name	Forage	Grain
	(days after treatment)	
2,4-D amine 4S	30	30
2,4-D LVE 4E	30	30
Aatrex, Atrazine 4L/90DF	60 PRE/45 POST	60 PRE/45 POST
Aim 2EC	Not specified	Not specified
Basagran 4S	12	Not specified
Bicep II Magnum 5.5EC	60 PRE/not specified POST	75
Callisto 4SC	Not labeled for forage	Not specified
Cinch ATZ	60	Not specified
Clarity 4S	Do not graze or feed prior to mature grain stage	30
Degree Xtra 4.04ME	Not labeled for forage	60
Dual II Magnum 7.64EC/Cinch	75	75
Facet L 1.5L	Not specified	Not specified
FirstAct 0.83EC	Not labeled for forage	45
FulTime NXT 4.04CS	60	Not specified
Huskie 2.06EC	7	60
ImiFlex 1SL	Not specified	Not specified
Lexar EZ 3.7SC	Not specified	Not specified
Lorox 50DF/Linex 4L	90	75
Lumax EZ 3.67SC	45	Not specified
Maestro 2EC	45	Not specified
Outlook 6EC	60	80
Peak 57WG	30 graze/40 silage	60
Permit 75WG	30	30
Prowl 3.3EC	Not labeled for forage	Not specified
Prowl H2O 3.8CS	Not labeled for forage	Not specified
Sandea 75WG	30	30
Sharpen 2.85SC	70	Not specified
Starane Ultra 2.8L	40	70
Verdict 5.57EC	70	Not specified
Warrant 3CS	60	Not specified
Yukon 67.5WDG	30	30
Zest 75WDG	Not labeled for forage	30

Table 2.3-15. Comments on harvest aid herbicides for sorghum.

Trade Name	Common Name	Site of Action Number	Product/A	lb ai/A
Aim 2EC	carfentrazone	14	1 fl oz	0.016
• Use as a harvest aid to desiccate a limited number of broadleaf weed species. • Application shall be made when the crop is mature and the grain has begun to dry down. • Use with a crop oil concentrate at 1% v/v (1 gal/100 gal). • Can be tank-mixed with glyphosate to improve the spectrum of control. • Apply in 10 gal/A water. • Include necessary adjuvants and make sure spray coverage is sufficient, otherwise poor control will result. • Allow at least 3 days between application and harvest.				
Defol 5	sodium chlorate		4.8 qt	6
• Labeled to dry weeds and facilitate harvest. • Apply to sorghum 7 to 10 days before anticipated harvest, when sorghum is mature and ready to harvest. • Use lower rates when grain moisture is low and weather is clear and dry; use higher rates when conditions for desiccation are poor. • Apply in at least 5 to 10 gallons of water by air, and 10 to 20 gallons of water with ground application.				
Glyphosate	glyphosate	9	varies with formulation	0.75–1.5 ae
• Apply glyphosate to sorghum at 30% grain moisture. • Apply glyphosate in 10 to 20 gallons of water/A to control weeds that may interfere with harvest or to control perennials such as quackgrass or Canada thistle. • Allow a minimum of 7 days between application and harvest. • Do not use on sorghum grown for seed. • Will not control glyphosate-resistant weeds. • See Table 2.1-8 for more information on various glyphosate formulations.				

Treatments are based on broadcast application, not wiper-bar or rope-wick applications.

Part II, Section 4

Soybean Pest Management

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A well-planned pest management program for soybean involves using multiple strategies. These should include preventive techniques such as monitoring, cultural controls, mechanical or physical controls, biological controls, and chemical control tactics. Preventive techniques may start with planting weed-free crop seed or choosing an alternative field or planting date. Regularly monitoring for pests is an important predictive tool. Rotating crops to disrupt pest life cycles and planting adapted varieties are good examples of cultural controls. Mechanical or physical controls may include tillage and mowing to disrupt certain pests. Biological controls may include using insect or disease organisms or even grazing animals in pasture production systems. Finally, chemical controls are an important component of many IPM systems, but their use should be based on sound management decisions. See Part II, Section 1 of this guide for more information about designing an integrated pest management program.

This guide provides chemical control suggestions based on university research and manufacturer recommendations. Management information for common soybean pest problems is outlined in the following pages under "Weeds," "Insects," and "Diseases." For more information on soybean management and variety selection, see Part I, Section 6. This publication strives for accuracy; however, omissions, inaccuracies, or dated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Herbicide-Resistant Soybean Varieties

Some soybean varieties have been genetically enhanced to withstand herbicide applications that otherwise would injure or kill soybean. Some of these enhanced varieties were developed by genetic engineering, while others were developed through traditional breeding methods. Genetically enhanced varieties allow herbicides to be used that provide a broader spectrum of control than would otherwise be available while reducing the risk of crop injury. Herbicide-resistant soybean varieties include Enlist E3, LibertyLink, LibertyLink GT27, Roundup Ready, STS and Bolt, Xtend, and Xtendflex soybean.

Enlist E3 are genetically engineered (GMO) to allow preemergence and over-the-top application of 2,4-D choline, glyphosate, and glufosinate. Enlist One and Enlist Duo with Colex-D® technology are the only herbicides containing 2,4-D that are labeled for preemergence and postemergence use with Enlist soybean. Refer to www.enlist.com for stewardship requirements. In the Mid-Atlantic region, this technology is best suited for burndown application in no-till for control of

winter annual weeds, including horseweed/marestail. Over-the-top application and use in double-crop soybean is not encouraged due to greater concern for off-target movement.

LibertyLink soybeans are GMO soybeans developed for over-the-top application of glufosinate (Liberty, Interline, Scout, others), which is a broad-spectrum postemergence herbicide that does not provide residual weed control.

LibertyLink GT27 soybeans are GMO soybeans developed to be resistant to glufosinate, glyphosate, and an HPPD (Group 27) herbicide (Alite 27). Both glufosinate and glyphosate provide nonselective, broad-spectrum postemergence weed control. Alite 27 is not labeled for use in LL GT27 soybean in the mid-Atlantic region.

Roundup Ready soybeans were developed to allow over-the-top application of glyphosate for broad-spectrum control of annual broadleaf, grasses, and perennials weeds. Exclusive use of glyphosate has led to the selection of glyphosate-resistant weed biotypes.

STS and Bolt soybeans are non-GMO soybeans developed to be resistant to sulfonylurea herbicides (Group 2). STS were developed for their tolerance to Harmony (thifensulfuron) and Classic (chlorimuron). Bolt soybeans were developed for tolerance to Resolve (rimsulfuron). These varieties have the Roundup Ready trait as well. Weed biotypes resistant to Group 2 herbicides are widespread in the region.

Roundup Ready 2 Xtend and XtendFlex soybeans are genetically engineered (GMOs) to allow preemergence and over-the-top application of dicamba. Roundup Ready 2 Xtend soybeans are also Roundup Ready (glyphosate resistant), and XtendFlex soybeans are resistant to glyphosate and glufosinate (Liberty) Only certain dicamba products (Engenia, XtendiMax, and Tavium) specially formulated for reduced drift are labeled for Xtend soybeans. All other dicamba products are not allowed. In addition, a number of stewardship guidelines are required, including buffer zones, using low-drift nozzles, at least 10 GPA spray volume, and making applications only when certain environmental conditions exist to reduce the potential for off-target movement. In the Mid-Atlantic region, this technology is best suited for burndown application in no-till for control of winter annual weeds, including horseweed/marestail. Over-the-top application and use in double-crop soybean is not recommended due to greater concern for off-target movement.

Weeds

Integrated Weed Management

The foundation of soybean weed management is a residual soil-applied herbicide program followed by a timely postemergence herbicide. Make residual soil-applied herbicide applications as close to planting as possible and postemergence applications three to four weeks after planting, when weeds are 4 inches in height or less. This approach relies on effective and timely postemergence weed control. Also, it is not necessary to control all weeds in a field to achieve maximum yield; weeds that germinate with the crop but are controlled in a timely fashion (three to four weeks after planting) will not impact final yields. Weed populations of 20 to 30 weeds per 100 square feet are sufficient to cause yield loss. However, weed populations of 10 plants per 100 square feet will have no impact on final yield. The impact of weed populations between 10 and 20 per 100 square feet is difficult to predict. The decision to treat the field depends on the weed species present, crop vigor, weather conditions, and herbicide cost.

Planting soybean in narrow rows (15 inches or less) will improve overall weed control since the crop canopy will close the rows sooner than wide rows and help to outcompete smaller weeds.

Chemical Weed Control

Herbicides are useful tools in most weed management programs. They should be used to supplement, not replace, other methods or tools available. The following are definitions of terms you will find in this and similar publications on herbicides:

- Early preplant (EPP): These herbicides are applied at least 14 days before planting. EPP applications are generally used in no-till systems to control existing vegetation and provide residual control of early emerging weed species.
- Preplant: These herbicides are applied from zero to 14 days before planting. Preplant applications are generally used in no-till systems to control existing vegetation and should include residual herbicides.
- Preplant incorporated (PPI): These herbicides are applied to the soil after primary tillage but before planting, and mechanically mixed with the top 1 to 3 inches of soil with one of a variety of secondary tillage implements.
- Preemergence (PRE): These herbicides are applied to the soil after the crop is planted but before emergence. Rainfall or irrigation is needed to move the herbicide into the zone of weed seed germination before weed emergence for maximum effectiveness. If adequate rainfall for herbicide activation does not occur, a shallow cultivation or rotary hoeing should be done or postemergence herbicide applied to control weeds that have germinated.
- Early postemergence (EPOST): These herbicides are applied over the top of the crop and weeds after they have emerged. The herbicide is applied at an early stage, usually within three weeks of planting.
- Postemergence (POST): These herbicides are applied over the top of the crop and weeds after they have emerged.

- Residual activity/soil-applied herbicides: These herbicides can be taken up by an emerging plant's roots and shoots and injure or kill the plant. All soil-applied herbicides, as well as many postemergence herbicides, have residual activity. Length of residual activity ranges from a few weeks to the entire growing season but is typically three to five weeks.
- Translocated herbicides: These herbicides move throughout the plant and can cause injury to the parts of the plants that do not come in direct contact with the herbicide spray.
- Contact herbicides: These herbicides do not move throughout the plant. They cause injury only to plant parts that come in contact with the spray. These herbicides are usually called "burners" because they burn the point of contact. Spray coverage is more critical to maximize effectiveness for contact than translocated herbicides. Therefore, a spray volume of 15 gallons per acre or more is recommended.
- Selective herbicides: These herbicides control some species but not others such that weeds can be controlled without injuring the crop.
- Nonselective herbicides: These herbicides control a broad spectrum of plant species, including most crops and weeds. These herbicides are generally used with no-tillage production and sprayed prior to planting when control of all plants is required.

Herbicide-Resistant Weeds in Soybean

Herbicide-resistant weeds are common in the Mid-Atlantic region. Populations of herbicide-resistant weeds are selected for by repeated use of the same herbicide site of action over a period of time. Resistance is most likely to occur when one specific mode of action is used repeatedly, exclusively, and frequently. Weed species with a very high amount of seed production and a genetic variation are more likely to develop resistant populations—for example, common lambsquarters and pigweed species. Resistance management requires use of herbicides with multiple modes of action and integrating mechanical (tillage and cultivation) and cultural weed control (cover crops, narrow row spacing, proper crop fertility, etc.) with chemical weed control.

ALS Resistance

Weeds resistant to the Group 2 herbicides in the Mid-Atlantic region include several pigweed species, common and giant ragweed, common chickweed, horseweed, Italian ryegrass, giant foxtail, Johnsongrass, and shattercane.

Glyphosate Resistance

Weeds resistant to the glyphosate herbicide (Group 9) in the Mid-Atlantic region include Palmer amaranth and waterhemp, common and giant ragweed, and horseweed. In soybean, these species can be managed with alternative herbicides, including those in Group 14 (PPO herbicides), Group 5 (triazine), Group 10 (requires LibertyLink soybean), or Group 4 (requires Xtend or Enlist E3 soybean).

PPO Resistance

Weeds resistant to Group 14 herbicides include common ragweed. This is not widespread in the region, but there are a few fields with biotypes resistant to Groups 2, 9, and 14. The only options in these fields are preemergence applications of metribuzin; timely postemergence applications of glufosinate in LibertyLink soybean; dicamba (Engenia, XtendiMax, and others) applications in Xtend soybean; or 2,4-D (Enlist One or Enlist Duo) applications in Enlist E3 soybean.

Triazine Resistance

Weeds resistant to the Group 5 herbicides in the Mid-Atlantic region include common lambsquarters, Palmer amaranth, redroot and smooth pigweed, horseweed, scattered populations of barnyardgrass, giant foxtail, goosegrass, and suspected populations of common ragweed and velvetleaf. Metribuzin is the primary triazine herbicide in many premixes. For triazine-resistant (TR) pigweed control, include a Group 14 (flumioxazin or sulfentrazone) or Group 15 herbicide (acetochlor, dimethenamid, metolachlor, or pyroxasulfone) at planting.

For TR lambsquarters, some of the Group 15 herbicides will help suppress emergence (acetochlor and pyroxasulfone), but they are not as active on lambsquarters as they are on pigweed. Group 14 herbicides provide better control.

No-Till Weed Management

Successful production of no-till soybean requires control of existing vegetation at planting (cover crops and weeds) and summer annual weeds that emerge after planting. Existing vegetation is traditionally controlled by the nonselective herbicides, which are often tank-mixed with residual herbicides. However, in many fields the presence of winter annual weeds, such as horseweed, requires an application while these plants are small and more susceptible to nonselective herbicides; this may require an application three to five weeks prior to planting. Some residual herbicides, such as Canopy or Envive, can enhance burndown weed control. However, when the products are applied 14 to 28 days before soybean planting, they provide residual weed control for only a week or two after planting soybean. In fields with weeds that are difficult to control, an application of a nonselective herbicide and 2,4-D should be used early to control winter annuals weeds, and a second application of the residual herbicides should be made at the time of soybean planting. This second application will improve overall weed control.

In no-till situations, burndown herbicides may be required to control weeds or cover crops present at the time of application. See appropriate tables for the relative effectiveness of burndown herbicides.

Fall applications are one strategy to manage difficult-to-control winter annuals. Winter annuals are more susceptible in the fall because they are smaller and have not been stressed by cold weather, and air and soil temperatures are higher than in early spring so plants are "actively" growing. However, many species may have a prolonged germination period and seedlings could emerge after a fall application. There has been interest in including a residual herbicide with the nonselective to reduce the likelihood of weed emergence. Products labeled for this use are Authority First, Authority XL, Autumn Super, Canopy EX, Envive, Fierce XLT, Gangster, and Valor XLT.

Local research has not found a residual herbicide that will consistently provide residual control over the winter and early spring, as most fields will still require an additional burndown application before planting. Furthermore, this approach leaves the soil surface bare over the winter and early spring months and therefore exposed to wind and water erosion.

Residual Herbicides That Can Enhance Preplant Burndown Control

Products containing cloransulam (FirstRate), chlorimuron (Classic), and thifensulfuron (Harmony) have some activity on emerged broadleaf weeds and can improve preplant burndown control. However, these products will not control ALS-resistant (Group 2) weeds. When using an herbicide with one of these active ingredients as part of a burndown program, use full labeled rates, follow label recommendations for adjuvants, and apply to small, actively growing weeds. If relying on these herbicides to provide residual weed control, applications should be made within seven to ten days of planting. Prepackage mixtures containing these specific active ingredients include the following:

- Cloransulam (FirstRate): Authority First, Gangster, Sonic, and Surveil
- Chlorimuron (Classic): Authority XL, Canopy DF/Blend, Canopy EX, Envive, Fierce XLT, Synchrony XP, and Trivence
- Thifensulfuron (Harmony): Afforia, Canopy EX, Envive, Synchrony
- Flumioxazin (Valor): Afforia, Envive, Fierce/Fierce EZ, Fierce XLT, Gangster, Surveil, and Trivence

Weed Management for Double-Crop Soybean Planted after Wheat or Barley

Weed control for soybean grown after a small grain crop has additional considerations. As with full-season no-till, the fields should be treated to kill all weeds present at the time of planting. This includes winter annual weeds as well as summer annual weeds. The situation may involve controlling weeds that have been cut off and damaged during the small grain harvest operation, leaving little leaf surface to be treated. Local research indicates that paraquat alone or in combination with 2,4-D (in Enlist E3) or dicamba (Xtend) can be effective at controlling horseweed "stumps" or those "topped" at harvest. Plants may be present that are resistant to both glyphosate and Group 2 herbicides (e.g., Palmer amaranth and horseweed). Summer annual grass species may be present that require an application of glyphosate or a Group 1 herbicide (Select, etc.). Herbicides that delay soybean planting, such as Sharpen on coarse-textured soils, are seldom used. Local research shows that a combination of glyphosate plus glufosinate (Liberty, Interline, Scout, others) before planting provides good control of many troublesome species without impacting grass control.

Postemergence weed control needs timely application. The late emerging weeds are often not as competitive as weeds emerging in the early summer, plants emerging four weeks after planting soybean often do not impact yields. Since double-cropped soybeans are treated in the late summer, be sure to observe plant back time periods for crops after specific herbicides. A nine-month crop rotation may be too short of an interval to treat soybeans postemergence and allow for an early spring-planted crop.

Management of Herbicide-Resistant Horseweed

Many of the horseweed populations in the region are resistant to glyphosate, but many populations in the region are also resistant to the ALS-inhibitors (Classic, FirstRate, etc.). The most economical treatments for control include 2,4-D ester at 2 pints per acre applied to small plants (less than 3-inch rosettes) to ensure effective control. Engenia, XtendiMax, and others are also effective options when applied to small plants and do not have a planting restriction for Xtend or XtendFlex soybean. Enlist One or Enlist Duo are effective options when applied to small plants and do not have a planting restriction for Enlist E3 soybean. Elevore is also an effective option, but it has a 14-day planting restriction. Herbicides containing saflufenacil, such as Sharpen, will also provide excellent horseweed control if applied to small plants, but observe plant-back restrictions on coarse soils or at higher rates. A primary goal for horseweed management in soybean should be effective control of emerged plants prior to planting since

Table 2.4-1. Soybean herbicides and their restrictions.

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide	Water Quality Advisory	Worker Reentry (hours)
2,4-D amine 4S	2,4-D amine	4	several	—	—	48
2,4-D LVE 4E	2,4-D LVE	4	several	—	—	12
Afforia 50.8WG	flumioxazin + thifensulfuron + tribenuron	14/2/2	Corteva	—	—	12
Aim 2EC	carfentrazone ethyl	14	FMC	—	—	12
Antares Complete	sulfentrazone + metribuzin + *S*-metolachlor	14/5/15	Helena	—	Yes	24
Anthem Maxx 4.3SC	pyroxasulfone + fluthiacet	15/14	FMC	—	Yes	12
Assure II 0.88E/Targa	quizalofop	1	AMVAC/Gowan	—	—	12
Authority Assist 4L	sulfentrazone + imazethapyr	14/2	FMC	—	Yes	12
Authority Edge 4.25SC	sulfentrazone + pyroxasulfone	14/15	FMC	—	Yes	12
Authority Elite/BroadAxe XC 7E	sulfentrazone + *S*-metolachlor	14/15	FMC/Syngenta	—	Yes	24
Authority First 70DF/Sonic	sulfentrazone + cloransulam	14/2	FMC	—	Yes	12
Authority MTZ 45DF	sulfentrazone + metribuzin	14/5	FMC	Yes	Yes	12
Authority Supreme 4.16SC	sulfentrazone + pyroxasulfone	14/15	FMC	—	Yes	12
Authority XL 70WG/Authority Maxx 66WG	sulfentrazone + chlorimuron	14/2	FMC	—	Yes	12
Basagran 4S	bentazon	6	Arysta LifeScience	—	Yes	12
Boundary 6.5EC	*S*-metolachlor + metribuzin	15/5	Syngenta	—	Yes	12
BroadAxe XC/Authority Elite 7E	sulfentrazone + *S*-metolachlor	14/15	Syngenta/FMC	—	Yes	24
Butyrac 200 2E	2,4-DB	4	Bayer CropScience	—	Yes	48
Cadet 0.91EC	fluthiacet	14	FMC	—	Yes	12
Canopy 75DF	chlorimuron + metribuzin	2/5	Corteva	—	Yes	12
Canopy Blend 58.3DG	chlorimuron + metribuzin	2/5	Corteva	—	Yes	12
Canopy EX 29.5WDG	chlorimuron + tribenuron	2/2	Corteva	—	—	12
Clarity 4S	dicamba DGA salt	4	BASF	—	Yes	24
Classic 25DF	chlorimuron	2	AMVAC	—	—	12
Cobra 2E	lactofen	14	Valent	—	—	12
Command 3ME	clomazone	13	FMC	—	—	12
Dual II Magnum 7.62EC	*S*-metolachlor	15	Syngenta	—	Yes	24
Durango DMA/Duramax 4S[2]	glyphosate	9	Corteva	—	—	4
Elevore 0.572SC	halauxifen	4	Corteva	—	Yes	12
Engenia 5S[3]	dicamba BAPMA salt	4	BASF	Yes	Yes	24
Enlist One 3.8SL4	2,4-D choline	4	Corteva	—	—	48
Enlist Duo 3.3SL[4]	2,4-D choline + glyphosate	4/9	Corteva	—	—	48
Enlite 48WDG	chlorimuron + flumioxazin + thifensulfuron	2/14/2	Corteva	—	—	12
Envive 41.3WDG	chlorimuron + flumioxazin + thifensulfuron	2/14/2	Corteva	—	—	12
EverpreX	*S*-metolachlor	15	Helm Agro US	—	—	4
Extreme 2.17L[2]	imazethapyr + glyphosate	2/9	BASF	—	Yes	48

Table 2.4-1. Soybean herbicides and their restrictions (continued).

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide	Water Quality Advisory	Worker Reentry (hours)
XtendiMax 2.9S[3]	dicamba DGA salt with VaporGrip	4	Bayer CropScience	Yes	Yes	24
Fierce 76WDG/Fierce EZ 3.04SC	pyroxasulfone + flumioxazin	15/14	Valent	—	Yes	12
Fierce MTZ 2.64SC/Kyber	flumioxazin + metribuzin + pyroxasulfone	14/5/15	Valent/Corteva	—	Yes	12
Fierce XLT 62.41WDG	pyroxasulfone + flumioxazin + chlorimuron	15/14/2	Valent	—	Yes	12
FirstRate 84WDG	cloransulam	2	AMVAC	—	Yes	12
Flexstar GT 3.5 2.82L[2]	fomesafen + glyphosate	14/9	Syngenta	—	Yes	24
Fusilade DX 2E	fluazifop	1	Syngenta	—	—	12
Fusion 2.56E	fluazifop + fenoxaprop	1/1	Syngenta	—	—	24
Gangster (co-pack)/Surveil (co-pack)	flumioxazin + cloransulam	14/2	Valent	—	Yes	12
Gramoxone 2SL/3SL	paraquat	22	Syngenta	Yes	—	12
Harmony SG 50WDG	thifensulfuron	2	Corteva	—	—	4
Harmony Extra SG/Audit 1:1	thifensulfuron + tribenuron	2/2	FMC/UPL	—	Yes	12
Interline 2.34SL[5]	glufosinate	10	UPL	—	—	12
Intermoc 3.57L	glufosinate + *S*-metolachlor	10/15	UPL	—	Yes	24
LeadOff 33.4WDG	rimsulfuron + thifensulfuron	2/2	Corteva	—	—	4
Liberty 2.34SL[5]	glufosinate	10	BASF	—	—	12
Lorox 50DF/Linex 4L	linuron	7	Nova Source	—	—	24
Marvel 3L	fluthiacet + fomesafen	14/14	FMC	—	Yes	24
Metribuzin 75DF/4L	metribuzin	5	various	—	Yes	12
Moccasin MTZ 4.5SC	*S*-metolachlor + metribuzin	15/5	UPL	—	Yes	24
Noventa 2.34SL[5]	glufosinate	10	BASF	—	—	12
OpTill 68WG	saflufenacil + imazethapyr	14/2	BASF	—	Yes	12
Optill PRO (co-pack)	saflufenacil + imazethapyr + dimethenamid	14/2/15	BASF	—	Yes	12
Outlook 6EC	dimethenamid	15	BASF	—	Yes	12
Panther MTZ	flumioxazin + metribuzin	14/5	Nufarm	—	Yes	12
Panther Pro	flumioxazin + metribuzin + imazethapyr	14/5/2	Nufarm	—	Yes	12
Panoflex 50WDG	thifensulfuron + tribenuron	2/2	Corteva	—	—	12
Permit Plus 74WDG[6]	halosulfuron + thifensulfuron	2/2	Gowan	—	—	12
Perpetuo 2.3SC	flumiclorac + pyroxasulfone	14/15	Valent	—	Yes	12
Preview 2:1SC	metribuzin + sulfentrazone	5/14	UPL	—	Yes	12
Poast 1.5E	sethoxydim	1	BASF	—	—	12
Poast Plus 1E	sethoxydim	1	BASF	—	—	12
Prefix 5.3EC	*S*-metolachlor + fomesafen	15/14	Syngenta	—	Yes	24
Prowl 3.3E/Prowl H2O 3.8CS	pendimethalin	3	BASF	—	—	12
Pursuit 2S	imazethapyr	2	BASF	—	Yes	12
Python 80WDG	flumetsulam	2	AMVAC	—	Yes	12
Raptor 1S	imazamox	2	BASF	—	—	4

Table 2.4-1. Soybean herbicides and their restrictions (continued).

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Restricted-Use Pesticide	Water Quality Advisory	Worker Reentry (hours)
Reflex 2E/Flexstar 1.88E	fomesafen	14	Syngenta	—	Yes	24
Resource 0.86EC	flumiclorac	14	Valent	—	—	12
Reviton SC	tiafenacil	14	Helm Agro US	—	Yes	12
Roundup WeatherMAX/PowerMAX 4.5S[2]	glyphosate	9	Bayer CropScience	—	—	4
Scepter 70DG	imazaquin	2	AMVAC	—	—	12
Scout 2.34SL[5]	glufosinate	10	Valent	—	—	12
Select 2E/Max 0.97E	clethodim	1	Valent	—	—	12
Sequence 5.25EW2	*S*-metolachlor + glyphosate	15/9	Syngenta	—	Yes	24
Sharpen 2.85SC	saflufenacil	14	BASF	—	Yes	12
Sonic 70WG/Authority First 70DF	sulfentrazone + cloransulam	14/2	Corteva	—	Yes	12
Spartan 4F	sulfentrazone	14	FMC	—	Yes	12
Spartan Charge	sulfentrazone + carfentrazone	14/14	FMC	—	Yes	12
Storm 4S	acifluorfen + bentazon	14/6	UPL	—	Yes	48
Surveil 48WG (co-pack)/Gangster	flumioxazin + cloransulam	14/2	Corteva	—	Yes	12
Synchrony XP 28.4WDG[6]	chlorimuron + thifensulfuron	2/2	Corteva	—	—	12
Tavium 3.38 CS[3]	dicamba DGA salt with VaporGrip + *S*-metolachlor	4/15	Syngenta	Yes	Yes	24
Tendovo 4.12 ZC	*S*-metolachlor + metribuzin + cloransulam-methyl	15/5/2	Syngenta	—	Yes	12
Treflan 4E/Tri-4/Trific/Trilin	trifluralin	3	Corteva	—	—	12
Tripzin ZC 4ZC	pendimethalin + metribuzin	3/5	UPL	—	Yes	2
Trivence 61.3WDG	chlorimuron + flumioxazin + metribuzin	2/14/5	Corteva	—	Yes	12
Ultra Blazer 2S	acifluorfen	14	UPL	—	Yes	48
Up-Stage 3CS	clomazone	3	UPL	—	—	12
Valor SX 51WDG/Valor EZ 4SC	flumioxazin	14	Valent	—	—	12
Valor XLT 40.3WDG	chlorimuron + flumioxazin	2/14	Valent	—	—	12
Verdict 5.57EC	saflufenacil + dimethenamid	14/15	BASF	—	Yes	12
Warrant 3CS	acetochlor	15	Bayer CropScience	—	Yes	12
Warrant Ultra 3.45CS	acetochlor + fomesafen	14/15	Bayer CropScience	—	Yes	24
XtendiMax 2.9S[3]	dicamba DGA salt with VaporGrip	4	Bayer Crop-Science/FMC	Yes	Yes	24
Zidua 85WDG/Zidua 4.17SC	pyroxasulfone	15	BASF	—	Yes	12
Zidua PRO 4.09SC	imazethapyr + pyroxasulfone + saflufenacil	2/15/14	BASF	—	Yes	12
Zone Defense	sulfentrazone + flumioxazin	14/14	Helm Agro US	—	Yes	12

[1] Generic alternatives to some of these products are available. See Table 2.1-10 (generics table) for additional herbicides that contain these active ingredients.
[2] May be applied over-the-top on glyphosate-resistant soybean varieties only.
[3] For use at planting and over-the-top on dicamba-resistant soybean varieties only.
[4] For use on 2,4-D-resistant soybean varieties only.
[5] For use on glufosinate-resistant soybean varieties only.
[6] For use on STS or Bolt soybean varieties only.

Table 2.4-2. Soybean herbicide prepackaged mixes, or co-packs, and equivalents.

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae lb/A)	An Equivalent Tank Mixture of
Afforia 50.8WG	0.408 lb flumioxazin	14	2.5 oz	0.064 lb flumioxazin	2 oz Valor SX 51WDG
	0.05 lb thifensulfuron	2		0.008 lb thifensulfuron	0.25 oz Harmony 50DF
	0.05 lb tribenuron	2		0.008 lb tribenuron	0.25 oz Express 50DF
Antares Complete	0.4 lb sulfentrazone	14	3 pt	0.15 lb sulfentrazone	4.8 fl oz Spartan 4F
	1.0 lb metribuzin	5		0.38 lb metribuzin	8.11 oz mertribuzin 75 DF
	4.7 lb *S*-metolachlor	15		1.76 lb *S*-metolachlor	1.85 pt Dual Magnum 7.62EC
Anthem 2.15SE	2.087 lb pyroxasulfone	15	6 fl oz	0.098 lb pyroxasulfone	3.02 fl oz oz Zidua 4.17SC
	0.063 lb fluthiacet	14		0.003 lb fluthiacet	0.42 fl oz Cadet 0.91E
Anthem Maxx 4.3SC	4.174 lb pyroxasulfone	15	3 fl oz	0.098 lb pyroxasulfone	3.02 fl oz Zidua 4.17SC
	0.126 lb fluthiacet	14		0.003 lb fluthiacet	0.42 fl oz Cadet 0.91E
Authority Edge 4.25SC	1.52 lb pyroxasulfone	15	6.6 fl oz	0.078 lb pyroxasulfone	2.39 fl oz Zidua 4.17SC
	2.73 lb sulfentrazone	14		0.141 lb sulfentrazone	4.5 fl oz Spartan 4F
Authority Elite 7SE or BroadAxe XC	0.7 lb sulfentrazone	14	28 fl oz	0.153 lb sulfentrazone	4.9 fl oz Spartan 4F
	6.3 lb *S*-metolachlor	15		1.38 lb *S*-metolachlor	1.45 pt Dual Magnum 7.62EC
Authority First 70DF	0.621 lb sulfentrazone	14	6.45 oz	0.25 lb sulfentrazone	8 fl oz Spartan 4F
	0.079 lb cloransulam	2		0.032 lb cloransulam	0.6 oz FirstRate 84WDG
Authority MTZ 45DF	0.18 lb sulfentrazone	14	16 oz	0.18 lb sulfentrazone	5.76 fl oz Spartan 4F
	0.27 lb metribuzin	5		0.27 lb metribuzin	5.8 oz metribuzin 75DF
Authority Supreme 4.16SC	2.08 lb sulfentrazone	14	7 fl oz	0.114 lb sulfentrazone	3.65 fl oz Spartan 4F
	2.08 lb pyroxasulfone	15		0.114 lb pyroxasulfone	3.5 fl oz Zidua 4.17SC
Authority XL 70WG	0.62 lb sulfentrazone	14	7 oz	0.27 lb sulfentrazone	5.8 fl oz Spartan 4F
	0.08 lb chlorimuron	2		0.035 lb chlorimuron	2.1 oz Classic 25DF
Boundary 6.5L	5.25 lb *S*-metolachlor	15	2 pt	1.24 lb *S*-metolachlor	1.3 pt Dual Magnum 7.62EC
	1.25 lb metribuzin	5		0.314 lb metribuzin	6.7 oz metribuzin 75DF
Canopy 75DF	0.107 lb chlorimuron	2	5 oz	0.033 lb chlorimuron	2.14 oz Classic 25DF
	0.643 lb metribuzin	5		0.2 lb metribuzin	4.27 oz metribuzin 75DF
Canopy Blend 58.3DG	0.083 lb chlorimuron	2	6.5 oz	0.033 lb chlorimuron	2.14 oz Classic 25DF
	0.5 lb metribuzin	5		0.2 lb metribuzin	4.27 oz metribuzin 75DF
Canopy EX 29.5WDG	0.227 lb chlorimuron	2	2.2 oz	0.031 lb chlorimuron	2 oz Classic 25DF
	0.068 lb tribenuron	2		0.009 lb tribenuron	0.2 oz Express 75DF
Enlist Duo	1.6 lb 2,4-D choline	4	4.75 pt	0.95 lb ae 2,4-D choline	2 pt Enlist One
	1.7 lb ae glyphosate	9		1.00 lb ae glyphosate	28.4 oz Roundup PowerMax
Envive 41.3WDG	0.292 lb flumioxazin	14	3.5 oz	0.064 lb flumioxazin	2.0 oz Valor SX 51WDG
	0.029 lb thifensulfuron	2		0.006 lb thifensulfuron	0.14 oz Harmony 75DF
	0.092 lb chlorimuron	2		0.020 lb chlorimuron	1.3 oz Classic 25DF
Extreme 2.17L	0.17 lb imazethapyr	2	3 pt	0.063 lb imazethapyr	4 fl oz Pursuit 2L
	1.48 lb aeglyphosate	9		0.56 lb ae glyphosate	1.5 pt Roundup 4S
Fierce 76WDG	0.335 lb flumioxazin	14	3 oz	0.063 lb flumioxazin	2 oz Valor SX 51WDG
	0.425 lb pyroxasulfone	15		0.08 lb pyroxasulfone	2.46 fl oz Zidua 4.17SC

Table 2.4-2. Soybean herbicide prepackaged mixes, or co-packs, and equivalents (continued).

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae lb/A)	An Equivalent Tank Mixture of
Fierce EZ 3.04SC	1.34 lb flumioxazin	14	6.0 fl oz	0.063 lb flumioxazin	2 oz Valor SX 51WDG
	1.70 lb pyroxasulfone	15		0.08 lb pyroxasulfone	2.46 fl oz Zidua 4.17SC
Fierce MTZ/Kyber	0.5 lb flumioxazin	14	1.25 pt	0.078 lb flumioxazin	2.45 oz Valor SX 51WDG
	1.5 lb metribuzin	5		0.234 lb metribuzin	4.99 oz metribuzin 75DF
	0.64 lb pyroxasulfone	15		0.10 lb pyroxasulfone	3.07 fl oz Zidua 4.17SC
Fierce XLT 62.41WDG	0.3117 lb pyroxasulfone	15	4 oz	0.078 lb pyroxasulfone	2.39 fl oz Zidua 4.17SC
	0.2457 lb flumioxazin	14		0.061 lb flumioxazin	1.93 oz Valor SX 51WDG
	0.0667 lb chlorimuron	2		0.017 lb chlorimuron	1.07 oz Classic 25DF
Flexstar GT3.5L	0.56 lb fomesafen	14	4.5 pt	0.315 lb fomesafen	1.3 pt Reflex 2E
	2.26 lb ae glyphosate	9		1.28 lb ae glyphosate	1.3 qt Touchdown Total 4.17S
Fusion 2.67E	2 lb fluazifop	1	8 fl oz	0.125 lb fluazifop	8 fl oz Fusilade DX 2E
	0.67 lb fenoxaprop	1		0.042 lb fenoxaprop	0.042 lb fenoxaprop
Gangster (co-pack)	0.36 lb flumioxazin	14	3 oz	0.080 lb flumioxazin	2.5 oz Valor SX 51WDG
	0.12 lb cloransulam	2		0.026 lb cloransulam	0.5 oz FirstRate 84WDG
InterMoc 3.57L	1.07 lb glufosinate	10	64 fl oz	0.54 lb glufosinate	30 fl oz Interline 2.34SL
	2.5 lb *S*-metolachlor	15		1.25 lb *S*-metolachlor	1.3 pt Dual Magnum 7.62EC
Marvel 3L	0.117 lb fluthiacet	14	7.25 fl oz	0.007 lb fluthiacet	0.9 fl oz Cadet 0.91E
	2.883 lb fomesafen	14		0.163 lb fomesafen	10.4 fl oz Reflex 2E
Moccasin MTZ	3.35 lb *S*-metolachlor	15	42 fl oz	1.10 lb *S*-metolachlor	1.15 pt Dual Magnum 7.62EC
	1.11 lb metribuzin	5		0.36 lb metribuzin	7.68 oz metribuzin 75DF
OpTill 68WG	0.502 lb imazethapyr	2	2 oz	0.063 lb imazethapyr	4 fl oz Pursuit 2L
	0.178 lb saflufenacil	14		0.022 lb saflufenacil	1 fl oz Sharpen 2.85SC
Optill PRO (co-pack)	0.502 lb imazethapyr	2	2 oz	0.063 lb imazethapyr	4 fl oz Pursuit 2L
	0.178 lb saflufenacil	14		0.022 lb saflufenacil	1 fl oz Sharpen 2.85SC
	6.0 lb dimethenamid	15	10 fl oz	0.47 lb dimethenamid	10 fl oz Outlook 6.0EC
Panther MTZ	3.0 lb metribuzin	5	12 fl oz	0.28 lb metribuzin	5.97 oz metribuzin 75DF
	0.67 lb flumioxazin	14		0.063 lb flumioxazin	1.98 oz Valor SX 51WDG
Panther Pro 4.23SC	3.0 lb metribuzin	5	12 fl oz	0.28 lb metribuzin	5.97 oz metribuzin 75DF
	0.67 lb flumioxazin	14		0.063 lb flumioxazin	1.98 oz Valor SX 51WDG
	0.56 lb imazethapyr	2		0.053 lb imazethapyr	3.39 fl oz Pursuit 2L
Perpetuo 2.3SC	0.59 lb flumiclorac	14	8 fl oz	0.037 lb flumiclorac	5.5 fl oz Resource 0.86EC
	1.71 lb pyroxasulfone	15		0.107 lb pyroxasulfone	3.28 fl oz Zidua 4.17SC
Permit Plus	0.662 lb halosulfuron	2	1.25 oz	0.052 lb halosulfuron	1.1 oz Permit 75WDG
	0.078 lb thifensulfuron	2		0.006 lb thifensulfuron	0.128 oz Harmony 75DF
Prefix 5.3EC	4.34 lb *S*-metolachlor	15	2 pt	1.05 lb *S*-metolachlor	1.1 pt Dual Magnum 7.62EC
	0.95 lb fomesafen	14		0.24 lb fomesafen	0.95 pt Reflex 2E
Preview 2:1 SC	2.23 lb metribuzin	5	16 fl oz	0.279 lb metribuzin	5.95 oz metribuzin 75DF
	1.12 lb sulfentrazone	14		0.14 lb sulfentrazone	3.0 fl oz Spartan 4F
Sequence 5.25EW	2.25 lb ae glyphosate	9	3.5 pt	0.98 lb ae glyphosate	1.88 pt Touchdown Total 4.17S
	3 lb *S*-metolachlor	15		1.31 lb *S*-metolachlor	1.38 pt Dual Magnum 7.62EC

Table 2.4-2. Soybean herbicide prepackaged mixes, or co-packs, and equivalents (continued).

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae lb/A)	An Equivalent Tank Mixture of
Sonic 70DF	0.621 lb sulfentrazone	14	6.45 oz	0.25 lb sulfentrazone	5.28 oz Authority 75DF
	0.079 lb cloransulam	2		0.032 lb cloransulam	0.6 oz FirstRate 84WDG
Spartan Charge	3.15 lb sulfentrazone	14	8.5 fl oz	0.21 lb sulfentrazone	6.69 fl oz Spartan 4F
	0.35 lb carfentrazone	14		0.023 lb carfentrazone	1.49 fl oz Aim 2EC
Storm 4S	2.67 lb bentazon	6	1.5 pt	0.50 lb bentazon	1 pt Basagran 4S
	1.33 lb acifluorfen	14		0.25 lb acifluorfen	1 pt Blazer 2S
Surveil 48WDG	0.36 lb flumioxazin	14	3.5 oz	0.080 lb flumioxazin	2.5 oz Valor SX 51WDG
	0.12 lb cloransulam	2		0.026 lb cloransulam	0.5 oz FirstRate 84WDG
Synchrony XP 28.4WDG	0.215 lb chlorimuron	2	0.375 oz	0.005 lb chlorimuron	0.32 oz Classic 25DF
	0.069 lb thifensulfuron	2		0.0014 lb thifensulfuron	0.03 oz Harmony 75DF
Tavium	1.12 lb dicamba	4	56.5 fl oz	0.50 lb dicamba	21.5 oz XtendiMax 2.9S
	2.26 lb *S*-metolachlor	15		1.00 lb *S*-metolachlor	1.05 pt Dual Magnum 7.62EC
Tendovo 4.12 ZC	3.47 lb *S*-metolachlor	15	48 fl oz	1.30 lb *S*-metolachlor	1.37 pt Dual Magnum 7.62EC
	0.642 lb metribuzin	5		0.241 lb metribuzin	5.14 oz metribuzin 75DF
	0.065 lb chloransulam	2		0.024 lb chloransulam	0.46 FirstRate 84WDG
Tripzin	2.9 lb pendimethalin	3	44 fl oz	1.00 lb pendimethalin	2.1 pt Prowl H20 3.8CS
	1.1 lb metribuzin	5		0.38 lb metribuzin	8.0 oz metribuzin 75DF
Trivence 61.3WDG	0.039 lb chlorimuron	2	6 oz	0.014 lb chlorimuron	0.9 oz Classic 25DF
	0.128 lb flumioxazin	14		0.048 lb flumioxazin	1.5 oz Valor 51WDG
	0.446 lb metribuzin	5		0.169 lb metribuzin	3.6 oz metribuzin 75DF
Valor XLT 40.3WDG	0.3 lb flumioxazin	14	3.5 oz	0.065 lb flumioxazin	2.1 oz Valor SX 51WDG
	0.103 lb chlorimuron	2		0.022 lb chlorimuron	1.44 oz Classic 25DF
Verdict 5.57EC	5 lb dimethenamid	15	5 fl oz	0.19 lb dimethenamid	4 fl oz Outlook 6EC
	0.57 lb saflufenacil	14		0.022 lb saflufenacil	1 fl oz Sharpen 2.85SC
Warrant Ultra 3.45CS	2.82 lb acetochlor	15	3 pt	1.06 lb acetochlor	2.8 pt Warrant 3CS
	0.631 lb fomesafen	14		0.24 lb fomesafen	15 fl oz Reflex 2E
Zidua PRO 4.09SC	2.28 lb pyroxasulfone	15	6 fl oz	0.107 lb pyroxasulfone	3.28 fl oz Zidua 4.17SC
	1.33 lb imazethapyr	2		0.063 lb imazethapyr	4 fl oz Pursuit 2L
	0.48 lb saflufenacil	14		0.022 lb saflufenacil	1 fl oz Sharpen 2.85SC
Zone Defense	0.62 lb sulfentrazone	14	5.0 oz	0.194 lb sulfentrazone	6.21 fl oz Spartan 4F
	0.15 lb flumioxazin	14		0.047 lb flumioxazin	1.47 oz Valor SX 51WDG

Table 2.4-3. Relative effectiveness of burndown herbicides for control of weeds in no-till full-season soybean.

Herbicide[1]	Site of Action Number	Brome, Downy	Burdock, Common	Chickweed[2]	Dandelion	Dock, Curly	Dogbane, Hemp; Dewberry; Milkweed; etc.	Evening Primrose, Cutleaf	Fleabanes, Annual	Foxtail spp.	Garlic, Wild	Geranium, Carolina	Groundsel, Common	Henbit/Deadnettle	Horseweed/Marestail[2,3]	Lambsquarters	Mustard spp.	Quackgrass	Ragweed, Common[2,3]	Smartweed	Thistle, Canada	Violet, Field/Pansy
2,4-D (spring-applied) (1 lb ae/acre)	4	N	7	6	8	7	N	**9**	7	N	7	—	6	N	**8+**	**9**	**9**	N	**9**	7	8	6
Dicamba (spring-applied) (0.5 lb ae/acre)[4]	4	N	7	6	7	8	N	8	7	N	7	—	6	N	**9**	**9+**	6	N	**9**	8	8	6
Elevore	4	N	—	N	—	N	—	N	6	N	6	6	—	**8+**	**9**	**9**	6	N	**9**	—	6	N
Glyphosate (fall-applied)[3]	9	**9**	**8+**	**9**	**9**	7	**8+**	7	8	—	**9**	8	**9**	8	**8+**[3]	—	**9**	**9**	—	—	**9**	7
Glyphosate (spring-applied)[3]	9	**9**	7	**9**	6	6	7	6	7+	**9+**	8	7	**9**	6	8[3]	**9**	8	8	**9**	7	8	6
Glyphosate + 2,4-D or dicamba (fall-applied)	9/4	**9**	**9+**	**9**	**9**	7	**9**	**9+**	**9**[5]	—	**9**	8	**9**	**8+**[6]	**9+**[3]	—	**9**4	**9**	—	—	**9+**	7
Glyphosate + 2,4-D or dicamba (spring-applied)	9/4	**9**	7+	**9**	8	7	7+	**9**	8	**9+**	8	7	**9**	**8+**	**9**[3]	**9**	**9**	**9**	**9**	**8+**	**8+**	7+
Glyphosate + metribuzin	9/5	**9**	7	**9**	6	6	7	6	8	**9**	8	7	**9**	**8+**	**8+**[3]	**9**	**9**	**9**	**9**	**9**	8	8
Gramoxone	22	7	N	**8+**	N	N	6	7	6	**9**	6	8	**8+**	7	7	8	8	6	8	7	6	8
Gramoxone + 2,4-D or dicamba[3]	22/4	7	7	**9**	7	7	6	**9**	7	**9**	7	8	**8+**	8	**8+**	**9**	**9**	6	**9**	**8+**	8	**8+**
Gramoxone + metribuzin	22/5	7	6	**9**	N	N	6	8	6	**9**	6	**9**	**8+**	8	8	8	**8+**	6	**9**	**9+**	6	8
Harmony Extra/FirstShot/Audit	2/2	N	6	**9**[2]	6	8	6	7	N	N	**8+**	—	**9**	**9**	7+[2]	**9**	**9**	N	6[2]	**9+**	8	N
Harmony Extra/FirstShot/Audit + 2,4-D	2,4	N	7	**9**	**9**	**9**	6+	**9**	6	N	**8+**	—	**9**	**9**	**8+2**	**9**	**9**	N	**9**	**9**	**8+**	7
Liberty, Interline, Scout, others	10	6	6	8	6	—	N	**9**	8	8	—	—	7	7	8	8	8	6	8	8	6	N
Reviton (2 oz)	14	7	—	8	7	—	—	8	7+	7	—	—	—	7	7	8	8	—	8	—	—	8
Sharpen (1 fl oz)	14	N	N	6	7	—	N	N	7+	N	—	—	8	6	8	8	8	N	8	8	6	N
Sharpen + glyphosate	14/9	**9**	7	**9**	8	—	7	6	8	**9+**	—	—	**9**	8	**9**[3]	**9**	**9**	8	**9**[3]	**9**	8	6
Valor	14	—	N	**9**	7[7]	N	N	6	N	N	—	—	7	N	6	**9**	8	N	7	7	N	**8+**

Relative effectiveness of herbicides on individual weeds that are commonly present prior to planting soybeans is listed in this table. Ratings are based on labeled application rates and weed size or growth stage, which often means an application is made weeks prior to planting. Delaying applications will result in reduced control. Treatments are rated only for control of vegetation existing at the time of application.

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = not applicable or no local data available; + = upper end of rating scale.

[1] See Table 2.1-10 (generics table) for additional herbicides that contain these active ingredients.

[2] Harmony Extra will not control ALS (Group 2) resistant common chickweed, horseweed/marestail, or common ragweed.

[3] Roundup and other glyphosate products are not effective on glyphosate-resistant (Group 9) horseweed/marestail or common ragweed.

[4] Ratings based on dicamba rate (0.5 lb ae/acre) for dicamba resistant soybean.

Table 2.4-3. Relative effectiveness of burndown herbicides for control of weeds in no-till full-season soybean (continued).

Herbicide[1]	Site of Action Number	Brome, Downy	Burdock, Common	Chickweed[2]	Dandelion	Dock, Curly	Dogbane, Hemp; Dewberry; Milkweed; etc.	Evening Primrose, Cutleaf	Fleabanes, Annual	Foxtail spp.	Garlic, Wild	Geranium, Carolina	Groundsel, Common	Henbit/Deadnettle	Horseweed/Marestail[2, 3]	Lambsquarters	Mustard spp.	Quackgrass	Ragweed, Common[2,3]	Smartweed	Thistle, Canada	Violet, Field/Pansy

[5] Based on control in early spring. Emergence of seedlings in the spring will reduce full-season control.

[6] Effectiveness is reduced if applied in certain tank mixes such as Roundup and other glyphosate products with photosynthesis inhibitors such as triazine herbicides, or 2,4-D/dicamba with Gramoxone. May still be tank-mixed for convenience, but burndown is improved if applied separately.

[7] Valor provides control of germinating dandelion seedling; however, it is weak on dandelion when applied POST.

Table 2.4-4. Relative effectiveness of herbicides for control of common cash or cover crops in the spring before planting soybeans.

Herbicide	Rate (lb ai or ae/acre)[1]	Alfalfa[2]	Austrian Winter Pea	Bluegrass/Timothy[2]	Bromegrass/Orchardgrass/Fescue[2]	Clover, Crimson	Clover, Red[2]	Clover, White	Mustards/Radish/Rapeseed	Rye, Cereal	Ryegrass, Annual	Triticale	Wheat, Winter	Vetch, Hairy
2,4-D ester	0.5	7+	N	N	N	7	8	6	7+	N	N	N	N	**9**
	1	8	N	N	N	8	**9**	7	**8+**	N	N	N	N	**10**
Dicamba	0.5	**9**	7	N	N	8	**9**	**9**	N	N	N	N	N	**9**
Elevore	0.004	—	7	N	N	N	—	—	N	N	N	N	N	8
Glyphosate	0.75	6	7	**9**	8	8	7	6	6	**9**	8	**9**	**9**	7
	1.5	7	8	**9+**	**8+**	**8+**	7+	7	7+	**9**	**9**	**9**	**9**	8
Glyphosate + 2,4-D ester	0.75 + 0.5	**8+**	**9**	**9**	8	**9**	8	8	8	**9**	8	**9**	**9**	**10**
Glyphosate + dicamba	0.75 + 0.5	**9**	**9**	**9**	8	**9**	**9**	**9**	7	**9**	8	**9**	**9**	**10**
Glyphosate + Liberty, Interline, Scout, others[3]	0.75 + 0.59	—	**9**	—	—	**9**	—	—	6	**9**	8	**9**	**9**	**9**
Glyphosate + Sharpen	0.75 + 0.022	—	**9**	—	—	8	—	—	7	**9**	**8+**	**9**	**9**	8
Gramoxone	0.5	N	7	7	6	8	7	7	7	7	6	7	8	7
	0.75	N	8	7+	7	**9**	8	7	8	8	6	7+	**8+**	8
Gramoxone + 2,4-D	0.75 + 0.5	7+	**9**	7	6	**9**	**8+**	8	**8+**	8	6	7	**8+**	**10**
Gramoxone + dicamba	0.75 + 0.5	**9**	**9**	7	6	**10**	**8+**	8	8	8	6	7	**8+**	**10**
Gramoxone + metribuzin	0.5 + 0.25	7	—	**9**	8	**10**	**8+**	7	**8+**	**8+**	7	7+	**8+**	**9**
Liberty, Interline, Scout, others[3]	0.59	—	**8+**	—	—	**9**	L	—	6	7	6	7	7	**9**
Liberty, Interline, Scout, others[3] + 2,4-D	0.59 + 0.5	—	**9**	—	—	**9**	—	—	8	7	6	6	7	**9+**
Reviton (2 fl oz)	0.044	—	—	N	N	8	—	—	—	N	N	N	N	N
Sharpen (1 fl oz)	0.022	—	6	N	N	N	—	—	N	N	N	N	N	N

Cover crop control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; L = listed as controlled on herbicide label, but local data are limited; N = less than 55% or no control; + = upper end of rating scale.

[1] 0.75 lb glyphosate = 32 fl oz of 41% glyphosate; 0.5 lb paraquat = 2 pt Gramoxone SL 2.0; see Table 2.1-8 (glyphosate table) for more information on glyphosate formulations.

[2] Application in the fall can improve control with some herbicides.

[3] Warm temperatures, high humidity, and bright sunlight improve the performance of Liberty 280. Weed control may be reduced when applications are made to weeds under stress from drought or cool temperatures.

Table 2.4-5. Comments on burndown herbicides for no-till soybeans.

Trade Name	Common Name	Site of Action Number	Product/A	lb ai/A
2,4-D 4L formulations (many trade names)	2,4-D	4	0.5–2 pt	0.25–1 lb ae
Enlist One 3.8SL	2,4-D choline	4	1.5–2 pt	0.71–0.95 lb ae

• For spring applications, the 2 pt rate of 2,4-D has been more effective and more consistent than lower rates. Applications made 30 days preplant have been more effective on horseweed than applications made 14 days preplant.
• Apply 2,4-D ester (LVE) at 2 pt at least 30 days before planting, 1 pt or less at least 7 days ahead of planting, or up to 2 pt at least 30 days before planting; some LVE formulations allow a 15-day interval between application and planting soybean (e.g., Salvo, Shredder E-99, Weedone 650).
• Enlist One may be applied through planting of Enlist E3 soybean varieties only.
• 2,4-D amine at 2 pt should be applied 30 days before planting and at 1 pt or less at least 15 days ahead of planting.
• Add 2,4-D to paraquat or glyphosate for added burndown of hard-to-control broadleaf weeds.
• Use 2,4-D for added control or suppression of mustard spp., plantains, horseweed, and 2,4-D susceptible annual broadleaf weeds.
• Do not apply 2,4-D prior to planting soybeans if you are not prepared to accept the results of soybean injury, including possible loss of stand and yield.
• The risk of injuring sensitive plants via off-target movement is much less when these products are used early burndown prior to planting full-season soybean in the spring compared to burndown applications prior to planting double-crop soybean during the summer months.
• Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary to limit spray drift. Consult labels for approved nozzles.
• 2,4-D can be difficult to completely remove from spray equipment, and residue is capable of injuring sensitive plants. Follow label instructions concerning sprayer cleanout.
• Cotton, grapes, pepper, sweet potato, tobacco, tomato, watermelon, and many other crops are very sensitive to 2,4-D. Follow application instructions on label to avoid injuring neighboring plants.
• See labels for details on drift management, including recommended nozzles and pressures, wind speed, boom height, temperature inversions, buffers, susceptible plants, and spray equipment cleanout.

Clarity 4S	dicamba DGA salt	4	0.5–1pt	0.25–0.5 lb ae
Engenia 5S	dicamba BAPMA salt		12.8 fl oz	0.5 lb ae
XtendiMax 2.9S	dicamba DGA salt with Vapor-Grip		22 fl oz	0.5 lb ae

• Applications made 30 days preplant have been more effective on horseweed than applications made 14 days preplant.
• Following application of Clarity, Engenia, and XtendiMax and a minimum accumulation of 1 inch of rainfall or overhead irrigation, wait at least 14 days before planting for 0.25 lb ae per acre or less and 28 days for 0.5 lb ae per acre. Do not apply dicamba prior to planting soybeans if you are not prepared to accept the results of soybean injury, including the possible loss of stand and yield.
• Engenia and XtendiMax may be applied through planting of Xtend soybean varieties only. See product websites for approved adjuvants, drift reduction agents, nozzles, and other tank mixes. Carefully read and follow product labels. *Engenia* and *XtendiMax are restricted use pesticides.*
• Add dicamba to paraquat or glyphosate for added burndown of hard-to-control broadleaf weeds.
• Use dicamba for added control of horseweed and dicamba-susceptible annual broadleaf weeds.
• Dicamba has little to no activity on mustard species including rapeseed and is not recommended for control of these weeds, even when tank-mixed with glyphosate.
• The risk of injuring sensitive plants via off-target movement is much less when these products are used early burndown or prior to planting full-season soybean in the spring compared to burndown applications prior to planting double-crop soybean during the summer months.
• Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary to limit spray drift. Consult labels for approved nozzles.
• Dicamba can be difficult to completely remove from spray equipment, and residue is capable of injuring sensitive plants. Follow label instructions concerning sprayer cleanout.
• *Water quality advisory.*

Canopy 75DF/ Canopy Blend 58.3DG	chlorimuron + metribuzin	2/5	4–8 oz	0.026–0.053
			5–9 oz	0.16–0.32

• Metribuzin will enhance the activity of paraquat or glufosinate when used as a tank mixture for burndown weed control.
• See comments in preemergence section.

Canopy EX 29.5DG	chlorimuron +	2	1.1–3.3 oz	0.016–0.047
	tribenuron			0.0047–0.013

• Apply with glyphosate or Gramoxone to no-till fields any time after harvest in the fall at 2.2 to 3.3 oz/A up to 14 days before soybean planting, or 1.1 to 2.2 oz/A up to 7 days before soybean planting; consult label for details.
• For best results apply to annual weeds less than 3 inches in height or diameter and perennial weeds less than 6 inches in height or diameter.
• The addition of 1 pint/A of 2,4-D ester is recommended and required for some species.
• Applications must include either a crop oil concentrate or a non-ionic surfactant. Crop oil concentrate is the required adjuvant unless tank-mixing with a product that precludes its use.
• On soils with pH 7.0 or less, Canopy EX can be applied at rates of 1.5–3.3 oz/A and will provide residual control or suppression of several winter and summer annual weeds through normal planting dates, but it will not provide season-long control.

Table 2.4-5. Comments on burndown herbicides for no-till soybeans (continued).

Trade Name	Common Name	Site of Action Number	Product/A	lb ai/A
Elevore 0.572SC	halauxifen-methyl	4	1 oz	0.004 lb ae
• Must be applied at least 14 days prior to planting. • Tank-mix with glyphosate or Gramoxone to improve spectrum of control. • Use Elevore for marestail/horseweed control.				
Glyphosate*	glyphosate	9	varies by formulation and acid equivalent	0.36–3 lb ae
• Fall applications of glyphosate are better than spring applications for control of orchardgrass sods and quackgrass. Spring applications may be used to control annual weeds. For control of most annual weeds, apply 0.75 to 1.13 lb ae/A. • Glyphosate may be applied in clear liquid nitrogen fertilizers and clear liquid complete-analysis fertilizers. Do not use glyphosate with suspension-type liquid fertilizers. • Use rates vary by product, formulation, and weed size. Higher rates are usually recommended for annual weeds taller than 6 inches. • To aid in the control of marestail/horseweed, mustard species, common lambsquarters, common ragweed, and other emerged, susceptible broadleaf weeds, 2,4-D or dicamba should be added. • Glyphosate is available in some prepackaged mixtures, but glyphosate rate may not be adequate for burndown control.				
Gramoxone SL 2.0	paraquat	22	2–4 pt	0.48–1.0
Gramoxone SL 3.0			1.3–2.7 pt	0.49–1.0
• Use appropriate precautions when handling paraquat to minimize exposure to the herbicide. • Apply in 20 to 60 gallons of water per acre; increase gallonage as density of stubble, crop residue, or weeds increases. • Rate is dependent on weed size (see label). Paraquat may not control weeds taller than 6 inches. • 2,4-D at 0.5 to 0.75 pint per acre may be added to this program for additional control of marestail (horseweed), common lambsquarters, common ragweed, and other emerged, susceptible broadleaf weeds. • Phosphate-containing liquid fertilizers diminish paraquat activity. • The addition of metribuzin will improve overall control with paraquat (this includes Glory, TriCor, Boundary, Canopy, Trivence, and Authority MTZ). Paraquat use restrictions: • Only certified applicators, who successfully complete the paraquat-specific training, can mix, load, or apply paraquat. • Application of paraquat "under the direct supervision" of a certified applicator is no longer allowed; registered technicians cannot apply. • Required training at http://usparaquattraining.com; certified applicators must repeat training every three years. • *Restricted-use pesticide.*				
Liberty 2.34SL	glufosinate	10	32–43 oz	0.59–0.79
• Liberty may be applied as a burndown treatment prior to the planting or emergence of any soybean variety. • Apply a minimum of 32 fl oz/A to young, actively growing weeds; burndown and in-crop applications may not exceed 87 fl oz/A per season. • Warm temperatures, high humidity, and bright sunlight improve the performance of Liberty 280. Weed control may be reduced when applications are made to weeds under stress from drought or cool temperatures. • Applications should be made between 2 hours after sunrise and 1 hour before sunset to avoid the possibility of reduced weed control. • Liberty performs better as a POST herbicide or burndown for double-cropped soybeans compared to burndown applications in April. • Liberty must be applied with ammonium sulfate at the rate of 3 lb/A. • Uniform, thorough spray coverage is necessary to achieve consistent weed control; do not use nozzles that produce large droplets; use at least 15 gal/A (20 gal/A if dense vegetation is present).				
Reviton	tiafenacil	14	1–3 oz	0.022–0.066
• Reviton may be applied as a burndown treatment prior to soybean planting. • Apply as a broadcast spray using conventional low-pressure ground spray equipment. • The maximum single application rate is 3 oz/A. Do *not* exceed 6 oz/A per year. • Do not reapply within 14 days. • No plant-back restriction at 1 oz. 7-day plant-back restriction at 2 to 3 oz. • Use higher rate for dense and/or mature weed infestations. • *Water quality advisory*.				
Sharpen 2.85SC	saflufenacil	14	1–2 oz	0.022–0.044
• Sharpen may be applied as a burndown treatment from 44 days early preplant through preemergence timings as directed on the label. • Apply Sharpen in a typical glyphosate or glufosinate burndown herbicide program to increase weed spectrum, including glyphosate-resistant horseweed; 1.5 oz provides more consistent horseweed control than lower rates. • The label requires use of methylated seed oil (MSO) plus a nitrogen source such as ammonium sulfate (AMS). • On coarse-textured soils with less than 2% organic matter: a minimum of 30 days between application of 1 to 1.5 oz of Sharpen and soybean planting is required; minimum of 44 days between application of 2 oz of Sharpen and soybean planting. • All other soils: no waiting period if 1 oz of Sharpen is applied; minimum of 14 days between applications of 1.5 oz of Sharpen and planting on all other soil types; and 30 days if 2 oz of Sharpen is used.				

Table 2.4-5. Comments on burndown herbicides for no-till soybeans (continued).

Trade Name	Common Name	Site of Action Number	Product/A	lb ai/A
• Do not apply during soybean cracking stage or after emergence, as severe crop damage will occur. Control of emerged grasses will require adding an additional herbicide. • Do not apply Sharpen with other Group 14 herbicides such as sulfentrazone or flumioxazin as a tank-mix or sequential application within 30 days, or crop injury may result on coarse-textured soils with less than 2% organic matter, and a minimum of 14 days is required on all other soil types (see label). • Local research indicates limited residual control with Sharpen at rates and use pattern for soybeans. • Sharpen is a Group 14 herbicide and due to concerns for long-term viability of this herbicide mode of action, extension specialists in the Mid-Atlantic region recommend not using it every year. This mode of action has greater utility in soybeans than corn, especially for control of glyphosate-resistant horseweed (marestail). As such, we suggest that Sharpen and other saflufenacil-containing products (e.g., Verdict, OpTill) be used in soybean and only in alternate years. The use of Sharpen in continuous corn should also be limited to every other year (alternating years with HPPD-containing herbicide [Group 27]).				
Valor SX 51WDG	flumioxazin	14	1–2.5 oz	0.032–0.08 lb
• Valor may be included in a typical burndown herbicide program to enhance the speed of burndown and increase weed spectrum. • Valor has fair to good postemergence activity on field pansy/violet. • Premixes containing Valor: Valor XLT contains chlorimuron (Classic) and can also be used as a PRE/burndown treatment; Fierce XLT is similar to Valor XLT but also contains pyroxasulfone (Zidua); Envive contains chlorimuron (Classic) and thifensulfuron (Harmony); Gangster or Surveil contains cloransulam (FirstRate).				

Refer to product label for rates and precautions for fall applications. Note: Many of these products have rotation restrictions that require soybeans only be planted in the spring after fall applications.

*See Table 2.1-8 (glyphosates) for information on various formulations of this herbicide.

Table 2.4-6. Water solubility and longevity of soil-applied herbicides.

Relative Moisture to Activate	ppm	Estimated Water to Activate*
Low	>500 ppm (very soluble)	0.33 inch
Medium	250–500 ppm	0.33–0.5 inch
High	100–250 ppm	0.5–0.75 inch
Very high	<100 ppm	>0.75 inch

*More water (additional irrigation) may be necessary if soil is dry at time of application, soils with higher clay content, or high plant residues are present.
Solubility (parts per million; ppm) refers to how many microliters of the herbicide will dissolve in 1 liter of water. The less soluble the herbicide, the more moisture (rain or irrigation) is needed to activate the herbicide and move it into the root zone. Solubility is used as a guideline for rainfall or irrigation required within a short time after application. Moisture needed also depends on the soil moisture at time of application.

Trade Name	Solubility (ppm)	Relative Moisture to Activate	Duration of Residual Control
Classic	pH 5: 11	Very high	4–5 weeks
	pH 6.5: 450	Medium	
	pH 7: 1,200	Low	
Command	1,100	Low	2–4 weeks
Dual Magnum	530	Medium	4–5 weeks
Express	pH 5: 48	Very high	1–2 weeks
	>pH 7: >2,040	Low	
FirstRate	pH 5: 3	Very high	2–4 weeks
	pH 7: 184	High	
Harmony SG	pH 5: 223	High	1–2 weeks
	>pH 7: >2,240	Low	
Lorox/Linex	75	Very high	4–5 weeks
Metribuzin	1,200	Low	4–5 weeks
Outlook	1,174	Low	2–4 weeks
Prowl/other pendimethalin formulations	1	Very high	4–5 weeks
Pursuit	1,400	Low	4–6 weeks
Python	5,600	Low	4–6 weeks
Reflex/Flexstar	600,000	Low	2–4 weeks
Sharpen	pH 5: 30	Very high	1–3 weeks
	pH 7: 2,100	Low	
Spartan	780	Low	4–6 weeks
Treflan/other formulations	1	Very high	4–5 weeks
Valor SX	2	Very high	4–5 weeks
Warrant	223	Medium	4–5 weeks
Zidua	3.49	Very high	4–5 weeks

Relative duration of residual control is for comparison only. Based on herbicide half-life (length of time it takes for half the herbicide to break down). Herbicide breakdown results from chemical and/or microbial activity. Since the speed of breakdown is affected by a number of factors including soil pH, soil temperature, and soil moisture, duration can vary for herbicides based on the specific conditions. Residual activity is not the same as herbicide carryover. Duration of residual control assumes (1) good activation, (2) no excessive rain or irrigation, and (3) that weed species are sensitive to the herbicide(s) applied.

Table 2.4-6. Water solubility and longevity of soil-applied herbicides (continued).

Premix	Constituents
Afforia	Valor SX, Harmony SG, Express
Antares Complete	Spartan, metribuzin, Dual Magnum
Anthem/Anthem Maxx	Cadet, Zidua
Authority Edge	Spartan, Zidua
Authority Elite/BroadAxe	Spartan, Dual Magnum
Authority First/Sonic	Spartan, FirstRate
Authority MTZ	Spartan, metribuzin
Authority Supreme	Spartan, Zidua
Authority XL	Spartan, Classic
Boundary	Dual Magnum, metribuzin
Canopy DF/Blend	Classic, metribuzin
Canopy EX	Classic, Express
Envive	Classic, Valor SX, Harmony SG
Fierce/Fierce EZ	Valor SX, Zidua
Fierce MTZ/Kyber	Valor, Zidua, metribuzin
Fierce XLT	Zidua, Valor, Classic
Gangster/Surveil	Valor SX, FirstRate
Moccasin MTZ	Dual Magnum, metribuzin
OpTill	Sharpen, Pursuit
OpTill PRO	Sharpen, Pursuit, Outlook
Panther MTZ	Metribuzin, Valor
Panther Pro	Metribuzin, Valor, Pursuit
Permit Plus	Harmony SG, Sandea
Prefix	Dual Magnum, Reflex
Preview 2:1	Metribuzin, Spartan
Sequence	Dual Magnum, glyphosate
Synchrony XP	Classic, Harmony SG
Tavim	Dual Magnum, Xtendimax
Tendovo	Dual Magnum, metribuzin, FirstRate
Tripzin	Prowl, metribuzin
Trivence	Classic, Valor SX, metribuzin
Valor XLT	Valor SX, Classic
Verdict	Sharpen, Outlook
Warrant Ultra	Warrant, Reflex
Zidua Pro	Zidua, Pursuit, Sharpen
Zone Defense	Spartan, Valor

Table 2.4-7. Relative effectiveness of soil-applied herbicides.

Grasses

Trade Name	Site of Action Number	Barnyardgrass	Bermudagrass	Corn, Volunteer	Crabgrass	Foxtail spp.	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wirestem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Command*	13	**8+**	6	7	**8+**	**9**	**9+**	N	8	N	N	**9**	8	7	7	**9+**
Dual products	15	**9**	N	N	**9**	**9**	**9+**	N	6	N	8	**8+**	6	N	6	8
Lorox/Linex	7	6	N	N	6	7	7	N	6	6	6	N	N	N	6	N
Metribuzin	5	6	N	N	6	N	6	N	6	N	6	N	N	N	6	N
Outlook	15	**9**	N	N	**8+**	**9**	**9**	N	6	N	7+	**8+**	6	N	6	7
Prowl	3	**8+**	N	N	**8+**	**8+**	**9**	N	7	N	6	**9**	8	N	7	**9**
Pursuit	2	8	N	6	7	8	N	N	6	N	7	7	N	N	6	N
Treflan*	3	**9**	N	6	**9**	**9**	**9**	7	8	N	N	**9**	**8+**	7	8	**9**
Warrant	15	**8+**	N	N	8	**8+**	**8+**	N	6	N	6	8	N	N	N	7
Zidua	15	**9**	N	N	**9**	**9**	**9+**	N	6	N	6	**8+**	7	N	6	**8+**
Mixtures																
Anthem Maxx	14/15	**9**	N	N	**9**	**9**	**9+**	N	6	N	6	**8+**	7	N	6	**8+**
Authority Edge	14/15	**8+**	N	N	**8+**	**8+**	**9**	N	6	N	7	8	6	N	6	8
Authority Elite/BroadAxe	14/15	**9**	N	N	**9**	**9**	**9+**	N	6	N	7	**8+**	6	N	6	8
Authority Supreme	14/15	**9**	N	N	**9**	**9**	**9+**	N	6	N	7	**8+**	7	N	6	**8+**
Boundary	5/15	8	N	N	8	8	**8+**	N	N	N	7	7	N	N	N	6
Canopy DF/Canopy Blend	2/5	6	N	7	6	N	—	N	N	N	7	N	N	N	8	6
Fierce/Fierce EZ/Fierce XLT	14/15/(2)	**9**	N	N	**9**	**9**	**9+**	N	6	N	6	**8+**	7	N	6	8
OpTill	2/15	7	N	6	7	7	—	N	6	N	6	6	6	N	6	N
Prefix	14/15	8	N	N	8	8	**8+**	N	N	N	7	7	N	N	N	6
Tendovo	15/5/2	**9**	N	6	**9**	**9**	**9+**	N	6	N	8	**8+**	6	N	6	8
Warrant Ultra	14/15	**8+**	N	N	8	**8+**	**8+**	N	6	N	6	8	N	N	N	7
Zidua PRO	15/2/14	**9**	N	N	**9**	**9**	**9+**	N	6	N	7	**8+**	7	N	6	**8+**

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; + = upper end of rating scale.

Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good; on rare occasion is crop injury observed; G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

Ratings are based on labeled application rates for the soil type and timely rainfall or irrigation to incorporate the herbicides. Ratings are also based on weed control three to weeks after application. Length of effective control (residual control) beyond four weeks after application often declines. Results may differ with variations in soil type, temperature, rainfall, soil moisture, soil organic matter, and soil pH. For ratings on herbicide combinations not listed, see the component parts.

*Command 4E, Treflan, and trifluralin require incorporation; Command 3ME may be applied preemergence and not incorporated.

Table 2.4-7. Relative effectiveness of soil-applied herbicides (continued).

Broadleaves

Trade Name[1]	Site of Action Number	Amaranth, Palmer/ Waterhemp[2]	Anoda, Spurred	Burcucumber	Cocklebur	Horseweed/ Marestail[2]	Jimsonweed	Lambsquarters[3]	Morningglory, Annual	Nightshade, Eastern Black	Pigweed[3]	Ragweed, Common[4]	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf	Soybean Tolerance, Medium Soils	Soybean Tolerance, Coarse Soils
Command[5]	13	6	**9+**	N	7+	N	**9**	**9+**	N	6	6	8	N	**8+**	**8+**	**9+**	E	E
Dual products/Cinch	15	**8+**	N	N	N	N	N	6	N	7+	8	6	N	N	N	N	E	E
FirstRate	2	N	**9**	N	**8+**	**9**[2]	8	**9**	8	N	**9**[3]	**9**[4]	8	7	8	**8+**	E	E
Lorox/Linex	7	7	N	N	7+	7	7	**8+**	N	7	8	8	N	7+	**9**	7	G	FG
Metribuzin	5	**8+**	7	6	8	**8+**	8	**9**	N	N	**8+**	7	N	**8+**	**9**	8	G	FG
Outlook	15	8	N	N	N	N	N	6	N	7+	8	6	N	N	6	N	VG	VG
Prowl	3	8	N	N	N	N	6	**9**	N	N	8	N	N	N	8	**8+**	VG	G
Pursuit	2	N	N	6	8	—	8	8	7	8	**9**[3]	7+[4]	6	8	**9**	8	VG	VG
Reflex	14	**9**	N	N	8	N	8	8	7	8	**9**	**9**	6	7	7	6	E	VG
Spartan	14	**9**	N	N	N	**8+**	6	**8+**	**9**	8	**9**	7+	6	6	7	8	VG	VG
Treflan[5]	3	**9**	N	N	N	N	N	**9**	N	N	**9**	N	N	N	6	7+	E	E
Valor	14	**9**	8	N	6	**8+**	8	**9**	7+	**9**	**9**	**8+**	6	8	7	7	G	F
Warrant	15	8	N	N	N	N	N	6	N	7	8	6	N	N	N	N	VG	G
Zidua	15	**9**	N	N	N	N	7	8	N	8	**9**	7	6	6	7	6	VG	VG
Mixtures																		
Afforia	2/2	**9**	8	N	6	**8+**	8	**9**	7+	**9**	**9**	8	7	8	7	7	G	FG
Anthem/Anthem Maxx	14/15	**9**	N	N	N	N	7	8	N	8	**9**	7	6	6	7	6	VG	VG
Authority Edge	14/15	**9**	N	N	6	**8+**	7	**9**	8	**8+**	**9**	7	6	6	7	7	VG	VG
Authority Elite/BroadAxe	14/15	8	N	N	6	**8+**	6	**8+**	7	7	8	6	6	6	7	7	VG	VG
Authority First/Sonic	2/14	**9**	**9**	N	8	**8+**	8	**8+**	8	8	**9**	**8+**	7	7+	7+	8	VG	VG
Authority MTZ	5/15	**9**	7	6	8	**8+**	**8+**	**9**	8	8	**9**	8	N	**8+**	**9**	8	G	FG
Authority Supreme	14/15	**9**	N	N	6	**8+**	7	**8+**	7	8	**9**	7	6	6	7	7	VG	VG
Authority XL	2/14	**9**	8	7	**8+**	**8+**	8	**8+**	**9**	8	**9**	8	6	8	**8+**	8	G	FG
Boundary	5/15	**8+**	7	N	7+	**8+**	7+	**8+**	N	6	**8+**	7	N	**8+**	**8+**	7	G	G

Trade Name[1]	Site of Action Number	Amaranth, Palmer/ Waterhemp[2]	Anoda, Spurred	Burcucumber	Cocklebur	Horseweed/ Marestail[2]	Jimsonweed	Lambsquarters[3]	Morningglory, Annual	Nightshade, Eastern Black	Pigweed[3]	Ragweed, Common[4]	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf	Soybean Tolerance, Medium Soils	Soybean Tolerance, Coarse Soils
Canopy DF/Canopy Blend	2/5	**9**	8	7	**9**	**8+**	**9**	**9**	7+	6	**9+**	7+	8	**9**	**9**	**9**	FG	F
Envive	2/2/14	**9**	8	7	**8+**	**8+**	**9**	**9**	7+	**9**	**9**	8	7	**8+**	**8+**	**8+**	G	F
Fierce/Fierce EZ	14/15	**9**	8	N	6	**8+**	8	**9**	7+	**9**	**9**	7	6	8	7	7	G	F
Fierce XLT	2/14/15	**9**	8	7	**8+**	**8+**	**9**	**9**	8	**9**	**9**	8	8	**8+**	**8+**	**8+**	G	F
Gangster (co-pack)/Surveil	2/14	**9**	8	N	**8+**	**8+**	8	**9**	8	**9**	**9**	**9**	8	8	8	**8+**	G	F
OpTill	2/14	6	N	6	8	6	8	8	7	8	**9**	7+	6	8	**9**	8	G	G–F
Prefix	14/15	**8+**	N	N	N	N	6	6	6	7+	**8+**	7	N	6	6	6	E	E
Tendovo	15/5/2	**9**	**9**	6	**8+**	**8+**	8	**9**	**9**	7+	**9**	**9**[4]	8	**8+**	**9**	**8+**	G	FG
Trivence	2/5/14	**9**	8	7	**9**	**8+**	**9**	**9**	8	**9**	**9**	8	7	**9**	**9**	**9**	G	F
Valor XLT	2/14	**9**	8	7	**8+**	**8+**	**9**	**9**	7+	**9**	**9**	8	7	**8+**	**8+**	**8+**	G	F
Verdict	14/15	7	N	N	N	N	N	7	7+	7	7	6	N	N	6	N	G	—[6]
Warrant Ultra	14/15	**8+**	N	N	N	N	8	8	7	8	**8+**	8	6	7	7	6	VG	G
Zidua PRO	15/2/14	**9**	N	N	N	**8+**	7	**8+**	**9**	8	**9**	7	6	6	7	8	VG	—[6]

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; + = upper end of rating scale.

Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good; on rare occasion is crop injury observed; G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

Ratings are based on labeled application rates for the soil type and timely rainfall or irrigation to incorporate the herbicides. Ratings are also based on weed control three to weeks after application. Length of effective control (residual control) beyond four weeks after application often declines. Results may differ with variations in soil type, temperature, rainfall, soil moisture, soil organic matter, and soil pH. For ratings on herbicide combinations not listed, see the component parts.

[1] See Table 2.1-10 (generics table) for additional herbicides that contain these active ingredients.

[2] Biotypes resistant to Group 2 herbicides are common in the region; do not rely on Group 2 herbicides to provide effective control.

[3] Triazine-resistant (Group 5) lambsquarters and pigweed are common in the region; metribuzin will not control these biotypes.

[4] Common ragweed biotypes resistant to Group 2 herbicides have been confirmed in Delaware, Maryland, and Virginia.

[5] Command 4E, Treflan, and trifluralin require incorporation; Command 3ME may be applied preemergence and not incorporated.

[6] Not labeled for application on this soil type.

Table 2.4-8. Comments on preplant or preemergence herbicides for conventional, minimum-till, or no-till soybean.

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Anthem Maxx 4.3SC	pyroxasulfone +	15	EPP, PPI, or PRE	2–5.5 oz	0.04–0.088
	fluthiacet	14			
• Fluthiacet (Cadet) does not provide any residual weed control. • See Zidua entry for more comments.					
Authority products	sulfentrazone	14	EPP, PPI, or PRE	varies	0.132–0.309
• Spartan contains the single active ingredient sulfentrazone, but products that include sulfentrazone are branded as "Authority"; several premixed products contain sulfentrazone (Authority/Spartan). • Each of these products contains different active ingredients and/or ratios. See various tables in this guide and product labels for additional details about these products. • Rates are based on region, soil type, and soil organic matter. Applications made after soil cracking occurs or crop emergence will result in severe crop injury; soybean stunting may occur if excessive rainfall occurs after application but before soybeans emerge. • Sulfentrazone provides good control of yellow nutsedge. • Observe labeled crop rotation restrictions for all products containing sulfentrazone (see Table 2.1-11). • Sulfentrazone becomes more available when soil pH exceeds 7.0, increasing the risk of soybean injury. • Refer to label regarding applications with/or in sequence with Sharpen and other Group 14 herbicides. • Products that contain sulfentrazone include Antares Complete (Authority + metribuzin + Dual), Authority Assist (Authority + Pursuit), Authority Edge (Authority + Zidua), Authority Elite/BroadAxe (Authority + Dual), Authority First/Sonic (Authority + FirstRate), Authority MTZ (Authority + metribuzin), Authority Supreme (Authority + Zidua), Authority XL/Maxx (Authority + Classic), and Spartan Charge (Authority + Aim). • *Water quality advisory.*					
Authority Edge 4.25SC	sulfentrazone +	14	EPP, PPI, or PRE	5.9–15.7 fl oz	0.126–0.335
	pyroxasulfone	15			0.070–0.186
• See Authority and Zidua entries for more comments. • *Water quality advisory.*					
Authority Elite 7E or BroadAxe XC	sulfentrazone +	14	EPP, PPI, or PRE	19–38.7 fl oz	0.104–0.153
	S-metolachlor	15			0.94–1.87
• Authority Elite and BroadAxe XC are the same products. • See Dual and Authority entries for more comments. • *Water quality advisory.*					
Authority First 70DF/Sonic	sulfentrazone +	14	EPP, PPI, or PRE	6.45–8 oz	0.25–0.31
	cloransulam	2			0.032–0.04
• Authority First and Sonic are identical products. • See FirstRate and Authority entries for more comments.					
Authority MTZ 45WDG	sulfentrazone +	14	EPP, PPI, or PRE	12–18 oz	0.135–0.202
	metribuzin	5			0.202–0.304
• See Authority and metribuzin entry for comments. • *Water quality advisory.*					
Authority Supreme 4.16SC	sulfentrazone +	14	EPP, PPI, or PRE	6–11.5 fl oz	0.098–0.187
	pyroxasulfone	15			0.098–0.187
• See Authority and Zidua entries for more comments. • *Water quality advisory.*					
Authority XL 70WG	sulfentrazone +	14	EPP, PPI, or PRE	3–9 oz	0.116–0.347
	chlorimuron	2			0.015–0.045
• Authority XL is a premix of Authority (sulfentrazone) + Classic (chlorimuron) and can be used as a burndown and/or preemergence application. • For burndown, Authority XL may be tank-mixed with glyphosate, Gramoxone, or 2,4-D plus COC or MSO to increase activity. • See Authority entry for more comments.					
Boundary 6.5EC	*S*-metolachlor +	15	EPP, PPI, or PRE	1.2–3 pt	0.74–1.9
	metribuzin	5			0.188–0.469
• See metribuzin and Dual entry for comments. • The amount of Dual in this premix is low compared to amount recommended when applied by itself. • *Water quality advisory.*					

Table 2.4-8. Comments on preplant or preemergence herbicides for conventional, minimum-till, or no-till soybean. (continued)

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Canopy 75DF Canopy Blend 58.3WDG	chlorimuron + metribuzin	2/5	EPP, PPI, o PRE	4–7 oz	0.027–0.047
				5.1–9 oz	0.16–0.28
• Apply prior to soybean emergence. Do not use on sand or any soil with less than 0.5% organic matter. • Do not apply more than 2.25 oz/A if soil pH is 7.0 or higher. • Observe crop rotation restrictions. Do not use on soils with a pH greater than 6.8, or carryover injury may result the following year. • Observe labeled crop rotation restrictions for all products containing chlorimuron (Classic) (see Table 2.1-11). • Adding chlorimuron to metribuzin improves control of common ragweed, cocklebur, velvetleaf, jimsonweed, and annual morningglory. • *Water quality advisory.*					
Command 3ME	clomazone	13	EPP or PRE	1.33–2.67 pt	0.5–1
• Command 3ME must be used as a preemergence soil-applied treatment without incorporation. • Do not apply within 1,200 feet of towns; residential areas; commercial fruit, nut, or vegetable production; or commercial greenhouses or nurseries. • Do not apply during temperature inversions or when wind speed is greater than 10 mph. Apply in a minimum spray volume of 10 gal/A. Use coarse sprays to reduce drift. • Observe labeled crop rotation restrictions (see Table 2.1-11).					
Dual Magnum 7.62EC/Dual II Magnum 7.64EC	*S*-metolachlor	15	EPP, PPI, or PRE	1–2 pt	0.95–1.9
• Dual is similar in activity to Outlook, Zidua, and Warrant. Dual II Magnum contains a crop-safening agent for corn. • For early preplant applications or fields with heavy surface plant residue, Dual rate may need to be increased by up to 20%. • Incorporation improves control of yellow nutsedge. • Dual can be applied after soybean emergence, but Dual will not control emerged weeds. • For extended residual or control of heavy weed infestations up to 2.6 pt/A is allowed. • Do *not* exceed 3.71 lb ai/A per year of any *S*-metolachlor-containing product • *Water quality advisory.*					
Envive 41.3DG	flumioxazin +	14	EPP or PRE	2.5–5.3 oz /A	0.044–0.094
	chlorimuron +	2			0.015–0.031
	thifensulfuron	2			0.004–0.009
• Do not mechanically incorporate into the soil after application. • Can be tank-mixed with products such as Command or pendimethalin for improved grass control. • If Envive is tank-mixed with group 15 herbicides and applied within 14 days of planting, plant under no-till or minimum tillage conditions on wheat stubble or field corn stubble. • Products containing flumioxazin have specific tank-cleaning instructions on the label or in technical bulletins to help avoid contaminant injury from spray tank residues. • Envive can provide some burndown and residual weed control when applied 2 weeks before planting up to 3 days after planting (before soybean emergence), but it often needs to be tank-mixed with glyphosate and/or 2,4-D to achieve complete burndown. • Refer to label regarding applications with/or in sequence with Sharpen and other Group 14 herbicides. • See Valor entry for more information.					
Fierce 76WDG	pyroxasulfone +	15	EPP or PRE	3–3.75 oz	0.08–0.10
	flumioxazin	14			0.063–0.78
Fierce EZ 3.04SC	pyroxasulfone +	15	EPP or PRE	6–7.5 fl oz	0.08–0.100
	flumioxazin	14			0.064–0.079
Fierce XLT 62.41WDG	pyroxasulfone +	15	EPP or PRE	3.75–5.25 oz	0.073–0.102
	flumioxazin+	14			0.057–0.08
	chlorimuron	2			0.016–0.022
• See Zidua and Valor entry for comments. • Fierce XLT improves morningglory control compared to Fierce or Fierce EZ due to addition of chlorimuron. • Products containing flumioxazin have specific tank-cleaning instructions on the label or in technical bulletins to help avoid contaminant injury from spray tank residues. • *Water quality advisory.*					

Table 2.4-8. Comments on preplant or preemergence herbicides for conventional, minimum-till, or no-till soybean. (continued)

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
FirstRate 84WDG	cloransulam	2	EPP, PPI, or PRE	0.6–0.75 oz	0.031–0.039
• Cloransulam provides good control of several annual broadleaves, including common lambsquarters, pigweed, common ragweed, velvetleaf, and cocklebur. Common ragweed is commonly resistant to FirstRate and other group 2 herbicides in the region. • FirstRate water-dispersible packets are not soluble in liquid fertilizer solutions; premixing in water is required. • Gangster and Surveil are co-packs that contain flumioxazin (Valor) and cloransulam (FirstRate). • Gangster/Surveil can be applied as a fall (after October 15) or spring preplant treatment or preemergence. • *Water quality advisory.*					
Gangster/Surveil co-pack/Surveil 48WDG	flumioxazin +	14	EPP or PRE	2.5–3 oz	0.08–0.096
	cloransulam	2		0.5–0.6 oz/3.5–4.2 oz	0.026–0.031
• Gangster and Surveil are co-packs that contain flumioxazin (Valor) and cloransulam (FirstRate). Surveil 48WDG is a single product containing both active ingredients. • Do not mechanically incorporate. • Products containing flumioxazin have specific tank-cleaning instructions on the label or in technical bulletins to help avoid contaminant injury from spray tank residues. • See FirstRate and Valor entries for more comments. • *Water quality advisory.*					
Intermoc	*S*-metolachlor +	15	EPP or PRE	64–80 fl oz	1.79–2.23
	glufosinate	10			
• Intermoc may be applied as burndown treatment prior to planting any soybean variety. • Apply a minimum of 64 fl oz/A to young, actively growing weeds. • Include AMS 2–4 lb/A. • Do not use nitrogen solutions as spray carriers. • Do not apply within 2 weeks of planting on course-textured soils. • Do not apply more than two applications per year, and do not apply more than 5 days apart. • Do not apply more than 122 fl oz/A per year.					
Lorox 50DF	linuron	7	EPP or PRE	0.75–2 lb	0.38–1
Linex 4L				1 to 2 pt	0.5–1
• Do not mechanically incorporate. • Do not use on sands or loamy sands, or on soils with less than 0.5% organic matter. • Do not apply after soybean emergence. • Provide good agitation in tank before and during application. • Follow labeled directions regarding soybean planting depth. • Do not plant any crop not on label within 4 months of application.					
Metribuzin 75DF	metribuzin	5	EPP, PPI, or PRE	4–8 oz	0.2–0.4
• Do not use on sands or loamy sands or on soils with less than 0.5% organic matter, or crop injury may result. If used on coarse-textured soils with less than 2% organic matter or if heavy rainfall follows soon after application, severe stand losses can occur. • Rates on coarse-textured soils in lower portion of the Eastern Shore and Delaware should be no more than 4 oz. • Soybean varieties have different levels of tolerance to metribuzin; refer to product label for list of susceptible varieties. • Do not apply after soybean emergence. • Metribuzin is a triazine (Group 5) herbicide and does not control triazineresistant weeds. • Potential for crop injury may increase if atrazine was used the previous year due to the additive effect of residual atrazine and metribuzin. • Plant at least 1.5 inches deep. • *Water quality advisory.*					
OpTill 68WG	saflufenacil +	14	EPP or PRE	2 oz	0.022
	imazethapyr	2			0.063
• On coarse-textured soils with less than 2% organic matter, a minimum of 30 days between application of Optill and soybean planting is required. • Optill may be applied as a preplant burndown application from early spring through preemergence; do not apply if soil cracking has begun or soybeans have emerged. • In a burndown program it is best to include glyphosate or glufosinate in addition to the necessary adjuvants (COC or MSO plus AMS or nitrogen solution) to improve control of emerged weeds, including horseweed. • Do not apply Optill with any other Group 14 herbicide (flumioxazin, sulfentrazone, fomesafen) as a tank mixture or sequential application within 14 days of planting, or crop injury may result. • Postemergence herbicides containing a Group 14 herbicide (Reflex or Flexstar GT) can be applied 14 days after soybean emergence. • Adequate soil moisture is necessary for optimum activity.					

Table 2.4-8. Comments on preplant or preemergence herbicides for conventional, minimum-till, or no-till soybean. (continued)

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
• Do not plant corn until 8.5 months after application. Consult label for other rotation restrictions. Do not apply products containing chlorimuron during the same season, or injury to rotational crops may result. • OpTill PRO is a co-pack of OpTill and Outlook. • *Water quality advisory.*					
Outlook 6.0EC	dimethenamid	15	EPP, PPI, or PRE	10–21 fl oz	0.47–0.98
• Outlook is similar in activity to Dual, Zidua, and Warrant. • For early preplant applications or fields with heavy surface plant residue, use 21 fl oz/A. • Incorporation improves control of yellow nutsedge.					
• Do not exceed a rate of 12 oz/A of Outlook on coarse soils with less than 1.5% organic matter. PPI applications are not recommended on these soils. Outlook will have very short residual when used on coarse-textured soils. • Outlook can be applied after soybean emergence (up to 5th trifoliate), but Outlook will not control emerged weeds. • OpTill PRO is a co-pack of OpTill and Outlook. • *Water quality advisory.*					
Prefix 5.3EC	*S*-metolachlor +	15	EPP, PPI, or PRE	2–3 pt	0.73–1.1
	fomesafen	14			0.16–0.24
• See Dual entry for more comments. • Prefix contains *S*-metolachlor (Dual Magnum) and fomesafen (Reflex) for annual grass, nutsedge, and broadleaf control. The ratio of fomesafen in this product is relatively low, below what is typically recommended for soil applications. • In most situations, Prefix provides foundational weed control but will likely need to be followed by additional weed control measures. • Be cautious of restrictions associated with fomesafen use in consecutive years and use rates that vary across the region. Refer to label for additional use restrictions. • Prefix followed by sequential applications of Reflex is prohibited; use of fomesafen as a postemergence treatment is preferable to use as a soil application. • Refer to label regarding applications with/or in sequence with Sharpen and other Group 14 herbicides.					
Prowl 3.3E	pendimethalin	3	EPP, PPI, or PRE	1.2–3.6 pt	0.5–1.5
Prowl H2O 3.8CS				2–3 pt	0.95–1.4
• Prowl 3.3E: do not exceed 2.4 pt/A rate when using surface application. • Under certain environmental conditions, preemergence applications may cause callus tissue development at soil line, resulting in brittle soybean stems and increased incidence of lodging. • Prowl (all formulations) should be applied preplant incorporated (PPI) north of I-80 due to stem callus and possible lodging concerns. • Do not apply to emerged soybeans. • Generic EC formulations are available; consult individual labels for rates and restrictions.					
Pursuit 2S	imazethapyr	2	EPP, PPI, or PRE	4 fl oz	0.063
• Adequate soil moisture is necessary for optimum activity. • Do not plant corn until 8.5 months after application. Consult label for other rotation restrictions. Do not apply products containing chlorimuron during the same season, or injury to rotational crops may result. • *Water quality advisory.*					
Python 80WDG	flumetsulam	2	EPP or PRE	0.8–1.33 oz	0.04–0.066
• Python may be tank-mixed with other herbicides to broaden the spectrum of control. Check individual herbicide labels for potential tank-mix partners. • Do not apply where soil pH is greater than 7.8. • Do not apply to emerged soybeans. • *Water quality advisory.*					
Reflex 2E	fomesafen	14	EPP or PRE	1–1.5 pt	0.25–0.375
Flexstar 1.88E				1.06–1.6 pt	
• Apply Reflex/Flexstar for broadleaf weed control; tank-mix with residuals that will improve annual grass activity. • Be cautious of restrictions associated with fomesafen use in consecutive years and the use rates that vary across the region. Refer to label for additional use restrictions. • Use of fomesafen as a postemergence treatment is preferable to use as a soil application. • Refer to label regarding tank mixtures. • *Water quality advisory.*					

Table 2.4-8. Comments on preplant or preemergence herbicides for conventional, minimum-till, or no-till soybean. (continued)

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Tendovo	*S*-metolachlor	15	EPP, PPI, or PRE	1.2–2.35 qt	1.041–4.077
	metribuzin	5			0.193–0.377
	chloransulam	2			0.020–0.038

• See comments for Dual Magnum, metribuzin, and FirstRate
• Incorporation improves control of yellow nutsedge.
• Do *not* exceed 3.71 lb ai/A per year of any *S*-metolachlor-containing product.
• Soybean injury may occur on soils with less than 0.5% organic matter.
• Soybean injury may occur if used on coarse-textured soils with less than 1% organic matter or if heavy rainfall follows soon after application.
• Soybean varieties have different levels of tolerance to metribuzin; refer to product label for list of susceptible varieties.
• Plant at least 1.5 inches deep.
• *Water quality advisory.*

Treflan 4E	trifluralin	3	PPI	1–2 pt	0.5–1

• Incorporate thoroughly to a depth of 2 to 3 inches within 24 hours of application. Label recommends two-pass incorporation.
• Plant soybeans after early season adverse weather has passed.
• Do not plant deeper than 2 inches.

Trivence 61.3WDG	chlorimuron +	2	EPP or PRE	6–10 oz	0.014–0.023
	flumioxazin +	14			0.048–008
	metribuzin	5			0.169–0.282

• Do not mechanically incorporate Trivence into the soil after application.
• Do not apply Trivence if soybeans have begun to emerge.
• Trivence has some burndown activity, but it should be tank-mixed with glyphosate or paraquat in most cases.
• Trivence can be tank-mixed with products such as Command or pendimethalin for improved grass control.
• If Trivence is tank-mixed with group 15 herbicides and applied within 14 days of planting, plant under no-till or minimum tillage conditions on wheat stubble or field corn stubble.
• Splashing soil from irrigation or heavy rainfall may cause injury to newly emerged soybeans. Do not irrigate when soybeans are cracking.
• Products containing flumioxazin have specific tankcleaning instructions on the label or in technical bulletins to help avoid contaminant injury from spray tank residues.
• Refer to label regarding applications with/or in sequence with Sharpen and other Group 14 herbicides.
• See Valor SX entry for additional information and mode of action statement.

Valor SX 51WDG	flumioxazin	14	EPP or PRE	2–2.5 oz	0.063–0.08 oz
Valor EZ 4SC				2–2.5 fl oz	

• Valor products may be tank-mixed with certain herbicides to broaden weed control spectrum.
• Do not use more than 3 oz/A of Valor SX or Valor EZ per season.
• Rate is dependent on weed species targeted, soil type, and soil organic matter; refer to label.
• Do not mechanically incorporate Valor products into the soil after application.
• Do not apply products containing flumioxazin if soybeans have begun to emerge. Splashing soil from irrigation or heavy rainfall may cause injury to newly emerged soybeans.
• If Valor SX or EZ is tank-mixed with group 15 herbicides and applied within 14 days of planting, plant under no-till or minimum tillage conditions on wheat stubble or field corn stubble.
• Valor SX or EZ at 1 to 2.5 oz/A can enhance the speed of burndown and increase weed spectrum of typical burndown herbicide programs.
• Refer to label regarding applications with, or in sequence with, Sharpen and other Group 14 herbicides.
• Gangster and Surveil are co-packs that contain flumioxazin (Valor) and cloransulam (FirstRate). Other premix products that contain flumioxazin include Afforia, Envive, Fierce, Trivence, Valor XLT, and others.
• Products containing flumioxazin have specific tank-cleaning instructions on the label or in technical bulletins to help avoid contaminant injury from spray tank residues.

Valor XLT 40WDG	flumioxazin +	14	EPP or PRE	3–5 oz/A	0.056–0.094
	chlorimuron	2			

• Do not mechanically incorporate into the soil after application.
• Can be tank-mixed with products such as Command or pendimethalin for improved grass control.
• If Valor XLT is tank-mixed with group 15 herbicides and applied within 14 days of planting, plant under no-till or minimum tillage conditions on wheat stubble or field corn stubble.
• Products containing flumioxazin have specific tank-cleaning instructions on the label or in technical bulletins to help avoid contaminant injury from spray tank residues.
• Refer to label regarding applications with, or in sequence with, Sharpen and other Group 14 herbicides.
• See Valor entry for more information.

Table 2.4-8. Comments on preplant or preemergence herbicides for conventional, minimum-till, or no-till soybean. (continued)

Trade Name*	Common Name	Site of Action Number	Application**	Product/A	lb ai/A
Warrant 3CS	acetochlor	15	EPP or PRE	1.25–2 qt	0.94–1.5
• Warrant can be soil applied for residual control of certain annual grasses and broadleaves. • Warrant can be applied after soybean emergence (up to R2 stage), but it will not control emerged weed seedlings. • Do not mechanically incorporate Warrant prior to planting (PPI). • *Water quality advisory.*					
Warrant Ultra 3.45CS	acetochlor +	15	EPP or PRE	48–70 fl oz	1.06–1.54
	fomesafen	14			0.24–0.34
• Warrant Ultra is a prepackaged mixture of Warrant and Reflex; however, the ratio of fomesafen in this product is relatively low, below what is typically recommended for soil applications. • Warrant Ultra can be soil applied for residual control of certain annual grasses and broadleaves. • Warrant Ultra can be applied after soybean emergence (up to R2 stage). Optimum timing is V2–V3. • Do not mechanically incorporate Warrant Ultra prior to planting (PPI). • Be cautious of restrictions associated with fomesafen use in consecutive years and the use rates that vary across the region. Refer to label for additional use restrictions. • Use of fomesafen as a postemergence treatment is preferable to use as a soil application. • *Water quality advisory.*					
Zidua 85WDG	pyroxasulfone	15	EPP, PPI, or PRE	1.5–3.5 oz	0.08–0.186
Zidua 4.17SC				2.5–5.75 fl oz	0.081–0.187
• Zidua has annual grass activity similar to Dual, Outlook, Warrant, etc., but it also provides control of several annual broadleaves. • Zidua can be applied as an early preplant application up through planting and then as an early POST application from emergence to sixth trifoliate stage. Zidua will not control emerged weed seedlings. • Must be activated by at least 0.5 inch of rainfall prior to weed germination or effectiveness may be reduced. • Zidua can be tank-mixed with other herbicides to increase the spectrum of control. • Refer to the labels for rotation restrictions (most vegetables have an 18-month rotation restriction); see Table 2.1-11. • Fierce is a prepackaged mixture of Zidua and Valor; Fierce XLT is Zidua, Valor, and Classic.					
Zidua PRO 4.09SC	pyroxasulfone +	15	EPP or PRE	4.5–6 fl oz	0.08–0.107
	imazethapyr +	2			0.047–0.062
	saflufenacil	14			0.017–0.023
• On coarse-textured soils with less than 2% organic matter, a minimum of 30 days between application of Zidua PRO and soybean planting is required. • Zidua PRO may be applied as a preplant burndown application from early spring through preemergence; do not apply if soil cracking has begun or soybeans have emerged. • In a burndown program it is best to include glyphosate or glufosinate in addition to the necessary adjuvants (COC or MSO plus AMS or nitrogen solution) to improve control of emerged weeds, including horseweed. • Do not apply Zidua PRO with any other Group 14 herbicide (flumioxazin, sulfentrazone, fomesafen) as a tank mixture or sequential application within 14 days of planting, or crop injury may result. • Postemergence herbicides containing a Group 14 herbicide (Reflex or Flexstar GT) can be applied 14 days after soybean emergence. • Outlook at 10 fl oz is lower than recommended rates for medium- and fine-textured soils.					

*See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients.
**Application timing: EPP = early preplant (application at least 7 days prior to planting); PPI = applied to conventionally tilled soil and then mechanically incorporated; PRE = preemergence (applied before the crop has emerged).
See specific product label to determine correct rate for soil type, tillage practices, and weed species found in each field. Mechanical incorporation reduces the need for timely rainfall after application and may improve control of certain weeds. Mechanical incorporation will improve weed control when no rainfall or irrigation occurs within 7 to 10 days after planting. In no-till situations, burndown herbicides may be required to control weeds or cover crops present at time of application.

Table 2.4-9. Soybean herbicide preplant or preemergence rates based on soil texture and organic matter.[1]

			<3% Organic Matter			≥3% Organic Matter			
Trade Name	Site of Action Number	Unit/A	Coarse	Medium	Fine	Coarse	Medium	Fine	Inc. for No-till[2]
Afforia 50.8WG	2/2/14	oz	2.5	2.5	2.5	2.5	2.5	2.5	no
Antares Complete	14/15/5	pt	2.25-2.5	2.5-2.75	2.5-3.0	2.5-2.75	2.75-3.0	3.0	no
Anthem Maxx 4.3SC	14/15	fl oz	3.0	4.0	4.5	3.25	4.5	5.25	no
Authority Edge 4.25SC	14/15	fl oz	5.9–8.8	7.0–11.0	9.0–12.0	7.0–9.4	9.0–12.0	12.0–15.7	no
Authority Elite 7E/BroadAxe	14/15	fl oz	25.0	28.0	28.0	25.0	28.0	34.0	no
Authority First 70WDG/Sonic	2/14	oz	6.45	6.45	6.45	8.0	8.0	8.0	no
Authority MTZ 45WG	5/14	oz	12.0	16.0	18.0	14.0	18.0	20.0	no
Authority Supreme 4.16SC	14/15	fl oz	6–6.9	6–9.8	7–11.5	6.9	7–9.8	8–11.5	no
Authority XL 70WG	2/14	oz	5.3	7.0	8.0	5.3	7.5	8.5	no
Boundary 6.5EC	5/15	pt	1.25	2.0	2.5	1.5	2.5	2.75	yes
Canopy 75DF	2/5	oz	4.0	5.0	6.0	4.0	5.0	7.0	no
Canopy Blend 58.3WDG	2/5	oz	5.1	6.4	7.75	5.1	6.4	9.0	no
Command 3ME	13	pt	1.25	2.0	2.67	1.25	2.67	2.67	no
Dual II Magnum 7.62EC	15	pt	1.25	1.33	1.33	1.25	1.33	1.67	yes
Envive 41.3WDG	2/2/14	oz	3.5	3.5	4.0	3.5	4.0	5.0	no
Fierce 76WDG	14/15	oz	3.0	3.0	3.0	3.0	3.0	3.0	no
Fierce EZ 3.04SC	14/15	fl oz	6.0	6.0	6.0	6.0	6.0	6.0	no
Fierce MTZ 2.64SC/Kyber	5/14/15	pt	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	no
Fierce XLT 62.41WDG	2/14/15	oz	4.0	4.0	4.75	4.0	4.5	5.0	no
FirstRate 84WDG	2	oz	0.6	0.6	0.6	0.75	0.75	0.75	no
Flexstar 1.88E	14	pt	1.3–1.6[3]	1.3–1.6[3]	1.3–1.6[3]	1.3–1.6[3]	1.3–1.6[3]	1.3–1.6[3]	no
Gangster/Surveil (co-pack)	2/14	oz	3.0	3.6	3.6	3.0	3.6	3.6	no
Linex 4L	7	pt	1.25	1.3	1.75	1.5	1.75	2.0	no
Lorox 50DF	7	lb	1.25	1.3	1.75	1.5	1.75	2.0	no
Metribuzin 75DF	5	oz	4.0	8.0	10.0	4.0	11.0	12.0	no
OpTill 68WG	2/14	oz	2.0	2.0	2.0	2.0	2.0	2.0	no
Outlook 6.0E	15	fl oz	14.0	16.0	18.0	14.0	16.0	18.0	no
Panther MTZ	5/14	fl oz	do not use	15	18	12	15–18	18	no
Panther Pro	5/14/2	fl oz	12–15	12–15	12–15	12–15	12–15	12–15	no
Perpetuo 2.3SC	14/15	fl oz	6.0–8.0	6.0–10.0	6.0–10.0	6.0–8.0	6.0–10.0	6.0–10.0	no
Prefix 5.3E	14/15	pt	2.0	2.25	2.5	2.25	2.5	2.5	yes
Preview 2:1SC	5/14	fl oz	11–14	14–21	18–23	14–21	18–23	21–26	no
Prowl 3.3E	3	pt	1.8	2.4	2.4	1.8	2.4	3.0	yes
Prowl H2O 3.8CS	3	pt	1.5	2.0	2.0	1.5	2.0	2.5	yes
Pursuit 2S	2	fl oz	4.0	4.0	4.0	4.0	4.0	4.0	no
Reflex 2E	14	pt	1.25–1.5[3]	1.25–1.5[3]	1.25–1.5[3]	1.25–1.5[3]	1.25–1.5[3]	1.25–1.5[3]	no
Spartan 4F	14	fl oz	6.0	8.0	10.0	8.0	10.0	12.0	no
Surveil 48WG	2/14	oz	3.5	4.2	4.2	3.5	4.2	4.2	no
Tendovo 4.12 ZC	15/5/2	qt	1.2–1.5	1.5–2.1	1.75–2.35	1.2–1.5	1.5–2.1	1.75–2.35	no

Table 2.4-9. Soybean herbicide preplant or preemergence rates based on soil texture and organic matter (continued).[1]

			<3% Organic Matter			≥3% Organic Matter			
Trade Name	Site of Action Number	Unit/A	Coarse	Medium	Fine	Coarse	Medium	Fine	Inc. for No-till[2]
Treflan 4E	3	pt	1.0	1.5	2.0	1.5	2.0	2.0	no
Trivence 61.3WDG	2/5/14	oz	7.0	8.0	8.0	7.0	8.0	8.0	no
Valor SX 51WDG	14	oz	2.5	2.5	2.5	2.5	2.5	2.5	no
Valor EZ 4SC	14	fl oz	2.5	2.5	2.5	2.5	2.5	2.5	no
Valor XLT 40.3WDG	2/14	oz	3.0	3.5	4.0	3.0	4.0	4.5	no
Warrant 3CS	15	qt	1.5	1.5	1.5	1.5	1.5	1.5	no
Warrant Ultra 3.45CS	14/15	fl oz	48.0	50.0	50.0–60.0[4]	48.0	60.0–70.0[4]	60.0–70.0[4]	no
Zidua 81WDG	15	oz	2.0	2.5	3.0	2.0	2.5	3.0	no
Zidua PRO 4.09SC	15/2/14	fl oz	6.0	6.0	6.0	6.0	6.0	6.0	no
Zidua SC 4.17SC	15	fl oz	3.3	4.1	4.9	3.3	4.1	4.9	no
Zone Defense	14/14	oz	3.5-4.0	4.5-5.0	5.0	4.0-5.0	5.0	–	no

[1] The herbicide rates presented above are for conventionally tilled soils for the given soil texture and organic matter levels. This table shows application rates for products applied alone. Rates may vary if tank-mixed with other products and/or if weed infestations are heavy or if used in conservation tillage situations. See specific product label for additional information on application rates and uses.
[2] In general, when increasing the product rate for no-till or reduced tillage, use the upper end of the rate range if applicable. See specific product label for additional information on application rates and uses.
[3] Do not use on sands or loamy sands or on soils with less than 0.5% organic matter, or crop injury may result. If used on coarse-textured soils with less than 2% organic matter or if heavy rainfall follows soon after application, severe stand losses can occur. Rates on coarse-textured soils should be no more than 4 oz.
[4] Maximum rate depends on the location; refer to label for rates based on area use map.

Table 2.4-10. Herbicides commonly used after soybean emergence (POST).

Trade Name	Site of Action Number	POST Activity	Residual Activity
Assure II/Targa	1	Translocated	None
Basagran	6	Contact	None
Cadet	14	Contact	None
Classic	2	Translocated	Broadleaf only
Cobra	14	Contact	None
Dual Magnum	15	None	Yes
Engenia/XtendiMax	4	Translocated	None
Enlist One	4	Translocated	None
FirstRate	2	Translocated	Yes
Fusilade DX	1	Translocated	None
Glyphosate	9	Translocated	None
Harmony SG	2	Translocated	None
Liberty/Interline/Scout/others	10	Contact	None
Permit/Sandea	2	Translocated	Broadleaf only
Poast	1	Translocated	None
Pursuit	2	Translocated	Yes
Raptor	2	Translocated	Yes
Reflex/Flexstar	14	Contact	Broadleaf only
Resource	14	Contact	None
Select Max	1	Translocated	None
Ultra Blazer	14	Contact	None
Warrant	15	None	Yes
Zidua	15	None	Yes

Residual activity: none; short = 1 to 2 weeks of residual control; yes = more than 2 weeks of residual control. See Table 2.4-7 for more information.
Comparable residual activity is given for comparison purposes only. The data are based on herbicide half-life, which is the length of time it takes for half the herbicide to break down. Herbicide degradation (breakdown) is the result of chemical and/or microbial activity, which can be dependent on soil pH, soil temperature, and soil moisture levels. Since degradation is dependent on a number of factors, length of time can vary for herbicides based on the specific environmental conditions. Residual activity is not the same as herbicide carryover. Herbicide rates may be less with POST applications than PRE, so the duration of residual control may not be as long.
Group 1 herbicides only control grass weed species (no activity on yellow nutsedge).
Group 15 herbicides do not control weeds that are emerged at time of application.

Premixes	Constituent Products	Site of Action Number
Anthem Maxx	Cadet, Zidua	14/15
Enlist Duo	Enlist One, glyphosate	4/9
Extreme	glyphosate, Pursuit	9/2
Flexstar GT	glyphosate, Reflex	9/14
Intermoc	Liberty/Interline/Scout/others, Dual Magnum	10/15
Permit Plus	Permit/Sandea, Harmony	2/2
Prefix	Dual Magnum, Reflex	15/14
Sequence	glyphosate, Dual Magnum	9/15
Storm	Basagran, Ultra Blazer	6/14
Synchrony	Harmony, Classic	2/2
Tavium	XtendiMax, Dual Magnum	4/15
Warrant Ultra	Warrant, Reflex	15/14

Table 2.4-11. Relative effectiveness of postemergence herbicides.

Grasses

Trade Name (rate/A)	Site of Action Number	Barnyardgrass	Bermudagrass	Corn, Volunteer	Crabgrass	Foxtail spp.[1]	Goosegrass	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Muhly, Wirestem	Nutsedge, Yellow	Panicum, Fall	Panicum, Texas	Quackgrass	Shattercane	Signalgrass, Broadleaf
Assure II (8 fl oz)	1	**9**	**9**	**9+**	**8+**	**9+**[1]	**9**	**9**	**9**	6	N	**9**	**8+**	**9**	**9+**	**9**
Basagran (1 qt)	6	N	N	N	N	N	N	N	N	N	7+	N	N	N	N	N
Classic (0.67 oz)	2	N	N	6	N	N	N	N	N	N	8	N	N	N	6	N
Fusilade DX (12 fl oz)	1	**9**	**9**	**9+**	**8+**	**8+**	**9**	**9**	**9**	**8+**	N	**9**	**8+**	**9**	**9+**	**9**
Glyphosate (0.75 lb ae)[2]	9	**9+**	**9**	**9+**[3]	**9+**	**9+**	**9+**	**9**	**9+**	**9**	7	**9**	**9+**	**9**	**9**	**9+**
Liberty, Interline, Scout, others (32 fl oz)[4]	10	8	6	7[5]	**8+**	**8+**[1]	6	6	**9**	7	6	**8+**	8	6	**9**	**8+**
Poast (1–1.5 pt)[6]	1	**9+**	**8+**	8	**9**	**9+**	**9**	8	**8+**	7	N	**9**	**9+**	8	**8+**	**9+**
Pursuit (4 fl oz)	2	8	N	6	7	**8+**[1]	N	7	**9**	N	7	8	6	6	**9**	8
Raptor (5 fl oz)	2	8	N	8	7	**8+**[1]	N	7	**8+**	N	6	8	6	N	**8+**	8
Select (8 fl oz)	1	**9**	**9**	**9**	**9**	**9+**	**9**	**9**	**9**	**8+**	N	**9**	**9+**	**8+**	**9**	**9+**
Mixtures																
Extreme (3 pt)[2]	2/9	**9+**	**8+**	**9**[3]	**9+**	**9+**	**8+**	**9**	**9+**	**9**	6	**8+**	**9**	**8+**	**9**	**9**
Flexstar GT (4.5 pt)[2]	9/14	**9+**	**9**	**9+**[3]	**9+**	**9+**	**9+**	**9**	**9+**	**9**	7	**9**	**9+**	**9**	**9**	**9+**
Fusion (8 fl oz)	1/1	**9**	**9**	8	**8+**	**9**[1]	**9**	8	8	6	N	**9**	**8+**	8	8	**9**
Permit Plus (0.75 oz)[7]	2/2	N	N	N	N	N	N	N	N	N	**9+**	N	N	N	N	N
Storm (1.5 pt)	6/14	N	N	N	N	N	N	N	N	N	7+	N	N	N	N	N
Synchrony (0.75 oz)[7]	2/2	N	N	6	N	N	N	N	6	N	8	N	N	N	6	N

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; + = upper end of rating scale.

Ratings are based on labeled application rates and weeds at 4 inches in height. Results may differ with variations in weed size, temperature, rainfall, soil moisture, and spray coverage. Ratings are based only on postemergence (POST) activity and do not reflect possible residual activity. For ratings on herbicide combinations not listed, see the component parts. Ratings assume good growing conditions and proper usage of adjuvants.

[1] Herbicide is less effective on yellow foxtail compared to giant foxtail. Ratings for yellow foxtail: Assure II/Targa = 7; Fusion = 8; Liberty = 6; Pursuit = 6; Raptor = 6.

[2] For use on glyphosate-resistant soybean varieties only.

[3] Glyphosate will not control glyphosate-resistant corn

[4] For use on glufosinate-resistant soybean varieties only.

[5] Liberty will not control glufosinate-resistant corn or many hybrids with Bt traits.

[6] Rate for Poast is 1 pt on annual grasses and 1.5 pt for perennial grasses.

[7] For use on STS, Bolt, or non-STS soybean varieties; a lower rate must be used on non-STS varieties.

Table 2.4-11. Relative effectiveness of postemergence herbicides (continued).

Broadleaves

Trade Name (rate/A)	Site of Action Number	Amaranth, Palmer/ Waterhemp[1,2]	Anoda, Spurred	Burcucumber	Cocklebur	Horseweed/ Marestail[1,2]	Jimsonweed	Lambsquarters	Morningglory, Annual	Nightshade, Eastern Black	Pigweed[1]	Ragweed, Common[2,3]	Ragweed, Giant	Sicklepod	Sida, Prickly	Smartweed	Velvetleaf	Soybean Tolerance
Basagran (1 qt)	6	6	**8+**	N	**9**	N	**9**	8	N	N	6	8	7	N	8	**9**	**8+**	FG
Cadet (0.9 oz)	14	7	7	N	N	N	N	7	7	7	7	N	N	N	7	N	**9+**	F
Classic (0.67 oz)	2	N[1]	N	8	**9+**	7[1]	**9**	7	7	N	**9**[1]	8[3]	7+	8	N	**8+**	8	F
Cobra (12.5 fl oz)	14	**9**	7	8	8	N	**9**	7	8	**8+**	**9**	**9**[3]	**8+**	6	6	7	**8+**	F
Engenia (12.8 fl oz), XtendiMax (22 fl oz)[4]	4	**8+**	8	**8+**	**9**	**8+**	**9**	**9**	8	8	**8+**	**8+**	7+	**8+**	8	**8+**	8	VG
Enlist One (2 pt)[5]	4	**8+**	8	7	**9**	**8+**	**8+**	**9**	8	8	**8+**	**8+**	7+	8	8	7	8	E
FirstRate (0.3 oz)	2	N	**9**	6	**9**	8[1]	8	N	**8+**	N	N	**9**[3]	**9**	6	N	8	**9**	VG
Glyphosate (0.75 lb ae)[6]	9	N[2]	**9**	**8+**	**9**	6[2]	**9**	**8+**	8	8	**9+**	**9**[2]	8	**9**	8	**8+**	8	E
Harmony SG (0.125 oz)[7]	2	N	N	7	7+	N	7	**9**	N	N	**9**[1]	6[3]	N	N	N	**9**	**8+**	—[8]
Liberty, Interline, Scout, others (32 fl oz)[7]	10	**8+**	7+	8	**9**	**8+**	**9**	**9**	8	8	**8+**	**9**	**8+**	**8+**	8	**8+**	8	VG
Pursuit (4 fl oz)[1]	2	N[1]	7	6	**9**	N	8	7	7+	**8+**	**9**[1]	8[3]	6	N	6	**8+**	**9**	FG
Raptor (5 fl oz)[1]	2	N[1]	7	6	**9**	N	8	**8+**	7	**8+**	**9**[1]	8[3]	8	N	6	8	**9**	G
Reflex/Flexstar (1.25 pt)	14	**9**	6	7	8	N	**9**	6	8	**8+**	**9**	**9**[3]	8	N	N	8	7+	FG
Resource (6 fl oz)	14	7+	6	6	6	N	7	7	N	8	7+	7+[3]	6	N	6	6	**9+**	FG
Ultra Blazer (1.5 pt)	14	**9**	6	7	8	N	**9**	7	8	8	**9**	**9**[3]	8	N	N	**8+**	7+	F

Table 2.4-11. Relative effectiveness of postemergence herbicides (continued).

Broadleaves

Trade Name (rate/A)	Site of Action Number	Amaranth, Palmer/ Waterhemp[1,2]	Anoda, Spurred	Burcucumber	Cocklebur	Horseweed/ Marestail[1,2]	Jimsonweed	Lambsquarters	Morningglory, Annual	Nightshade, Eastern Black	Pigweed[1]	Ragweed, Common[2,3]	Ragweed, Giant	Sicklepod	Sida, Prickly	Smartweed	Velvetleaf	Soybean Tolerance
Mixtures																		
Extreme (3 pt)[5]	2/9	N[1,2]	**8+**	8	**9**	6[2]	**9**	**8+**	7+	8	**9**	**8+**[2,3]	8	**9**	7	**8+**	**9**	VG
Flexstar GT (4.5 pt)[5]	9/14	**9**2	**9**	**8+**	**9**	6[2]	**9**	**8+**	8	8	**9**	**9**[2,3]	**9**	**9**	8	**8+**	**8+**	F
Permit Plus (0.75 oz)[8]	2/2	N[1]	—	7	**9**	N	7	**9**	6	6	**9**[1]	**9**[3]	8	N	7	**9**	**9**	—[9]
Storm (1.5 pt)	6/14	**8+**	8	6	8	N	**9**	7	7+	7	**8+**	**8+**[3]	7	6	7	**8+**	8	FG
Synchrony (0.75 oz)[8]	2/2	N[1]	N	**8+**	**9+**	8[1]	**9**	**9**	7	N	**9+**[1]	8[3]	7+	**8+**	N	**9**	**9**	—[9]

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; + = upper end of rating scale.
Crop tolerance: E = excellent; almost never any crop injury observed; VG = very good; on rare occasion is crop injury observed; G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).
Ratings are based on labeled application rates and weeds at 4 inches in height. Results may differ with variations in weed size, temperature, rainfall, soil moisture, and spray coverage. Ratings are based only on postemergence (POST) activity and do not reflect possible residual activity. For ratings on herbicide combinations not listed, see the component parts. Ratings assume good growing conditions and proper usage of adjuvants.
[1] Group 2 resistance has been confirmed for this species and it is widespread in the region; Group 2 herbicides will not control these biotypes.
[2] Glyphosate resistance has been confirmed for this species and is widespread in the region.
[3] Common ragweed biotypes resistant to Groups 2 and 14 herbicides have been confirmed in the region. Group 14 resistance is limited to the DelMarVa region and New Jersey.
[4] For use on dicamba-resistant (Xtend or Xtendflex) soybean varieties only.
[5] For use on 2,4-D resistant (Enlist E3) soybean varieties only.
[6] For use on glyphosate-resistant soybean varieties only.
[7] For use on glufosinate-resistant soybean varieties only.
[8] For use on STS, Bolt, or non-STS soybean varieties; a lower rate must be used on non-STS varieties.
[9] Excellent crop tolerance for STS or Bolt varieties, but fair or worse ratings if used on non-STS varieties.

Table 2.4-12. Effectiveness of postemergence herbicides on perennial broadleaf weeds in soybean (based on seasonal control).

Trade Name	Site of Action Number	Artichoke, Jerusalem	Bindweed, Hedge	Dandelion	Dewberry	Dock spp.	Dogbane, Hemp	Groundcherry	Horsenettle	Ivy, Poison	Milkweed, Common	Pokeweed	Thistle, Canada
Basagran	6	6+	7	N	N	7	N	N	6	N	N	N	7
Classic	2	7+	8	7	7	7	7	—	7	6	6	7+	7
Cobra, Reflex, Ultra Blazer	14	6	7	N	N	6	6	6	7	N	6	7	6
Engenia/XtendiMax[1]	4	8	**8+**	7+	6	8	7	7	7	7+	6	7+	8
Enlist One[2]	4	—	**9**	**9+**	6	8	6	7	6	7	6	7	7
FirstRate	2	—	—	—	—	—	—	—	6	—	—	6	L-S
Glyphosate (broadcast)[3]	9	8	8	7	8	8	**8+**	7+	8	8	8	**8+**	**9**
Glyphosate (wiper application)[4]	9	7+	N	N	N	N	7+	6	N	6	7+	**8+**	7
Liberty, Interline, Scout, others	10	—	N	7	—	6	6	6	7	—	6	6	6
Pursuit/Raptor	2	7	7+	7	6	7	7	—	8	6	6	6	6
Synchrony	2/2	7+	7	7	7	6	7	—	N	6	7+	7+	7+

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; — = no local data available; + = upper end of rating scale; L-S = labeled as suppressed.

[1] For use on dicamba-resistant (Xtend and XtendFlex) soybean varieties only.

[2] For use on 2,4-D-resistant (Enlist E3) soybean varieties only.

[3] Broadcast applications of certain glyphosate products for use on glyphosate-resistant soybean varieties only. Refer to product label use restrictions. Information on various glyphosate formulations can be found in Table 2.1-8 (glyphosates).

[4] Mix one-third glyphosate product with two-thirds water. Two passes in opposite directions is most effective.

Table 2.4-13. Weed sizes for postemergence soybean herbicides.

Herbicides	Assure II/Targa[1]			Fusilade DX[1,2]			Fusion			Liberty		Poast[1]				Pursuit 2L		Raptor		Glyphosate[3]		Select/Clethodim[4,5]		
	Grass Size (in.)	Rate/A (fl oz)		Grass Size (in.)	Rate/A (fl oz)		Grass Size (in.)	Rate/A (fl oz)		Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)[6]		Rate/A (fl oz)[6]		Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)	Rate/A (lb ae/A)	Grass Size (in.)	Rate/A (fl oz)[6]	
Grasses		Alone	w/BH		Alone	w/BH		Alone	w/BH			Alone	w/BH	Alone	w/BH								Alone	w/BH
Annuals																								
Barnyardgrass	2–6	8	S7	2–3	12	12	2–4	8	10	3	22	<4	—	18	—	1–3	1.44	2–5	5	4–8	0.75	1–4	4	—
										5	29	<8	4	24	24							2–8	6	8–10
												<12[8]	—	36	—	1–3	1.44	2–4*	5	4–8	0.75	1–4	4–5	—
Crabgrass	2–6	8	S7	1–2	12	12	1–4	8	10	3	22	<6	4	24	24							2–6	6	8–10
										5	29	<8[8]	—	36	—									
Foxtail, Giant	2–4	5	5	2–6	12	12	2–8	7	10	6	22	<4	18	—	—	1–6	1.44	2–6	5	4–8	0.75	1–4	4	—
	2–8	7	7				≤168	8–14	—	12	29	<8	6	24	24							2–12	6	8–10
												<16	36	—	—									
Foxtail, Green	2–4	7	8	2–4	12	12	2–4	8	10	6	22	<4	18	—	—	1–3	1.44	2–6	5	4–8	0.75	2–8	6	8–10
										12	29	<8	6	24	24									
												<16[8]	36	—	—									
Foxtail, Yellow	2–4	7	S7	2–4	12	12	2–4	8	10	3	22	<8	6	24	24	1–3	1.44	2–6	5	4–8	0.75	2–8	6	8–10
										4	29	<16[8]	—	36	—									
Goosegrass	2–6	7	8	2–4	8		2–4	8	8–12	2	22	6		16	—	—	—	2–4	5			2–6	6	
										3	29													
Panicum, Fall	2–6	7	8	2–6	12	12	26	8	10	3	22	<4	18	—	—	—*	—*	2–6	5	4–8	0.75	1–4	4–5	—
										5	29	<8	4	24	24					2–8	0.19	8–10	2–8	8–10
												<12[8]	36											
Panicum, Texas	2–4	8		2–8	12		2–8	8	8–12	4	22	8		16	—	—	—	—	—			2–6	6	
										6	29													
Shattercane	6–12	5	5	6–12	6	12	6–12	6	8	6	22	<18	—	24	—	1–8	1.44	2–8	5	4–8	0.75	4–10	4	—
										3	29											6–18	6	8–10
Signalgrass, Broadleaf	2–6	10		2–4	12		2–4	8–10	10–12	3	22	8		16	—	1–8	4	2–5	5			2–6	6	
										5	29													

Table 2.4-13. Weed sizes for postemergence soybean herbicides (continued).

Herbicides	Assure II/Targa[1]			Fusilade DX[1,2]			Fusion			Liberty		Poast[1]				Pursuit 2L		Raptor		Glyphosate[3]		Select/Clethodim[4,5]		
		Rate/A (fl oz)			Rate/A (fl oz)			Rate/A (fl oz)				Grass Size (in.)[6]		Rate/A (fl oz)[6]									Rate/A (fl oz)[6]	
Grasses	Grass Size (in.)	Alone	w/BH	Grass Size (in.)	Alone	w/BH	Grass Size (in.)	Alone	w/BH	Grass Size (in.)	Rate/A (fl oz)	Alone	w/BH	Alone	w/BH	Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)	Rate/A (lb ae/A)	Grass Size (in.)	Alone	w/BH
Volunteer Corn	6–18	5	5	12–24	6	12	12–24	6	8	10	22	<12	18	—	—	—	—	2–89	5	4–8	0.75	4–12	4	—
										12	29	<20	12	24	24							12–24	6	8–10
Perennials																								
Bermudagrass																								
First application	<6	10		4–8	12		4–8	12			22	6 stolon		24		—	—	—	—			3	8	
Second application	<6	7		4–8	8		4–8	8			22	4 stolon		16		—	—	—	—			3	8	
Johnsongrass (rhizome)																								
First application	10–24	10	10	8–18	12	12	8–18	12		—*	—*	20–25		24		6–12*	1.44	6–12*	5	<18	0.75–1.5	12–24	8	16
Second application	6–10	7	—	6–12	8	—	6–12	8				6–12		24						<24		6–18	6	—
Quackgrass																								
First application	6–10		10	S7	6–10	12	12	6–10	12	—*	—*	6–8		36	—	—	—	4–8*	5	6–8	0.75–1.5	4–8	8	16
Second application	4–8		7		<10	8	—	10	8			6–8		36				4–8*	8	—				
Wirestem Muhly																								
First application	4–8*		8	S7	4–12	12	12	4–12	8	—*	—*	<6		36	—	—	—	—	—	<8	0.75–1.5	4–8+	8	16
Second application	4–8*		7	—	4–12	12	—	4–12	8			<6		36								4–8	8	—

This table lists postemergence soybean herbicides, their rates, and height ranges of weed species that are controlled or suppressed. This table is only a "quick reference"; refer to the herbicide label for additional information on application and timing. Postemergence grass herbicide rates may vary if tank-mixed with broadleaf herbicides due to antagonism. Split applications should be made if target growth stages for broadleaves and grasses do not correspond or if grasses to be managed are difficult-to-control species such as perennials. For split applications, it is best to apply postemergence grass herbicides 24 hours before or about 7 days after broadleaf herbicide application.

Table 2.4-13. Weed sizes for postemergence soybean herbicides (continued).

Herbicides	Assure II/Targa[1]			Fusilade DX[1,2]			Fusion			Liberty		Poast[1]				Pursuit 2L		Raptor		Glyphosate[3]		Select/Clethodim[4,5]		
		Rate/A (fl oz)			Rate/A (fl oz)			Rate/A (fl oz)				Grass Size (in.)[6]		Rate/A (fl oz)[6]									Rate/A (fl oz)[6]	
Grasses	Grass Size (in.)	Alone	w/BH	Grass Size (in.)	Alone	w/BH	Grass Size (in.)	Alone	w/BH	Grass Size (in.)	Rate/A (fl oz)	Alone	w/BH	Alone	w/BH	Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)	Rate/A (fl oz)	Grass Size (in.)	Rate/A (lb ae/A)	Grass Size (in.)	Alone	w/BH

*Suppression only; provides <75% control.
[1] May be tank-mixed with certain broadleaf herbicides only; refer to herbicide labels.
[2] Special reduced rates may be possible if applied early and under certain conditions; refer to label.
[3] For use on glyphosate-resistant soybean varieties only. Split applications may be necessary if new weed flushes occur.
[4] Select/Clethodim can be applied at a special high rate of 8 oz/A for annual grasses and 16 oz/A for perennials. These high rates should be used only for heavy grass pressure or when grasses are at maximum height.
[5] Select/Clethodim application rates vary when tank-mixed with certain broadleaf herbicides. Average rate ranges are shown above. Refer to label for additional information.
[6] Refers to rate per acre of herbicide if applied alone or if tank-mixed with broadleaf herbicides ("w/BH"). For Poast, target grass sizes are smaller if tank-mixed with broadleaf herbicides.
[7] Split applications may be necessary. May not provide adequate control of this species if tank-mixed with a broadleaf herbicide.
[8] Rescue application only; better control will result if applied alone. Do not tank-mix Fusion with broadleaf herbicides for rescue treatments.

Table 2.4-13. Weed sizes for postemergence soybean herbicides (continued).

Broadleaves	Amaranth, Palmer/ Waterhemp	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquarters	Morningglory, Annual	Nightshade, Eastern Black	Pigweed	Ragweed, Common	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf
Trade Name (rate/A)	Height Range (inches) at Application													
Basagran (2 pt)	–	4	–	≤10	≤10	≤2*	–	–	–	≤3	≤6	3	≤10	≤6
Cadet (0.9 fl oz)	≤4	–	≤3	–	≤2	≤3*	≤3	≤2	≤4	–	–	–	≤2	≤36
Classic (0.5 oz)	1–2	–	–	2–6	2–4	–	1–2	–	1–2	–	–	–	1–2	–
Classic (0.66 oz)	1–3	–	2–3*	2–8	2–5	–	1–3	–	1–3	2–3	2–4*	–	1–3	2–4
Classic (0.75 oz)	1–4	–	2–6*	2–12	2–6	–	1–4	–	1–4	2–4	2–6	–	1–4	2–6
Cobra (12.5 fl oz)[1]	6 lvs	2*	4 lvs	6 lvs	4 lvs	–	<4 lvs	6 lvs	6 lvs	6 lvs	4 lvs	3	4 lvs*	4 lvs
Engenia (12.8 fl oz)/ XtendiMax (22 fl oz)[2]	≤4	≤4	≤4	≤4	≤4	≤4	≤4	≤4	≤4	≤4	≤4	≤4	6	2
Enlist One (2 pt)[3]	≤6	≤6	–	≤6	≤6	≤6	≤6	≤6	≤6	≤6	≤6	≤6	≤6	≤6
FirstRate (0.3 oz)	–	–	–	<10	<4	–	<6	–	–	<10	<10	–	<6	<6
Flexstar GT 3.5 (3.5 pt)	≤4	4	–	≤4	≤4	≤4	≤3	≤4	≤4	≤4	≤4	2	≤4	≤4
Glyphosate (0.75 lb ae)[4]	4–8	2	4–8	4–8	4–8	3–6	3–6	4–8	4–8	4–8	4–8	2	3–6	4–8
Harmony SG (0.125 oz)	2–8	–	–	2–6*	2–4*	2–4	–	–	2–8	–	–	–	2–6	2–6
Liberty (32 fl oz)	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3

Table 2.4-13. Weed sizes for postemergence soybean herbicides (continued).

Broadleaves	Amaranth, Palmer/ Waterhemp	Anoda, Spurred	Burcucumber	Cocklebur	Jimsonweed	Lambsquar-ters	Morningglory, Annual	Nightshade, Eastern Black	Pigweed	Ragweed, Common	Ragweed, Giant	Sida, Prickly	Smartweed	Velvetleaf
Trade Name (rate/A)	**Height Range (inches) at Application**													
Permit Plus (0.75 oz)	≤6	–	≤3	≤9	≤4	≤4	≤3	–	≤6	≤9	≤3	–	≤6	≤9
Pursuit 2L (4 fl oz)	1–8	1–2	–	1–8	1–3	1–2*	1–2*	1–3	1–8	1–3*	1–3*	–	1–3	1–3
Raptor (5 fl oz)	2–8	–	–	2–8	2–6	2–5	2–4	2–5	2–8	2–5*	2–5	4*	2–5	2–8
Reflex (1.25 pt)[1]	2–6 lvs	2 lvs	–	2 lvs	6 lvs	2 lvs	2 lvs	4 lvs	2–6 lvs	4 lvs	4 lvs	–*	4 lvs	2 lvs
Resource (6 fl oz)[1]	≤3 lvs[4]	–	–	–	–	2–3 lvs*	–	–	≤3 lvs[5]	≤4 lvs	–	3	–	≤8 lvs
Storm (1.5 pt)	2–3	2	–	≤6	≤6	≤2*	≤2	≤2	2–3	≤3	≤6	2	≤6	≤2*
Synchrony[6]	2–8	3*	2–3*	2–8	2–5	2–4	1–3*	–	2–8	2–4	2–4*	–	2–8	2–8
Ultra Blazer (1.5 pt)	≤4	–	–	≤2	≤6	≤2	≤2	≤2	≤4	≤3	–	–	≤6	–

See Table 2.1-10 (generics) for additional herbicides that contain these active ingredients and Table 2.1-8 for information on glyphosate formulations.
*Suppression only; additional control measures may be necessary.
[1] Labels refer to weed size by number of leaves (lvs).
[2] For use on dicamba-resistant (Xtend) soybean varieties only.
[3] For use on 2,4-D-resistant (Enlist E3) soybean varieties only.
[4] For use on glyphosate-resistant soybean varieties only.
[5] Smooth pigweed control only.
[6] For use on STS, Bolt, or non-STS varieties; use lower rate on non-STS soybeans.

Table 2.4-14. Comments on postemergence herbicides for soybeans.

Trade Name	Common Name	Site of Action Number	Application Timing	Product/A	lb ai/A
Residual Herbicides Labeled for Postemergence Use The following herbicides can be added with postemergence herbicides to improve residual weed control. They will not provide control of emerged weeds, so they should be applied to weed-free soil surfaces or with products that will provide postemergence control of weeds present at the time of application. Consult labels when tank-mixing with any herbicide. Some pesticides or adjuvants used in combination with the following herbicides could increase the chance of soybean injury.					
Anthem Maxx 4.3SC	pyroxasulfone +	15	preemergence up to 6th trifoliate (R6)	2–5.7 fl oz	0.033–0.186
	fluthiacet	14			0.002–0.006
• Do not exceed a seasonal total of 3.4 fl oz on coarse soils or 5.7 fl oz on all other soils. • Contains fluthiacet (Cadet) and pyroxasulfone (Zidua); see Cadet and Zidua for more information. • Make applications at least 60 days before harvest.					
Dual Magnum 7.62EC Dual II Magnum 7.64EC	*S*-metolachlor	15	postemergence	1–2 pt	0.95–1.9
• Application timing is not specified on label. • Do not exceed a seasonal total of 3.9 pt/A. • Make applications at least 75 days before harvest. • A prepackaged mixture with glyphosate is available as Sequence; application timing is cracking through third leaf stage. • A prepackaged mixture with fomesafen (Reflex) is available as Prefix; label mentions early postemergence application timing. The ratio of fomesafen (Reflex) is too low for consistent postemergence control of emerged weeds. DO NOT exceed 3.71 lb ai/A/year of any *S*-metolachlor containing product. *Water quality advisory.*					
Outlook 6EC	dimethenamid-P	15	cracking stage to 5th trifoliate (V5)	12–21 fl oz	0.56–0.98
• Rates vary with soil type; refer to label. • Limited residual control when applied to coarse-textured soils. • Do not exceed a seasonal total of 24 fl oz.					
Perpetuo	pyroxasulfone	15	emergence to 6th trifoliate (V6)	6–10 fl oz	0.108–0.180
	flumiclorac	14			
• Do not apply more than 8 fl oz/A on coarse soils. • Contains flumiclorac (Resource) and pyroxasulfone (Zidua); see Resource and Zidua for more information.					
Warrant 3CS	acetochlor	15	emergence to R2	1.25–2 qt	0.94–1.5
• Rates vary with soil type and organic matter; refer to label. • Do not exceed 4 qt/A per year. • Label recommends application at V2 to V3 stage. • A prepackaged mixture with fomesafen (Reflex) is available as Warrant Ultra; the ratio of fomesafen (Reflex) is too low for consistent postemergence control of emerged weeds.					
Zidua 85WDG	pyroxasulfone	15	emergence to 6th trifoliate (V6)	1–3.5 oz wt	0.053–0.186
Zidua SC 4.17SC				1.75–5.75 fl oz	0.057–0.187
• Rates vary with soil type; refer to label. • Can be applied from emergence to the sixth trifoliate stage. • Do not exceed 2.1 oz wt and 3.5 fl oz/A per season on coarse-textured soils, 3 oz wt and 5 fl oz on medium-textured soils, and 3.5 oz wt and 5.75 fl oz on fine-textured soils of Zidua 85WDG and Zidua SC 4.17SC, respectively.					
Postemergence Herbicides The following herbicides are commonly applied postemergence to control emerged weeds. Most of these herbicides require an adjuvant to improve control; refer to proper tables to assist with adjuvant selection.					
Assure II 0.88E/Targa	quizalofop	1	postemergence	5–10 fl oz	0.03–0.06
• Do not use crop oils manufactured from vegetable oils. • When tank-mixing with a broadleaf herbicide, always read both labels to make sure the right surfactant and concentration are used. • Apply when grasses are within the recommended growth stage specified on the label. • Perennial grasses may require a second application for complete control. • Apply to actively growing grasses in 10 to 40 gal/A of water using flat-fan or hollow-cone nozzles. • To avoid antagonism (reduced grass control) from broadleaf herbicides, spray 2 to 3 days before the broadleaf herbicide or wait 7 days after the broadleaf herbicide application. • Assure II/Targa must be applied at least 80 days before harvest.					

Table 2.4-14. Comments on postemergence herbicides for soybeans (continued).

Trade Name	Common Name	Site of Action Number	Application Timing	Product/A	lb ai/A
Basagran 4S	bentazon	6	postemergence	1.5–2 pt	0.75–1
• Application should be made while weeds are small and actively growing and before weeds reach the maximum size listed on the product label. Basagran will not control pigweed species. • Add crop oil concentrate or nitrogen solution to spray mixture as directed. • Apply in a minimum of 20 gal of water/A and at a minimum pressure of 40 psi. • Tank-mixing with Reflex or Ultra Blazer improves pigweed control. • Apply at least 30 days prior to harvest as forage. • *Water quality advisory*.					
Butyrac 200 2L	2,4-DB	4	postemergence	0.7–0.9 pt	0.175–0.22
• 2,4-DB is not recommended for use by itself due to limited control and potential for crop injury. Rather, 2 oz of 2,4-DB can improve morningglory, cocklebur, and jimsonweed control when tank-mixed with other postemergence herbicides. • Potential for crop injury is increased under hot, dry growing conditions. • If more than 2 oz/A rate is used, apply as directed, spraying into rows when soybeans are 8 to 12 inches high and cocklebur, morningglory, jimsonweed, and pigweed have not exceeded a height of 3 inches. • The tops of weed seedlings must be sprayed. Use precision-directed spray application equipment. Apply with sprayer nozzles mounted on skids or gauge wheels. Do not spray more than one-third of the base of soybean as severe injury may occur. • Apply at least 60 days prior to harvest (forage or grain).					
Cadet 0.91EC	fluthiacet	14	emergence to full flowering (R2)	0.4–0.9 fl oz	0.0028–0.006
• Apply 0.4 to 0.6 fl oz/A with glyphosate (RR soybean) or glufosinate (LL soybean), or 0.6 to 0.9 fl oz when applied alone. • Include the necessary spray additives (NIS or COC plus AMS or nitrogen solution). Applications should be made when susceptible broadleaf weeds are small. Cadet is very effective on velvetleaf, but other broadleaf weeds must be small (less than 3 inches) to achieve control/suppression. Tank-mixing with other herbicides will usually be necessary to provide broad-spectrum weed control. • Cadet does not provide residual weed control. • Cadet can cause bronzing or browning of the soybean leaves. • Marvel is prepackaged mixture with Reflex and Cadet, but the rate of Reflex is below what is typically recommended and needed for effective weed control. • Apply at least 60 days prior to grain harvest.					
Classic 25DF	chlorimuron	2	after 1st trifoliate (V1)	0.5–0.75 oz wt	0.008–0.012
• Application should be made while weeds are small and actively growing. • Always read the label to determine the proper adjuvants. • Observe labeled crop-rotation restrictions for all products containing Classic (see Table 2.1-11). • If the soil pH is greater than 7.0, at Classic rates of 0.5 oz/A or greater, do not plant corn for at least 9 months after application. Use of STS and Bolt varieties will reduce the risk of injury. • Classic plus Harmony SG is available as a prepackaged mixture called Synchrony XP. Synchrony XP can be applied to non-STS soybean varieties at 0.375 oz/A use rate or to STS and Bolt varieties at rates up to 1.125 oz/A. • There is widespread resistance to Classic and other group 2 herbicides in the region. • Apply at least 60 days prior to harvesting for grain.					
Cobra 2E	lactofen	14	postemergence	6–12.5 fl oz	0.09–0.19
• Soybeans should have 1 to 2 trifoliate leaves. • Applications should be made while weeds are small and actively growing. • Use surfactant or crop oil concentrate as directed. • Cobra often causes foliar injury to soybeans. • Use 6 to 8 fl oz/A for control of 4- to 6-leaf common ragweed or pigweed. • Apply at least 45 days prior to harvesting for grain or prior to R6 (full seed).					
Engenia	dicamba BAPMA salt	4	emergence through June 30	12.8 fl oz for Engenia	0.5 (ae)
XtendiMax	dicamba DGA salt with VaporGrip			22 fl oz for Xtendimax	0.5 (ae)
• Apply over-the-top to dicamba-tolerant (Xtend or XtendFlex) soybean varieties only until June 30. • Refer to product label and Engeniatankmix.com **and** xtendimaxapplicationrequirements.com **for** details on approved adjuvants, drift reduction agents, other tank mixes, drift management, recommended nozzles and pressures, wind speed, boom height, temperature inversions, buffers, susceptible plants, spray equipment cleanout, and other use guidelines that must be followed when using these products. • Drift reduction agent (DRA) and volatility reduction agent (VRA) must be included. • These are restricted-use pesticides.					

Table 2.4-14. Comments on postemergence herbicides for soybeans (continued).

Trade Name	Common Name	Site of Action Number	Application Timing	Product/A	lb ai/A
• The risk of injuring sensitive plants via off-target movement is much less when these products are used in early burndown or prior to planting full-season soybean in the spring compared to postemergence applications. • Tavium (dicamba DGA salt with VaporGrip + *S*-metolachlor) can be used in Xtend soybean varieties to extend soil residual control of grasses and select broadleaf weeds (see Dual Magnum). • Reduced grass control can occur when tank-mixed with group 1 herbicides as well as glyphosate. • *Water quality advisory.*					
Enlist One 3.8SL	2,4-D choline	4	emergence up to R1	1.5–2 pt	0.71–0.95 ae
Enlist Duo 3.3SL	2,4-D choline +	4		3.5–4.75 pt	0.71–0.95 ae
	glyphosate	9			0.74–1.0 ae
• Apply over-the-top to 2,4-D tolerant (Enlist E3) soybean varieties only. • Apply in a broadcast spray volume from 10 to 15 gal/A for best results. • Applications should be made while weeds are small (4 inches) and actively growing. • Do not apply more than one preemergence application, with no more than two postemergence applications per season. • Make one to two applications with a minimum of 12 days between applications. • Spray droplet size plays an important role in minimizing off-target movement. Nozzles that produce extremely coarse or ultra-coarse droplets while limiting the amount of driftable fine droplets are necessary. Comply with guidelines for drift management (see labels for details). • Reduced grass control can occur when tank-mixed with group 1 herbicides as well as glyphosate. • Refer to product label and Enlist.com/TankMix for details on approved adjuvants, drift reduction agents, other tank mixes, drift management, recommended nozzles and pressures, wind speed, boom height, temperature inversions, buffers, susceptible plants, spray equipment cleanout, and other use guidelines that must be followed when using these products. • For all applications, consult label for run-off mitigation measures. • Training is available online at https://www.enlist.com/en/enlist-360-training.html.					
Extreme	glyphosate +	9	postemergence	1.5 qt	0.56 (ae)
	imazethapyr	2			0.06
• Prepackaged mixture of glyphosate plus Pursuit. The amount of glyphosate in Extreme is lower compared to the amount when applied; additional glyphosate may be needed for some species. • Pursuit is a Group 2 herbicide, and there is widespread resistance in the region to this family of herbicides. • Apply at least 85 days prior to harvesting for grain. • Refer to comments in sections for individual herbicides for more information.					
FirstRate 84WDG	cloransulam	2	1st trifoliate to R1	0.3–0.6 oz	0.016–0.031
• Tank-mix to broaden weed spectrum. • FirstRate may be applied up to 0.6 oz for heavy weed infestations or added residual control. • FirstRate water-dispersible packets are not soluble in liquid fertilizer solutions; premixing in water is required. UAN will improve velvetleaf control. • Two applications of 0.3 oz/A are allowed. Do not exceed 1.05 oz/A per season. • FirstRate is a Group 2 herbicide, and there is widespread resistance in the region to this family of herbicides. • Apply at least 65 days prior to harvesting for grain and 14 days prior to harvesting for forage. • *Water quality advisory.*					
Flexstar GT 3.5	glyphosate +	9	postemergence	3–4.5 pt	1–1.47 (ae)
	fomesafen	14			0.24–0.35
• Prepackaged mixture of glyphosate plus Reflex; refer to comments in those sections for more information.					
Fusilade DX 2E	fluazifop	1	postemergence	6–12 fl oz	0.09–0.18
Fusion 2.56EC	fluazifop +	1			0.094–0.188
	fenoxaprop	1			0.031–0.062
• See label for rate and size of weed to be controlled. • Most annual grasses should be treated when 2 to 4 inches in height. Perennial grasses may require a second application to achieve complete control. • To avoid antagonism (reduced grass control) from broadleaf herbicides, spray 2 to 3 days before the broadleaf herbicide or wait 7 days after the broadleaf herbicide application. • Apply before soybeans begin to bloom.					

Table 2.4-14. Comments on postemergence herbicides for soybeans (continued).

Trade Name	Common Name	Site of Action Number	Application Timing	Product/A	lb ai/A
Glyphosate	glyphosate	9	postemergence	varies by formulation and acid equivalent*	0.75–1.5 (ae)
• Apply over-the-top to glyphosate-resistant (Roundup Ready) soybean varieties only. • There are many formulations available; be sure to read the label for rates, adjuvants, etc. • Treat in-crop from soybean emergence through full flowering of soybeans. • If additional weed emergence is anticipated, consider including an herbicide that provides residual control. • Perennial weeds may require higher rates and repeat applications. Best control may be obtained when perennial weeds are treated in the bud to bloom growth stage. • Include ammonium sulfate in the tank to improve control of weeds and be sure to read the label to determine if additional adjuvants are required or recommended. • Observe maximum rates per application and per crop. • If glyphosate-resistant weeds are present or Palmer amaranth is in the vicinity, include a second, highly effective herbicide to control these species. • Avoid drift to adjacent crops or other desirable vegetation.					
Harmony SG 50DF	thifensulfuron	2	at least 1st trifoliate (V1)	0.125 oz wt (1/8 oz)	0.004
• Harmony SG is a very concentrated formulation. Be sure to use the proper application rate; otherwise, soybean injury may occur. • Various formulations of Harmony 50SG and generic 75DF thifensulfuron are available; be sure proper rate is applied. • Apply when weeds are actively growing and before they reach the maximum size listed on product label. • Any crop may be planted within 45 days following Harmony SG application. • For adequate velvetleaf control, add 1 gallon of liquid nitrogen solution per acre. • Use of STS or Bolt varieties will reduce the risk of injury. • Harmony SG plus Classic is available as a prepackaged mixture called Synchrony XP. • Harmony SG plus Sandea/Permit is available as a prepackaged mixture called Permit Plus. • Synchrony XP can be applied to non-STS soybean varieties at the 0.375 oz/A use rate or to STS or Bolt varieties at rates up to 1.125 oz/A. • Harmony SG, generic thifensulfuron products, Permit Plus, and Synchrony XP labels state that the first trifoliate leaf of the soybean is fully expanded before the application is made. • Apply Harmony 7 days before harvesting forage green; 30 days before harvesting dried forage; and 60 days before harvesting for grain. • Harmony is a Group 2 herbicide, and there is widespread resistance in the region to this family of herbicides.					
Intermoc	*S*-metolachlor +	15	postemergence	64 fl oz	1.79
	glufosinate	10			
Apply over the top to glufosinate-resistant soybean varieties (e.g., LibertyLink) only. Apply a minimum of 64 fl oz/A to young, actively growing weeds. Include AMS 2-4 lb/A. Do not use nitrogen solutions as spray carriers. Do not apply more than 2 applications per year, and do not apply more than 5 days apart. Do not apply more than 122 fl oz/A per year. *Water quality advisory.*					
Liberty/Interline/Scout/others 2.34L	glufosinate	10	emergence to bloom stage (R1)	32–43 fl oz	0.59–0.79
• Apply over the top to glufosinate-resistant soybean varieties (e.g., LibertyLink) only. • For best results, plant in narrow rows and apply up to 43 fl oz Liberty about 4 weeks after residual herbicides were applied, when weeds are less than 3 inches tall, inches tall, and before the soybean canopy begins to interfere with spray coverage. • If using sequential applications of Liberty, apply at a minimum of 5 days after the first application and do not apply more than 87 fl oz/A per season and before soybean bloom stage (R1).. • A residual soil-applied product or a sequential POST application may be necessary depending on weed species and severity. • Liberty provides no soil residual activity. • Tank-mixing Liberty with other herbicides including residual products (e.g., Dual Magnum, Outlook, Warrant) is allowed. Local university research has not observed increased injury with most herbicide combinations; some stunting and leaf burn were observed when Liberty was tank-mixed with Prefix. • Liberty must be applied with ammonium sulfate at the rate of 3 lb/A. • Use of surfactants or crop oils may increase risk of crop response. • Uniform, thorough spray coverage is necessary to achieve consistent weed control; do not use nozzles that produce large droplets; use at least 15 gal/A (20 gal/A if dense vegetation is present). • Applications should be made between dawn and 2 hours before sunset to avoid the possibility of reduced weed control. For best results, apply during warm temperatures, high humidity, bright sunlight, and not when there is heavy fog or dew on leaves. • Liberty has been observed to antagonize grass control with postemergence grass herbicides. • Apply 70 days before harvesting for grain or forage.					

Table 2.4-14. Comments on postemergence herbicides for soybeans (continued).

Trade Name	Common Name	Site of Action Number	Application Timing	Product/A	lb ai/A
Permit Plus 74WDG	halosulfuron +	2	1st trifoliate to R2 stage	0.75 oz wt	0.031
	thifensulfuron	2			0.004
• Permit Plus can be applied from V1 stage up until 88 days before harvest. • Permit Plus is excellent for yellow nutsedge control. • Can be tank-mixed with glyphosate. • See Harmony entry for more information. • Permit Plus contains two Group 2 herbicides, and there is widespread resistance in the region to this family of herbicides. • Permit Plus is labeled only for STS or Bolt varieties.					
Poast 1.5E	sethoxydim	1	postemergence	0.75–1.5 pt	0.14–0.28
• Application should be made when grasses are actively growing and within the recommended stage of growth on the Poast label. Perennial grasses may require a second application to achieve complete control. • Nitrogen fertilizer additives may improve control of some species. • To avoid antagonism (reduced grass control) from broadleaf herbicides, spray 2 to 3 days before the broadleaf herbicide or wait 7 days after the broadleaf herbicide application. • Poast must be applied at least 75 days before harvest.					
Pursuit 2S	imazethapyr	2	before bloom (R1)	4 fl oz	0.063
• A prepackaged mixture with glyphosate is available as Extreme. The amount of glyphosate is lower than the rate commonly used when glyphosate is applied alone. • Only one application of Pursuit can be made per soybean growing season. • Extreme can only be applied to soybean varieties designated Roundup Ready. • Observe rotation restrictions for products containing imazethapyr (see Table 2.1-11). • Pursuit is a Group 2 herbicide, and there is widespread resistance in the region to this family of herbicides. • Apply at least 85 days prior to grain harvest. • *Water quality advisory.*					
Raptor 1S	imazamox	2	before bloom (R1)	4–5 fl oz	0.031–0.039
• Occasionally, internode shortening and/or temporary yellowing of soybeans may occur, especially if plants are under environmental stress. • When adequate soil moisture is present, Raptor will provide residual activity against susceptible germinating weeds. • Apply when weeds are actively growing and before they reach the maximum size listed on the product label. Add a non-ionic surfactant and fertilizer solution as directed. • Less persistent than Pursuit, but follow the labeled crop rotation restrictions (see Table 2.1-11). • Raptor is a Group 2 herbicide, and there is widespread resistance in the region to this family of herbicides. • Apply at least 85 days prior to grain harvest.					
Reflex 2E or	fomesafen	14	postemergence	1–1.6 pt	0.25–0.375
Flexstar 1.88E					0.235–0.376
• Do not apply Reflex or Flexstar or other fomesafen-containing products more than once every 2 years. • Follow the labeled rotation restrictions (see Table 2.1-10). • Flexstar can cause more soybean injury than Reflex. • Tank-mixing Reflex with glyphosate formulated as a potassium salt can cause compatibility issues; glyphosate formulations as isopropyl or diammonium salts do not have this issue. • Flexstar GT contains glyphosate plus fomesafen and should be applied only to glyphosate-resistant soybeans. • Marvel is prepackaged mixture with Reflex and Cadet, but the rate of Reflex is below what is typically recommended and needed for effective weed control. • Prefix is a premix of Reflex and Dual and must be applied at least 90 days before grain harvest. Warrant Ultra is a premix of Reflex with Warrant and must be applied at least 45 days before grain harvest. Both have a low ratio of Reflex, below what is typically recommended for effective control. • Apply Reflex 45 days prior to grain harvest. • Do not apply within 14 days of an application of saflufenacil (Kixor or Sharpen). • *Water quality advisory.*					
Resource 0.86EC	flumiclorac	14	postemergence	4–12 fl oz	0.027–0.08
• Apply to actively growing weeds at growth stages recommended on the label. • Tank-mixing broadens the weed control spectrum; use higher rates for larger velvetleaf. Resource has activity against several other weeds when they are in the 2- to 3-leaf stage, including cocklebur, lambsquarters, common ragweed, jimsonweed, pigweed species, and prickly sida, but control declines on larger weeds. • Apply in a minimum of 10 gal of water/A and a minimum pressure of 30 psi. • In most cases, use a crop oil concentrate or other additive according to product label. • Apply at least 60 days prior to grain harvest.					

Table 2.4-14. Comments on postemergence herbicides for soybeans (continued).

Trade Name	Common Name	Site of Action Number	Application Timing	Product/A	lb ai/A
Select 2E or	clethodim	1	postemergence	6–16 fl oz	0.094–0.25
Select Max 0.97EC				6–32 fl oz	0.05–0.25
• Clethodim is also available as Select Max, which contains a specialized adjuvant system; thus, non-ionic surfactant plus ammonium sulfate (AMS) is the standard adjuvant recommendation. Also, Select Max does not require additional adjuvants (other than AMS) when tank-mixed with a "loaded" glyphosate product and provides greater flexibility in additive selection when tank-mixed with other products. • Select 2E should always include crop oil concentrate at 1 qt/A. Add ammonium sulfate at 2.5 lb/A to improve quackgrass control. • To avoid antagonism (reduced grass control) from broadleaf herbicides, spray 2 to 3 days before the broadleaf herbicide or wait 7 days after the broadleaf herbicide application. • Apply at least 60 days prior to grain harvest.					
Storm	bentazon +	6	postemergence	1–1.5 pt	0.33–0.5
	acifluorfen	14			0.167–0.25
• Prepackaged mixture of Basagran plus Ultra Blazer; refer to comments in those sections for more information. • Apply at least 50 days prior to grain harvest.					
Synchrony XP 28.4XP	chlorimuron +	2	fully expanded 1st trifoliate (V1)	0.375–1.125 oz	0.005–0.015
	thifensulfuron	2			0.0016–0.0045
• Synchrony XP may be applied postemergence to STS or Bolt soybeans at a use rate of 0.375 to 1.125 oz/A and to non-STS soybeans at 0.375 oz/A. • Synchrony XP may be tank-mixed to improve the weed-control spectrum. • Carefully observe crop rotation intervals and note that extended crop rotation intervals apply when Synchrony XP is applied following preemergence applications of other sulfonylurea or imidazolinone herbicides (see Table 2.1-11). • Synchrony contains two Group 2 herbicides, and there is widespread resistance in the region to this family of herbicides. • Apply at least 60 days before harvest.					
Ultra Blazer 2S	acifluorfen	14	at least 1st trifoliate (V1)	0.5–1.5 pt	0.125–0.38
• Apply in a minimum of 20 gal of water/A and at a minimum pressure of 40 psi. • Do not apply when weeds or crop are under stress; applications made under these conditions generally will be less satisfactory than those made under optimum conditions. • Tank-mixing with Basagran improves velvetleaf and common lambsquarters control. • Apply at least 50 days prior to grain harvest. • *Water quality advisory.*					

*Various glyphosate formulations exist; see Table 2.1-8 for more information.

Table 2.4-15. Spray additives and rainfastness for burndown or postemergence soybean herbicides.

Trade Name	Adjuvant(s)	Rate	Rainfastness (hours)
2,4-D (burndown)	none recommended		1
	or non-ionic surfactant	1 qt/100 gal	
	or crop oil concentrate	1–2 qt/A	
Aim/Cadet/Marvel	non-ionic surfactant	2 pt/100 gal	1
	or crop oil concentrate plus	1 gal/100 gal	
	ammonium sulfate or	2–4 lb/A	
	nitrogen solution (optional)	2–4 gal/100 gal	
Assure II/Targa	non-ionic surfactant	1 qt/100 gal	1
	or crop oil concentrate	4 qt/100 gal	
Basagran	crop or vegetable oil concentrate	5 qt/100 gal (2 pt/A maximum)	8
	or nitrogen solution	2–4 qt/A	
	or ammonium sulfate (for velvetleaf)	2.5 lb/A	
Classic	non-ionic surfactant	1 qt/100 gal	1
	or crop oil concentrate	1 gal/100 gal	
	plus nitrogen solution	2–4 pt/A	
	or ammonium sulfate (for velvetleaf)	2–4 lb/A	
Cobra*	non-ionic surfactant	1 qt/100 gal	0.5
	or crop oil concentrate	1–2 pt/100 gal	
	plus/or nitrogen solution	4 qt/A	
	or ammonium sulfate	2.5 lb/A	
Elevore (burndown)	crop oil concentrate or	4–8 pt/100 gal	1
	methylated seed oil	4–8 pt/100 gal	
Engenia	consult https://wwwengeniaherbicide.com/tank-mix.html		4
Enlist One	consult enlisttankmix.com		1
Enlist Duo	consult enlisttankmix.com		1
Envive (burndown)	crop oil/modified seed oil	1 gal/100 gal	1
	or non-ionic surfactant	1 qt/100 gal	
Extreme	non-ionic surfactant	1 pt/100 gal	1
	plus ammonium sulfate	2.5 lb/A	
FirstRate	non-ionic surfactant	1–2 pt/100 gal	2
	plus nitrogen solution	2.5 gal/100 gal	
	or ammonium sulfate	2 lb/A	
	or crop oil concentrate	1.2 gal/100 gal	
	plus nitrogen solution (optional)	2.5 gal/100 gal	
Flexstar	non-ionic surfactant	1–2 qt/100 gal	1
	or crop oil concentrate	2–4 qt/100 gal	
	plus nitrogen solution	1 gal/100 gal (minimum)	
	or ammonium sulfate	4 lb/100 gal (minimum)	
Flexstar GT	ammonium sulfate	8.5–17 lb/100 gal	1
Fusilade	non-ionic surfactant	1–2 qt/100 gal	1
	or crop oil concentrate	2–4 qt/100 gal	

Table 2.4-15. Spray additives and rainfastness for burndown or postemergence soybean herbicides (continued).

Trade Name	Adjuvant(s)	Rate	Rainfastness (hours)
	plus nitrogen solution	1 gal/A	
	or 10-34-0 (optional)	2 pt/A	
Fusion	non-ionic surfactant	1–2 qt/100 gal	1
	or crop oil concentrate	2–4 qt/100 gal	
	plus nitrogen solution (optional)	4 gal/100 gal	
Glyphosate	non-ionic surfactant	2 qt/100 gal	1–6
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Gramoxone SL 2.0 or 3.0	non-ionic surfactant	1 qt/100 gal	0.5
	or crop oil concentrate	1 gal/100 gal	
Harmony Extra/FirstShot/Audit (burndown)	non-ionic surfactant	0.5–2/100 gal	
	or crop oil concentrate	1 gal/100 gal	
	or methylated seed oil	1 gal/100 gal	
	plus ammonium nitrogen fertilizer	2 qt/acre	
Harmony SG[2]	non-ionic surfactant	1–2 pt/100 gal	1
	or crop oil concentrate	2 qt/100 gal	
	plus nitrogen solution	4 gal/100 gal	
	or ammonium sulfate (for velvetleaf)	2–4 lb/A	
Liberty/Interline/Scout/others	ammonium sulfate	3 lb/A	4
Permit Plus	non-ionic surfactant	1–2 pt/100 gal	4
	or crop oil concentrate	2 qt/100 gal	
	plus nitrogen solution	4 gal/100 gal	
	or ammonium sulfate (for velvetleaf)	2–4 lb/A	
Perpetuo	crop oil concentrate	1 pt/A	1
	or methylated seed oil	1 pt/A	
Poast	crop or vegetable oil concentrate	2 pt/A	1
	or Dash HC	1 pt/A	
	plus nitrogen solution	2–4 qt/A	
	or ammonium sulfate (certain species)	2.5 lb/A	
Prefix	non-ionic surfactant	1 qt/100 gal	1
	do NOT use crop oil concentrate	—	
Pursuit	non-ionic surfactant	1 qt/100 gal	1
	or crop oil concentrate	2 pt/A	
	or vegetable oil concentrate	1.5–2 pt/A	
	plus nitrogen solution	1–2 qt/A	
	or ammonium sulfate	2.5 lb/A	
Raptor	crop oil concentrate	2 pt/A	1
	or vegetable seed oil	1.5–2 pt/A	
	or non-ionic surfactant	1 qt/100 gal	
	plus nitrogen solution	1–2 qt/A	
	or ammonium sulfate	2.5 lb/A	
Reflex	non-ionic surfactant	1–2 qt/100 gal	1

Table 2.4-15. Spray additives and rainfastness for burndown or postemergence soybean herbicides (continued).

Trade Name	Adjuvant(s)	Rate	Rainfastness (hours)
	or crop oil concentrate	2–4 qt/100 gal	
	plus nitrogen solution (optional)	4 qt/A	
Resource	crop oil concentrate	2–4 qt/100 gal	1
	plus nitrogen solution (optional)	2–4 qt/A	
Reviton	methylated seed oil	1 gal/100 gal	1
	plus ammonium sulfate	8.5 lb/100 gal	
	or nitrogen solution	2.5 gal/100 gal	
Roundup WeatherMAX/PowerMAX	no NIS/COC required		<1
	ammonium sulfate (optional)	8.5–17 lb/100 gal	
Select	crop oil concentrate	2–4 qt/100 gal	1
	plus nitrogen solution (optional)	1–2 qt/A	
Sharpen (burndown)	methylated seed oil	1 gal/100 gal	1
	plus ammonium sulfate	8.5–17 lb/100 gal	
	or nitrogen solution	1.25–2.5 gal/100 gal	
Storm	non-ionic surfactant	1–2 pt/100 gal	8
	or crop oil concentrate	1–2 pt/A	
	or nitrogen solution	2 qt/A	
	or ammonium sulfate (for velvetleaf or pigweed)	2 lb/A	
Synchrony XP	crop oil concentrate	1 gal/100 gal	1
	plus nitrogen solution	2–4 qt/A	
	or 10-34-0	1–2 qt	
	or ammonium sulfate (for velvetleaf)	2–4 lb/A	
Tavium	consult www.TaviumApplicationRequirements.com		4
Ultra Blazer	non-ionic surfactant	1–2 pt/100 gal	6
	or crop oil concentrate	1–2 pt/100 gal	
	or ammonium sulfate	2.5 lb/A	
	or nitrogen solution (for velvetleaf)	2–4 qt/A	
Valor SX/EZ (burndown)	crop oil concentrate	1–2 pt/A	1
	or methylated seed oil	1 gal/100 gal	
	or non-ionic surfactant	1 qt/100 gal	
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Valor XLT (burndown)	crop oil concentrate	1–2 pt/A	1
	or non-ionic surfactant	1 qt/100 gal	
	plus ammonium sulfate (optional)	8.5–17 lb/100 gal	
Warrant Ultra	non-ionic surfactant	1–2 qt/100 gal	1
	or crop oil concentrate	2–4 qt/100 gal	
XtendiMax	consult xtendimaxapplicationrequirements.com		4

Spray additives, or adjuvants, are products included in the spray tank to improve the performance of herbicides. These include non-ionic surfactants (NIS), crop oil concentrate (COC), methylated or ethylated seed oil (MSO or ESO), or nitrogen solutions. In general, NIS should contain at least 80% active ingredient and COC should contain at least 15% emulsifier. Nitrogen solutions can be 28, 30, or 32% ammonium-based fertilizer solutions; ammonium sulfate (AMS) should be spray-grade dry ammonium sulfate (21-0-0) or another equivalent liquid formulation of AMS (refer to product label for use rate information).
*Adjuvants for use with Cobra depend on relative humidity and weed species.
**Use crop oil concentrate (COC) under drought-stressed conditions.

Table 2.4-16. Grain harvesting interval and forage restrictions for soybean herbicides.

Trade Name	Forage (OK to feed)	Grain (days to harvest)
2,4-D	No	—
2,4-DB	60 days	60
Afforia	No	—
Aim/Cadet	No	60
Antares Complete	40 days	-
Anthem Maxx	No	60
Assure II/Targa	No	80
Authority Edge	—	—
Authority Elite	30	—
Authority First/Sonic	No	65
Authority MTZ	No	—
Authority Supreme	—	—
Authority XL	No	—
Basagran	30 days	None
Boundary	40 days	—
BroadAxe	30 days	—
Canopy DF/Blend	No	—
Classic	No	60
Cobra	No	45
Command	No	—
Dual II Magnum	No	—
Elevore	—	—
Engenia	7 days (forage), 14 days (hay)	Before full bloom
Enlist One/Enlist Duo	56 days	30
Envive	No	—
Extreme	No	85
Fierce/Fierce EZ/Fierce XLT	No	—
FirstRate	25 days	70
Flexstar GT	No	45
Fusilade	No	Before bloom
Fusion	No	Before bloom
Gangster	No	—
Glyphosate	No	14
Gramoxone (preharvest)	No	Application restriction[1]
Harmony SG	7 days (green), 30 days (dried)	60
Intermoc	No	90
Liberty	70 days	70
Lorox	Yes	—
Marvel	No	60
Metribuzin	40 days	—
OpTill	No	85

Table 2.4-16. Grain harvesting interval and forage restrictions for soybean herbicides (continued).

Trade Name	Forage (OK to feed)	Grain (days to harvest)
OpTill PRO	No	85
Outlook	No	—
Panther MTZ	No	90
Panther Pro	No	85
Permit Plus	30 days	88
Perpetuo	No	60
Poast/Poast Plus	Yes[2]	75
Prefix	No	90
Preview 2:1	No	—
Prowl	Yes	—
Pursuit	No	85
Python	No	—
Raptor	No	85
Reflex/Flexstar	No	45
Resource	No	60
Reviton	—	—
Roundup (in-crop)[3]	14 days	14
Select	No	60
Sequence	No	90
Sharpen	65 days	—
Storm	No	50
Surveil	No	—
Synchrony XP	No	60
Tendovo	45 days	75
Treflan	Yes	—
Trivence	No	—
Ultra Blazer	No	50
Valor SX/Valor EZ/Valor XLT	No	—
Warrant	No	No
Warrant Ultra	No	45
XtendiMax	7 days (forage), 14 days (hay)	Before full bloom
Zidua	Yes	—
Zidua PRO	No	85
Zone Defense	No	—

— = not addressed on the label.
[1] When at least 65% of the seed pods have reached a mature brown or when seed moisture is 30% or less.
[2] Do not feed green forage.
[3] Allow 7 days between preharvest application and grain harvest.

Table 2.4-17. Comments on harvest aids for soybeans.

Trade Name	Common Name	Site of Action Number	Timing	Product/A	lb ai/A
Aim 2EC	carfentrazone	14	At least 3 days before harvest	1.5 fl oz	0.024
• Use as a harvest aid to desiccate a limited number of broadleaf weed species. • Use a non-ionic surfactant at 2 pt/100 gal spray solution or crop oil concentrate at 1 gal/100 gal spray solution plus ammonium sulfate at 2 to 4 lb/A or nitrogen solution at 2 to 4 gal/100 gal spray solution. • Application shall be made when the crop is mature and the grain has begun to dry down. Do not apply within 3 days of harvest. • Apply in 10 gal/A water. • Do not feed treated soybean forage or hay to livestock. • Include necessary adjuvants and make sure spray coverage is sufficient; otherwise, poor control will result.					
Clarity 4S	dicamba	4	At least 7 days before harvest	8–64 fl oz	0.25–2
• Apply Clarity to actively growing weeds after soybean pods have reached mature brown color and at least 75% leaf drop has occurred. • Use a non-ionic surfactant at 1 qt/100 gal spray solution or crop oil concentrate at 1 gal/100 gal spray solution plus nitrogen solution at 2 to 4 qt/A. • Do not feed soybean fodder or hay following a preharvest application of Clarity. • *Water quality advisory.*					
Defol 5	sodium chlorate		7 to 10 days before harvest	4.8 qt	6
• Labeled to dry weeds in early maturing soybeans and to facilitate harvest. • Apply to soybeans 7 to 10 days before anticipated harvest, when beans are mature and ready to harvest. • No adjuvant recommended. • Do not graze treated field or feed treated fodder. • Apply in at least 5 gallons of water by air, and 20 gallons of water with ground application.					
Glyphosate	glyphosate	9	At least 7 days before harvest	Varies with formulation	Up to 0.75
• Refer to individual herbicide label to be sure the formulation used is labeled for this type of application. • Apply glyphosate to soybeans after pods have set and lost all green color (80 to 90% drop of leaves has occurred). • Use a non-ionic surfactant at 2 qt/100 gal spray solution plus ammonium sulfate (optional) at 8.5 to 17 lb/100 gal spray solution. • Apply glyphosate in 10 to 20 gal/A water to control weeds that may interfere with harvest or to control perennials such as quackgrass or Canada thistle. • Do not graze or harvest the treated crop for livestock feed within 25 days of application. • Do not use on soybeans grown for seed. • Will not control glyphosate-resistant weeds or dry down Roundup Ready varieties. • See Table 2.1-8 (glyphosates) for more information on glyphosate formulations.					
Gramoxone SL 2.0	paraquat	22	At least 15 days before grain harvest; at least 3 days before soybean grown for seed harvest	8–16 fl oz	0.125–0.25
Gramoxone SL 3.0				5.4–10.7 fl oz	
• Gramoxone may be used for drying certain weeds and quickening berry drop of eastern black nightshade just before soybean harvest. • Soybean plants must be mature. For indeterminate varieties: 65% or more of the seed pods have reached mature brown color or seed moisture is 30% or less. For determinate varieties: beans are fully developed, half of leaves had dropped, and remaining leaves are yellowing. • Use a non-ionic surfactant at 1 pt/100 gal spray solution or crop oil concentrate at 1 gal/100 gal spray solution. • Do not graze or harvest for forage or hay. Paraquat use restrictions: • Only certified applicators who successfully complete the paraquat-specific training can mix, load, or apply paraquat. • Application of paraquat "under the direct supervision" of a certified applicator is no longer allowed; registered technicians cannot apply. • Required training at http://usparaquattraining.com; certified applicators must repeat training every three years. • *Restricted-use pesticide.*					
Sharpen 2.85SC	saflufenacil	14	At least 3 days before harvest	1.0–2.0 fl oz	0.022–0.044
• Apply after physiological maturity when greater than 50% leaf drop has occurred and remaining leaves are yellow. • Include methylated seed oil (MSO) at 1 gal/100 gal (1% v/v) plus ammonium sulfate (AMS) at 8.5 to 17 lb/100 gal or urea ammonium nitrate (UAN) at 1.25 to 2.5 gal/100 gal. • Do not apply to soybeans grown for seed production.					

Treatments are based on broadcast application, not wiper-bar or rope-wick applications.

Table 2.4-18. Soybean herbicide half-lives and their potential to injure fall-established cover crops.

Trade Name	Common Name	Normal Rate/ Acre	Half-Life (days)[1]	Fall-Established Cover Crops	OK to Plant	Concern For
2,4-D 4S	2,4-D	1–2 pt	7	All grasses	Wait 30 days before planting sensitive broadleaves	Amine formulations more water soluble and can leach into seed zone
Assure II/Targa 0.88E	Quizalofop	8 oz	60	Most broadleaves	All grasses if less than 120 days or at high rates	Plant anything after 120 days
Authority 75DF (Authority First, BroadAxe, Sonic, Spartan)	Sulfentrazone	4 oz	32–302	Cereals and ryegrass	Small-seeded legumes, mustards, sorghum[2]	Labeled on tobacco, sunflowers, transplanted tomato
Classic 25DF (Authority XL, Canopy, Envive, Fierce, Fierce XLT, Synchrony, Trivence, Valor XLT, etc.)	Chlorimuron	0.5–2 oz	40	Cereals and ryegrass	Small-seeded legumes, mustards, sorghum	More persistent in high-pH soils (>7) and with higher soil applied rates
Dual II Magnum 7.62E/Cinch	Metolachlor	1.67 pt	15–50	Cereal grains, legumes	Annual ryegrass or other small-seeded grasses	Higher rates and later applications more of a potential problem
FirstRate 84WDG (Authority First, Sonic)	Cloransulam	0.3 to 0.6 oz	8–33	Wheat, triticale, rye	Small-seeded legumes, mustards, sorghum	The restriction for transplanted tobacco is 10 months for 0.3 ounce per acre; sugarbeet and sunflower have a 30-month restriction
Glyphosate 4L	Glyphosate	0.75–1.25 lb ae	473	All	None	Glyphosate does not have soil activity at normal use rates
Gramoxone 2S	Paraquat	2 pt	1,000[3]	All	None	Paraquat does not have soil activity at normal use rates
Harmony 50WDG	Thifensulfuron	1⁄8 oz	12	No restrictions for wheat, barley, and oats	None with 45-day waiting interval	Harmony Extra also contains tribenuron
Liberty 2.34L	Glufosinate	22–36 fl oz	73	All	Food or feed residues rather than crop injury may be a concern	Glufosinate does not have soil activity at normal use rates
Metribuzin 75DF (Sencor)	Metribuzin	0.33 lb ai	14–60	Cereal grains and ryegrass	Slight risk for small-seeded legumes and mustards	Nonfood/feed winter cover crops allowed
Outlook 6E (Verdict)	Dimethenamid-P	16 fl oz	20	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops should be OK after corn harvest
Prowl H2O 3.8CS	Pendimethalin	3 pt	44	Cereal grains	Small-seeded legumes and annual ryegrass	We have not seen this herbicide carry over in the Mid-Atlantic; nonfood/feed winter cover crops should be OK
Pursuit 2S (Authority Assist, Optill, Zidua Pro)	Imazethapyr	4 fl oz	60–90	Wheat, triticale, rye, alfalfa, clover	Oats, sorghum, mustards	Any crop can be planted 40 months after Pursuit application
Python 80WDG	Flumetsulam	1 oz	14–120	Cereal grains	Small-seeded legumes, mustards, and annual ryegrass	Cover crops and forage grasses are restricted for 9 months

Table 2.4-18. Soybean herbicide half-lives and their potential to injure fall-established cover crops (continued).

Trade Name	Common Name	Normal Rate/ Acre	Half-Life (days)[1]	Fall-Established Cover Crops	OK to Plant	Concern For
Raptor 1E	Imazamox	5 fl oz	20–30	Wheat, triticale, rye, alfalfa, clovers	Slight risk for mustards	Most cash crops allowed 9 months following application
Reflex 2E/Flexstar 1.88E (Warrant Ultra)	Fomesafen	1.5 pt	100	Cereal grains	Small-seeded legumes, mustards, sorghum	Since fomesafen is often applied postemergence, soil activity can surprise users
Scepter 1.5AS	Imazaquin	0.66 pt	60–90	Cereal grains	Small-seeded legumes, mustards	Carryover much more of a risk with drought
Select 2E	Clethodim	10 oz	3	All broadleaves	None assuming at least 30 days	Plant anything after 30 days
Sharpen 2.85SC (Optill, Verdict, Zidua Pro)	Saflufenacil	3 fl oz	7–35	All	None	This product has been reported more persistent in western Canada
Valor 51WDG (Afforia, Envive, Fierce, Surveil, Trivence, Valor XLT, etc.)	Flumioxazin	2.5 oz	12–20	All grasses	Small-seeded legumes and mustards	Based on the half-life, all nonfood/feed winter cover crops should be OK
Warrant	Acetochlor	2 pt	10–20	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops are allowed after corn harvest
Zidua (Fierce, Anthem, etc.)	Pyroxasulfone	2.5 oz	20	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops should be OK after corn harvest

This table does not directly address preharvest establishment of cover crops such as interseeding or aerial seeding, which may be more restrictive.

[1] Herbicide half-life is defined as the time it takes for 50 percent of the herbicide active ingredient to dissipate. See the "Managing Herbicides" section for additional information. Herbicide half-life estimates are derived from the *WSSA Herbicide Handbook* and other scientific literature.

[2] Common small-seeded legumes include alfalfa, clovers, and hairy vetch.

[3] Herbicide does not have soil residual activity at normal application rates.

there are very few options to control it once soybeans have emerged.

Management of Herbicide-Resistant Palmer Amaranth and Common Waterhemp

Palmer amaranth control is difficult because (1) it emerges throughout the summer, (2) it grows rapidly, so once the plants emerge there are only a few weeks before it becomes too tall to control, and (3) many of the populations are resistant to glyphosate as well as Group 2 herbicides.

Effective management of Palmer amaranth requires a residual soil-applied herbicide applied within seven to ten days of planting and at the full labeled rates. Applying residual herbicides two weeks or more ahead of planting means there is a limited period of control once soybeans are planted. Postemergence applications must be made timely to small susceptible Palmer amaranth plants—according to various trials, within four weeks after the soil-applied herbicides were applied. The most consistent options have been fomesafen (Reflex or Flexstar GT), Liberty/Interline/Scout/others (with LibertyLink soybean), dicamba (XtendiMax, Engenia, and others) in Xtend soybean, and 2,4-D (Enlist One or Enlist Duo) in Enlist E3 soybean. The postemergence herbicide applications should include a product that provides residual control of Palmer amaranth, such as fomesafen (Reflex), Dual, Outlook, Warrant, or Zidua. In double-cropped soybeans, rotation intervals may limit the use of Reflex.

Insects

Historically, soybeans growing in the northeastern United States have been relatively free of insect pests, so the need for control has been rare; however, some recently arrived exotic species can build to damaging numbers, necessitating insecticide use in some parts of Pennsylvania, particularly in southeastern portions of the Commonwealth.

One reason for the historical lack of economically important insect pests of soybeans is that soybeans have a great capacity to compensate for damage inflicted by hail and by foliage-feeding insects. Soybean plants can tolerate up to 35 percent defoliation until bloom, about 15 percent while pods are small and soft, and about 35 percent when pods start hardening. Below these levels, defoliation does not adversely affect crop yield, so control is not suggested. However, insect pest challenges faced by Pennsylvania soybean growers can now include soybean aphid and stink bugs (particularly brown marmorated stink bug), which are not defoliators. These insect species, whose pest populations can vary greatly from year to year, are phloem feeders that use needlelike mouthparts to extract sap from plants, so plant tolerance based on tissue removal simply does not apply. Moreover,

Figure 2.4-1. Key periods of soybean insect pests in Pennsylvania.

populations of these sucking insects can grow quickly, making their management even more challenging.

Currently, 10 or so insect species can occasionally be abundant enough to cause economic losses in soybean production. Most are found on the foliage: bean leaf beetle, green cloverworm, grasshopper, Japanese beetle, Mexican bean beetle, potato leafhopper, and soybean aphid. Stink bugs, particularly brown marmorated stink bug, will feed on foliage as well as pods. A field usually reaches economic thresholds when more than one of these foliage pests are present at the same time. Soybean aphid can spread from the Midwest into eastern states, usually arriving in late June to mid-July, and threaten Pennsylvania soybeans. These invasions have occurred in past years (e.g., 2001, 2003, 2005, 2007, 2009, 2013, 2014) with populations that approached or exceeded the economic threshold of 250 aphids per plant. From 2015 onward, very few aphids have materialized in Pennsylvania soybeans, so it is difficult to predict what will happen in coming years. The seed corn maggot is a seed-feeding insect that can reduce stands, especially in tilled systems and when a living green cover crop is incorporated into the soil prior to planting and conditions are cool and moist for long periods after the seed is planted. Under extended hot, dry periods, the two-spotted spider mite can cause severe damage. Slugs, which are mollusks and not insects, can cause serious stress to plants before V3. Recent research at Penn State has revealed that neonicotinoid seed treatments can exacerbate slug damage by decreasing populations of ground beetles that typically contribute to slug control; therefore, one step toward improving slug control is removing insecticidal seed treatments from slug-prone fields. Figure 2.4-1 shows the key periods of soybean insect pest occurrence in Pennsylvania.

See Table 2.4-19 for a quick reference to insecticides recommended for soybean insect control, and Table 2.4-20 for specific rates, restrictions, and other information.

Table 2.4-19. Summary of recommended insecticides and seed treatments for soybean insect control.

Insecticides

Soybean Pest	AB	AC	AF	AL	AM	AN	AZ	BN	BNI	Bt	CB	CF	DF	DI	DM	ES	EX	FL	GC	LC	MF	ML	PE	SP	ST	SU	TH	ZB	ZC
Bean leaf beetle	▲	▲		▲		▲	▲	▲	▲		▲	▲		▲	▲	▲			▲	▲			▲				▲	▲	▲
Grasshopper	▲	▲				▲		▲	▲		▲	▲	▲	▲	▲	▲			▲	▲								▲	▲
Green cloverworm	▲	▲		▲		▲	▲	▲	▲	▲	▲	▲	▲		▲	▲			▲	▲	▲		▲	▲	▲		▲	▲	▲
Japanese beetle	▲					▲		▲	▲		▲	▲			▲	▲			▲	▲			▲					▲	▲
Mexican bean beetle	▲	▲		▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲			▲				▲				▲	▲	▲
Potato leafhopper	▲	▲		▲		▲	▲	▲	▲		▲	▲		▲	▲	▲		▲	▲	▲			▲					▲	▲
Seedcorn maggot												▲																	
Slugs																						▲							
Soybean aphid	▲	▲	▲					▲	▲			▲		▲	▲	▲		▲	▲	▲						▲		▲	▲
Stink bugs	▲					▲		▲	▲		▲	▲								▲								▲	▲
Two-spotted spider mite	▲				▲							▲		▲			▲											▲	

Always check the label. In some cases all formulations listed are not labeled for the pest.
AB = acetamiprid + bifenthrin (Argyle), AC = acephate (Orthene), AF = Afidopyropen (Sefina) AL = alpha-cypermethrin (Fastac), AM = abamectin (Agri-Mek), AN = acephate + bifenthrin (Acenthrin), AZ = azadirachtin (Neemix), BN = beta-cyfluthrin (Baythroid), BNI = beta-cyfluthrin + imidacloprid (Leverage 360), Bt = *Bacillus thuringiensis*, CB = carbaryl (Sevin), CF = chlorantraniliprole + bifenthrin (Elevest), DF = diflubenzuron (Dimilin), DI = dimethoate (Dimethoate), DM = deltamethrin (Delta Gold), ES = esfenvalerate (Asana XL), EX = etoxazole (Zeal SC), FL = flupyradifurone (Sivanto), GC = gamma-cyhalothrin (Proaxis), LC = lambda-cyhalothrin (Lambda Cy, Taiga, Warrior), MF = methoxyfenozide (Intrepid), ML = metaldehyde (Deadline MPs, Metarex), PE = permethrin (Ambush, Arctic, Perm-up, Pounce), SP = spinosad (Blackhawk, Entrust, Tracer), ST = spinetoram (Radiant), SU = sulfoxaflor (Transform), TH = thiodicarb (Larvin), ZB = zeta-cypermethrin + bifenthrin (Hero), ZC = zeta-cypermethrin (Mustang Max).

Neonicotinoid Seed Treatments. Pests not listed here are not controlled well by seed-applied insecticides. Note that even for the pests listed seed treatments tend to provide inconsistent control.

Soybean Pest	CL	IM	TM
Bean leaf beetle	▲	▲	▲
Potato leafhopper	▲	▲	▲
Seedcorn maggot	▲	▲	▲
Slugs (Note: neonicotinoid seed treatments tend to make slug populations worse)			

CL = clothianidin (Nipslt), IM = imidacloprid (Gaucho), TM = thiamethoxam (Cruiser).

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control.

- "**R**" after the insecticide name indicates that the compound has a restricted-use label.
- "**O**" indicates that the pesticide is labeled for organic use. However, check with your organic certifier to be sure that the material is allowed for your organic system.
- Reentry intervals are in hours unless indicated otherwise. For all reentry intervals of 0, do not enter the field without protective clothing until the spray has dried.
- "N/A" under harvest restrictions indicates that the harvest interval is not applicable at the time the compound is being applied. However, the user should be aware that the harvest restrictions exist.
- For certified organic insect control materials, refer to the Organic Materials Review Institute materials list at https://www.omri.org/, call 514-343-7600, or check with your local certifier and see https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program.
- Pesticide use can many times be avoided by using a combination of pest management methods. See Part I, Section 11: Organic Crop Production and Part II, Section 1: Pest Management to learn about IPM programs and methods for organic production.
- Each year there is an increase in the number of products offering mixtures of two active ingredients. If growers are faced with an outbreak of a pest complex, the two-ingredient mixtures may be of value; however, these products tend to be more expensive, and single ingredients can be just as effective. In general, we feel that the value of these two-ingredient mixtures is questionable for managing above-threshold populations of a single pest species.
- Insurance treatments are not necessarily economical or effective parts of IPM programs.
- **Most of these products are highly toxic to bees and many other beneficial insect species. Try to minimize use when crop is blooming and bees are likely to be present.** See labels for details.

Suggested insecticides, rates, and restrictions for BEAN LEAF BEETLE.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 15% of leaf area removed and five or more beetles per foot of row.					
Acephate (Orthene 97)	0.5 to 1 lb	0.49 to 0.97 lb	14	24	Do not apply more than 2 lb ai per acre per season. Do not feed treated plants to livestock.
Acephate + bifenthrin **R** (Acenthrin)	8 to 21 oz	0.37 to 0.97 lb acephate; 0.03 to 0.079 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	5 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.06 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	See label		12	12	Insect growth regulator derived from neem tree; effective for control of larvae only. Apply in sufficient water for adequate coverage.
Beta-cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material (0.088 lb ai per acre per season).
Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	2.8 oz	0.022 lb beta-cyfluthrin; 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop per season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl **R** (Sevin)	Many formulations available		12	12	Relatively safe for humans and livestock. See label for specific uses, rates, and restrictions.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for BEAN LEAF BEETLE (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not apply more than 8.5 oz per season.
Dimethoate R	Various formulations available		21	48	Do not feed or graze for 5 days after last application. See label for specific uses, rates, and formulations.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to 5 days for control to occur. Read label for additional restrictions and limitations.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Do not apply more than 0.96 pt per season (0.06 lb per acre per season).
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	3.5 to 4.5 oz	0.02 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Pounce 25WP)	2 to 6.4 oz	0.05 to 0.1 lb	60	12	Do not apply more than 0.4 lb ai per acre per season. Do not graze treated areas or harvest for forage or hay. See label for specific uses, rates, and formulations.
Thiocarb **R** (Larvin 3.2)	18 to 30 oz	0.45 to 0.75 lb	28	48	Do not exceed 0.75 lb ai per acre per application or 3 lb ai per acre per season. Do not feed treated forage to livestock. Use lower rates for maximum protection of beneficial arthropods.
Zeta-cypermethrin **R** (Mustang Max)	2.8 to 4 oz	0.0175 to 0.025 lb	21	12	Do not apply more than 0.15 lb ai (24 oz) per season. Do not make applications fewer than 7 days apart. Do not graze or harvest treated soybean forage for livestock.
Zeta-cypermethrin + bifenthrin **R** (Hero)	2.6 to 6.1 oz	0.025 to 0.06 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for BEAN LEAF BEETLE (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Seed Treatments					
Clothianidin (Nipslt)	1.28 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.
Imidacloprid (Gaucho)	1.6 to 3.2 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.
Thiamethoxam (Cruiser 5FS)	1.28 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.

Suggested insecticides, rates, and restrictions for GRASSHOPPER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 30% of leaf area removed before bloom or 15% between bloom and pod fill, or when 5 to 10% of pods are damaged.					
Acephate (Orthene 97)	0.25 to 0.5 lb	0.24 to 0.49 lb	14	24	Do not apply more than 2 lb ai per acre per season. Do not feed treated plants to livestock.
Acephate + bifenthrin **R** (Acenthrin)	12 oz	0.56 lb acephate; 0.045 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	5 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.06 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Alpha-cypermethrin **R** (Fastac)	3.23 to 3.8 fl oz	0.02 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Beta-cyfluthrin **R** (Baythroid XL)	2 to 2.8 oz	0.016 to 0.022 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	2.8 oz	0.022 lb beta-cyfluthrin; 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl (Sevin)	Many formulations available		21	12	Relatively safe for humans and livestock. See label for specific uses, rates, and restrictions.
Chlorantraniliprole (Prevathon)	8 to 20 oz	0.027 to 0.067 lb	14 (grain); 1 (forage)	4	For best results add methylated seed oil (MSO) adjuvant at 1 gal per 100-gal spray volume. See label for more details. Make no more than four applications per acre per crop. Minimum interval between treatments is 3 days. Do not apply more than 60 fl oz or 0.2 lb ai per acre per crop.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for GRASSHOPPER (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	Performance improved with the addition of a methylated seed oil adjuvant. No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not apply more than 8.5 oz per season.
Diflubenzuron **R** (Dimilin 25W or 2L)	2 to 4 oz	0.13 to 0.25 lb	21	12	Insect growth regulator; does not control adults. Apply before grasshoppers reach second to third instar. Do not make more than two applications per season. Does not provide immediate kill; from 3 to 5 days may be required before populations are reduced.
Dimethoate	Various formulations available		21	48	See label for specific uses, rates, and formulations. Do not feed or graze for 5 days after last application.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	For first and second instar nymphs use 3.9 to 5.8 oz. Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to five 5 for control to occur. Read label for additional restrictions and limitations.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Do not apply more than 0.96 pt per season (0.06 lb per acre per season).
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	1.6 to 3.8 oz	0.025 to 0.03 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	3.5 to 4.5 oz	0.02 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Zeta-cypermethrin **R** (Mustang Max)	3.2 to 4 oz	0.02 to 0.025 lb	21	12	Do not make applications fewer than 7 days apart. Do not apply more than 0.15 lb ai (24 oz) per season. Do not graze or harvest treated soybean forage for livestock.
Zeta-cypermethrin + bifenthrin **R** (Hero)	2.6 to 6.1 oz	0.025 to 0.06 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for GREEN CLOVERWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 12 or more worms per linear foot of row and 15% of leaf area is removed.					
Acephate (Orthene 97)	0.5 to 1 lb	0.49 to 0.97 lb	14	24	Do not apply more than 2 lb ai per acre per season. Do not feed treated plants to livestock.
Acephate + bifenthrin **R** (Acenthrin)	8 to 21 oz	0.37 to 0.97 lb acephate; 0.03 to 0.079 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	5 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.06 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bacillus thuringiensis O	Many formulations available under numerous names; check label for rates and restrictions				An alternative to synthetic pesticides; provides reasonable control. Maintain continuous agitation to ensure uniform suspension.
Beta-cyfluthrin **R** (Baythroid XL)	0.8 to 1.6 oz	0.007 to 0.013 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	0.8 to 1.6 oz	0.007 to 0.013 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.10 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl **R** (Sevin)	Many formulations available		21	12	Relatively safe for humans and livestock. See label for specific uses, rates, and restrictions.
Chlorantraniliprole (Prevathon)	14 to 20 oz	0.047 to 0.067 lb	14 (grain); 1 (forage)	4	Make no more than four applications per acre per crop. Minimum interval between treatments is 3 days. Do not apply more than 60 fl oz or 0.2 lb ai per acre per crop.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Deltamethrin **R** (Delta Gold)	1 to 1.5 oz	0.0125 to 0.025 lb	21	12	Apply when larvae are small. Insect growth regulator; does not control adults. Do not apply more than two applications per season. Does not provide immediate kill; from 3 to 5 days may be required before populations are reduced.
Difluorobenzamide (Dimilin 25W or 2L)	2 to 4 oz	0.125 to 0.25 lb	21	12	Apply when larvae are small. Insect growth regulator; does not control adults. Do not make more than two applications per season.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for GREEN CLOVERWORM (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Esfenvalerate **R** (Asana XL)	2.9 to 5.8 oz	0.015 to 0.03 lb	21	12	Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to 5 days for control to occur. Read label for additional restrictions and limitations.
Gamma-cyhalothrin **R** (Proaxis)	1.9 to 3.2 oz	0.008 to 0.013 lb	30	24	Do not apply more than 0.96 pt per season (0.06 lb per acre per season).
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	2.5 to 3.5 oz	0.017 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Methoxylenozide (Intrepid 2F)	4 to 8 oz	0.06 to 0.12 lb	14	4	Use higher rate for heavier infestation. Do not apply more than 64 oz (1 lb ai) or make more than four applications per season.
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Pounce 25WP)	2 to 6.4 oz	0.05 to 0.1 lb	60	12	Do not graze treated areas and do not harvest for forage or hay. Do not apply more than 0.4 lb ai per acre per season. See label for specific uses, rates, and formulations.
Spinetoram (Radiant)	2 to 4 fl oz	0.016 to 0.031 lb	28	4	No more than three applications and 16 fl oz (0.125 lb ai) per year.
Spinosad **O** (Blackhawk) (Entrust) (Tracer)	1 to 2.2 oz	0.03 to 0.1 lb	28	4	Does not harm beneficial insect complex in field. Do not feed treated forage or hay to meat or dairy animals. Do not apply more than 8.3 oz Blackhawk, 3.7 oz Entrust, or 6 oz Tracer per acre per year.
Thiocarb **R** (Larvin 3.2)	10 to 30 oz	0.25 to 0.75 lb	28	48	Do not exceed 0.75 lb ai per acre per application or 3 lb ai per acre per season. Do not feed treated forage to livestock. Use lower rates for maximum protection of beneficial arthropods.
Zeta-cypermethrin **R** (Mustang Max)	2.8 to 4 oz	0.0175 to 0.025 lb	21	12	Do not make applications fewer than 7 days apart. Do not apply more than 0.15 lb ai (24 oz) per season. Do not graze or harvest treated soybean forage for livestock.
Zeta-cypermethrin + bifenthrin **R** (Hero)	2.6 to 6.1 oz	0.025 to 0.06 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for JAPANESE BEETLE.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 20% of leaf area removed during bloom and pod fill.					
Acephate + bifenthrin **R** (Acenthrin)	8 to 21 oz	0.37 to 0.97 lb acephate; 0.03 to 0.079 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	6 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.07 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Alpha-cypermethrin **R** (Fastac)					Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Beta-cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	2.8 oz	0.022 lb beta-cyfluthrin; 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl **R** (Sevin)	Many formulations available		21	12	Relatively safe for humans and livestock. See label for specific uses, rates, and restrictions.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Cyfluthrin + imidacloprid **R** (Leverage 360)	2.8 oz		45	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not apply more than 8.5 oz per season.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to 5 days for control to occur. Read label for additional restrictions and limitations.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Do not apply more than 0.96 pt (0.06 lb per acre) per season.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for JAPANESE BEETLE (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Lambda-cyhalothrin **R**	1.6 to 3.8 oz	0.025 to 0.03 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
(Lambda Cy)					
(Mystic Z)					
(Taiga Z)					
(Warrior or Warrior II)					
Lambda-cyhalothrin + thiamethoxam **R**	3.5 to 4.5 oz	0.02 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
(Endigo ZC)					
Permethrin **R**	2 to 12.8 oz	0.05 to 0.1 lb	60	12	Do not graze treated areas and do not harvest for forage or hay. Do not apply more than 0.4 lb ai per acre per season. See label for specific uses, rates, and formulations.
(Ambush 25W)					
(Arctic 3.2EC)					
(Pounce 25WP)					
Zeta-cypermethrin **R**	2.8 to 4 oz	0.0175 to 0.025 lb	21	12	Do not make applications fewer than 7 days apart. Do not apply more than 0.15 lb ai (24 oz) per season. Do not graze or harvest treated soybean forage for livestock.
(Mustang Max)					
Zeta-cypermethrin + bifenthrin **R**	4 to 10.3 oz	0.04 to 0.1 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.
(Hero)					

Suggested insecticides, rates, and restrictions for MEXICAN BEAN BEETLE.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 30% of leaf area removed before bloom and 15% of leaf area removed after bloom.					
Acephate	0.5 to 1 lb	0.49 to 0.97 lb	14	24	Do not apply more than 2 lb ai per acre per season. Do not feed treated plants to livestock.
(Orthene 97)					
Acephate + bifenthrin **R**	8 to 21 oz	0.37 to 0.97 lb acephate; 0.03 to 0.079 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
(Acenthrin)					
Acetamiprid + bifenthrin **R**	5 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.06 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
(Argyle OD)					
Alpha-cypermethrin **R**	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
(Fastac)					
Azadirachtin **O**	See label		12	12	Insect growth regulator derived from neem tree. Apply in sufficient water for adequate coverage. Effective for control of larvae only.
(Neemix 4.5)					
Beta-cyfluthrin **R**	1.6 to 2.8 oz	0.013 to 0.022 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
(Baythroid XL)					

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for MEXICAN BEAN BEETLE (continued).

Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	2.8 oz	0.022 lb beta-cyfluthrin; 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl **R** (Sevin)	Many formulations available		21	12	Relatively nontoxic to humans and livestock. See label for specific uses, rates, and restrictions.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not apply more than 8.5 oz per season.
Diflubenzuron **R** (Dimilin 25W or 2L)	2 to 4 oz	0.13 to 0.25 lb	21	12	Apply when larvae are small. Insect growth regulator; does not control adults. Do not make more than two applications per season. Does not provide immediate kill; from 3 to 5 days may be required before populations are reduced
Dimethoate	Various formulations available		21	48	Do not feed or graze for 5 days after last application. See label for specific uses, rates, and formulations.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to 5 days for control to occur. Read label for additional restrictions and limitations.
Gamma-cyhalothrin **R** (Proaxis)	1.9 to 3.2 oz	0.008 to 0.013 lb	30	24	Do not apply more than 0.96 pt (0.06 lb) per acre per season.
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	2.5 to 3.5 oz	0.017 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Pounce 25WP)	2 to 6.4 oz	0.05 to 0.1 lb	60	12	Do not apply more than 0.4 lb ai per acre per season. Do not graze treated areas and do not harvest for forage or hay. See label for specific uses, rates, and formulations.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for MEXICAN BEAN BEETLE (continued).

Thiocarb **R** (Larvin 3.2)	10 to 30 oz	0.25 to 0.75 lb	28	48	Do not exceed 0.75 lb ai per acre per application or 3 lb ai per acre per season. Do not feed treated forage to livestock. Use lower rates for maximum protection of beneficial arthropods.
Zeta-cypermethrin **R** (Mustang Max)	2.8 to 4 oz	0.0175 to 0.025 lb	21	12	Do not apply more than 0.15 lb ai (24 oz) per season. Do not make applications fewer than 7 days apart. Do not graze or harvest treated soybean forage for livestock.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.
Seed Treatment					
Thiamethoxam (Cruiser 5FS)	1.28 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.

Suggested insecticides, rates, and restrictions for POTATO LEAFHOPPER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: V1, one per plant; V2, three per plant; V3, six per plant; R4, nine per plant; or four per sweep if plants are moisture stressed, and eight per sweep if plants not moisture stressed.					
Acephate (Orthene 97)	0.5 to 1 lb	0.49 to 0.97 lb	14	24	Do not apply more than 2 lb ai per acre per season. Do not feed treated plants to livestock.
Acephate + bifenthrin **R** (Acenthrin)	12 to 21 oz	0.56 to 0.97 lb acephate; 0.045 to 0.079 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	5 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.06 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	See label		12	12	Insect growth regulator derived from neem tree. Apply in sufficient water for adequate coverage. Effective for control of nymphs only.
Beta-cyfluthrin **R** (Baythroid XL)	0.8 to 1.6 oz	0.013 to 0.025 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material (0.088 lb ai per acre per season).
Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	2.4 to 2.8 oz	0.019 to 0.022 lb beta-cyfluthrin; 0.003 to 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.10 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for POTATO LEAFHOPPER (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	Formulated	Active	Harvest (days)	Reentry (hours)	(Read the label for dosage, method, and limitations)
Carbaryl **R** (Sevin)	Many formulations available		21	12	Relatively safe for humans and livestock. See label for specific uses, rates, and restrictions.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Chlorpyrifos + lambda-cyhalothrin **R** (Cobalt Advanced)	16 to 38 oz	0.37 to 0.74 lb chlorpyrifos; 0.016 to 0.038 lb lambda-cyhalothrin	30	24	Do not feed treated soybean forage, hay, and straw to meat or dairy animals or allow meat or dairy animals to graze in treated areas. Do not apply more than 59 oz of Cobalt Advanced per season. See label for further limitations on applying Cobalt Advanced and other chlorpyrifos-containing products.
Deltamethrin **R** (Delta Gold)	1 to 1.5 oz	0.012 to 0.018 lb	21	12	Do not apply more than 8.5 oz per season.
Dimethoate	Various formulations available		21	48	See label for specific uses, rates, and formulations. Do not feed or graze within 5 days of application.
Esfenvalerate **R** (Asana XL)	2.9 to 5.8 oz	0.015 to 0.03 lb	21	12	Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to 5 days for control to occur. Read label for additional restrictions and limitations.
Flupyradifurone (Sivanto)	7 to 10.5 fl oz	0.015 to 0.03 lb	7 (forage); 21 (grain)		Maximum allowed per year: 28 fl oz per acre (0.365 lb ai per acre).
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Do not apply more than 0.96 pt (0.06 lb) per acre per season.
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	2.5 to 3.5 oz	0.017 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Methyl parathion **R** (Penncap-M)	2 to 3 pt	0.44 to 0.66 lb	20	4 days	Do not make more than two applications per season.
Permethrin **R** (Ambush 25W) (Arctic 3.2EC) (Pounce 25WP)	2 to 6.4 oz	0.05 to 0.1 lb	60	12	Do not graze treated areas or harvest for forage or hay. Do not apply more than 0.4 lb ai per acre per season. See label for specific uses, rates, and formulations.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for POTATO LEAFHOPPER (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Zeta-cypermethrin **R** (Mustang Max)	2.8 to 4 oz	0.0175 to 0.025 lb	21	12	Do not apply more than 0.15 lb ai (24 oz) per season. Do not make applications fewer than 7 days apart. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.
Seed Treatments					
Clothianidin (Nipslt)	1.28 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.
Imidacloprid (Gaucho)	1.6 to 3.2 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.
Thiamethoxam (Cruiser 5FS)	1.28 oz per 100 lb of seed				Early season protection only. Will not prevent later season problems.

Suggested insecticides, rates, and restrictions for SEEDCORN MAGGOT.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: none; good idea to use a seed treatment if soil typically is cold and wet after soybean is planted, especially if a green living cover crop has been tilled.					
Seed Treatments					
Clothianidin (Nipslt)	1.28 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.
Imidacloprid (Gaucho)	1.6 to 3.2 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems. Do not graze or feed livestock on soybean hay or forage.
Thiamethoxam (Cruiser 5FS)	1.28 oz per 100 lb of seed				Systemic insecticide. Early season protection from overwintered population only. Will not prevent later season problems.

Seedcorn maggot notes: Seedcorn maggot can cause serious injury to both soybean and corn fields. Certain field conditions are more likely to lead to seedcorn maggot problems (see Table 2.1-6). If these conditions exist, a planter-box treatment is relatively inexpensive and a good investment.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for SLUGS.

	Rate per Acre		Restrictions		Comments
Molluscicide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: heavy feeding on cotyledons and unifoliate leaves.					
Metaldehyde (Deadline MPs) (Metarex)	10 lb	0.4 lb	0	12	See comments in corn section, Table 2.2-21.
Sodium ferric EDTA (Ferroxx)	5 to 20 lb per acre or 0.11 to 0.44 lb per 1,000 sq ft	0.25 to 1 lb	0	0	See label for more details.

Slug notes: Slug damage is most severe during cool, wet weather, especially in fields under reduced tillage with a fairly heavy cover of organic matter. Soybean plants usually recover from slug feeding; however, during periods of prolonged wet weather in May and June, extensive plant mortality may occur. Slug damage can be made worse when corn seed is coated with a neonicotinoid insecticides; these insecticides do not control slugs, which are molluscs, not insects, and kill natural enemies that are insects that can contribute to insect control.

Suggested insecticides, rates, and restrictions for SOYBEAN APHID.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 250 aphids per plant with an increasing population.					
Acephate (Orthene 97)	0.5 to 1 lb	0.49 to 0.97 lb	14	24	Do not apply more than 2 lb ai per acre per season. Do not feed treated plants to livestock.
Acephate + bifenthrin **R** (Acenthrin)	8 to 21 oz	0.37 to 0.97 lb acephate; 0.03 to 0.079 lb bifenthrin	14	24	Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	5 to 9 oz	0.04 to 0.07 lb acetamiprid; 0.06 to 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Afidopyropen (Sefina)	3.0 oz	0.01 lb	7	12	***Expected to be softer on natural enemies.*** Do not apply more than 6 ozs (0.02 lb a.i.) per acre per year.
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Beta-cyfluthrin **R** (Baythroid XL)	2 to 2.8 oz	0.016 to 0.022 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
Beta-cyfluthrin +imidacloprid **R** (Leverage 360)	2.8 oz	0.022 lb beta-cyfluthrin; 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for SOYBEAN APHID (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	Formulated	Active	Harvest (days)	Reentry (hours)	(Read the label for dosage, method, and limitations)
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Deltamethrin **R** (Delta Gold)	1.5 to 1.9 oz	0.018 to 0.022 lb	21	12	Do not apply more than 8.5 oz per season.
Dimethoate	Various formulations available		21	48	See label for specific uses, rates, and formulations. Do not feed or graze within 5 days of application.
Esfenvalerate **R** (Asana XL)	5.8 to 9.6 oz	0.03 to 0.05 lb	21	12	Do not feed or graze livestock on treated plants. Do not exceed 0.2 lb ai per acre per season. Allow 3 to 5 days for control to occur. Read label for additional restrictions and limitations.
Flupyradifurone (Sivanto)	7 to 10.5 fl oz	0.09 to 0.14 lb	7 (forage); 21 (grain)		Maximum allowed per year is 28 fl oz per acre (0.365 lb ai per acre).
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	21	24	Do not apply more than 0.96 pt (0.06 lb) per acre per season.
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	2.5 to 3.5 oz	0.017 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Sulfoxaflor (Transform WG)	0.75 to 1.0 oz	0.023 to 0.031 lb	7	24	No more than four applications and 8.5 oz (0.27 lb) per year. Highly toxic to bees.
Zeta-cypermethrin **R** (Mustang Max)	2.8 to 4 oz	0.0175 to 0.025 lb	21	12	Do not apply more than 0.15 lb ai (24 oz) per season. Do not make applications fewer than 7 days apart. Do not graze or harvest treated soybean forage for livestock.
Zeta-cypermethrin + bifenthrin **R** (Hero)	4 to 10.3 oz	0.04 to 0.1 lb	21	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treated soybean forage, straw, or hay for livestock feed.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for STINK BUGS, INCLUDING BROWN MARMORATED STINK BUG.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: 3.5 stink bugs per 15 sweeps in 30-inch-row soybeans; 2.5 stink bugs per 15 sweeps in narrow-row beans; or one stink bug per foot of row.					
Acephate + bifenthrin **R** (Acenthrin)	12 to 21 oz	0.56 to 0.97 lb acephate; 0.045 to 0.079 lb bifenthrin	14	24	For brown marmorated stink bug use the 21 oz rate. Do not apply more than 2.09 lb product per acre per season. Do not graze or cut crop for hay or forage.
Acetamiprid + bifenthrin **R** (Argyle OD)	9 oz	0.07 lb acetamiprid; 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Alpha-cypermethrin **R** (Fastac)	3.2 to 3.8 fl oz	0.020 to 0.025 lb	30 (grain); 60 (forage)	12	Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Beta-cyfluthrin **R** (Baythroid XL)	1.6 to 2.8 oz	0.013 to 0.022 lb	45	12	Green forage may be fed 15 days after last application. Maximum allowed per crop season is 11.2 oz of material.
Beta-cyfluthrin + imidacloprid **R** (Leverage 360)	2.8 oz	0.022 lb beta-cyfluthrin; 0.004 lb imidacloprid	15	12	Green forage may be fed 15 days after last application. Minimum interval between applications is 7 days. Maximum allowed per crop season is 11.4 oz of material (0.1 lb cyfluthrin per acre per season; 0.14 lb imidacloprid per acre per season).
Bifenthrin **R** (Bifenture) (Brigade 2EC)	2.1 to 6.4 oz	0.033 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Carbaryl **R** (Sevin)	Many formulations available		21	12	Relatively safe for humans and livestock. See label for specific uses, rates, and restrictions.
Chlorantraniliprole + bifenthrin **R** (Elevest)	4.8 to 9.6 oz	0.084 to 0.167 lb	18	12	No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Chlorpyrifos + lambda-cyhalothrin **R** (Cobalt Advanced)	16 to 38 oz	0.31 to 0.74 lb chlorpyrifos; 0.016 to 0.038 lb lambda-cyhalothrin	30	24	Do not feed treated soybean forage, hay, and straw to meat or dairy animals or allow meat or dairy animals to graze in treated areas. Do not apply more than 59 oz of Cobalt Advanced per season. See label for further limitations on applying Cobalt Advanced and other chlorpyrifos-containing products. Cobalt Advanced replaces Cobalt, which is composed of chlorpyrifos and gamma-cyhalothrin. Cobalt can still be used in PA; see label for details.
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior or Warrior II)	1.6 to 3.8 oz	0.025 to 0.03 lb	30 or 45	24	Do not graze or harvest treated soybean forage, straw, or hay for livestock feed. Do not apply more than 0.06 lb ai per acre per season. See label for specific uses, rates, and formulations. Warrior II uses half the rate of Warrior.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for STINK BUGS, INCLUDING BROWN MARMORATED STINK BUG (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Lambda-cyhalothrin + thiamethoxam **R** (Endigo ZC)	2.5 to 3.5 oz	0.017 to 0.03 lb	30	24	Do not apply this product within 45 days of planting if soybean seeds were treated with a neonicotinoid product.
Zeta-cypermethrin **R** (Mustang Max)	3.2 to 4 oz	0.02 to 0.025 lb	21	12	Do not make applications fewer than 7 days apart. Do not apply more than 0.15 lb ai (24 oz) per season. Do not graze or harvest treated soybean forage for livestock.

Stink bug notes: Most of these insecticides are broadly active and claim to have activity on "stink bugs"; however, there is little information available on efficacy of these products against the brown marmorated stink bug. Anecdotally, fruit growers have had success controlling brown marmorated stink bug with bifenthrin, which may work well in soybean. It appears clear that most products provide little if any residual control; once treated, populations should be monitored closely for recovery.

Suggested insecticides, rates, and restrictions for TWO-SPOTTED SPIDER MITE.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: treat when plants along field margin or within field show discoloration and mites are present.					
Abamectin **R** (Agri-Mek SC)	1.75 to 3.5 fl oz	0.01 to 0.019 lb	7 (forage or hay)	12	Do not apply more than 7 fl oz per acre (or 0.038 lb ai per acre) per year. Do not allow livestock to graze in treated areas or harvest treated soybean forage, straw, or hay as feed for meat or dairy animals. Do not feed treated soybean fodder or silage to meat or dairy animals.
Acetamiprid + bifenthrin **R** (Argyle OD)	9 oz	0.07 lb acetamiprid; 0.11 lb bifenthrin	28	12	Do not exceed two applications or 10 fl oz per acre per calendar year. Do not graze livestock in treated areas or cut treated crops for feed.
Bifenthrin **R** (Bifenture) (Brigade 2EC)	5.12 to 6.4 oz	0.08 to 0.1 lb	18	12	Do not apply more than 0.3 lb ai per acre per season.
Chlorantraniliprole + bifenthrin **R** (Elevest)	7.7 to 9.6 oz	0.134 to 0.167 lb	18	12	Coverage is essential for control of this pest. Under heavy outbreak conditions, tank mixing with another product that is labeled for this pest is recommended for control. No more than three applications per year. Do not apply more than total of 0.2 lb ai per acre chlorantraniliprole and 0.3 lb ai per acre bifenthrin per year. This total includes applications of this product and other chlorantraniliprole- or bifenthrin-containing products.
Dimethoate	Various formulations available		21	48	See label for specific uses, rates, and formulations. Do not feed or graze within 5 days of last application. There are reports of mite populations that appear to be resistant to dimethoate. If you have used this product repeatedly over the years, consider other options to avoid further selection for resistance.

Table 2.4-20. Suggested insecticides, rates, and restrictions for soybean insect control (continued).

Suggested insecticides, rates, and restrictions for TWO-SPOTTED SPIDER MITE (continued).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Etoxazole (Zeal SC)	2 to 6 fl oz	0.045 to 0.135 lb	21	12	Do not apply after R5 stage. Do not apply more than 0.135 lb ai per acre per calendar year. Do not graze treated soybean fields or feed treated forage or hay to livestock.
Zeta-cypermethrin + bifenthrin **R** (Hero)	10.3 oz	0.1 lb	12	12	Do not make applications fewer than 30 days apart. Do not apply more than 0.4 lb ai per season. Do not graze or harvest treat soybean forage, straw, or hay for livestock feed.

Spider mite notes: Spider mite infestations can begin after extended hot, dry periods in the summer, usually in late July and August. Infestations usually begin along the edges and progress into fields. Spraying the edges after early detection can prevent the need to treat entire fields, though we have seen earlier infestations within the field in late June and early July if spring is hot and dry where the whole field needs treatment. The pyrethroids Proaxis, Mystic Z, Taiga Z, and Warrior are also labeled on soybean for two-spotted spider mite. However, all are for suppression only. Products containing some of the active ingredients listed above would be a better choice. Some mite populations appear resistant to dimethoate. Consider using another active ingredient to avoid continued selection for resistance if dimethoate has been used repeatedly in past years. Efficacy data show that bifenthrin, chlorpyrifos, or dimethoate are effective active ingredients for spider mites. You will note, however, that we include Cobalt and Hero as control options for spider mites. Both of these products are mixtures of two active ingredients, but the chlorpyrifos and bifenthrin, respectively, are providing the majority of the control. It is not clear if the second ingredient is contributing at all to spider mite control. These products may be useful if you have other labeled pests in the field, but generally we feel that the value of these two-ingredient mixtures is questionable.

Bean Leaf Beetle

Bean leaf beetle is a native insect species that can be problematic on an introduced legume crop—that is, soybeans. Populations of bean leaf beetle tend to be most troublesome in the eastern half of Pennsylvania and appear more common in areas with abundant woods, where the beetles spend the winter. In spring, bean leaf beetles colonize the earliest emerging soybean fields, where they can appear to cause significant damage to cotyledons and young leaves of seedlings. However, this damage, despite appearances, is rarely economically significant, and plants typically grow through the injury. Moreover, insecticidal seed treatments that are quite common on soybean varieties tend to provide adequate protection. Bean leaf beetle has two generations per year, and the mid- to late summer generation feeds on foliage and growing pods. If substantial populations feed on pods, economic damage can occur. Bean leaf beetle is the primary vector for bean pod mottle virus, which can significantly sap soybean yield and is sporadic in Pennsylvania.

Brown Marmorated Stink Bug

The brown marmorated stink bug is a relatively new pest species in Pennsylvania soybeans, but its large populations in some parts of the state in 2010 and 2012 caught many folks by surprise and caused significant yield losses. Fortunately, in recent years (e.g., 2014–2016) in most parts of Pennsylvania, brown marmorated stink bug populations have been low. When problematic, this pest species has been most common in Pennsylvania in the southern tier of counties, but the populations have been relatively spotty, seemingly associated with fields in proximity to woodlots. In soybean fields, populations accumulate on field edges, often adjacent to woods or corn fields. These edge-accumulating populations are often evident after the pest is gone via a stay-green syndrome where the edges of the field that were infested senesces much more slowly (stays green) than the rest of the field. This syndrome appears to be a physiological response of the plant to stink bug feeding. Stink bugs tend to accumulate in soybean fields when pods start to appear; they seem able to feed on new growth, but mostly concentrate on pods, feeding with their needlelike mouthparts through the pod on the developing seeds. Soybeans in the R4 growth stage are most susceptible to stink bugs, and beans become less susceptible to damage at the R7 stage and beyond. A range of insecticides is available against this pest species, but few offer significant residual control, so multiple applications may be necessary.

Green Cloverworm

The green cloverworm can be found at subeconomic levels in most soybean fields. Occasionally, however, conditions produce a population explosion of this pest, which in turn results in heavy defoliation of soybean plants. It does not pay to control green cloverworm populations until there are eight or more worms per linear foot of row.

Damage to soybeans is caused by the larval stage. The larvae are pale green with two narrow white strips along each side of the body. They are bare, slender, about 1.25 inches long when fully grown, and easily distinguishable from other insect larvae by the number of prolegs on the abdomen (short, fleshy legs along the middle of the body). Cutworms and armyworms have four pairs, loopers have two pairs, and green cloverworm larvae have three pairs of prolegs. Typically, green cloverworm populations are held in check by fungal and viral diseases.

Adult moths overwinter in buildings, under trash, and in other protected sites. There are two generations per year in Pennsylvania. The first generation develops on alfalfa, clover, and other legumes during May and June. The larvae of the second generation are active from late June to early August and occasionally are serious pests of soybeans.

Japanese Beetle

Japanese beetle damage is similar to green cloverworm damage. However, this insect seldom is a major problem in soybean production. Large numbers of Japanese beetles frequently gather in soybean fields during late July and August. The brown, skeletonized leaves resulting from their feeding are fairly obvious. Actual yield reductions caused by Japanese beetle feeding are very low; therefore, control usually is not recommended.

Mexican Bean Beetle

Both the adult and larval Mexican bean beetle feed on soybean foliage, resulting in skeletonized leaves. Although the Mexican bean beetle is not currently a major pest of soybeans in Pennsylvania, leaf damage has been seen in the southeastern sections of the state. As soybean acreage increases and production intensifies, the Mexican bean beetle may become an important pest of soybeans.

Adult beetles are terrapin shaped, slightly larger than 0.25 inch long, yellow to coppery, and have 16 small black spots. They deposit clusters of 40 to 50 yellow eggs on the undersides of soybean leaves. Larvae are yellow and covered with numerous branched spines.

The insect overwinters as an adult beetle under trash and in protected sites. There probably are two generations per year. Very little damage is done to soybean fields before August or until the second generation is active.

Potato Leafhopper

The potato leafhopper is a pest primarily of alfalfa in Pennsylvania, but it can occasionally infest soybeans. The insect migrates into the state around mid-May and begins feeding on plants in the legume and rose family. When infestation

levels are high in alfalfa, leafhoppers may move into soybeans. Also, if a soybean field is next to a recently cut alfalfa field, leafhoppers may move to the soybeans and cause injury. If plants are small, economic damage is possible.

Seedcorn Maggot

On rare occasions, the seed corn maggot reduces stands in soybean fields. See the corn insect section for more information on this pest.

Slugs

Slugs are becoming a more common problem in Pennsylvania soybean fields, particularly in the central and western counties. Slugs are most problematic in continuous corn production or simplified corn-soybean rotations that do not include cover crops. Penn State research has revealed that more complex rotations that have cover crops are less prone to slug problems. Fields planted very early can suffer a lot of damage if the weather turns cool and wet and the seeds or young plants languish. Fields planted late can also suffer damage because of small plant size and the timing of the slug hatch in the spring, which typically occurs in early May. When plants are in the succulent cotyledon stage, slugs can consume the cotyledons and growing points of the plant. When this happens, the field will experience significant stand reduction. Baits can be effective at rescuing heavily damaged portions of fields, but it may be difficult and expensive to gain control over large acres with baits alone because they are not as rainfast, so we would spread them to a density of four to six pellets per square foot. Recent research at Penn State has revealed that neonicotinoid seed treatments can exacerbate slug damage by decreasing populations of ground beetles that typically contribute to slug control; therefore, one control option to try is to plant untreated seeds to help grow ground beetle populations. Crops grown from untreated seeds of course need to be scouted regularly for emerging pest populations.

Soybean Aphid

This new invasive pest of soybeans was first detected in Pennsylvania during the summer of 2001. In Asia, where it is a native species, the pest has been responsible for significant yield reductions. It is also known to transmit several virus species that can have additional impacts on yield. Studies have shown large reductions in soybean yield when the pest builds to high densities. Currently, the threshold for the soybean aphid is an average of 250 aphids per plant with an increasing population. The soybean aphid population in Pennsylvania is largely migratory with individual winged aphids being blown here from states to our north and west. Aphid populations have been economically damaging in odd-numbered years (e.g., 2005, 2007, 2009), when some fields were harboring thousands of aphids per plant. Our most recent outbreak year was 2009, and many counties experienced large aphid populations; however, this outbreak was less uniform than previous outbreaks, and some counties never developed damaging populations. In 2011, when we expected large populations of aphids again, they did not materialize. Populations have been more or less low ever since, but we did have some outbreaks in some fields in 2015; basically, soybean aphid has become less predictable, but it is not as severe as it was in the early 2000s. Natural enemies, particularly ladybird beetle adults and larvae, play an important role in moderating soybean aphid populations, and ill-advised applications of insecticides can disrupt natural control. Soybean aphid has a secondary host plant, buckthorn, where it spends the winter. Buckthorn is uncommon in the southern parts of the state but increases northward until New York state, where it is quite common. It seems that soybean aphid populations are worse in areas where buckthorn is most common. Beginning in June, growers should regularly scout their fields for aphids. Timing of the insecticides (at 250 aphids per plant) is the most important detail for gaining control.

Two-Spotted Spider Mite

Spider mites, *Tetranychus urticae*, can cause economic losses in soybeans under extended hot, dry conditions, as have been observed in recent years. In most years, however, this pest is of little concern in Pennsylvania due to natural control provided by some beneficial fungi as well as insect predators. However, due to the hotter temperatures and drier conditions we have seen over the past decade, we are experiencing more infestations from this pest.

Populations build up under hot, dry conditions because generation time is reduced substantially and fungal diseases are suppressed by high temperatures. At 66°F, a generation is completed in about 20 days. In contrast, at 90°F, the pest completes a generation in about 7 days, and each adult female produces several hundred offspring. At this rate, if one female contributed 50 new females per generation, she alone would be responsible for 6.25 million female mites feeding in the field by the end of one month of 90°F temperatures. From this example, it is easy to see why spider mite outbreaks can occur rapidly during extended hot, dry periods.

Spider mites are minute and are closely related to spiders and ticks. It takes a small hand lens to see them. They are greenish white to green and in some cases reddish. This mite can be identified from other mites by two dark spots on its abdomen. Mites typically live in colonies and produce a thin web on lower leaf surfaces.

Mites go through four stages of development: egg, larva, nymph, and adult. Eggs are small and oval (microscopic) and generally are laid on the underside of leaves. The larvae have six legs, while the nymphal and adult stages have eight legs.

Both the larval and nymphal stages have little impact on yield. Adult females are responsible for most injury to soybeans. Spider mites have piercing-sucking mouth parts and feed by sucking sap from the plant. Mite injury somewhat resembles herbicide injury or some foliar diseases. Typical damage symptoms are small yellow speckles on the leaves. As injury becomes more severe, the leaves become yellow and develop brown lesions, and the plants die. Rain is the surest way to stop the spread of mite damage. Several miticides can be used, however, if dry, hot conditions are expected to persist (Table 2.4-19). Note that populations of mites vary in their susceptibility to dimethoate, with some appearing to be resistant, so treated areas should be monitored carefully to ensure adequate control is achieved. If resistance is suspected, consider alternative materials (Table 2.4-20).

Diseases

Disease management of soybean is best achieved through crop rotation, balanced fertility, and the use of certified seed to reduce potential issues in the field. In Pennsylvania, many foliar diseases of soybean do not cause an economic impact. With that said, there have been severe epidemics of frogeye leaf spot in fields where soybeans followed soybeans in no-till conditions. The more economically important diseases are those of the roots and stems, such as white mold, charcoal rot, brown stem rot, and sudden death syndrome. These diseases cause early death of the plants, resulting in reduced pod fill and small seed size. Diseases that directly affect the seeds, such as downy mildew, purple seed stain, and Phomopsis seed decay, can reduce the size, quality, and appearance of the soybean seed. In general, the disease levels in Pennsylvania often do not warrant a foliar fungicide application, and an economic return from an application is not likely. See Table 2.4-21 for the efficacy of fungicides for soybean disease control based on appropriate application timing.

Seed Treatments

The use of fungicide seed treatments is beneficial when early planting into cold, wet soils or no-till planting into heavy residue. In these conditions, the fungicide will help protect the seed and seedling from seed decay and other early-season diseases (Table 2.4-22). In early planted soybeans, the successful use of fungicide seed treatments may take precedence over thoroughly inoculating the seed with nitrogen-fixing bacteria. As the soil warms, proper inoculation should be considered more beneficial than fungicide seed treatments due to the reduced threat of seedling diseases and less time the seed is in the soil before emergence.

Regardless of fungicide treatment or if the soybeans purchased are pre-inoculated, it is always good insurance to add dry inoculants to the soybeans prior to planting. It is important to remember that the inoculant is a living organism and should be kept cool and in the dark (refrigerator) until ready to use. In some studies, fungicide-treated seed has been found to reduce the number of live bacteria in the inoculant. In fungicide-treated seed, it is best to apply dry inoculant, mix thoroughly, and plant the seeds within four hours to maximize the potential for nodulation.

Early-Season Diseases

Brown Spot

Brown spot, also known as Septoria leaf spot, is a foliar disease identified as small, angular brown spots that begin on the lower leaves. This disease is spread mainly by rain splash and moves up the plant with rain events. Under severe conditions, brown spot can lead to rapid defoliation of the soybean plant. These outbreaks commonly occur after prolonged periods of rain and/or high relative humidity. The disease can be controlled easily with fungicides; however, under Pennsylvania growing conditions, disease levels warranting control are rarely observed. Soybean varieties resistant to brown spot are not available. Control recommendations include tillage to incorporate crop residues soon after harvest, planting disease-free seed, and rotation to other crops.

Seed Rots and Seedling Diseases

Seed rots and seedling diseases often occur when soybeans are planted into cold, wet soils. There are several common pathogens associated with these disorders, including *Pythium*, *Rhizoctonia*, and *Phytophthora*. Typical symptoms include ungerminated, rotted seed or germinated seeds with discolored roots and stems. Common causes are seeds imbibing water below 50°F (the lower end of optimal germination temperature), improper seed-to-soil contact (not imbibing enough water to germinate), and crusting (inability of the shepherd's crook to emerge). Fungicide seed treatments can help alleviate some of these issues, but best management practices should include planting into a proper seed bed to ensure a good stand.

Phytophthora root and stem rot is able to infect soybean at any growth stage. The use of fungicide-treated soybean seed should help reduce the early-season losses. Typically, symptoms start at the soil surface as black lesions that develop up the stem. These lesions can then girdle the stem, causing wilt-like symptoms and premature death. This disease is transported in water and is often found in areas of poor drainage such as highly compacted head rows or areas known to have standing water in the field.

Mid-Season Diseases

Anthracnose

Anthracnose can infect at any time during development, but symptoms typically appear during the early reproductive

Table 2.4-21. Efficacy of fungicides for soybean disease control based on appropriate application timing.

Class	Active Ingredient	Product	Rate/A (fl oz)	Aerial Web Blight	Anthracnose	Brown Spot[1]	Cercospora Leaf Blight[2]	Frogeye Leaf Spot[3]	Phomopsis/ Diaporthe (Pod and Stem Blight)	Soybean Rust	Target Spot	White Mold[4]	Harvest Restriction[5]
Strobilurin (FRAC 11)	Azoxystrobin 22.9%	Quadris 2.08 SC; multiple generics[6]	6–15.5	VG	VG	P-G	P	P	U	G–VG	P–F	P	14 days
	Fluoxastrobin 40.3%	Aftershock 480 SC	2–5.7	VG	G	P–G	P	P	U	U	U	NL	R5 (beginning seed)
		Evito 480 SC											30 days
	Picoxystrobin	Aproach 2.08 SC	6–12	VG	G	P–G	P	P	U	G	U	G[9]	14 days
	Pyraclostrobin 23.6%	Headline 2.09 EC/SC	6–12	VG	VG	P–G	P	P	U	VG	P–F	NL	21 days
Triazole (FRAC 3)	Cyproconazole 8.9%	Alto 100SL	2.75–5.5	U	U	VG	F	F	U	VG	U	NL	30 days
	Flutriafol 11.8%	Topguard 1.04 SC	7–14	U	VG	VG	P–G	G–VG	U	VG–E	P	F	21 days
	Propiconazole 41.8%	Tilt 3.6 EC; multiple generics[6]	4-6	P	VG	G	NL	F	NL	VG	U	NL	R5 (beginning seed)
	Prothioconazole 41.0%	Proline 480 SC[7]	2.5–5	NL	NL	NL	NL	G–VG	NL	VG	U	F	21 days
	Tetraconazole 20.5%	Domark 230 ME	4–5	NL	VG	VG	P–G	F–G	U	VG–E	P	F	R5 (beginning seed)
Thiophanates (FRAC 1)	Thiophanate-Methyl	Topsin-M; multiple generics	10–20	U	U	U	F	VG	U	G	U	F	21 days
2,6-Dinitro-Anilines (FRAC 29)	Fluazinam 40.0%	Omega 500 DF	0.75–1 pint	NL	NL	NL	NL	NL	NL	NL	U	G	R3 (beginning pod)
Carboximides (FRAC 7)	Boscalid 70%	Endura 0.7 DF	3.5–11	U	NL	VG	U	P	NL	NL	U	VG	21 days
	Inpyrfluxam 31.25%	Excalia 2.84 SC	2	E	NL	NL	NL	NL	NL	U	NL	NL	R5
Mixed Modes of Action	Azoxystrobin 25.3%	Topguard EQ 4.29 SC	5–7	VG	U	VG	U	G–VG	U	E	P	U	21 days
	Flutriafol 18.63%												
	Azoxystrobin 18.2%	Quadris Top 2.72 SC	8–14	U	U	G–VG	P–G	VG	F–G	VG	P	NL	14 days
	Difenconazole 11.4%												
	Azoxystrobin 19.8%	Quadris Top SBX 3.76 SC	7–7.5	VG	U	G–VG	P–G	VG	F–G	VG	F–G	U	14 days
	Difenoconazole 19.8%												
	Azoxystrobin 7.0%	Quilt 1.66 SC; multiple generics[6]	14–20.5	U	U	G	F	F	U	VG	P	NL	21 days
	Propiconazole 11.7%												

Table 2.4-21. Efficacy of fungicides for soybean disease control based on appropriate application timing (continued).

Class	Active Ingredient	Product	Rate/A (fl oz)	Aerial Web Blight	Anthracnose	Brown Spot[1]	Cercospora Leaf Blight[2]	Frogeye Leaf Spot[3]	Phomopsis/ Diaporthe (Pod and Stem Blight)	Soybean Rust	Target Spot	White Mold[4]	Harvest Restriction[5]
Mixed Modes of Action	Azoxystrobin 13.5%	Quilt Xcel 2.2 SE	10.5–21	E	VG	G	F	F	U	VG	P	NL	R6
	Propiconazole 11.7%												
	Benzovindiflupyr 2.9%	Trivapro	13.7–20.7	E	U	G-VG	P–G	F–G	G	VG–E	U	NL	14 days; R6
	Azoxystrobin 10.5%												
	Propiconazole 11.9%												
	Cyproconazole 7.17%	Aproach Prima 2.34 SC	5–6.8	VG	U	G	P–G	F–G	U	VG-E	F–G	NL	14 days
	Picoxystrobin 17.94%												
	Fluopyram 17.4%	Propulse 3.34 SC	6–10.2	NL	NL	U	NL	U	U	U	NL	G	21 days
	Prothioconazole 17.4%												
	Flutriafol 26.47%	Lucento 4.17 SC	3–5.5	VG	U	VG	F-G	VG	U	VG-E	F–G	U	21 days
	Bixafen 15.5%												
	Flutriafol 19.3%	Fortix SC; Preemptor SC	4–6	U	U	G–VG	P–G	G–VG	U	U	P	U	R5
	Fluoxastrobin 14.84%												
	Prothioconazole 16.0%	Delaro 325 SC	8–11	VG	U	VG	U	G–VG	U	U	NL	NL	21 days
	Trifloxystrobin 13.7%												
	Prothioconazole 14.9%	Delaro Complete 3.83 SC	8.0-11.0	U	U	VG	U	U	U	U	NL	U	21 days
	Trifloxystrobin 13.1%												
	Fluopyram 10.9%												
	Pydiflumetofen 6.9%	Miravis Top 1.67 SC	13.7	VG	U	VG	F–G	VG	G	NL	F–G	U	14 days
	Difenoconazole 11.5%												
	Pyraclostrobin 28.58%	Priaxor 4.17 SC	4–8	E	VG	G–VG	P–G	P–F	U	VG-E	F–G	P	21 days
	Fluxapyroxad 14.33%												
	Pyraclostrobin 28.58%	Priaxor D 4.17 SC and 1.9 SC	4 (each component)	VG	U	VG	P–G	F-G	G	VG–E	F–G	P	21 days; R5
	Fluxapyroxad 14.33%												
	Tetraconazole 20.50%												

Table 2.4-21. Efficacy of fungicides for soybean disease control based on appropriate application timing (continued).

Class	Active Ingredient	Product	Rate/A (fl oz)	Aerial Web Blight	Anthracnose	Brown Spot[1]	Cercospora Leaf Blight[2]	Frogeye Leaf Spot[3]	Phomopsis/ Diaporthe (Pod and Stem Blight)	Soybean Rust	Target Spot	White Mold[4]	Harvest Restriction[5]
Mixed Modes of Action	Trifloxystrobin 32.3%	Stratego YLD 4.18 SC[8]	4–4.65	VG	VG	G	F	F–G	U	VG	P	NL	21 days
	Prothioconazole 10.8%												
	Tetraconazole 7.48%	Affiance 1.5 SC	10–14	U	VG	VG	F	F–G	U	U	U	U	R5; 14 days
	Azoxystrobin 9.35%												
	Tetraconazole 17.76%	Zolera FX 3.34 SC	4.4–6.8	U	U	U	U	F–G	U	U	U	U	R5; 30 days
	Fluoxastrobin 17.76%												
	Thiophanate-methyl 21.3%	Acropolis	20–23	NL	U	U	U	VG	U	VG–E	U	U	R5
	Tetraconazole 4.2%												
	Mefentrifluconazole 11.61%	Revytek	8–15	VG	U	VG	F-VG	VG	U	VG-E	F–VG	P	21 days
	Pyraclostrobin 15.49%												
	Fluxapyroxad 7.74%												
	Mefentrifluconazole 17.56%	Veltyma	7.0-10.0	U	U	U	U	U	U	U	U	NL	21 days
	Pyraclostrobin 17.56%												

Efficacy categories: NR = not recommended; P = poor; F = fair; G = good; VG = very good; E = excellent; NL = not labeled for use against this disease; U = unknown efficacy or insufficient data to rank product efficacy.

[1] In areas where QoI-fungicide resistant isolates of the brown spot pathogen are present, QoI fungicides may result in poor disease control.

[2] Cercospora leaf blight efficacy relies on accurate application timing, and standard R3 application timings may not provide adequate disease control. Fungicide efficacy may improve with earlier or later applications; however, efficacy has been inconsistent with some products. Fungicides with a solo or mixed QoI or MBC mode of action may not be effective in areas where QoI or MBC resistance has been detected in the fungal population that causes Cercospora leaf blight.

[3] In areas where QoI-fungicide resistant isolates of the frogeye leaf spot pathogen are not present, QoI fungicides may be more effective than indicated in this table.

[4] White mold efficacy is based on R1 to R2 application timing, and lower efficacy is obtained at R3 or later application timings, or if disease symptoms are already present at the time of application.

[5] Harvest restrictions are listed for soybean harvested for grain. Restrictions may vary for other types of soybean (edamame, etc.) and soybean for other uses such as forage or fodder.

[6] Multiple generic products containing this mode of action may also be labeled in some states.

[7] Proline has a supplemental label (2ee) for white mold in NY.

[8] Stratego YLD has a supplemental label (2ee) for white mold on soybean only in IL, IN, IA, MI, MN, NE, ND, OH, SD, WI.

[9] Rating is based on two applications of a 9 fl oz/A rate of Aproach at R1 and R3.

The North Central Regional Committee on Soybean Disease (NCERA-137) has developed the following information on foliar fungicide efficacy for control of major foliar soybean diseases in the United States. Efficacy ratings for each fungicide listed in the table were determined by field-testing the materials over multiple years and locations by the members of the committee. Efficacy ratings are based on level of disease control achieved by the product, and are not necessarily reflective of yield increases obtained from product application. Efficacy depends on proper application timing, rate, and application method to achieve optimum effectiveness of the fungicide as determined by labeled instructions and overall level of disease in the field at the time of application. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and are based on a single application of the labeled rate as listed in the table, unless otherwise noted. Table includes systemic fungicides available that have been tested over multiple years and locations. The table is not intended to be a list of all labeled products. Multiple fungicides are labeled for soybean rust only, powdery mildew, and Alternaria leaf spot, including tebuconazole (multiple products) and myclobutanil (Laredo). Contact fungicides such as chlorothalonil may also be labeled for use. This table was revised in January 2022. A more updated version may be available.

Many products have specific use restrictions about the amount of active ingredient that can be applied within a period of time or the amount of sequential applications that can occur. Please read and follow all specific use restrictions prior to fungicide use. This information is provided only as a guide. It is the responsibility of the pesticide applicator by law to read and follow all current label directions. Reference to products in this publication is not intended to be an endorsement to the exclusion of others that may be similar. Persons using such products assume responsibility for their use in accordance with current directions of the manufacturer. Members or participants in the NCERA-137 group assume no liability resulting from the use of these products.

Table 2.4-22. Fungicide efficacy for control of soybean seedling diseases.

Active Ingredient	*Pythium* sp.[1]	*Phytophthora*	*Rhizoctonia* sp.	*Fusarium* sp.[1,2]	Sudden Death Syndrome (*Fusarium virguliforme*)	*Phomopsis* sp.
Azoxystrobin	P–G	NS	VG	F–G	NR	P
Carboxin	U	U	G	U	NR	U
Ethaboxam	E	E	NR	NR	NR	NR
Fludioxonil	NR	NR	G	F–VG	NR	G
Fluopyram	NR	NR	NR	NR	VG	NR
Fluxapyroxad	U	U	E	G	NR	G
Ipconazole	P	NR	F–G	F–E	NR	G
Mefenoxam	E[3]	E	NR	NR	NR	NR
Metalaxyl	E[3]	E	NR	NR	NR	NR
Oxathiapiprolin	P–G	E	NR	NR	NR	NR
PCNB	NR	NR	G	U	NR	G
Penflufen	NR	NR	G	G	NR	G
Prothioconazole	NR	NR	G	G	NR	G
Pydiflumetofen	NS	NS	NS	NS	VG	NS
Pyraclostrobin	P–G	NR	F-G	F	NR	G
Sedaxane	NR	NR	E	NS	NR	G
Thiabendazole	NR	NR	NS	NS	P	G
Trifloxystrobin	P	P	F–E	F–G	NR	P–F

Efficacy categories: E = excellent; VG = very good; G = good; F = fair; P = poor; NR = not recommended; NS = not specified on product label; U = unknown efficacy or insufficient data to rank product. Note: Efficacy ratings may be dependent on the rate of the fungicide product on seed. A number of different species of *Pythium* and *Fusarium* impact seed and seedling health in soybean. Therefore, wide ranges in efficacy may be observed in fungicide active ingredients listed in the table. This is why several fungicide active ingredients are combined in seed treatments to provide protection against a broader spectrum of pathogens. Contact your local Extension plant pathologist for recommended fungicide product rate information for your area.

[1] Products may vary in efficacy against different *Fusarium* and *Pythium* species.

[2] Listed seed treatments do not have efficacy against *Fusarium virguliforme*, causal agent of sudden death syndrome.

[3] Areas with mefenoxam- or metalaxyl-insensitive populations may see less efficacy with these products.

The members of the Identification and Biology of Seedling Pathogens of Soybean project, funded by the North Central Soybean Research Program and the United Soybean Board, and the North Central Regional Committee on Soybean Diseases (NCERA-137) have developed the above ratings for how well fungicide seed treatments control seedling diseases of soybeans in the United States. Efficacy ratings for each fungicide active ingredient listed in the table were determined by field-testing the materials over multiple years and locations by the members of this group, and include ratings summarized from national fungicide trials published in Plant Disease Management Reports (and formerly Fungicide and Nematicide Tests) by the American Phytopathological Society at www.apsnet.org. Each rating is based on the fungicide's level of disease control and does not necessarily reflect efficacy of fungicide active ingredient combinations and/or yield increases obtained from applying the active ingredient.

Common Fungicide Trade Names and Active Ingredients

Product/Trade Name	Active Ingredient
Acceleron	DX-612 Fluxapyroxad
	DX-309 Metalaxyl
	DX-109 Pyraclostrobin
Allegiance FL	Metalaxyl
Allegiance LS	Metalaxyl
Apron XL LS	Mefenoxam
ApronMaxx RFC	Fludioxonil
	Mefenoxam
ApronMaxx RTA	Fludioxonil
	Mefenoxam

Table 2.4-22. Fungicide efficacy for control of soybean seedling diseases (continued).

Product/Trade Name	Active Ingredient
CruiserMaxx	Fludioxonil
	Mefenoxam
CruiserMaxx Advanced or Cruiser Maxx Plus	Fludioxonil
	Mefenoxam
CruiserMaxx Vibrance or Vibrance Trio	Fludioxonil
	Mefenoxam
	Sedaxane
Dynasty	Azoxystrobin
EverGol Energy SB	Metalaxyl
	Penflufen
	Prothioconazole
ILeVO	Fluopyram
Inovate Pro	Ipconazole
	Metalaxyl
Intego	Ethaboxam
Lumisena	Oxathiopiprolin
	Metalaxyl
Maxim 4FS	Fludioxonil
Mertect 340 F	Thiabendazole
Prevail	Carboxin
	Metalaxyl
	PCNB
Saltro	Pydiflumetofen
Trilex 2000	Metalaxyl
	Trifloxystrobin
Vibrance	Sedaxane
Warden CX	Fludioxonil
	Mefenoxam
	Sedaxane
Warden RTA	Fludioxonil
	Mefenoxam

The list includes the most widely marketed products available. It is not intended to be a list of all labeled active ingredients and products. Additional active ingredients may be available but have not been evaluated in a manner allowing a rating. Products listed are the most common products available as of the release date of the table (January 2022); all available products may not be listed. Additional active ingredients may be included in some products for insect and nematode control, however; only active ingredients for pathogen control are listed and rated.

Many active ingredients and their products have specific use restrictions. Read and follow all use restrictions before applying any fungicide to seed, or before handling any fungicide-treated seed. This information is provided only as a guide. It is the applicator's and user's legal responsibility to read and follow all current label directions. Reference in this publication to any specific commercial product, process, or service, or the use of any trade, firm, or corporation name is for general informational purposes only and does not constitute an endorsement, recommendation, or certification of any kind by members of the group, or by the North Central Soybean Research Program. Individuals using such products assume responsibility for their use in accordance with current directions of the manufacturer.

stages as irregularly shaped brown areas on the stems, petioles, and pods. Infected leaves often have reddish veins, leaf rolling, and premature defoliation. This disease may also girdle petioles, leading to premature defoliation. Pods that are affected may not produce seeds, produce smaller, brown, moldy, shriveled seeds, or show no symptoms at all. Infected seeds often do not germinate, or they die shortly after germinating with symptoms similar to damping-off. Typical signs of the disease are seen after maturation as dark specks covering stems, pods, and petioles. The causal agent of this disease survives in infected plant debris and seeds.

Charcoal Rot (Summer Wilt)

Charcoal rot, also known as summer wilt, can occur during periods of hot, dry weather, which causes plant stress. Plants affected with charcoal rot often appear wilted or drought-stressed but do not regain turgor after rain. These plants often seem to have accelerated maturity and are easily found when the field is near R6–R7 since these patches have already lost their leaves. The disease causes a reddish-brown discoloration of the taproot and progresses up the stem producing small, black microsclerotia (reproductive structures) that resemble charcoal dust on the stem. The microsclerotia can survive in the soil for two years or longer. The symptoms are similar to white mold without the white, cottony growth and large sclerotia. The best control measures include using certified, disease-free seed and crop rotation. In a field with a history of charcoal rot, rotate to a cereal crop for two years. Charcoal rot can also cause corn stalk rot, so a corn-soy rotation will not effectively reduce inoculum. The disease can also infect alfalfa and clover; therefore, if rotating to a forage crop, choose a grass rather than a legume.

Downy Mildew

Downy mildew usually starts as small, irregularly shaped yellow lesions on the leaf surface. On the underside of the leaf, a small gray or brown tuft is evident as the lesions age. In some situations, downy mildew will infect the pod and cause a wrinkled, discolored seed. This disease is relatively common in Pennsylvania with little known economic impact.

Frogeye Leaf Spot

Frogeye leaf spot is characterized by dark brown spots surrounded by a red or brown margin. As the lesions age, the margins maintain their brown color, with a gray to white center, which may contain minute dark spots. This is a very common disease with usually little economic impact in the Northeast. In some situations, such as soybean no-till planted into soybean stubble, the disease can be severe and cause defoliation. The best method of control is crop rotation. Fungicide-resistant populations of the fungus that causes this disease have been identified in several states across the country and as close as Virginia. These populations are no longer sensitive to the strobilurin (FRAC Group 11) fungicides. When applying a fungicide to manage this disease, use a product that includes modes of action other than FRAC Group 11.

Soybean Vein Necrosis Virus

This virus produces symptoms that include mottled yellow leaf discoloration radiating from main veins, often in younger leaves. mottled yellow discoloration radiating from main veins, often in younger leaves. These yellowed areas often turn reddish-brown to brown or necrotic with time. This virus is transmitted by thrips, tiny, slender-bodied insects about 1/32 to 1/5 inch long. Young thrips are often yellow and later have dark patches and fringed wings as adults. Thrips are very numerous in soybean fields and considered to have little impact except for transmitting this disease. This disease has been found to be widespread across Pennsylvania fields, and no yield loss data have been compiled at this time.

White Mold (Sclerotinia Stem Rot)

White mold, also known as Sclerotinia stem rot, has caused localized outbreaks in Pennsylvania and poses a serious threat to soybean production in the Commonwealth. Fields near river bottoms where the environmental conditions (fog and extended periods of high humidity) favor disease development are most at risk for white mold. Average yield losses attributed to these epidemics are estimated to be between 10 and 20 percent. In severely diseased fields, the yield losses may exceed 50 percent.

Wilting of the plants is often the first indication that white mold is developing within a soybean canopy. Upon inspection, diseased plants are found to have stem lesions and signs of white, cottony mold growth. As the disease progresses, the leaves and stems of infected plants turn brown. Hard black structures, known as sclerotia, are often present on and within infected stem and pod tissue.

White Mold Management

White mold has proved to be a difficult disease to manage in Pennsylvania and many soybean production regions. Producers can reduce the risk of severe white mold by following these recommendations.

Variety selection. High levels of resistance to white mold are not currently available; however, soybean varieties do differ in response to white mold. Soybeans that are less susceptible to white mold are available for some maturity groups, and these varieties can effectively reduce the risk of severe white mold. When considering varieties with unknown white mold resistance, select a taller growing variety with medium canopy width to help reduce the humidity within the canopy.

Avoid planting fields with a history of white mold with highly susceptible varieties.

Crop rotation. Each year, a portion of the pathogen population will die because of adverse weather conditions or the activities of other organisms. Rotation to a nonhost crop such as corn, wheat, or other grass will provide time for the fungal population to drop and reduce the risk of severe disease. Fields with 5 to 25 percent disease should not be planted to soybean for at least one year. Fields with 26 to 50 percent disease should not have soybeans for two years, and fields with greater than 50 percent disease should be rotated away from soybeans for at least two to three years.

Tillage. Tillage practices have been shown to influence the survival of the fungus. Deep-plowing a field can bury sclerotia deep enough that they can no longer germinate and release spores. However, buried sclerotia are known to survive longer than those left on the soil surface, and subsequent plowing can bring them back near the soil surface. In contrast, minimum tillage and no-till practices favor the natural decline of the fungal populations in the absence of a susceptible crop.

Canopy management. Management practices that favor rapid canopy closure can result in an environment that is favorable for disease development. In fields with a history of white mold, the use of wider row spacing (15- to 30-inch rows) and reducing plant populations to below 125,000 plants per acre will help reduce canopy humidity and increase canopy air movement. Drilled beans at narrow row spacings pose the highest threat.

Weed control. Many broadleaf weeds can also be hosts of the fungus. Not controlling these weeds can allow the spread of the disease within a field and may reduce the effectiveness of the crop rotation.

Adjust harvest priorities. Since the sclerotia (reproductive structures) are about the size of soybeans, fields with severe white mold and sections of fields that are heavily diseased should be harvested last to avoid spreading the fungus within and between fields. Thoroughly clean all harvesting equipment before moving from diseased fields to locations where white mold is absent.

Chemical control. Certain fungicide treatments are labeled and show promising results for management of white mold. However, application timing is key to achieving efficacy. In order to penetrate the soybean canopy, the ideal growth stage for treatment is R1. A treatment at R3 can still provide some control, but it is less effective. When rotating back into a field with a history of white mold, an application of a fungicide by R1 may be warranted up to five years postinfestation.

Late-Season Diseases

Brown Stem Rot

Brown stem rot has been increasing in occurrence in Pennsylvania. Although infection often occurs early in the season, foliar symptoms of brown stem rot often appear after pod set and include interveinal chlorosis and necrosis, leading to leaf rolling and leaf death. These symptoms are similar to sudden death syndrome and stem canker. The easiest way to diagnose this disease is by digging up the roots and splitting the stem from the crown up the stem to look for the characteristic browning often evident in the pith, or center of the stem. The fungus responsible for this disease overwinters in the soil and in soybean debris. Losses in Pennsylvania have not been determined, but those in other states reportedly have been as high as 25 percent. Losses occur because of reduced pod fill, small seed size, and lodging of infected plants. Severity appears to be greatest when cool weather occurs during pod fill followed by hot, dry weather. Control measures include using a BSR-resistant variety and proper crop rotation to corn, small grains, or forage legumes to reduce pathogen levels.

Diaporthe-Phomopsis Complex

Diaporthe-phomopsis complex consists of stem blight, stem canker, and seed decay often found as one or more symptoms on affected plants. Stem blight is found on mature stems as linear rows of black specks on the stems and random black specks on the pods. Stem canker often begins during the early reproductive stages on the lower leaf nodes as small, reddish-brown lesions that expand, often girdling the stems and causing wilting and plant death. The leaves remain attached after plant death. Phomopsis seed decay causes infected seeds to be shriveled, elongated, and cracked with a white, chalky appearance. Although infection can occur at any time after pod set, symptoms are not evident until near maturity. In fields with prior history, harvest as soon as possible because seeds throughout the plant may be affected under wet conditions. Control measures should include crop rotation and prompt harvest. Fungicide applications have not been consistent in controlling these diseases.

Sudden Death Syndrome

At onset, sudden death syndrome looks very similar to brown stem rot, beginning as interveinal chlorosis and then necrosis of the upper leaves after flowering. Affected plants are often in wet or compacted areas of the field, and these areas may enlarge over time. To distinguish sudden death syndrome from brown stem rot, it is important to dig up the roots of affected plants. Sudden death syndrome is often associated with root rots, and light blue spore patches may be present near the soil line. Note that this blue coloration will disappear with age as the sample dries out, so check immediately after

digging. Once dug up, split the stem from the crown to a couple inches above the soil line. Sudden death syndrome will have a white pith (the center portion of the root), and brown stem rot will have a brown pith and usually no root rot. Since both diseases cause premature death of the plants, the effect is often reduced seed size, reduced pod fill, and lodging of affected plants. The causal agent is a soilborne fungus and will remain in the soil. Best management practices include avoiding early plantings into cold soils, alleviating compacted and/or wet areas in the field, and using proper crop rotation. Varieties with some moderate resistance to sudden death syndrome are available and should be planted when rotating back into an affected field. In-furrow fungicide applications and foliar applications of fungicides have had no significant effect in reducing the disease. Some seed treatments, including ILeVO and Saltro, have been shown to increase yields when used in fields with a history of sudden death syndrome. In certain circumstances, phytotoxicity may be observed on the seed leaves of soybeans treated with both ILeVO and a preemergence herbicide. However, plants generally grow out of this with no long-term impact on growth or yield.

Seed Diseases

Phomopsis seed decay and purple seed stain are two common seed diseases in Pennsylvania. These diseases can result in significant reduction in grain quality and yield losses when environmental conditions favor disease development. Losses are most significant when harvest is delayed by wet weather. No mycotoxins are associated with these diseases.

Cercospora leaf blight and purple seed stain are caused by one pathogen that causes two very different symptoms within soybean. Cercospora leaf blight appears as leathery, bronzed leaves near the top of the soybean canopy and can be easily confused with ozone damage or sunburn. Purple seed stain is easily distinguished by the pronounced purple to pink discoloration of infected seed. The discoloration may occur as specks or as large irregular blotches on the surface of the seed. In some cases, the entire seed coat may be discolored. Seed with purple seed stain may have reduced germination, and seedling diseases may also result from the seed infections.

Management of Seed Diseases

The fungi that cause Phomopsis seed decay and purple seed stain survive in crop residues left on the soil surface. Producers can reduce their risk of disease by using certified seed and crop rotation to limit exposure to the inoculum source. A one- to two-year rotation to corn or small grains should be sufficient to reduce the pathogen population in most fields. Tillage can also be used to hasten decomposition of crop residues, but these practices may have negative impacts on soil erosion.

Part II, Section 5

Small Grain Pest Management

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A well-planned pest management program for small grains involves using multiple strategies. These should include preventive techniques such as monitoring, cultural controls, mechanical or physical controls, biological controls, and chemical control tactics. Preventive techniques may start with planting weed-free crop seed or choosing an alternative field or planting date. Regularly monitoring for pests is an important predictive tool. Rotating crops to disrupt pest life cycles and planting adapted varieties are good examples of cultural controls. Mechanical or physical controls may include tillage and mowing to disrupt certain pests. Biological controls may include using insect or disease organisms or even grazing animals in pasture production systems. Finally, chemical controls are an important component of many IPM systems, but their use should be based on sound management decisions. See Part II, Section 1 of this guide for more information about designing an integrated pest management program.

This guide provides chemical control suggestions based on university research and manufacturer recommendations. Management information for common small grain pest problems is outlined in the following pages under "Weeds," "Insects," and "Diseases." For more information on small grain management and variety selection, see Part I, Section 7. This publication strives for accuracy; however, omissions, inaccuracies, or dated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Weeds

Integrated Weed Management

A well-planned weed management program for small grains involves using multiple strategies. These strategies include preventive techniques such as monitoring, cultural controls, mechanical or physical controls, biological controls, and chemical control tactics. Preventive techniques start with planting weed-free crop seed or choosing an alternative field or planting date. Regularly monitoring for pests is an important predictive tool. Rotating crops to disrupt weed life cycles and planting adapted varieties are good examples of cultural controls. Mechanical or physical controls may include tillage and mowing. Biological controls may include using insect or disease organisms or even grazing animals in pasture production systems. Finally, chemical controls are an important component of many integrated pest management (IPM) systems, but their use should be based on sound management decisions. See the introductory chapter of this guide for more information on an IPM system.

A good small grain stand is highly competitive and may not require herbicides to control weeds. Planting an adapted variety at recommended populations into a weed-free field should serve as the foundation for weed control in small grains. It is difficult to get a uniform stand by spinning small grain seeds on the soil surface and incorporating the seeds with a vertical tillage implement. Lack of uniform wheat stand complicates weed management. Furthermore, many herbicides require a planting depth up to 1 inch deep, which is not achieved by incorporating with a vertical tillage implement.

This section provides chemical control suggestions based on university research and manufacturer recommendations. Management information for common small grain weed problems is outlined in the following pages. This publication strives for accuracy; however, omissions, inaccuracies, or dated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Fall-Planted Small Grains

This section pertains to fall-planted small grains for the Mid-Atlantic region. Herbicide application timing, expected control levels, and comments are based on fall planting. See below for spring oats.

Fields should be scouted in late fall or early spring to determine if weed populations warrant treatment. Early application while weeds are still small is the key to successful control of weeds in small grains. Apply herbicides only at recommended stages of crop growth in order to avoid crop injury. See Figure 2.5-1 and Tables 2.5-3 through 2.5-5.

Wheat and barley are sensitive to triazine residues; therefore, use a short residual herbicide program in crops preceding small grains. See the corn weed control section for information on the effect of pH on triazine residues and weed control programs that reduce triazine residues.

Specific Weed Issues

Downy brome control is listed on Finesse, Outrider, Olympus Flex, and PowerFlex labels. (Refer to the label to determine if chess or cheat species will be controlled). Outrider, PowerFlex, and Olympus Flex provide control of downy brome when applied in the fall and suppression when applied in the spring. Soybeans can be planted three months after PowerFlex application. However, be cautious of crop rotation intervals when using Finesse, Outrider, or Olympus Flex. Aside from STS soybean and IR corn, most other rotational crops cannot be planted for at least 12 to 18 months or more after application depending on the herbicide used.

Figure 2.5-1. Growth stages in cereals when herbicides may be applied.

[1] Local research has demonstrated that Dimetric/TriCor should be applied during greenup in early spring to reduce risk of crop injury.
[2] Local research has found fall applications of PowerFlex is the best timing to reduce risk of crop injury.

Group 2 (ALS)–resistant common chickweed populations have been identified in the Mid-Atlantic region since Group 2 herbicides such as Harmony Extra are routinely used in small grains. If Group 2-resistant chickweed is suspected, contact your local county educator to report the incident. Starane Ultra (Corteva) at 0.3 to 0.4 pint per acre up to flag leaf growth stage on wheat, barley, and oats has resulted in good chickweed control in university trials. However, it will not control other key species such as wild garlic, mustards, and henbit. (It will, however, injure/kill underseeded legumes.) Starane Ultra can be tank-mixed with Harmony Extra to broaden the spectrum of control. Valor also provides very effective residual control of common chickweed and can be used in an early preplant burndown program before seeding wheat. Apply up to 2 ounces per acre of Valor (plus other burndown herbicides) at least seven days before planting wheat (see Table 2.5-8). Metricor and TriCor (metribuzin) have a 24(c) use label and at 2 to 4 ounces per acre have provided excellent control of Group 2-resistant chickweed in university trials when applied in either fall or spring (see Table 2.5-8). See Table 2.5-8 for comments on crop safety with metribuzin and Valor.

Herbicide-resistant annual ryegrass (or Italian ryegrass) in the region is resistant to Group 1 (ACCase) herbicides, which include Axial and Hoelon. Other populations are resistant to Group 2 (ALS herbicides) such as Osprey, PowerFlex, and Finesse. There is concern about developing populations resistant to both herbicide groups. Valor and Zidua (or Anthem Flex) have fair to good residual control of annual ryegrass but will not control it if emerged seedlings are present at time of application. POST applications of Osprey or PowerFlex or Axial XL will control susceptible populations.

Do not rely on these herbicide groups to control annual ryegrass in rotation crops to reduce the risk of developing resistant populations.

Spring Oats

Oats are sensitive to triazine residues; therefore, use a short residual herbicide program when small grains follow in the crop rotation. Refer to Part II, Section 2: Corn Pest Management for information on the effect of pH on triazine residues and weed control programs that reduce triazine residues.

In addition to comments for other small grains, the following comments regarding herbicide use in small grains pertain:

- 2,4-D: Use only 0.5 pint per acre for oats. Certain varieties, especially 'Pennuda', are more sensitive to 2,4-D than other small grains.
- Callisto: For use on oats only (Callisto should not be applied to other small grains). If PRE, apply 6 fluid ounces per acre of Callisto prior to oat emergence. If POST, apply 3 fluid ounces per acre of Callisto after oat emergence but before weeds reach 5 inches tall. Callisto controls many broadleaf weeds. Callisto may cause temporary injury of the oat crop. Callisto has a 10-month rotation restriction to soybeans and an 18-month rotation restriction to most vegetables.
- Clarity/dicamba: On spring-seeded oats, apply before five-leaf stage.
- Harmony Extra: On spring-seeded oats, apply at three-leaf to before jointing (growth stages 2 to 5). Apply at 0.45 to 0.6 ounce per acre. Do not use on 'Ogle', 'Porter', or 'Premier' oat varieties.
- Harmony SG: On spring-seeded oats, apply at three-leaf to before jointing (growth stages 2 to 5). Apply at 0.45 to 0.6 ounce per acre. Do not use on 'Ogle', 'Porter', or 'Premier' oat varieties.
- MCPA amine or ester: Safer than 2,4-D (amine formulation only) on oats underseeded with legumes, but use the lower rate (0.25 to 0.5 pint) and apply in 5 to 10 gallons of water per acre; legumes should be 2 to 3 inches tall and cereal should be 8 inches tall to provide canopy to protect legume.

Insects

Few insects are of economic importance to Pennsylvania small-grain production. Insecticide applications seldom are needed. Other methods of insect management, such as rotating crops, plowing under crop residues, adjusting planting dates to avoid damage, planting resistant varieties, and using biological control, are alternatives to chemical control. Chemical control, however, is necessary under some conditions.

As is true of management in other crops, the pest problem should be identified properly before a control action is instigated. Figure 2.5-2 shows key periods of small-grain insect occurrence in Pennsylvania. Tables 2.5-12 and 2.5-13 describe insecticides for use in small grains.

Aphids

In Pennsylvania, corn leaf aphid and English grain aphid, among other species of aphids, are common on small grains and vectors of barley yellow dwarf virus. Corn leaf aphids occur in small numbers throughout the season, but during warm periods in early autumn, large numbers can develop on grain seedlings. The English grain aphid is most abundant in late spring and feeds primarily around the grain heads. The principal damage from aphids is the transmission of virus disease into the plants. This damage is most likely to be a problem in years with extended warm periods during autumn.

Barley yellow dwarf virus causes barley to turn yellowish and stunts the plants. In wheat and oats, the leaves can turn reddish. Fall aphid problems on winter wheat can be avoided or at least reduced by not planting until or after October 1. The lower temperatures and lessening daylight during October slow the rate of aphid buildup. Except for years with unusually warm weather during October and November, chemical control of aphids on winter wheat is not suggested.

In addition to transmitting viruses, these aphids can injure plants by sucking out sap and injecting toxins, causing a yellowish-brown spot to appear on the plant. The appearance of small, deadened areas and the presence of aphids indicate a need for treatment. During autumn, when plants are relatively small, populations of 25 aphids per foot of row may warrant treatment. During the spring, populations exceeding 100 per foot of row are needed before treatment is warranted.

Corn leaf aphids are blue-green with darker spots surrounding the base of the cornicles (two antenna-like extensions on the posterior end of the body). The cornicles on the corn leaf aphid are short, broad, and have dark basal spots. Legs and cornicles also are black.

English grain aphids have a green or yellow-green (occasionally orange or brown) body with black antennae and cornicles. The legs have areas of green and black. The cornicles are long, narrow, and black.

Armyworm

In some years, armyworms (also called "true armyworms" to differentiate them from fall armyworms) cause high losses to small grains by cutting off the seed heads of the plants. Such damage is frequent in areas of the fields where lodging is present. Damage from armyworms normally occurs during mid- to late June. Rescue chemical sprays are possible but not practical unless applied by aircraft. Armyworm populations

Figure 2.5-2. Key periods of small grain insect pests in Pennsylvania.

of three to five larvae per square foot are necessary before control is economical.

Because the adults are moths, only the larvae damage small grains. Larvae are pale green to tan and have a narrow broken stripe down each side. Each abdominal proleg has a diagonal dark stripe around it. (Prolegs are the legs at the posterior end of the larva.) Fully grown larvae are 0.75 to 1.5 inches long.

Armyworm overwinters in southern states and migrates into Pennsylvania each spring, often on storm fronts. Arriving females will mate and lay eggs on small-grain leaves. Young larvae feed on the small-grain foliage, giving the leaves a ragged appearance. As the grain begins to head out, larvae begin feeding on the stalk just below the head, making the head fall off.

Cereal Leaf Beetle

During the past few years, damage from cereal leaf beetle has become more common. It is not clear why outbreaks are occurring, though it is likely that a lack of scouting is catching growers off guard. Cereal leaf beetle is most easily controlled when growing populations are detected early and killed. Although some feeding by the adult beetles and larvae may be seen on fall-sown small grains, particularly wheat, the heaviest infestations and damage have been occurring on oats. Control measures are not necessary until late May or early June, and only when the infestation averages one or more larvae over 1/8 inch long per stem at boot stage, or one larva per flag leaf as oat heads begin to form. Parasites released in Pennsylvania from 1976 to 1978 appear to be established and are helping to hold down the cereal leaf beetle population, and it is possible that overuse of insecticides is disrupting natural control.

Adults are about a quarter inch long, elongate, and have metallic bluish-black wing covers and a reddish-orange thorax. When full grown, larvae are a quarter inch long with a brownish-black head and legs. The body is yellowish and covered with fecal matter. Large larvae may be mistaken for slugs, but slugs are nocturnal and rarely active during the day Overwintering adults appear in early April. After the eggs are deposited, larvae hatch and begin to feed on the leaves for about three to four weeks. Both adult and larval feeding appear as a long narrow strip along the leaf.

Hessian Fly

The Hessian fly usually can be controlled by planting resistant varieties and/or planting after the fly-free date, which varies from early September to early October in Pennsylvania. See the online Hessian fly fact sheet from the Penn State Department of Entomology for specific dates for the counties of Pennsylvania. Note: Keep in mind that the warmer years we recently experienced are likely to influence the fly-free dates, but the extent of the adjustment has yet to be determined. The current dates are likely to suffice because warmer temperatures, if anything, will force the flies to be active earlier in autumn. Plowing under infested fields immediately after harvest also can help. Volunteer wheat can be disked under to prevent later summer infestations. One of the newer seed treatments, Cruiser, has been labeled for Hessian fly control; however, we recommend using cultural practices to manage this insect, especially using fly-free planting dates.

The Hessian fly is similar in appearance and size to a small mosquito. The life span of the adult is generally no more than three days. The Hessian fly completes two generations per year. The spring generation emerges from the flaxseed stage when the average daily temperature is 45 to 50°F. Emergence usually occurs over several weeks, during which time females lay eggs on wheat leaves (and in some cases rye or barley). The newly hatched maggots work their way under the leaf sheath near the nodes. Maggots change to puparium about the time wheat heads out and remain in stubble as "flaxseeds" until fall. Adults of the fall generation begin emerging around early September and live about three days, during which time the females lay eggs. Larvae hatch and begin feeding on young wheat seedlings.

Plant injury caused by larval feeding stunts the plant. Stunted plants usually wither and die; if they survive, their growth and yield are reduced. Significant grain yield reduction can be expected when 20 percent or more of the tillers are infested. Infested tillers are dark green.

Table 2.5-1. Small grain herbicides and their restrictions.

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Restricted-use Pesticide[2]	Water Quality Advisory[3]	Worker Reentry (hours)[4]
2,4-D (4 lb/gal)	2,4-D	4	Several	—	—	12–48
Aim 2EC	carfentrazone	14	FMC	—	—	12
Anthem Flex 4SE	pyroxasulfone + carfentrazone	15/14	FMC	—	Yes	12
Axial Bold 0.69L	pinoxaden + fenoxaprop	1/1	Syngenta	—	—	48
Axial Star 1.15L	pinoxaden + fluroxypyr	1/4	Syngenta	—	—	48
Axial XL 0.42L	pinoxaden	1	Syngenta	—	—	48
Axiom 68DF	flufenacet + metribuzin	15/5	Bayer CropScience	—	—	12
Callisto 4SC[5]	mesotrione	27	Syngenta	—	—	12
Clarity 4S	dicamba	4	BASF	—	—	24
Curtail 2.38L	clopyralid + 2,4-D	4/4	Corteva	—	Yes	48
Elevore	halauxifen	4	Corteva	—	Yes	12
Express 50SG	tribenuron	2	FMC	—	—	12
Finesse Cereal and Fallow 75DF	chlorsulfuron + metsulfuron methyl	2/2	FMC	—	—	4
Gramoxone SL 2/Gramoxone SL 3	paraquat	22	Syngenta	Yes	—	12
Harmony Extra 50DF/Audit 1:1	thifensulfuron + tribenuron	2	FMC/UPL	—	—	12
Harmony SG 50DF	thifensulfuron	2	FMC	—	—	4
Huskie 2.06L	pyrasulfotole + bromoxynil	27/6	Bayer CropScience	—	Yes	24
Huskie Complete 2.4L	pyrasulfotole + bromoxynil +thiencarbazone	27/6/2	Bayer CropScience	—	Yes	24
Maestro 2EC	bromoxynil	6	Nufarm	—	—	24
MCPA (4 lb/gal)	MCPA	4	Several	—	—	12–48
Metricor 75DF[6]/TriCor75DF[6]	metribuzin	5	UPL	—	Yes	12
Moxy 2EC	bromoxynil	6	WinField United	—	—	24
Osprey 4.5WDG	mesosulfuron	2	Bayer CropScience	—	—	4
Outrider 75WDG	sulfosulfuron	2	Valent	—	—	12
Pixxaro 2.43 EC	fluroxypyr + halauxifen	4/4	Corteva	—	—	12
Peak 57WDG	prosulfuron	2	Gowan	—	—	12
PowerFlex HL 13WDG	pyroxsulam	2	Corteva	—	—	12
Prowl H2O 3.8CS	pendimethalin	3	BASF	—	—	24
Quelex 20.4WDG	halauxifen + florasulam	4/2	Corteva	—	Yes	12
Rezuvant 1.3EC	halauxifen + fluroxypyr + pinoxaden + safener	4/4/1	Corteva	—	Yes	48
Reviton	tiafenacil	14	Helm	—	—	12
Roundup PowerMAX 4.5S/ Roundup WeatherMAX 4.5S/other glyphosates	glyphosate	9	Bayer Crop-Science/others	—	—	4–12
Sentrallas 1.55L	thifensulfuron + fluroxypyr	2/4	FMC	—	—	24
Sharpen 2.85SC	saflufenacil	14	BASF	—	Yes	12
Starane Flex	florasulam + fluroxypyr	2/4	Corteva	—	—	24
Starane Ultra 2.8L	fluroxypyr	4	Corteva	—	—	24

Table 2.5-1. Small grain herbicides and their restrictions (continued).

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Restricted-use Pesticide[2]	Water Quality Advisory[3]	Worker Reentry (hours)[4]
Stinger 3S	clopyralid	4	Corteva	—	Yes	12
Talinor 1.77EC	bicyclopyrone + bromoxynil	27/6	Syngenta	—	Yes	24
Tarzec 31.95WG	halauxifen + pyroxsulam	4/2	Corteva	—	—	12
Valor SX 51WDG/Valor EZ 4L	flumioxazin	14	Valent	—	—	12
Zidua 85WDG/Zidua 4.17SC	pyroxasulfone	15	BASF	—	Yes	12

[1] Generic alternatives to some of these products are available. See Table 2.1-10.
[2] Only licensed applicators may purchase and apply restricted-use pesticides.
[3] These herbicides have an "Environmental Hazard Warning" on their labels and have been detected in water supplies from normal agricultural use. Special precautions apply for their use on coarse-textured soils or where water tables are shallow. See the product label for specific restrictions.
[4] If soil-applied products are injected or incorporated at application time, under certain circumstances the Worker Protection Standard allows workers to enter the treated area if they will have no contact with anything that has been treated. Personal protective equipment is required for early entry to treated areas if contact with treated soil, plants, or water is involved.
[5] Callisto is only registered for use in spring oats.
[6] Tricor/Metricor have 24c Local Needs Label for use in specific states. Only approved brands of metribuzin can be used in approved states. Refer to the labels.

Table 2.5-2. Herbicides labeled for use in small grains by small grain species.

	Fall-Seeded				
Trade Name	**Wheat**	**Barley**	**Rye**	**Triticale**	**Spring Oats**
2,4-D*	▲	▲	▲	▲	▲
Aim	▲	▲	▲	▲	▲
Anthem Flex	▲				
Audit 1:1	▲	▲	▲	▲	▲
Axial Star	▲	▲			
Axial XL, Axial Bold	▲	▲			
Axiom	▲			▲	
Callisto					▲
Clarity/dicamba	▲	▲	▲	▲	▲
Curtail	▲	▲			
Finesse Cereal and Fallow	▲	▲		▲	
Gramoxone	▲	▲			
Harmony Extra, Express	▲	▲		▲	▲
Harmony SG	▲	▲		▲	▲
Huskie	▲	▲	▲	▲	
Huskie Complete	▲				
Maestro	▲	▲	▲	▲	▲
MCPA	▲	▲	▲		▲
Metricor/TriCor	▲	▲			
Osprey	▲			▲	
Outrider	▲				
Peak	▲	▲	▲	▲	▲
PowerFlex HL	▲			▲	
Prowl H2O	▲			▲	
Quelex	▲	▲		▲	
Roundup	▲	▲	▲	▲	▲
Sentrallas	▲	▲			▲
Sharpen	▲	▲	▲	▲	▲
Starane Flex	▲	▲	▲	▲	▲
Starane Ultra	▲	▲		▲	▲
Stinger	▲	▲			▲
Talinor	▲	▲			
Valor	▲				
Zidua	▲				

*2,4-D is manufactured by various companies; labels may vary among manufacturers.

Table 2.5-3. Small grain herbicide prepackaged mixes or co-packs and equivalents.

Trade Name	Components (ai or ae/gal or lb)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae lb/A)	An Equivalent Tank Mixture of
Anthem Flex 4SE	3.733 lb pyroxasulfone	15	2.75 fl oz	0.08 lb pyroxasulfone	2.46 fl oz Zidua 4.17SC
	0.267 lb carfentrazone	14		0.006 lb carfentrazone	0.4 fl oz Aim 2EC
Audit 1:1 50WDG	0.25 thifensulfuron	2	0.75 oz wt	0.0117 lb thifensulfuron	0.37 oz Harmony SG 50DF
	0.25 tribenuron	2		0.0117 lb tribenuron	0.37 oz Express 50DF
Axial Bold 0.69L	0.457 lb pinoxaden	1	15 fl oz	0.053 lb pinoxaden	16.4 fl oz Axial 0.42L
	0.228 lb fenoxaprop	1		0.027 lb fenoxaprop	0.44 oz ai fenoxaprop
Axial Star 1.15L	0.42 lb pinoxaden	1	16.4 fl oz	0.053 lb pinoxaden	16.4 fl oz Axial 0.42L
	0.73 fluroxypyr	4		0.094 lb fluroxypyr	4.3 fl oz Starane Ultra 2.8L
Axiom 68DF	0.544 lb flufenacet	15	6 oz wt	0.2 lb flufenacet	6.4 fl oz Define 4SC
	0.136 lb metribuzin	5		0.05 metribuzin	1.1 oz Metribuzin 75DF
Curtail 2.4L	0.38 lb clopyralid	4	1 qt	0.095 lb clopyralid	4.1 fl oz Stinger 3S
	2 lb 2,4-D	4		0.5 lb 2,4-D	16 fl oz 2,4-D amine 4L
Finesse Cereal and Fallow 75DF	0.625 chlorsulfuron	2	0.25 oz wt	0.001 chlorsulfuron	0.12 oz Glean XP 75DF
	0.125 metsulfuron	2		0.125 metsulfuron	1.2 oz Ally XP 60DF
Harmony Extra 50DF	0.333 thifensulfuron	2	0.75 oz wt	0.015 thifensulfuron	0.5 oz Harmony SG 50DF
	0.167 tribenuron	2		0.0078 tribenuron	0.25 oz Express 50DF
Huskie 2.06L	0.31 lb pyrasulfotole	27	13 fl oz	0.031 lb pyrasulfotole	0.5 oz ai pyrasulfotole
	1.75 bromoxynil	6		0.178 bromoxynil	11.4 fl oz Maestro 2EC
Huskie Complete 2.4L	0.26 lb pyrasulfotole	27	13.7 fl oz	0.027 lb pyrasulfotole	0.44 oz ai pyrasulfotole
	2.09 bromoxynil	6		0.224 lb bromoxynil	14.3 fl oz Maestro 2EC
	0.042 lb thiencarbazone	2		0.004 lb thiencarbazone	0.072 oz ai thiencarbazone
Quelex 20.4WDG	0.1 lb halauxifen	4	0.75 oz wt	0.005 lb halauxifen	1.1 fl oz Elevore 0.57L
	0.1 florasulam	2		0.005 lb florasulam	0.075 oz ai florasulam
Pixxaro 2.43EC	0.1 fluroxypyr	4	6 fl oz	0.109 lb fluroxypyr	5 fl oz Starane Ultra 2.8EC
	2.33 halauxifen	4		0.0047 lb halauxifen	1.06 fl oz Elevore 0.57SC
Sentrallas 1.55L	0.25 lb thifensulfuron	2	12 fl oz	0.02 lb thifensulfuron	0.5 oz Harmony SG 50DF
	1.3 fluroxypyr	4		0.122 lb fluroxypyr	5.6 fl oz Starane Ultra 2.8L
Starane Flex 0.875 L	0.042 florasulam	2	13.5	0.004 lb florasulam	0.07 oz ai florasulam
	0.833 fluroxypyr	4		0.088 lb fluroxypyr	4 fl oz Starane Ultra 2.8L
Supremacy 42WDG	0.36 fluroxypyr	4	5 oz wt	0.113 lb fluroxypyr	5.2 fl oz Starane Ultra 2.8L
	0.045 thifensulfuron	2		0.014 lb thifensulfuron	0.5 oz Harmony SG 50DF
	0.015 tribenuron	2		0.005 lb tribenuron	0.16 oz Express 50DF
Tarzec 31.95WG	0.067 lb halauxifen	4	1 oz wt	0.00435 lb halauxifen	0.09 fl oz Elevore 0.57SC
	0.25 lb pyroxsulam	2		0.0156 lb pyroxsulam	1.9 oz wt PowerFlex HL 13.1WG

Table 2.5-4. Relative effectiveness of burndown treatments for no-till small grains.

Trade Name	Clarity/ dicamba	Finesse	Gramoxone	Harmony Extra (fall-applied)	Roundup/ Glyphosate (fall-applied)	Roundup/ Glyphosate (spring-applied)	Sharpen
Site of Action Number	4	2/2	22	2	9	9	14
Chickweed, Common[1]	7	**9**	**8+**	**9**	**9**	**9**	6
Clover, Red	**9**	8	8	6	**8+**	7	—
Dandelion	7	7+	N	6	**8+**	6	7
Dogbane, Hemp; Dewberry; Milkweed; etc.	6	N	6	N	**8+**	6	N
Foxtail spp.	N	N	**9**	N	**9**	**9**	N
Lambsquarters, Common	**9**	8	8	**9**	**9**	**9**	8
Marestail[2]	8	**9**	7	7	**9**	**9**	**9+**
Mustard spp.	**9**	**8+**	8	**9**	**9**	**9**	L
Ragweed, Common[3]	**9**	N	8	6	**9**	**9**	8
Rye Cover, Volunteer Small Grains	N	N	**9**	N	**10**	**10**	N
Smartweed	**9**	6	7	**9**	7	7	L
Sod, Alfalfa	8	—	N	N	**8+**	7	N
Sod, Bromegrass or Quackgrass	N	N	6	N	**9**	7	N
Sod, Orchardgrass or Fescue	N	N	N	N	**9**	7	N
Thistle, Canada	8	6	6	7	**9**	7	6
Timothy or Bluegrass	N	N	7	N	**10**	**10**	N
Vetch, Hairy	**9**	—	7	7	8	6	6

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size (young weeds) or growth stage. Treatments are rated only for control of vegetation existing at the time of application.
Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control; L = labeled but no university data; — = not applicable or no information available.
[1] Common chickweed biotypes resistant to Group 2 herbicides are found in the region; if you suspect resistant biotypes in your area, do not rely on herbicides from these groups to control resistant biotypes.
[2] Horseweed/marestail biotypes resistant to Group 9 (glyphosate) and Group 2 herbicides are widespread in the region; do not rely on herbicides from these groups to control resistant biotypes.
[3] Common ragweed biotypes resistant to Group 9 (glyphosate) and Group 2 herbicides are found in the region; if you suspect resistant biotypes in your area, do not rely on herbicides from these groups to control resistant biotypes.

Table 2.5-5. Comments on burndown herbicides for no-till small grains.

Trade Name*	Common Name	Site of Action Number	Application	Product/A	lb ai/A
Clarity 4S, numerous others	dicamba DGA salt	4	preplant or preemergence to postemergence	2–4 fl oz	0.06–0.125
• The 4 fl oz rate controls small annual broadleaf weeds and there is no waiting period prior to planting at this rate. • Clarity/dicamba may be used at greater than 4 fl oz prior to planting wheat; however, for each pt/A of dicmaba applied, delay crop planting for 20 days.					
Finesse Cereal and Fallow 75DF	chlorsulfuron +	2	preplant or preemergence to postemergence	0.2–0.4 oz	0.0078–0.0156
	metsulfuron	2			0.0016–0.0031
• Do not apply preplant or preemergence to barley or triticale • Plant seed at least 1 inch deep to reduce risk of injury. • Should be tank-mixed with another burndown herbicide to broaden spectrum of control. • Rotation to Bolt or STS soybeans is 4 months; Plenish trait is 6 months. • Rotation for field corn and all other soybeans is 18 months. • Include a nonionic surfactant at 0.125 to 0.5% v/v.					
Gramoxone SL 2	paraquat	22	preplant or preemergence	2–4 pt	0.5–1
Gramoxone SL 3				1.3–2.6 pt	
• Apply in 20 to 60 gal/A for control of emerged annual weeds. • Add 8 to 32 oz non-ionic surfactant per 100 gal of spray. • Phosphate-containing liquid fertilizer solutions diminish paraquat activity if used as a carrier. • Use appropriate precautions when handling paraquat to minimize exposure to the herbicide. • Do not use flood jet tips larger than size 20 or spacing greater than 40 inches Paraquat use restrictions: • Only certified applicators who successfully complete the paraquat-specific training can mix, load, or apply paraquat. • Application of paraquat "under the direct supervision" of a certified applicator is no longer allowed; registered technicians cannot apply. • Required training at http://usparaquattraining.com; certified applicators must repeat training every three years. • *Restricted-use pesticide.*					
Harmony Extra SG 50DF	thifensulfuron +	2	preplant or preemergence to postemergence	0.45–0.9 oz	0.014–0.028
	tribenuron	2			
• For use on wheat, barley, and oats only. • Apply burndown treatment before or shortly after planting but before small grain emergence.					
Roundup 3S/glyphosate**	glyphosate	9	preplant or preemergence	1–3 qt	1–3 lb ae/A
• Apply before, during, or after planting but before crop emergence. • Use the low rate for annual weeds up to 6 inches tall and higher rates for weeds taller than 6 inches.					
Sharpen 2.85SC	saflufenacil	14	preplant or preemergence	1–2 fl oz	0.022–0.044
• Should be tank-mixed with another burndown herbicide to broaden spectrum of control. • For optimum burndown activity, include methylated seed oil (MSO) plus ammonium sulfate (AMS) at 8.5 to 17 lb/100 gallons. • Apply 1 to 2 oz/A for burndown activity. Sequential applications are allowed prior to crop emergence but do not apply more than 4 fl oz/A total per cropping season.					

See specific product label to determine correct rate for soil type and weed species found in each field. These treatments may be used in conventional, reduced-till, and no-till systems. Tables 2.5-1 and 2.5-4 list characteristics and efficacy of burndown herbicides.

*The legitimate use of 2,4-D for burndown in wheat is uncertain. None of the 2,4-D ester or amine labels specify application just prior to wheat seeding or emergence. Some research suggests a minimum delay of 7 to 10 days after application at rates up to 1 pt/A 2,4-D ester. However, use of 2,4-D burndown in wheat is ambiguous at best and, if injury occurs, liability rests with the consultant or applicator.

**Various formulations of this product are available (see Table 2.1-8). Refer to current product label for active ingredient concentration, application rate, and other restrictions.

Table 2.5-6. Relative effectiveness of fall-planted small grain herbicides for winter annuals.

		Grasses					*Broadleaves*																	
Trade Name	**Site of Action Number**	**Bluegrass, Annual[1]**	**Bluegrass, Roughstalk**	**Brome spp.[2]**	**Ryegrass, Annual[2]**	**Oatgrass, Bulbous[3]**	**Bedstraw, Catchweed**	**Buckwheat, Wild**	**Carrot, Wild**	**Chickweed, Common[2]**	**Corn, Chamomile**	**Cornflower**	**Groundsel, Common**	**Henbit/Purple Deadnettle**	**Horseweed/Marestail[4]**	**Knawel**	**Lettuce, Prickly**	**Mustard spp.**	**Pansy, Field**	**Pennycress, Field**	**Shepherdspurse**	**Speedwell sp.[5]**	**Vetch, Hairy/Annual**	**Crop Tolerance**
Preplant																								
Finesse	2/2	6	—	6	6	—	N	6	8	**9**	**9**	—	L	**9**	8	**9**	**9**	**8+**	—	8	**9**	7+	6	FG
Sharpen	14	N	N	N	N	N	N	N	N	L	N	—	8	—	L	N	L	L	N	L	L	—	—	E
Valor	14	6	—	6	**9**	N	—	6	N	8	—	—	L	8	**9**	N	L	7	N	8	8	—	—	FG
Delayed Preemergence																								
Axiom	5/15	**8+**	N	7	**8+**	—	—	—	N	**8+**	**8+**	—	—	**9**	8	**9**	—	**8+**	N	8	6	—	—	FG
Prowl	3	6	—	—	8	—	—	—	N	7+	—	—	—	**8+**	N	N	—	7+	N	—	7+	N	N	VG
Zidua/Anthem Flex	15	**9**	—	8	**8+**	—	—	—	N	7	—	—	—	8	8	6	—	—	N	—	—	—	N	VG
Delayed Preemergence to Early Postemergence																								
Axial	1	N	N	N	**9**[6]	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	G
Osprey	2	**8+**	**8+**	8	**9**	—	N	N	—	7	7	N	N	7	N	8	N	8	6	N	N	N	**8+**	G
Postemergence																								
2,4-D	4	N	N	N	N	N	7	6	7	6	—	6	6	6	**8+**	N	**9**	**9**	N	**9**	**9**	6	8[7]	F
Aim	14	N	N	N	N	N	8	6	N	N	—	N	N	6	N	6	6	6	—	8	6	6	6	VG
Clarity/dicamba	4	N	N	N	N	N	N	**8+**	6	7	—	6	7	7	8	7	8	7	N	7	8	6	**9**	F
Finesse	2/2	7+	—	6	7+	—	6	N	8	**8+**	7	—	L	**8+**	7	**9**	8	8	—	8	8	7	7	G
Harmony Extra	2/2	N	N	N	N	N	N	8	7+	8	—	N	**9**	**9**	7	**8+**	8	**9**	7	**9**	**9**	N	7	VG
Harmony SG	2	N	N	N	N	N	N	8	N	7	—	N	**9**	7	N	—	7	**9**	—	**9**	**9**	N	6	VG
Huskie	6/27	N	N	N	N	N	L	L	—	7	N	7	—	**8+**	**8+**	N	—	L	N	L	L	N	—	VG
Maestro/Moxy	6	N	N	N	N	N	N	**9**	—	6	—	—	**9**	6	7	N	6	**9**	—	8	8	N	6	VG
MCPA	4	N	N	N	N	N	N	8	6	6	—	—	6	6	**8+**	—	**9**	**9**	N	**9**	**8+**	6	7	FG
Metricor/TriCor	5	**8+**	6	6+	N	8	—	—	N	**9**	—	8	—	**9**	N	**8+**	—	7	N	L	N	8	6	FG[8]
Peak	2	N	N	N	N	N	N	8	7	7	—	—	N	6+	6	—	**8+**	**9**	—	**9**	8	N	**9**	G

Table 2.5-6. Relative effectiveness of fall-planted small grain herbicides for winter annuals (continued).

		Grasses					*Broadleaves*																		
Trade Name	**Site of Action Number**	**Bluegrass, Annual[1]**	**Bluegrass, Roughstalk**	**Brome spp.[2]**	**Ryegrass, Annual[2]**	**Oatgrass, Bulbous[3]**	**Bedstraw, Catchweed**	**Buckwheat, Wild**	**Carrot, Wild**	**Chickweed, Common[2]**	**Corn, Chamomile**	**Cornflower**	**Groundsel, Common**	**Henbit/Purple Deadnettle**	**Horseweed/Marestail[4]**	**Knawel**	**Lettuce, Prickly**	**Mustard spp.**	**Pansy, Field**	**Pennycress, Field**	**Shepherdspurse**	**Speedwell sp.[5]**	**Vetch, Hairy/Annual**	**Crop Tolerance**
PowerFlex	2	7+	7+	8	**9**	—	7	6	—	8	**9+**	8	N	7	6	**9**	6	**9**	7	**9**	8	8	**9**	FG
Quelex	2/4	N	N	N	N	N	L	L	—	**9**	L	8	—	7	**9**	**8+**	6	L	N	L	L	N	L	VG
Starane Ultra	4	N	N	N	N	N	L	—	—	7+	—	8	—	8	L	6	—	L	N	L	—	N	**8+**	G
Stinger	4	N	N	N	N	N	N	**9**	—	N	—	—	**9**	N	**9+**	—	**9**	N	N	N	N	N	**9**	FG

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage. Results may differ with variations in weed size, temperature, rainfall, and soil moisture. Crop tolerance rating of VG or E is rarely significant.

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75% ; 6 = 55–65%; N = less than 55% or no control; L = labeled but no university data; — = not applicable or no information available; + = upper end of rating scale.

Crop tolerance: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).

[1] Annual bluegrass control is listed on the Osprey label. Fall applications are best.

[2] See Part II, Section 1: Pest Management for more detailed information on these weeds.

[3] Outrider provides fair to good control (8) of bulbous oatgrass.

[4] Horseweed biotypes resistant to Group 2 herbicides are widespread in the region; do not rely on herbicides from these groups to control resistant biotypes.

[5] There are several speedwell (Veronica) species, including corn, common, ivy leaf, and others. Depending on the species, their life cycle is either annual or perennial. Many of the commonly used small grain herbicides provide little or no control of speedwell. Finesse has a few annual and perennial speedwells listed on its label and usually provides 80 to 90 percent control of them. PowerFlex has provided control of certain speedwell species in some university trials. Be cautious of crop rotation intervals if using Finesse. If speedwell is small, Aim provides some control/suppression.

[6] Will not control Group 1 (ACCase) resistant annual ryegrass biotypes.

[7] 2,4-D ester provides better control of hairy vetch than 2,4-D amine.

[8] Crop tolerance with Metricor/TriCor is dependent on weather at time of application and variety. Crop tolerance is improved if applications are made in the early spring rather than in the fall or the late spring.

Table 2.5-7. Relative effectiveness of fall-planted small grain herbicides for postemergence perennial weed control.

Trade Name	Site of Action Number	Bedstraw, Smooth	Cockle, White	Dandelion	Dock spp.	Garlic or Onion, Wild	Thistle, Canada	Crop Tolerance
2,4-D	4	6	7+	7+	6+	7	7	FG
Aim	14	6	N	N	N	N	N	VG
Clarity/dicamba	4	N	8	6	7	6	7	F
Finesse	2/2	N	8	7+	8+	8+	7	G
Harmony Extra	2/2	N	—	6	8	9	7	VG
Harmony SG	2	N	—	6	7	9	N	VG
Huskie	6/27	L-s	L	L-s	L-s	—	—	VG
Maestro	6	N	6	6	6	N	6	G
MCPA	4	6	N	8	6+	6	7	FG
Metricor/TriCor	5	—	—	L	N	N	N	FG*
Peak	2	N	—	6	8	9	6+	VG
PowerFlex	2	N	N	N	N	N	N	FG**
Quelex	2/4	L	—	L-s	—	—	L-s	VG
Starane Ultra	4	L	—	7	—	—	N	VG
Stinger	4	N	7+	7+	7	N	8	FG

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage. Results may differ with variations in weed size, temperature, rainfall, and soil moisture. Crop tolerance rating of VG or E is rarely significant.
Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75% ; 6 = 55–65%; N = less than 55% or no control; L = labeled but no university data; L-s = labeled for suppression or partial control only; — = not applicable or no information available; + = upper end of rating scale.
Crop tolerance: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (seldom is crop injury observed as long as proper management practices are followed, e.g., seedling depth, seed slit closure, herbicide rate and application timing, adjuvants); FG = fair to good (occasionally crop injury is observed even with proper management practices; injury is often due to herbicide interactions with environmental conditions); F = fair (some crop injury is commonly observed).
*Crop tolerance with Metricor/TriCor is dependent on weather at time of application and variety. Crop tolerance is improved if applications are made in the spring rather than in the fall.
**Based on University of Delaware trials, PowerFlex applications in the spring can result in significant stunting.

Table 2.5-8. Comments on herbicides for small grains.

Trade Name	Common Name	Site of Action Number	Application	Product/A	lb ai/A
2,4-D amine 4S	2,4-D	4	full tiller to prejointing (growth stages 3–6)	0.5–2 pt	0.25–1
• For use on wheat, barley, rye, and oats. • Use lower rates for small annual weeds. • Use lower rate (0.25 to 0.5 pt/A) if underseeded with legume (alfalfa, red or white clover are labeled; vetch and sweet clover will be severely injured). • Spraying small grains too young or after jointing can result in reduced yields or uneven ripening. • In general, apply when small grain is 4 to 8 inches tall. • May be tank-mixed with Harmony Extra SG, dicamba, or Maestro. • No rotation restriction to soybean; 3-month rotation restriction to vegetables; see Table 2.1-11.					
2,4-D LVE 4E	2,4-D	4	full tiller to prejointing (growth stages 3–6)	0.5–2 pt	0.25–1
• For use on wheat, barley, rye, and oats. • Use lower rates for annual weeds. • For wild garlic or onion control, apply 1.5–2 pt. • Avoid use if temperatures are expected to exceed 75°F. • No rotation restriction to soybean; 3-month rotation restriction to vegetables; see Table 2.1-11.					
Aim 2EC	carfentrazone	14	up to the jointing stage (growth stages 1–5)	0.5–2 fl oz	0.008–0.016
• For use on wheat, barley, and oats to control certain broadleaves. • Apply before weeds are 4 inches tall. • Aim provides control/suppression of a limited number of weeds species; should be tank-mixed other common small grain herbicides to improve control and increase weed spectrum. Some research has shown that Aim provides suppression of Star-of-Bethlehem and speedwell. • No rotation restrictions to soybean or vegetables; see Table 2.1-11.					
Anthem Flex					
• See Zidua					
Axial XL 0.42L	pinoxaden	1	2-leaf to preboot (growth stages 2–8)	16.4 fl oz	0.053
• For use on wheat or barley. • Do not apply within 60 days of harvest. • Controls certain grassy weeds such as annual ryegrass, foxtails, barnyardgrass, and wild oat. Apply Axial XL before weeds have more than five leaves on the main stem. • Axial XL does not control downy brome or ACCase-resistant grasses. • Axial XL will not control broadleaf weeds and should be tank-mixed with other labeled herbicides to enhance weed control spectrum. • Rotation to grain crops (including soybeans) is 90 days; to leafy and root crops is 30 days; all other vegetables, after 90 days; see Table 2.1-11. • Axial Star is a premix containing pinoxaden plus fluroxypyr (Starane Ultra), and Axial Bold is a premix containing pinoxaden plus fenoxaprop.					
Axiom 68 DF	flufenacet +	5	spiking to 2 leaf (growth stage 1)	4–10 oz	0.133–0.333
	metribuzin	15			0.033–0.083
• For use on wheat and triticale. • Plant seeds 1 to 2 inches deep to improve crop safety; use only when wheat is planted with a drill. • Apply when crop is between full germination and 2-leaf stage; apply before broadleaf weeds reach the 1-leaf stage. Axiom will not control grasses after they have emerged. • Use rate depends on soil texture; see product label. • Some crop varieties are more sensitive; see product label. • No rotation restriction to soybean; 12-month rotation restriction to vegetables; see Table 2.1-11. • *Water quality advisory.*					
dicamba (numerous)	dicamba DMA salt	4	full tiller to jointing (growth stages 3–6)	2–4 fl oz	0.06–0.12
Clarity 4S	dicamba DGA salt				
• For use on fall-seeded barley and wheat. • Crop safety and weed control will be similar for all dicamba formulations. • Spraying small grains after jointing can result in reduced yields or uneven ripening. • May be tank-mixed with Maestro or 2,4-D to broaden spectrum of control. • Do not use if legumes are underseeded. • No rotation restrictions.					

Table 2.5-8. Comments on herbicides for small grains (continued).

Trade Name	Common Name	Site of Action Number	Application	Product/A	lb ai/A
Finesse Cereal and Fallow 75DF	chlorsulfuron	2	preemergence to postemergence (after 1-leaf but before boot stage)	0.2–0.4 oz	0.0078–0.0156
	metsulfuron	2			0.0016–0.0031

- Do not apply preplant or preemergence to barley or triticale
- Plant seed at least 1 inch deep to reduce risk of injury.
- Finesse will not control ALS-resistant weed populations; control of susceptible ryegrass populations can be erratic.
- Rotation to Bolt or STS soybeans is 4 months; Plenish trait is 6 months.
- Rotation for field corn and all other soybeans is 18 months.
- Include a nonionic surfactant at 0.125 to 0.5% v/v.
- Two applications can be used, but do not exceed 0.4 oz per crop.

Harmony Extra SG 50DF	thifensulfuron +	2	2-leaf to before visible flag leaf (growth stages 1–7)	0.45–0.9 oz	0.009–0.018
	tribenuron	2			0.005–0.009

- For use on wheat, barley, and oats.
- Do not apply within 45 days of harvest.
- Controls wild garlic and broadleaf weeds. Tank-mix with Express 50SG for improved wild carrot control. Not recommended for cornflower.
- Rates depend on type of weeds and severity.
- Fall applications have been more consistent than spring applications for weed control in regional trials.
- For garlic control use higher rates of Harmony Extra SG plus 2,4-D when garlic is less than 12 inches tall.
- Always premix Harmony Extra SG in water before adding to the spray tank.
- Tank-mix with other herbicides to increase weed control spectrum; improve control of ALS-R common chickweed with Quelex or Starane Ultra.
- Tank-mixing with dicamba or Maestro may result in reduced control of certain broadleaf weeds.
- Do not tank-mix with Malathion.
- Be aware many products contain thifensulfuron plus tribenuron, but often not at the same concentration as Harmony Extra.
- Any crop may be planted 45 days after application; see Table 2.1-11.

Harmony SG 50DF	thifensulfuron	2	2-leaf to before visible flag leaf (growth stages 1–7)	0.45–0.9 oz	0.014–0.028

- Harmony SG can be used on fall-seeded wheat, barley, triticale, and oats.
- Do not apply within 45 days of harvest.
- Harmony SG controls wild garlic and broadleaf weeds. Not recommended for cornflower or common chickweed.
- The common rate is 0.75 oz/A, but higher or lower rates may be used.
- Tank-mix with other herbicides to increase weed control spectrum; Quelex and Starane Ultra improve control of ALS-R common chickweed.
- Harmony SG also may be used as a preplant burndown application before small grain emergence.
- Any crop may be planted 45 days after application; see Table 2.1-11

Huskie 2.06L	pyrasulfotole +	6	first-leaf to flag-leaf emergence (growth stages 1–7)	11–15 oz	0.026–0.036
	bromoxynil	27			0.151–0.205

- For use on wheat, barley, rye, and triticale.
- Huskie controls small annual broadleaf weeds.
- Preharvest interval is not specified on label.
- In some university trials, Huskie provided control of marestail at the rosette stage when applied in the spring.
- Four-month rotation restriction to soybean; more than 9 months for vegetables; see Table 2.1-11.
- Water quality advisory.

Maestro 2EC/Moxy 2E	bromoxynil	6	emergence to boot stage (growth stages 1–9)	1–2 pt	0.25–0.5

- For use on wheat, barley, rye, and oats.
- May be applied to a small-grain/alfalfa underseeding.
- Apply before weeds have more than four leaves or are 2 inches tall, or rosettes exceed 1 inch in diameter.
- Use flat fan nozzles and a minimum of 10 gal/A for best results.
- Weak on chickweed and henbit.
- May be tank-mixed with Harmony Extra SG, MCPA, 2,4-D, or Clarity.
- 30-day rotation restriction for all crops; see Table 2.1-11.

Table 2.5-8. Comments on herbicides for small grains (continued).

Trade Name	Common Name	Site of Action Number	Application	Product/A	lb ai/A
MCPA amine or ester 4L	MCPA	4	full tiller to prejoint stage (growth stages 3–6)	0.5–1 pt	0.25–0.5
• For use on wheat, barley, rye, and oats. • Safer on small grains underseeded with legumes than 2,4-D (amine formulation only), but use the lower rate (0.25–0.5 pt) and apply in 5–10 gal water/A; legumes should be 2 to 3 inches tall and cereal should be 8 inches tall to provide canopy to protect legume. • For best results, apply while weeds are small, typically when cereal is 4–8 inches tall. • No rotation restrictions indicated.					
Metricor 75DF/TriCor 75DF	metribuzin	5	2-leaf to 4-tiller (growth stages 1–5)	2–4 oz	0.09–0.19
• For use on wheat and barley. • For control of Group 2 (ALS) resistant common chickweed: Metricor and Tricor are approved for use under 24(c) labels in Delaware and Pennsylvania (expires December 2025). • The typical use rate is 2 to 4 oz/A (3 oz/A is recommended) either in the fall or spring when the crop is in the 2-leaf to 4-tiller growth stage. • Rate depends on soil texture; see product label. • Local research has shown wheat safety is best with an early spring application (at greenup). Potential for injury increases with late spring applications or fall applications. • Plant wheat at least 1 inch deep. • Metribuzin can be tank-mixed with other small grain herbicides to broaden control spectrum. • Certain wheat and barley varieties are sensitive to metribuzin. Refer to the respective label for additional details on varieties and other use restrictions. • In general, fall-applied herbicide generally provided more consistent common chickweed control, but spring metribuzin treatments were adequate as well. • For best results, apply metribuzin when chickweed is small (4 to 6 inches in diameter). • No rotation restriction to soybean; 4 to 18 months for vegetables; see Table 2.1-11. • *Water quality advisory.*					
Osprey 4.5 WDG	mesosulfuron	2	emergence to jointing stage (growth stages 1–5)	4.75 oz	0.013
• For use on winter wheat and triticale. • Preharvest interval is not specified on label. • In our region, Osprey will be primarily targeted for control of annual ryegrass, including ACCase-resistant biotypes and downy brome; can provide control/suppression of annual bluegrass. • Applications should be made when weeds are young and actively growing at the 1-leaf to 2-tiller stage. • To broaden weed control spectrum, Osprey may be tank-mixed with other herbicides, including Harmony Extra SG, Harmony SG, MCPA, Maestro, and Stinger. • Osprey Xtra is a premix containing mesosulfuron plus thiencarbazone. • Do not topdress with nitrogen fertilizer within 14 days following an Osprey application. • Certain insecticides and fungicides may be tank-mixed. • Soybean can be planted after 90 days of application, corn after 12 months, vegetables after 10 months, and alfalfa after 10 months; see Table 2.1-11.					
Peak 57WDG	prosulfuron	2	3-leaf to before visible second node (growth stages 2–6)	0.25–0.5 oz (1 pack/6–12 A)	0.009–0.018 oz
• For use on wheat, barley, oats, rye, and triticale. • Peak controls wild garlic and broadleaf weeds. • Peak can be tank-mixed with glyphosate as a burndown plus residual treatment; can be used prior to planting. • For best results apply when weeds are small and use the 0.5 oz/A rate if used alone. • May be tank-mixed with Clarity, 2,4-D, MCPA, or Maestro to broaden weed spectrum; however, certain application timing restrictions may apply. • Do not apply organophosphate (op) insecticide 15 days before or 10 days after Peak application. • Be cautious of crop rotation restrictions (10 months for soybean and 22 months for alfalfa; see label for other cropping restrictions); see Table 2.1-11. • *Water quality advisory.*					

Table 2.5-8. Comments on herbicides for small grains (continued).

Trade Name	Common Name	Site of Action Number	Application	Product/A	lb ai/A
PowerFlex HL 13WDG	pyroxsulam	2	3-leaf to jointing (growth stage 6)	2 oz	0.016
• For use on wheat and triticale. • Do not apply within 60 days of harvest. • Crop stunting and chlorosis are commonly observed with spring applications; stunted wheat can be observed for weeks after application. Stunting and chlorosis have not been observed with fall applications. • The PowerFlex activity on certain grass and broadleaf weeds, including annual ryegrass, downy brome, and annual bluegrass, is improved with fall applications. • Tarzec is a premix containing halauxifen plus pyroxsulam. • Soybean can be planted 3 months after application. Vegetables can be planted after 9 to 12 months; see Table 2.1-11.					
Prowl H2O 3.8SC	pendimethalin	3	first-leaf to before the flag leaf is visible (growth stages 1–7)	1.5–3 pt	0.7–1.4
• For use on wheat or triticale. • Wheat or triticale must be planted 0.5 to 1 inch deep to avoid crop injury. • Must be applied before weed emergence. Any emerged weeds will not be controlled, so use a tank mixture to control emerged weeds. • For best results, apply Prowl H2O once the wheat rows are visible and before weeds have emerged. • Prowl controls many annual grass and broadleaf weeds. • Wheat or triticale must be planted 0.5 to 1 inch deep to avoid crop injury. • No rotation restriction to soybean or vegetables; see Table 2.1-11.					
Quelex 20.4WDG	halauxifen	4	2-leaf to flag leaf emergence (growth stages 2–8)	0.75 oz	0.005
	florasulam	2			0.005
• For use on wheat, barley, or triticale. • Best to apply to small, actively growing weeds (2- to 4-leaf stage). • Quelex is a slow-acting herbicide. • Quelex provides good control of Group 2 (ALS)–resistant common chickweed; Harmony Extra plus Quelex has provided control of ivyleaf speedwell and henbit (better than either herbicide applied alone). • Do not compost any plant material from the treated area. • Do not apply within 60 days of crop harvest. • Rotation is 45 days to soybeans and 15 months to most vegetables; see Table 2.1-11. • *Water quality advisory.*					
Sharpen 2.85SC	saflufenacil	14	preplant or preemergence	1–4 fl oz	0.022–0.088
• For use on wheat, barley, oats, rye, and triticale. • Be sure seed row is sufficiently covered with soil to avoid washing and concentrating the herbicide in the seed zone. • Apply Sharpen for burndown and/or limited residual control of certain annual broadleaf weeds; see Table 2.5-4. • Sharpen does not control grass weeds. • Do not apply Sharpen if crop has emerged. • No rotation restriction to soybean; 1 to 5 months for vegetables, depending on species; see Table 2.1-11.					
Starane Ultra 2.8L	fluroxypyr	4	2-leaf to early boot (growth stages 2–9)	4.8–6.4 fl oz	0.09–0.13
• For use on wheat, barley, triticale, and oats. • Do not apply within 90 days of harvest. • The Starane Ultra label lists control of bedstraw, chickweed, hemp dogbane, prickly lettuce, ragweed, and velvetleaf and to suppress bindweed, wild buckwheat, mustard species, and others. • Starane Ultra provides fair to good control of Group 2 (ALS)–resistant common chickweed; Harmony Extra plus Starane Ultra has provided control of ivyleaf speedwell, henbit, and jagged chickweed (better than either herbicide applied alone). • 120-day rotation restriction to crops not listed, including soybean. 24(c) labels in Delaware and Virginia permit 90-day rotation to soybeans. • Axial Star is a premix containing pinoxaden (Axial) plus fluroxypyr. Starane Flex is a premix containing fluroxypyr plus florasulam. Supremacy is a premix containing thifensulfuron plus tribenuron plus fluroxypyr. Pixxaro is a premix containing halauxifen plus fluroxypyr.					

Table 2.5-8. Comments on herbicides for small grains (continued).

Trade Name	Common Name	Site of Action Number	Application	Product/A	lb ai/A
Stinger 3S	clopyralid	4	3-leaf to early boot (growth stages 2–9)	0.25–0.33 pt	0.1–0.125

• For use on wheat, barley, and oats.
• For best results, apply while weeds are actively growing.
• For Canada thistle, apply when thistle is 1 to 2 feet tall.
• Preharvest interval is not specified on label.
• May be tank-mixed with any other small grain herbicide to increase weed spectrum. (Curtail is a premix of clopyralid and 2,4-D. See product label for details.)
• Do not use plant residues or manure from animals that consumed forage from treated areas for compost or mulch where susceptible plants may be grown the following season.
• 10.5-month rotation restriction to soybean for soils with greater than 2% organic matter; 18-month restriction for soils with less than 2% organic matter. See label, as vegetable rotation varies greatly by species; see Table 2.1-11.
• *Water quality advisory.*

Valor SX 51WDG or Valor EZ 4L	flumioxazin	14	early preplant	1–2 oz or 1–2 fl oz	0.032–0.064

• For use on wheat only in Delaware, Maryland, New Jersey, Pennsylvania, and Virginia.
• Must be applied 7 days prior to planting in no-till or minimum-till wheat; 30-day preplant restriction from conventionally tilled wheat.
• When using as a burndown, apply 2 oz/A.
• Wheat must be planted a minimum of 1 inch deep.
• Valor improves control of horseweed and other broadleaf weeds when tank-mixed with other herbicides that broaden control spectrum.
• With sandy soils, stunting and stand loss can occur if seed is not planted at least 1 inch deep and heavy rain occurs shortly after application.
• No rotation restriction to soybean; more than 4 months for vegetables; see Table 2.1-11.

Zidua 85WDG or Zidua 4.17SC	pyroxasulfone	15	delayed pre- to early postemergence (4th tiller; growth stages 1–3)	0.7–2.5 oz or 1.25–4 fl oz	0.04–0.13
Anthem Flex 4SE	pyroxasulfone +	15		2–4.5 fl oz	0.004–0.01
	carfentrazone	14			

• For use on wheat only.
• All products can be applied as a delayed preemergence (80% germination with 0.5-inch-long shoot to spiking) to control annual grasses and small-seeded broadleaf weeds. Application before wheat germination, followed by rainfall, can lead to significant stand loss.
• Do not use on broadcast seeded wheat; do not plant wheat deeper than 1.5 inches (but at least 1 inch deep).
• Do not apply if more than 0.25 inches of rain is expected within 48 hours.
• Crop injury may result under prolonged wet soil conditions.
• Consult label; soil texture influences rate.
• Zidua alone will not control emerged weeds; Anthem Flex contains carfentrazone (Aim), which will provide control of certain weed species if they are very small at time of application.
• No rotation restriction to soybean; 18 months for vegetables; see Table 2.1-11.
• *Water quality advisory.*

See specific product label to determine correct rate for soil type and weed species found in each field. Tables 2.5-5, 2.5-6, and 2.5-7 list characteristics and efficacy of herbicides. A good small grain stand is very competitive and normally does not require an herbicide treatment. It is important to control all existing vegetation at planting time, prior to no-till production.

Table 2.5-9. Spray additives and rainfastness for burndown or postemergence herbicides in small grains.

Trade Name	Adjuvant(s)[1]	Rate	Apply in Nitrogen Carrier (50:50)	Rainfastness (hours)
2,4-D amine 4S/2,4-D LVE 4E	non-ionic surfactant	1 qt/100 gal	yes	1
	or crop oil concentrate	4 qt/100 gal		
Aim	non-ionic surfactant	1 qt/100 gal	yes	6–8
	or crop oil concentrate	1 gal/100 gal		
	plus ammonium sulfate	2–4 lb/A		
	or nitrogen solution (optional)	2–4 gal/100 gal		
Anthem Flex[2]	non-ionic surfactant	1 qt/100 gal	N/A	1
	or crop oil concentrate	1–2 pt/A		
	or methylated seed oil	1–2 pt/A		
	plus nitrogen solution (optional)	1–2 qt/A		
	or ammonium sulfate (optional)	8.5 lb/100 gal		
Axial XL	none required		yes	0.5
Axiom	do not add crop oil concentrate, vegetable, or petroleum oils	no	N/A	
Callisto	non-ionic surfactant	1 qt/100 gal	yes	N/A
	or crop oil concentrate	1 gal/100 gal		
	plus ammonium sulfate	8.5 lb/100 gal		
Clarity/dicamba	non-ionic surfactant	1 qt/100 gal	yes	4
	or crop oil concentrate plus	1 gal/100 gal		
	nitrogen solution	2–4 qt/A		
Finesse	non-ionic surfactant	0.5-2 qt/100 gal	yes	6
Harmony Extra	non-ionic surfactant	see table below	yes	several
	nitrogen solution (optional)	2 qt/A		
Harmony SG	non-ionic surfactant	see table below	yes	several
	nitrogen solution (optional)	2 qt/A		
Huskie	ammonium sulfate	0.5–1 lb/A	yes	1
	or urea ammonium nitrate	1–2 qt/A		
Maestro	non-ionic surfactant	1 qt/100 gal	yes	N/A
	or crop oil concentrate	1 gal/100 gal		
	or nitrogen solution	2–4 gal/100 gal		
MCPA	no information		yes	N/A
Metricor/TriCor	not recommended		not recommended	N/A
Osprey	methylated seed oil (MSO)	2 gal/100 gal	yes, but no more than 15% of solution	4
	or non-ionic surfactant	2 pt/100 gal		
	plus nitrogen solution	1–2 qt/A		
Peak	non-ionic surfactant	1–2 qt/100 gal	yes, but do not use crop oil with N carrier	4
	or crop oil concentrate	1–4 qt/A		
	nitrogen solution (optional)	2–4 qt/A		

Table 2.5-9. Spray additives and rainfastness for burndown or postemergence herbicides in small grains (continued).

Trade Name	Adjuvant(s)[1]	Rate	Apply in Nitrogen Carrier (50:50)	Rainfastness (hours)
PowerFlex	non-ionic surfactant plus	1–2 qt/100 gal	yes	4
	nitrogen solutions (optional)	1–2 qt/A		
	or crop oil concentrate (nitrogen solution is not recommended with COC)	1 gal/100 gal		
Quelex	non-ionic surfactant	0.8–2 qt/100 gal	yes[3]	4
	or crop oil concentrate	2–4 qt/100 gal		
	or methylated seed oil	2–4 qt/100 gal		
Sharpen	methylated seed oil	1 gal/100 gal	N/A	1
	nitrogen solution	1.25–2.5 gal/100 gal		
Starane Ultra	none recommended		N/A	1
Stinger	none recommended		yes	6
Valor	methylated seed oil	1 qt/A	N/A	1
	nitrogen solution	1–2 qt/A		
Zidua	none recommended		N/A	N/A

[1] In general, non-ionic surfactants should contain at least 80% surface active agent; crop or vegetable oil concentrates should be nonphytotoxic, containing at least 15% approved emulsifier; nitrogen solution is ammonium-based fertilizer such as 28%, 30%, or 32% N; and ammonium sulfate should be spray-grade dry ammonium sulfate (21-0-0). You also may use 10-34-0 with some products.
[2] Anthem Flex label recommends an adjuvant if emerged weeds are present at time of application (and are susceptible to carfentrazone [Aim]).
[3] When applied with liquid nitrogen fertilizer, use non-ionic surfactant at no more than 1 qt/100 gal instead of crop oil or methylated seed oil.

Adjuvant Recommendations for Harmony SG and Harmony Extra SG

Carrier	Situation	Rate of NIS/100 gallons
Water	normal	1 qt
Nitrogen diluted with water (>50% nitrogen)	normal	0.5 to 1 pt
Liquid nitrogen fertilizer	garlic over 8 inches	0.5 pt
Liquid nitrogen fertilizer	garlic less than 8 inches	none
Liquid nitrogen fertilizer	with 8 fl oz of 2,4-D	none
Water	with 8 fl oz of 2,4-D	1 pt

Table 2.5-10. Comments on herbicides for harvest aid in small grains.

Trade Name	Common Name	Site of Action Number	Product/A	lb ai/A
2,4-D LVE 4E	2,4-D	4	1–2 pt	0.5–1
• For use on wheat, barley, rye, and oats. (Only certain 2,4-D products have all of these small grains listed.) • Apply when grains are in the hard dough stage. • 2,4-D is generally not recommended as a harvest aid due to its volatility and potential damage to the crop during application. • Avoid use if temperatures are expected to exceed 75°F. • No adjuvants are recommended. • 14-day preharvest interval.				
Aim 2EC	carfentrazone	14	2 fl oz	0.26 oz
• Use as a harvest aid to desiccate a limited number of broadleaf weed species. • Application shall be made when the crop is mature and the grain has begun to dry down. • Ensure spray coverage is sufficient, otherwise poor control will result. • Methylated seed oil or crop oil concentrate at 1 to 2 gal/100 gal is required; liquid nitrogen fertilizer at 2 to 4 gal/100 gal or ammonium sulfate at 2 to 4 lb/A can be added to the methylated seed oil or crop oil. • Allow at least 7 days between application and harvest.				
Clarity 4S	dicamba DGA salt	4	8 fl oz	0.25
dicamba (numerous)	dicamba DMA salt			
• For use on fall-seeded barley and wheat. • Do not apply to grain grown for seed. • Apply when grains are in the hard dough stage. • Apply with a nonionic surfactant (1 qt/100 gal) or crop oil concentrate or methylated seed oil (1 to 2 qt/100 gal). • Apply 7 days before harvest.				
Roundup PowerMAX 4.5S/Glyphosate*	glyphosate	9	1–2 pt	0.5–1
• Do not apply to wheat grown for seed; feed barley is only barley type labeled. • Apply to feed barley after the hard dough stage when grain moisture is 20% or less; apply to wheat after the hard dough stage when grain moisture is 30% or less. • Be cautious of drift. • See specific glyphosate formulations for adjuvant recommendations. • Apply at least 7 days before harvest.				
Sharpen 2.85SC	saflufenacil	14	1–2 fl oz	0.022–0.044
• For use on wheat, barley (feed only), and triticale. • Apply after hard dough stage and grain is less than 30% moisture. • Ground applications require 10 gallons spray volume per acre; aerial requires 5 gallons. • No rotation restriction to soybean; 1 to 5 months for vegetables. • Apply with methylated seed oil (1 gal/100 gal) plus ammonium sulfate (8.5 lb/100 gal) or urea ammonium nitrate (UAN) (1.25 to 2.5 gal/A). • Apply at least 3 days before harvest; label recommends 10 days for optimum desiccation effect. • *Water quality advisory.*				

Paraquat/Gramoxone is not labeled as a harvest aid in small grains.
*Various formulations of this product are available; see Table 2.1-8. Refer to current product label for active ingredient concentration, application rate, and other restrictions. Adjust application rate if using Roundup WeatherMAX 4.5S (e.g., 1 qt Roundup 4S = 22 fl oz WeatherMAX 4.5S).

Table 2.5-11. Grazing and feeding restrictions for small grain herbicides and livestock use.

	Days After Treatment Before:					
	Grazing					
Trade Name	Beef	Dairy	Feeding Straw	Withdrawals for Meat	Silage	Preharvest Interval for Grain
2,4-D[1]	0	14	0	14	—[2]	14
2,4-D (late)[1]	No	No	No	—	—	14
Aim	7	7	7	—	7	7
Anthem Flex	7	7	—	—	—	7
Axial XL	30	30	60	—	30	60
Axiom	30	30	—	—	—	Not specified
Callisto[3]	30	30	30	—	30	50
Clarity/dicamba	0	7	37	30	37	7
Finesse	No	No	—	—	—	45
Harmony Extra	7	7	Yes	—	7/30	45
Harmony SG	7	7	Yes	—	7/30	45
Huskie	25	25	60	—	25	60
Maestro	30	30	30	30	30	Not specified
Metricor/Tricor	14	14	No	—	21	Not specified
MCPA[1]	0	7	0	7	—	Not specified
Osprey	30	30	60	—	30	Not specified
Peak	30	30	30	—	40	60
PowerFlex	7	7	28	—	28	60
Prowl H2O	11	11	60	—	11	60
Quelex	7	7	21	—	—	60
Sharpen	30	30	30	—	30	3
Starane Ultra	7	7	40	—	14	120/90[4]
Stinger	0	7	No	7	—	Not specified
Valor	5 inches in height	5 inches in height	—	—	—	Not specified
Zidua	7	7	—	—	—	Not specified

[1] 2,4-D and MCPA labels may vary depending on brand name. Consult label for restrictions.
[2] — = no information available.
[3] Callisto is labeled for use in spring oats only.
[4] 24c label allows for 90 day plant back to soybeans for Delaware and Virginia only.

Table 2.5-12. Summary of recommended insecticides and seed treatments for small grain insect control.

Insecticides

Small Grain Pest	AL	BT	CB	CL	CN	DI	EN	FL	GC	LC	MA	SP	ST	SU	ZE
Aphids	▲				▲	▲	▲	▲	▲	▲	▲			▲	▲
Armyworm	▲	▲	▲	▲	▲				▲	▲	▲	▲	▲		▲
Cereal leaf beetle	▲		▲		▲				▲	▲	▲	▲	▲		▲
Hessian fly															
Wireworm															

Check label for small grain crops that insecticides are registered on.
AL = alpha-cypermethrin (Fastac), BT = *Bacillus thuringiensis*, CB = carbaryl, CL = chlorantraniliprole (Prevathon), CN = cyfluthrin (Baythroid), DI = dimethoate, EN = endosulfan, FL = flupyradifurone (Sivanto), GC = gamma-cyhalothrin (Proaxis), LC = lambda-cyhalothrin (Lambda Cy, Mystic, Taiga, Warrior), MA = malathion, PM = methyl parathion (Penncap-M), SP = spinosad (Blackhawk, Entrust, Tracer), ST = spinetoram (Radiant), SU = sulfoxaflor (Transform), ZE = zeta-cypermethrin (Mustang Max).

Seed Treatments. Pests not listed here are not controlled well by seed-applied insecticides. Note that even for the pests listed, the neonicotinoid seed treatments tend to provide inconsistent control.

Small Grain Pest	BR	CL*	IM*	TH*
Aphids			▲	▲
Hessian fly			▲	▲
Wireworm	▲	▲		▲

BR = broflanilide, CL = clothianidin (NipsIt), IM = imidacloprid (Gaucho), TH = thiamethoxan (Cruiser).
*neonicotinoid insecticide

Table 2.5-13. Suggested insecticides, rates, and restrictions for small grain insect control.

- "**R**" after the insecticide name indicates that the compound has a restricted-use label.
- "**O**" indicates that the pesticide is labeled for organic use. However, check with your organic certifier to be sure that the material is allowed for your organic system.
- For certified organic insect control materials, refer to the Organic Materials Review Institute materials list at https://www.omri.org/, call 514-343-7600, or check with your local certifier and see https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program.
- Pesticide use can many times be avoided by using a combination of pest management methods. See Part I, Section 11: Organic Crop Production, and Part II, Section 1: Pest Management to learn about IPM programs and methods for organic production.
- **Most of these products are highly toxic to bees and many other beneficial insect species.** See labels for details.

Suggested insecticides, rates, and restrictions for APHIDS: CORN LEAF AND ENGLISH GRAIN.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: fall, 25 aphids per foot of row; spring, 100 aphids per foot of row.					
Alpha-cypermethrin **R** (Fastac)	3.2 to 3.9 fl oz	0.02 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for wheat and triticale. Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Cyfluthrin **R** (Baythroid 2)	1.8 to 2.4 oz	0.028 to 0.038 lb	30	12	Registered for wheat. Do not make more than two applications per season.
Dimethoate	Various formulations and products; see label for rates and restrictions				
Endosulfan **R**	0.66 to 1 qt	0.5 to 0.75 lb	—	24	Do not apply after heads begin to form. Registered on wheat, barley, oats, and rye.
Flupyradifurone (Sivanto)	7 to 10.5 fl oz	0.09 to 0.14 lb	7 (forage); 21 (grain)	4	Labeled on barley, buckwheat, millet (pearl and proso), oats, rye, triticale, and wheat. Maximum allowed per year: 28 fl oz per acre (0.365 lb ai per acre).
Gamma-cyhalothrin **R** (Proaxis)	1.92 to 3.2 oz	0.008 to 0.012 lb	45	24	Do not apply more than 0.48 pt per season. Registered on wheat, wheat hay, and triticale.
Lambda-cythalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior and Warrior II)	1.92 to 2.56 oz	0.02 to 0.03 lb	30	24	Registered for wheat, wheat hay, and triticale. Warrior II uses half the rate of Warrior.
Malathion	Many formulations available; label for rates		12		Only for English grain aphid. Relatively low toxicity to humans.
Sulfoxaflor (Transform WG)	0.75 to 1.5 oz	0.023 to 0.047 lb	14 (grain); 7 (silage)	24	No more than two applications and 3.0 oz (0.09 lb) per year. Highly toxic to bees.
Seed Treatments					
Imidacloprid (Gaucho)	0.8 to 3 oz per 100 lb of seed				Registered on barley, oats, rye, triticale, and wheat. Product comes in at least two strengths (e.g., Gaucho 480 and 600); be sure to check labels for specific doses or treatment recommendations.
Thiamethoxam (Cruiser 5FS)	0.75 to 1.33 oz per 100 lb of seed				Registered on wheat and barley. Helps prevent spread of aphid-borne viruses.

Table 2.5-13. Suggested insecticides, rates, and restrictions for small grain insect control (continued).

Suggested insecticides, rates, and restrictions for ARMYWORM

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: six larvae per square foot.					
Alpha-cypermethrin **R** (Fastac)	1.8 to 3.8 fl oz	0.012 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for wheat and triticale. Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Bacillus thuringiensis **O**	Many products available; see label for rates		21	12	May not be as effective as other compounds, but it offers a biological alternative.
Carbaryl (Sevin)	Many products available; see label for rates and restrictions				Registered for use on wheat and proso millet.
Chlorantraniliprole (Vantacor)	1.2 to 2.5 oz	0.047 to 0.098 lb	14	4	Labeled on barley, oats, rye, triticale, wheat, among others. Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply annually more than 5.1 fl oz or 0.2 lb a.i.
Cyfluthrin **R** (Baythroid 2E)	1.8 to 2.4 oz	0.028 to 0.038 lb	30	12	Registered for wheat. Maximum allowed per crop season is 11.2 oz of material.
Gamma-cyhalothrin **R** (Proaxis)	1.92 to 3.2 oz	0.0075 to 0.012 lb	45	24	Do not apply more than 0.48 pt per season. Registered on wheat, wheat hay, and triticale.
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	30	24	Registered for barley, wheat, wheat hay, and triticale. Warrior II uses half the rate of Warrior.
Malathion	Many products available; see label for rates and restrictions				Relatively low toxicity to humans and animals. Registered for barley, oats, rye, and wheat.
Spinetoram (Radiant)	3 to 6 fl oz	0.023 to 0.047 lb	21 (grain); 3 (silage)	4	Registered for the following cereal grains: barley, buckwheat, milo, oats, rye, triticale, wheat. No more than three applications and 18 fl oz (0.14 lb ai) per year.
Spinosad **O** (Blackhawk) (Entrust) (Tracer)	1 to 2 oz	0.05 to 0.1 lb	21	4	Do not apply within 21 days of grain or straw harvest or within four days of forage or hay harvest. Registered on wheat, barley, buckwheat, rye, oats, and triticale. Does not harm beneficial insect complex in field.
Zeta-cypermethrin **R** (Mustang Max)	1.76 to 4 oz	0.011 to 0.025 lb	21	12	Do not apply more than 0.125 lb ai per season. Registered on wheat and triticale.

Table 2.5-13. Suggested insecticides, rates, and restrictions for small grain insect control (continued).

Suggested insecticides, rates, and restrictions for CEREAL LEAF BEETLE.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: oats, one or more larvae over 0.13 inch long per stem or flag leaf, and damage is evident.					
Alpha-cypermethrin **R** (Fastac)	1.8 to 3.8 fl oz	0.012 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for wheat and triticale. Do not apply more than 11.4 fl oz of product (0.075 lb ai) per acre per season.
Carbaryl (Sevin)	Several formulations available; see label for rates		21	12	Registered for use on wheat. Do not apply when foliage is wet or when rain is excessive.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	45	24	Do not apply more than 0.48 pt per season. Registered on wheat, wheat hay, and triticale.
Lambda-cyhalothrin **R** (Lambda Cy) (Mystic Z) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	30	24	Registered for wheat, wheat hay, and triticale. Warrior II uses half the rate of Warrior.
Malathion	Many products available; see label for rates and restrictions				Relatively low toxicity to humans and animals. Registered for barley, oats, rye, and wheat.
Spinetoram (Radiant)	2 to 6 fl oz	0.016 to 0.047 lb	21 (grain); 3 (silage)	4	Registered for the following cereal grains: barley, buckwheat, milo, oats, rye, triticale, wheat. No more than three applications and 18 fl oz (0.14 lb ai) per year.
Spinosad **O** (Blackhawk) (Entrust) (Tracer)	0.5 to 2 oz	0.05 to 0.1 lb	21	4	Do not apply within 21 days of grain or straw harvest or within 14 days of forage or hay harvest. Registered on wheat, barley, buckwheat, rye, oats, and triticale.
Zeta-cypermethrin **R** (Mustang Max)	1.76 to 4 oz	0.011 to 0.025 lb	21	12	Do not apply more than 0.125 lb ai per season. Registered for wheat and triticale.

Suggested insecticides, rates, and restrictions for HESSIAN FLY.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
No insecticide control is suggested; use of Hessian fly–free dates and resistant varieties is typically sufficient.					
Seed Treatments					
Imidacloprid (Gaucho)	0.8 to 3 oz per 100 lb of seed				Registered on barley, oats, rye, triticale, and wheat. Product comes in at least two strengths (Gaucho 480 and 600); be sure to check labels for specific doses or treatment recommendations.
Thiamethoxam (Cruiser 5FS)	0.75 to 1.33 oz per 100 lb of seed				Commercially applied.

Table 2.5-13. Suggested insecticides, rates, and restrictions for small grain insect control (continued).

Suggested insecticides, rates, and restrictions for SLUGS.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Metaldehyde (Deadline M-Ps) (Metarex)	10 lb	0.4 lb	0	12	See comments in corn section Table 2.2-21. All cereal grains.
Sodium Ferric EDTA (Ferroxx)	5 to 20 lb per acre, or 0.11 to 0.44 lb per 1,000 sq ft	0.25 to 1 lb	0	0	See label for more details.

Slug notes: Slug damage is most severe during cool, wet weather, especially in fields under reduced tillage with a fairly heavy cover of organic matter. Small grain plants usually recover from slug feeding; however, during periods of prolonged wet weather in May/June or September/October, extensive plant mortality may occur. Slug damage can be made worse when corn seed is coated with a neonicotinoid insecticide; these insecticides do not control slugs, which are molluscs, not insects, and kill natural enemies that are insects that can contribute to insect control.

Suggested insecticides, rates, and restrictions for WIREWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Seed Treatments					
Broflanilide (Teraxxa)	0.26 fl oz per 100 lb of seed				Commercially applied systemic insecticide labeled on wheat, barley, oats, rye, triticale, among others
Clothianidin* (Nipslt)	1.28 oz per 100 lb of seed				Commercially applied systemic insecticide. Early season protection on barley, oats, and wheat from overwintered population only. Will not prevent later season problems.
Thiamethoxam* (Cruiser MAXX Cereals)	0.75 to 1.33 oz per 100 lb of seed				Commercially applied systemic insecticide to barley, triticale, and wheat. Claims suppression of wireworm only.

*These are neonicotinoid seed coatings, which can make slugs populations worse. For more details, see note under "Slugs."

Table 2.5-14. Wheat disease thresholds.

Wheat Growth Stage	Disease	Indicator Leaf*	Disease Level**
Flag leaf emergence (GS 8) to boot (GS 10)	Powdery mildew	Second leaf	2 to 3 pustules
Flag leaf emergence (GS 8) to boot (GS 10)	Septoria leaf blotch	Second leaf	1 to 2 lesions
Flag leaf fully emerged (GS 9) to boot (GS 10)	Leaf rust	Flag leaf	3 to 7 pustules

*Leaf to be observed for the presence of disease. The flag leaf is considered to be the first leaf, and other leaves are numbered down the plant.
**Disease level is based on the average of 40 tillers randomly collected from throughout the field.

Slugs

Slugs can be a challenging problem in small grains, and they can show up under extended periods of cool and wet conditions, which have been common in recent autumns.

Heavy residue and dense leaf canopies can provide ideal habitats for slugs. The cause of slug outbreaks in a field is not totally understood, but wheat planted no-till following an old stand of alfalfa, hay, or heavy crop residue appears to be more susceptible. Fields near wooded areas also may provide habitat and food for slugs.

Diseases

Disease management is an important part of winter wheat production in Pennsylvania. The most common diseases in the Commonwealth are powdery mildew, Fusarium head blight (scab), and Septoria leaf blotch. Other diseases, such as barley yellow dwarf and leaf rust, can be severe, but, fortunately, disease epidemics occur only sporadically in our region. Many of these diseases can cause considerable yield losses if left uncontrolled. This section describes some of the disease management strategies available for small grains in Pennsylvania.

Disease-Resistant Varieties

Planting disease-resistant varieties is the most effective and economical way to manage many diseases of wheat. Many wheat varieties are available that have a high level of resistance to powdery mildew, leaf rust, and wheat spindle streak virus. Varieties with a moderate level of resistance to Septoria leaf blotch and Fusarium head blight can also help reduce symptoms and manage these diseases. Use the information provided by Penn State Extension and seed companies to select varieties that have resistance to as many diseases as possible. However, be aware that disease reactions may change rapidly if new races of the pathogen develop. This type of "race shift" is most commonly reported for powdery mildew and leaf rust. Selection of disease-resistant varieties, when used in combination with crop rotation, appropriate planting date, proper soil fertility, and fungicide-treated seed, is an effective way to maintain consistently high wheat yields.

Scouting for Disease

Monitoring wheat fields for disease is essential to identify fields that may need a fungicide application when growing susceptible and moderately susceptible varieties. Assess the average disease level on at least 40 tillers randomly selected from throughout the field. Fields should be checked for disease at flag leaf emergence (Feekes growth stage 8).

Seed Rot and Seedling Diseases

As with other crops, wheat seed can rot if placed in wet, cold soils. The typical pathogens that cause seed rots and seedling diseases are similar to those of corn and soybeans: *Pythium*, *Phytophthora*, *Rhizoctonia*, and *Fusarium* species. Damping off and other seedling diseases are common in high-traffic areas where compaction is often a problem. The best method for preventing seed rot and seedling diseases is to use fungicide-treated seed planted into a proper seedbed and maintained adequate soil fertility.

Foliar Diseases

Barley Yellow Dwarf Virus

Barley yellow dwarf virus can be a problem in early planted wheat or barley. The virus appears as leaf discolorations of yellow, red, or purple from tip to base and margin to midrib. In early infections, if the plants survive, they often exhibit discoloration and slow growth along with brilliant yellowing of older leaves. Discoloration of the flag leaf, either yellowed or reddened, is indicative of later infection. Barley yellow dwarf virus is transmitted by more than 20 species of aphids, with the bird cherry-oat aphid, the corn leaf aphid, the English grain aphid, and the greenbug being the most important vectors. Although insecticides are available to treat the aphids, the most common and practical practice is to plant wheat after the Hessian fly-free date, when most of the aphid populations have crashed, and avoid the disease. With a warm, early spring, the virus can be relatively severe on both spring- and fall-planted small grain crops, including barley, oats, and wheat.

Powdery Mildew

Powdery mildew can infect any time after emergence. Commonly found on the upper surface of lower leaves, powdery mildew is a superficial disease except for the haustoria, which penetrates the plant surface and absorbs nutrients from the plant. The disease is often in patches of white, cottony growth that eventually turns a dull gray-brown. The tissue on the opposite side of the leaf is often yellowed, and it then turns tan or brown. Excessive nitrogen applications will exacerbate this disease both by promoting dense growth and reducing plant defenses. The disease survives from harvest to planting on volunteer plants, so mowing or herbicides can be used to reduce the inoculum levels. In severe cases, fungicides are used to control the disease in the spring.

Rusts

Rusts in wheat are composed of leaf, stripe, and stem rusts. All rust diseases have a similar appearance in that they protrude from the leaf surface with a blisterlike appearance. Stem rust appears as orange-red, oval lesions that tear through the outer layer of plant tissue on the stems, leaf sheaths, blades,

and occasionally on the head. This rust is relatively uncommon in Pennsylvania in the last several years. Leaf rust is a brown, round, or slightly elongated lesion commonly found on the leaf blades and may appear on the leaf sheaths. Stripe rust occurs as yellow-orange, small, blisterlike lesions that merge to form stripes on the leaf blades and occasionally on the head.

Septoria Leaf and Glume Blotch

Septoria leaf and glume blotch (a complex of *Septoria* and *Stagonospora*) has two phases affecting wheat: after emergence and, often more economically important, at flag leaf emergence. In the fall, Septoria can cause seedling blight, reducing initial stands. In the spring, as the wheat further develops, Septoria will often infect lower leaves, near the ground. Symptoms appear as chlorotic (yellowed) flecks that expand into irregular lesions. Other symptoms may appear as dark-green, water-soaked lesions that become dry and yellow and then turn red brown. Lesions that begin at the leaf base (near the stem) may kill the entire leaf. The disease is considered a threat once there are at least one to two lesions on the second leaf (first leaf below the flag leaf) at flag leaf emergence through boot stage. Glume blotch can attack the heads, causing brown spots on the glumes (outer chaff), lemmas (inner chaff), and the awns. These colonized florets have grain fill impaired, resulting in low test weight and shriveled seeds.

Soilborne Wheat Mosaic Virus

Soilborne wheat mosaic virus is another viral disease of wheat that has been found in Pennsylvania. This virus appears in the early spring as new leaves with mosaics (mixtures of dark green, light green, and yellow spots irregularly distributed throughout the leaf) and reduced tillering. Areas in the field appear as though no nitrogen has been applied due to the yellow discoloration and reduced tillering. This virus is vectored by a soilborne fungus, with no practical control measures known. Symptoms will disappear after the average daily temperature reaches 68°F. The best control method for this virus is crop rotation for two to three years if it is a significant problem.

Seed and Head Diseases

Fusarium Head Blight

Fusarium head blight (or scab) infects wheat during anthesis, or flowering stage, which lasts for about seven days. The results are then seen during the late heading stage (about three weeks later) when spikes on the green heads look bleached or prematurely ripened. After ripening, the blighted seeds appear shriveled, are called tombstones, and may exhibit signs of orange-pink mold. These tombstones have low test weight, are often sterile, and may contain mycotoxins. The Fusarium species that cause head blight are also linked to stalk and ear rots in corn. The Fusarium species are excellent saprophytes that can colonize dead tissue and persist. Wheat no-till drilled into corn infected with stalk rot and taken off for silage is still likely to exhibit higher incidence of head blight than if the field was tilled.

Fusarium head blight is known to produce the mycotoxins deoxynivalenol (DON) and zearalenone in both infected grain and straw. DON is known to cause vomiting, feed refusal, and lower weight gain at low levels when fed to animals. Zearalenone has estrogen-like properties that can cause reproductive problems in animals. Although grain is commonly tested, caution should be used when using straw as an alternative roughage source in years of high levels of head blight.

Management of FHB requires an integrated approach. The best prevention of FHB and subsequent toxin production is achieved when growers combine the use of resistant cultivars with properly timed fungicide applications. Due to the narrow infection period, it is difficult to apply contact fungicides directly to the flowers. If the decision is made to apply a fungicide, a triazole product should be applied from the beginning to mid-flowering (Table 2.5-15). Research has shown a correlation with higher levels of mycotoxins in wheat sprayed with strobilurin fungicides. Therefore, strobilurin fungicides (Quadris, Headline) or mixtures containing strobilurin fungicides (Quilt, Stratego, TwinLine) should not be applied after the boot stage. Weekly web-based disease forecasts and regional commentary can be found at www.wheatscab.psu.edu. Check this site regularly to determine if a fungicidal spray is necessary to control Fusarium head blight in flowering wheat.

Fungicide Applications

The upper leaves and glumes contribute the most to the wheat yield, and it is important to protect these leaves from disease damage. Fungicides should only be considered for susceptible varieties with a yield potential of 60 bushels per acre or more if weather forecasts indicate that conditions are likely to favor continued disease development. Disease thresholds and suitable fungicides for powdery mildew, Fusarium head blight, Septoria, and leaf rust are provided in Tables 2.5-14 and 2.5-15. Table 2.5-16 provides the estimated yield losses attributed to powdery mildew based on variety susceptibility and disease level.

Many varieties of wheat that are resistant to powdery mildew have been developed to have resistance to all races of the pathogen. This type of resistance is not subject to dramatic failures when new races of the pathogen are introduced into a region. Varieties with this type of resistance will often develop low levels of disease, but that rate of development and severity of the disease is reduced.

Table 2.5-15. Efficacy of fungicides for wheat disease control based on appropriate application timing.

Class	Active Ingredient	Product	Rate/A (fl oz)	Powdery Mildew	Stagonospora Leaf/ Glume Blotch	Septoria Leaf Blotch	Tan Spot	Stripe Rust	Leaf Rust	Stem Rust	Head Scab[1]	Harvest Restriction
Strobilurin (FRAC 11)	Picoxystrobin 22.5%	Aproach SC	6–12	G	VG	VG[2]	VG	E[3]	VG	VG	NL	Feekes 10.5
	Pyraclostrobin 23.6%	Headline SC	6–9	G	VG	VG[2]	E	E[3]	E	G	NL	Feekes 10.5
	Azoxystrobin 22.9%	Quadris 2.08 SC	4–12	G	VG	VG	E	E	E	VG	NL	Feekes 10.5.4
Triazole (FRAC 3)	Metconazole 8.6%	Caramba 0.75 SL	10–17	VG	VG	—	VG	E	E	E	G	30 days
	Tebuconazole 38.7%	Folicur 3.6 F[4]	4	NL	NL	NL	NL	E	E	E	F	30 days
	Prothioconazole 41%	Proline 480 SC	5–5.7	—	VG	VG	VG	VG	VG	VG	G	30 days
	Prothioconazole 19%	Prosaro 421 SC	6.5–8.2	G	VG	VG	VG	E	E	E	G	30 days
	Tebuconazole 19%											
	Propiconazole 41.8%	Tilt 3.6 EC[4]	4	VG	VG	VG	VG	VG	VG	VG	P	Feekes 10.5.4
	Metconazole 10.91%	Sphaerex	4.0 – 7.3	VG	VG	VG	VG	E	E	E	G	30 days
	Prothioconazole 18.19%											
Mixed Modes of Action[5]	Trifloxystrobin 22.6%	Absolute Maxx SC	5	G	VG	VG	VG	VG	E	VG	NL	35 days
	Tebuconazole 22.6%											
	Cyproconazole 7.17%	Aproach Prima SC	3.4–6.8	VG	VG	VG	VG	E	VG	—	NR	45 days
	Picoxystrobin 17.94%											
	Prothioconazole 16.0%	Delaro 325 SC	8	G	VG	VG	VG	VG	VG	VG	NL	Feekes 10.5 and 35 days
	Trifloxystrobin 13.7%											
	Pydiflumetofen 13.7%	Miravis Ace SE	13.7	VG	VG	VG	VG	VG	VG	VG	G	Feekes 10.5.4
	Propiconazole 11.4%											
	Propiconazole 11.7%	Nexicor EC	7–13	VG	VG	E	E	E	E	VG	NL	Feekes 10.5
	Fluxapyroad 14.3%											
	Pyraclostrobin 28.6%											
	Azoxystrobin 13.5%	Priaxor	4–8	G	VG	VG	E	VG	VG	G	NL	Feekes 10.5
	Propiconazole 11.7%											
	Propiconazole 11.7%	Quilt Xcel 2.2 SE[4]	10.5–14	VG	VG	VG	VG	E	E	VG	NL	Feekes 10.5.4
	Azoxystrobin 13.5%											

Table 2.5-15. Efficacy of fungicides for wheat disease control based on appropriate application timing (continued).

Class	Active Ingredient	Product	Rate/A (fl oz)	Powdery Mildew	Stagonospora Leaf/ Glume Blotch	Septoria Leaf Blotch	Tan Spot	Stripe Rust	Leaf Rust	Stem Rust	Head Scab[1]	Harvest Restriction
Mixed Modes of Action[5]	Prothioconazole 10.8%	Stratego YLD	4	G	VG	VG	VG	VG	VG	VG	NL	Feekes 10.5 and 35 days
	Trifloxystrobin 32.3%											
	Benzovindiflupyr 2.9%	Trivapro SE	9.4–13.7	VG	VG	VG	VG	E	E	VG	NL	Feekes 10.5.4
	Propiconazole 11.9%											
	Azoxystrobin 10.5%											
	Flutriafol 18.63%	Topguard EQ	4.0-7.0	VG	NL	VG	VG	E	E	VG	NL	Feekes 10.5.4
	Azoxystrobin 25.30%											

Efficacy categories: NL = not labeled; NR = not recommended; P = poor; F = fair; G = good; VG = very good; E = excellent; — = insufficient data to make statement about efficacy of this product.
[1] Application of products containing strobilurin fungicides may result in elevated levels of the mycotoxin deoxynivalenol (DON) in grain damaged by head scab.
[2] Product efficacy may be reduced in areas with fungal populations that are resistant to strobilurin fungicides.
[3] Efficacy may be significantly reduced if solo strobilurin products are applied after stripe rust infection has occurred.
[4] Multiple generic products containing the same active ingredients also may be labeled in some states.
[5] Products with mixed modes of action generally combine triazole and strobilurin active ingredients. Miravis Ace, Nexicor, Priaxor, and Trivapro include carboxamide active ingredients.
The North Central Regional Committee on Management of Small Grain Diseases (NCERA-184) developed the above information on fungicide efficacy for control of certain foliar diseases of wheat for use by the grain production industry in the United States. Efficacy ratings for each fungicide listed in the table were determined by field testing the materials over multiple years and locations by the members of the committee. Efficacy is based on proper application timing to achieve optimum effectiveness of the fungicide as determined by labeled instructions and overall level of disease in the field at the time of application. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and are based on a single application of the labeled rate as listed in the table. Table includes most widely marketed products and is not intended to be a list of all labeled products.
This information is provided only as a guide. It is the responsibility of the pesticide applicator by law to read and follow all current label directions. No endorsement is intended for products listed, nor is criticism meant for products not listed. Members or participants in the NCERA-184 committee assume no liability resulting from the use of these products. This table was revised May 2020.

Table 2.5-16. Estimated yield loss to powdery mildew disease severity and varietal resistance.

	Estimated Yield Loss Given Detectable Disease (1%) at Different Canopy Levels During Head Emergence*		
Varietal Reaction	**Third Leaf**	**Second Leaf**	**Flag Leaf**
Susceptible	6%	16%	25%
Moderately susceptible	4%	10%	16%
Moderately resistant	2%	5%	8%
Resistant	—	—	—

*A disease level of 1% is equal to approximately two or three pustules per leaf. Estimates of yield loss are based on six varieties over three years.
Source: Modified from Lipps, P. E., and Madden, L. V., *Phytopathology* 79:462–70.

Fungicide Seed Treatments

Seed treatments on wheat are usually targeted at preventing seedborne diseases such as common bunt or loose smut. These pathogens survive in association with wheat seed and can build to high levels in several years when seed is saved.

Treatments are also effective at reducing stand and yield losses from seed rots and early season diseases like those caused by *Fusarium*, *Pythium*, and *Rhizoctonia*. This can be especially important if planting is delayed and the seed bed is cool and wet. Fungicidal treatments will not provide control of bacterial diseases or viruses. Seed treatment will also not protect wheat and barley from the head scab that occurs in the spring; it only provides protection for the damping off that may occur at germination as the result of planting some scabby seed. Seed treatment will not correct bin-run seed-quality issues, although it may improve general establishment.

It is best to select multiple seed treatments to provide activity against the range of pathogens and added protection from insects.

The addition of a seed treatment insecticide may help reduce the incidence of barley yellow dwarf virus in fall-planted small grains.

Part II, Section 6

Forage Pest Management

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A well-planned pest management program for forage crops involves using multiple strategies. These should include preventive techniques such as host-plant resistance, monitoring, cultural controls, mechanical or physical controls, biological controls, and chemical control tactics. Preventive techniques may start with planting weed-free crop seed or choosing an alternative field or planting date. For potato leafhopper control in alfalfa, there are glandular-haired resistant varieties available that offer excellent control. Regularly monitoring for pests is an important predictive tool. Rotating crops to disrupt pest life cycles and planting adapted varieties are good examples of cultural controls. Mechanical or physical controls may include tillage and mowing to disrupt certain pests. Biological controls may include using insect or disease organisms or even grazing animals in pasture production systems. Finally, chemical controls are an important component of many IPM systems, but their use should be based on sound management decisions. See Part II, Section 1 of this guide for more information about designing an integrated pest management program.

This guide provides chemical control suggestions based on university research and manufacturer recommendations. Management information for common forage crop pest problems is outlined in the following pages under "Weeds," "Insects," and "Diseases." For more information about Pennsylvania forage management and variety selections, refer to Part I, Section 8 or www.forages.psu.edu on the web. This publication strives for accuracy; however, omissions, inaccuracies, or dated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Weeds

Integrated Weed Management

Managing weeds in forages requires a different approach from managing weeds in row crops. Proper management to establish and maintain a dense stand of forage will render it competitive to most common weeds. Managing soil pH, nutrients, grazing or cutting, and insects, as well as using disease-resistant varieties and selective herbicides when necessary, will help the forage stand be competitive. A well-planned pest management program for forage crops involves using multiple strategies. These should include prevention, monitoring, cultural control, mechanical or physical control, biological control, and chemical control tactics. Preventive techniques may start with planting weed-free crop seed or choosing an alternative field or planting date. Regularly monitoring for pests is an important predictive tool. Mechanical or

physical controls may include tillage and mowing to disrupt certain pests. Mixed grazing by including small ruminants in the livestock community will help manage brushy weeds in a pasture. Finally, chemical controls are an important component of many integrated pest management (IPM) systems, but their use should be based on sound management decisions. See Part II, Section 1: Pest Management for more information about designing an IPM program.

This guide provides chemical control recommendations based on university research and manufacturer recommendations. Table 2.6-1 contains general information about herbicides available for use in legume or grass forages, including pastures and hayfields.

This publication strives for accuracy; however, omissions, inaccuracies, or outdated information can occur because of the dynamics of pests and pest management. Seek out additional information from the manufacturer or other reliable sources when making important management decisions. Remember, this guide is not a substitute for the manufacturer's product label.

Legumes

If weeds become a problem, they can compete for or interfere with light, nutrients, water, and space, directly influencing yield and forage stand. For instance, winter annuals and perennials such as common or mouseear chickweed, henbit, and purple deadnettle have been reported to reduce alfalfa stands by more than 30 percent. They emerge in the fall and winter and develop a thick, lush mat early in the spring that can compete with the first forage cutting. Once they complete their life cycle in early summer, summer annuals, such as foxtails, lambsquarters, and pigweeds, or perennial weeds such as dandelion or dock species can fill in the bare spots and continue to reduce forage yield and quality.

Unlike most grain or fiber crops from which weeds are separated at harvest, weeds often are harvested along with the forage crop, potentially reducing hay quality. Reductions in quality often are in the form of low protein content and feed digestibility. Forage value of weeds may vary from species to species. For example, dandelion is comparable to alfalfa in protein and total digestible nutrients (TDN). Dandelion control may not necessarily improve the quality of hay, but it may be of some value in reducing the time necessary to dry the hay since dandelion dries more slowly than alfalfa. Increased drying time may mean greater harvest losses due to untimely rainfall.

Quality of monocot weeds (grasses) can also be similar to that of the forage. In general, weedy grasses have about 75 percent of the quality of alfalfa. Controlling quackgrass in alfalfa can increase forage protein levels 4 to 7 percent. Weeds with woody stems or flower stalks, such as yellow rocket, white cockle, rough fleabane, curly dock, and broadleaf dock, have lower protein levels (about 50 percent of the quality of alfalfa), so controlling them is even more important.

When weeds are present or persist in spite of good management, herbicides can help improve yield and quality. Weed control at establishment or in the seedling year is most critical for maintaining a healthy forage stand. When weeds are controlled during the seedling year, the forage crop seldom requires additional herbicide treatments for at least the first two years of the stand.

Weed management in legume forages can be divided into two phases: control in the establishment or seedling year and control in an established stand.

Control Before and During Establishment

Managing weeds in forages begins long before crop establishment. Certain types of weeds are potentially serious problems for forages, so it is important to eliminate them in advance. In particular, perennial broadleaf and grass weeds such as dandelion, curly dock, Canada thistle, horsenettle, and quackgrass are much easier to manage prior to planting a forage crop. While combating such weeds in the establishment year, prudent use of a genetically modified, glyphosate-tolerant (Roundup Ready) alfalfa seed could be of value. Biennial weeds, including musk thistle and burdock, should be eliminated before establishing forage. If these weeds are not removed before the seeding is made, they commonly persist throughout the life of the forage. The cost of controlling weeds before or at the time of seeding should be considered an investment that will be returned for the life of the stand.

- Below are some general rules for managing weeds at establishment or in the seedling year:
- Weeds that emerge with the crop are generally more destructive.
- Maintain the forage relatively weed-free for the first 60 days.
- Weeds that emerge beyond 60 days will not influence that year's forage yield.
- Later emerging weeds may still influence forage quality.
- Winter annual weed competition in early spring is most damaging to forage.
- Broadleaf weeds are generally more competitive against legumes than grassy weeds.

Herbicides are needed most often during establishment, and several options exist for managing weeds in pure legume seedings. Weed control is also very important while the forage is young and prone to competition from invading species. In no-till seedings, adequately controlling the existing vegetation, especially perennials, is very important. Burndown herbicides available for use in legume forage seedings are listed in Tables 2.6-2 and 2.6-3. Herbicides available for use in legumes are listed in Table 2.6-4. The effectiveness of various

Table 2.6-1. Forage and pasture herbicides and their restrictions.

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Crop	Restricted-Use Pesticide[2]	Water Quality Advisory[3]	Worker Reentry (hours)[4]
2,4-D amine or ester (3.8 lb ae/gal)	2,4-D	4	several	grass	—	yes	48 or 12
Aim 2EC	carfentrazone	14	FMC	grass and legume	—	—	12
Balan 60DF	benefin	3	Loveland	legume	—	—	12
Butyrac 200 2E	2,4-DB	4	several	legume	—	yes	48
Chaparral 71.6WG	aminopyralid + metsulfuron	4/2	Corteva	grass	—	yes	48
Chateau 51WDG	flumioxazin	14	Valent	alfalfa	—	—	12
Cimarron Max (co-pack)	metsulfuron + 2,4-D + dicamba	2/4/4	Bayer CropScience	grass	—	—	48
Cimarron Plus 63WDG	metsulfuron + chlorsulfuron	2/2	Bayer CropScience	grass	—	—	4
Clarity/dicamba 4S	dicamba	4	BASF/several	grass	—	yes	24
Crossbow 3L	2,4-D + triclopyr	4/4	several	grass	—	yes	until dry
Curtail 2.38L	clopyralid + 2,4-D	4/4	Corteva	grass	—	yes	4
DuraCor SC	aminopyralid+ florpyra-uxifen	4/4	Corteva	grass	—	yes	48
Eptam 7E/20G	EPTC	8	Gowan	legume	—	—	12
Escort XP 60DF	metsulfuron	2	Bayer CropScience	grass	—	—	4
Facet 1.5L	quinclorac	4	BASF	grass	—	yes	12
Freelexx 3.7SL	2,4-D (choline)	4	Corteva	grass	—	yes	48
Gramoxone SL 2.0/3.0	paraquat	22	Syngenta	legume	yes	—	12
GrazonNext HL 3.74E	aminopyralid + 2,4-D	4/4	Corteva	grass	—	yes	48
Grazon P+D 2.54SL	picloram +2,4-D	4/4	Corteva	grass	yes	yes	48
Huskie 2.06EC[5]	pyrasulfotole + bromoxynil	27/6	Bayer CropScience	grass	—	yes	24
Kerb 50W	pronamide	3	Corteva	legume	yes	—	24
Maestro 2E	bromoxynil	6	Nufarm	legume	—	—	24
MCPA amine or ester (3.7 lb ae/gal)	MCPA	4	several	grass and legume	—	yes	48 or 12
Metribuzin 75DF/4L	metribuzin	5	several	legume	—	yes	12
Metsulfuron 60WG	metsulfuron	2	several	grass	—	—	4
Milestone 2L	aminopyralid	4	Corteva	grass	—	yes	48
PastureGard HL 4SL	triclopyr + fluroxypyr	4/4	Corteva	grass	—	yes	12
Plateau 2AS	imazapic	2	BASF	legume and grass	—	yes	12
Poast 1.5E	sethoxydim	1	BASF	legume	—	—	12
Prescott 3E	triclopyr + clopyralid	4/4	Alligare	grass	—	yes	48
Prowl H2O 3.8CS	pendimethalin	3	BASF	alfalfa and grass	—	—	24
Pursuit 2AS	imazethapyr	2	BASF	alfalfa and grass mix	—	yes	4
Raptor 1AS	imazamox	2	BASF	legume	—	—	4

Table 2.6-1. Forage and pasture herbicides and their restrictions (continued).

Trade Name[1]	Common Name	Site of Action Number	Manufacturer	Crop	Restricted-Use Pesticide[2]	Water Quality Advisory[3]	Worker Reentry (hours)[4]
Remedy Ultra 4L	triclopyr	4	Corteva	grass	—	yes	until dry
Roundup 3S/Roundup WeatherMAX 4.5S/glyphosate[6]	glyphosate	9	Bayer CropScience/ others	grass and legume	—	—	4–12
Sandea 75DF/Permit	halosulfuron	2	Gowan	grass	—	yes	12
Satellite HydroCap 3.8CS	pendimethalin	3	United Phos-phorus, Inc.	alfalfa	—	—	24
Select Max 1E/Select 2E	clethodim	1	Valent	legume	—	—	24
Sharpen 2.85SC[7]	saflufenacil	14	BASF	grass and alfalfa	—	yes	12
Sinbar 80W	terbacil	5	NovaSource	legume	—	yes	12
Spike 20P/80DF	tebuthiuron	7	Corteva	grass	—	yes	—
Starane Ultra 2.8L	fluroxypyr	4	Corteva	grass	—	—	12
Stinger 3S	clopyralid	4	Corteva	grass	—	yes	12
Surmount 1.34E	picloram + fluroxypyr	4/4	Corteva	grass	yes	yes	12
Tordon 22K 2SL	picloram	4	Corteva	grass	yes	yes	48
Vastlan 4SL	triclopyr	4	Corteva	grass	—	yes	24
Velpar 2L/90DF	hexazinone	5	Bayer CropScience	legume	—	yes	24
Velpar AlfaMax 77.7WG	hexazinone + diuron	5/7	Bayer CropScience	alfalfa	—	yes	24
Warrant 3L	acetochlor	15	Bayer	alfalfa	—	yes	12
Weedmaster 3.87L	dicamba + 2,4-D	4/4	Nufarm	grass	—	yes	48
Yukon 67.5WG	halosulfuron + dicamba	2/4	Gowan	grass	—	—	24

[1] Generic or post-patent alternatives to some of these products are available.
[2] Only licensed applicators may purchase and apply restricted-use pesticides. To become licensed, contact your state's Department of Agriculture.
[3] These herbicides have properties that may result in groundwater or surface water contamination. Do not apply them in areas where soils are permeable or coarse and groundwater is near the surface. Practices should be followed to minimize the potential for dissolved runoff and/or runoff erosion. See the herbicide label for specific restrictions.
[4] If soil-applied products are injected or incorporated at application time, under certain circumstances the Worker Protection Standard allows workers to enter the treated area if they will have no contact with anything that has been treated. Personal protective equipment is required for early entry to treated areas if contact with treated soil, plants, or water is involved.
[5] Huskie is recently registered on grass forage; there is little local experience for this use.
[6] Various formulations available. Refer to product label application rates and other restrictions.
[7] Listed on a supplemental label for use in dormant alfalfa.

Table 2.6-2. Relative effectiveness of burndown treatments for no-till forages.

Species	Gramoxone	Roundup/Glyphosate	
		(Fall-Applied)	(Spring-Applied)
Chickweed	**8+**	**9**	**9**
Clover, red	8	**8+**	7
Dandelion	N	**8+**	6
Dogbane, hemp; dewberry; milkweed; etc.	6	**8+**	6
Foxtail spp.	**9**	**9**	**9**
Horseweed (marestail)	7	**9**	**9**
Lambsquarters	8	**9**	**9**
Mustard spp.	8	**9**	**9**
Ragweed, common	8	**9**	**9**
Rye cover, volunteer small grains	**9**	**10**	**10**
Smartweed, annual	7	7	7
Sod, alfalfa	N	**8+**	7
Sod, bromegrass or quackgrass	6	**9**	**9**
Sod, orchardgrass or fescue	N	**9**	7
Thistle, Canada	6	**9**	8
Timothy, bluegrass	7	**10**	**10**
Vetch, hairy	7	8	6

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage. Treatments are rated only for control of vegetation existing at the time of application.
Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control.

Table 2.6-3. Comments on burndown herbicides for no-till legume forages.

Trade Name*	Common Name	Crop(s)	Product/A	lb ai/A
Gramoxone SL 2.0	paraquat	alfalfa, clovers	2–4 pt	0.5–1
Gramoxone SL 3.0			1.3–2.7 pt	

• Gramoxone SL controls emerged weeds only (no residual activity).
• Apply in a minimum of 10 gal/A (ground, 20–60 gal/A preferred) or 5 gal/A (aerial) of water.
• Apply before, during, or after planting but before crop emerges.
• Phosphate-containing liquid fertilizer carrier solutions diminish Gramoxone activity.
• Gramoxone SL is effective on small annual weeds.
• Improved activity on perennial grass sods can be achieved when 2 applications are made. Graze or mow sod to a height of 3 inches or less and apply 2 pt/A followed in 10 to 14 days by 1.5 pt/A.
• Use appropriate precautions when handling Gramoxone to minimize exposure to the herbicide.
• Do not use flood jet tips larger than size 20 or spacing greater than 40 inches.
• See Tables 2.6-7 and 2.6-8.
• *Restricted-use pesticide.*

Roundup 3S** or Roundup PowerMAX 4.5S	glyphosate	alfalfa, clover, and alfalfa or clover- grass mixtures	1.5–4 qt or 1–3 qt	1–3

• Glyphosate controls emerged weeds only (no residual activity).
• Make ground applications in 10 to 40 gal/A of water. Increase the spray volume within this range as the weed density increases.
• Glyphosate may be applied in clear liquid nitrogen fertilizers and clear liquid complete-analysis fertilizers. Do not use Roundup/glyphosate with suspension-type liquid fertilizers.
• Preplant applications can be made before, during, or after planting but before the crop emerges.
• Glyphosate is effective on annual, biennial, and perennial weeds, as well as small grain cover crops.
• Repeated applications may be needed for effective perennial weed control.
• Fall applications are better than spring applications for control of orchardgrass sods and quackgrass.
• Spring applications may be used for control of annual weeds.
• Existing perennial grass stands can be renovated by applying 0.7 to 3.3 qt/A (consult the label for rates for specific species). The existing crop can be grazed or harvested for feed after applications totaling 2 qt/A or less. For applications greater than 2 qt/A, remove livestock before application and wait 8 weeks before grazing or harvest.
• See Tables 2.6-7 and 2.6-8.

See specific product label to determine correct rate for the weed species found in individual fields.
*See Table 2.6-1 for additional formulations or trade names containing these same active ingredients.
**Various formulations of this product are available; see Table 2.1-8. Refer to current product label for active ingredient concentration, application rate, and other restrictions.

Table 2.6-4. Application timings for herbicides used in legume forages.

Trade Name	Crop(s)[1]	Establishment	Seedling Stand POST	Established Stand POST	Fall/Spring Dormant (Seedling)	Fall/Spring Dormant (Established)	POST Cutting	Spot-spray or Wiper Applicator
2,4-DB	Alfalfa/clovers		NR[2]	NR				
Aim 2EC	Alfalfa/clovers		NR			< 3 inches regrowth		
Balan	Alfalfa/clovers	PPI						
Chateau	Alfalfa					<6 inches regrowth	< 6 inches regrowth	
Eptam	Alfalfa/clovers	PPI						
Glyphosate	Alfalfa/clovers	Preplant renovation						Spot spray and wiper
Gramoxone SL	Alfalfa/clovers	Preplant			< 1 year	> 1 year	Within 5 days of cut[3]	Spot spray
Kerb	Alfalfa/clovers				1-trif[4]	> 1 season[5]		
Maestro (Buctril)	Alfalfa		4-trif[6]					
MCPA	Alfalfa/clovers		2-trif[7]			> 1 season[3]		
Metribuzin	Alfalfa					> 1 year		
Poast	Alfalfa/clovers		NR	NR				Spot spray
Prowl H2O/Satellite HydroCap	Alfalfa		2-trif to 6 inches		2-trif	After 1 cut	< 6 inches regrowth	
Pursuit	Alfalfa/clovers		2-trif	Fall	2-trif	> 1 season	< 3 inches regrowth	
Raptor	Alfalfa		2-trif		2-trif	> 1 season	< 3 inches regrowth	
Roundup PowerMAX/WeatherMAX	Roundup Ready alfalfa	Preplant renovation	emergence to first cut8	After first cut; 1 appl./cut[8]				Spot spray and wiper
Select Max	Alfalfa		NR	NR				Spot spray
Sinbar	Alfalfa					> 1 year	< 2 inches regrowth	
Velpar	Alfalfa					> 1 year4	< 2 inches regrowth	
Warrant	Alfalfa		4-trif	NR			Within 7 days of cut	

Table 2.6-4. Application timings for herbicides used in legume forages (continued).

Trade Name	Crop(s)[1]	Establishment	Seedling Stand POST	Established Stand POST	Fall/Spring Dormant (Seedling)	Fall/Spring Dormant (Established)	POST Cutting	Spot-spray or Wiper Applicator

Establishment: Herbicide is applied preplant in no-till establishment to control existing weeds, preplant in existing stands of alfalfa or clover to kill the existing crop and plant a new one (renovation), or preplant incorporated (PPI) or preemergence (PRE) in conventional tillage for residual weed control.
Seedling stand POST: Herbicide is applied postemergence (POST) to seedling alfalfa or clover that has reached a specific growth stage and is actively growing.
Established stand POST: Herbicide is applied POST to alfalfa or clover that has been established for a minimum length of time and is actively growing.
Fall/spring dormant: Herbicide is applied POST to dormant alfalfa or clover legume; may be for seedling legume at a specific growth stage, for legume established for a minimum length of time, or for either. Herbicide rate may be different for seedling or established stands.
POST cutting: Herbicide is applied to alfalfa or clover between forage or hay cuttings, but within a certain time period after cutting or before the legume achieves a specified level of regrowth.
Spot-spray application: Herbicide is applied only to weed-infested areas of the field, usually with hand-held equipment.
[1] See herbicide comments table or herbicide label to determine for which clovers herbicide application is labeled.
[2] NR = no alfalfa size restriction on label; application based on weed stage.
[3] Application labeled for alfalfa only, not clover.
[4] Spring application.
[5] Fall application before soil freeze-up.
[6] Trifoliate leaf stage (#-trif) that must be reached before herbicide application.
[7] Application labeled for clover only, not alfalfa.
[8] For use on Roundup Ready alfalfa only; up to 5 days before cutting.

Table 2.6-5. Relative effectiveness of herbicides on weeds and crop tolerance in legume forages.

	Preemergence							*Postemergence*									
Trade Name	**Balan**	**Chateau**	**Eptam**	**Kerb**	**Metribuzin**	**Prowl H2O**	**Sinbar**	**Aim**	**Butyrac/2,4-DB**	**Gramoxone**	**Maestro**	**Poast**	**Pursuit**	**Raptor**	**Roundup/Glyphosate**	**Select/Clethodim**	**Velpar**
Site of Action Number	3	14	8	3	5	3	5	14	4	22	6	1	2	2	9	1	5
Crop Tolerance*	VG	F	FG	VG	F	FG	FG	G	G	FG	F	E	G	G	G	E	FG
Winter Annuals																	
Bluegrass, annual	**8+**	7+	**8+**	**8+**	8	6+	7+	N	N	**8+**	N	6	6	6	**9**	7+	8
Brome, downy	**9**	N	**9**	**9**	**9**	6	**9**	N	N	**9**	N	**9**	6	N	**9**	**9**	**9**
Chickweed, common	8	**8+**	7	8	**9**	7	6	6	6	**9**	6	N	**8+**	**8+**	**9+**	N	**9**
Fleabane, annual	N	7	N	N	7	N	N	N	7+	7+	N	N	7+	7	**9**	N	8
Henbit/deadnettle	6	**8+**	**9**	8	**9**	8	**9**	7+	6	**9**	8	N	7	7	8	N	**9**
Horseweed/marestail	N	**8+**	N	N	6	N	7	N	8	6	6	N	N	N	**9**	N	7
Mustard, wild	N	7	6	6	**9**	6	**9**	8	**10**	**9**	8	N	**9**	**9**	**9**	N	**9**
Pennycress, field	N	6	6	6	**9**	6	**9**	**9**	**9**	**9**	**9**	N	**9**	**9**	**9**	N	**9**
Pepperweed spp.	N	7	6	6	**9**	6	**9**	8	**10**	**9**	8	N	**9**	**9**	**9**	N	**9**
Radish, wild	N	7	N	N	7	6	7	8	7	7	6	N	**8+**	**8+**	**9**	N	7
Rocket, yellow	N	6	N	N	**9**	6	**9**	**8+**	8	8	7	N	**8+**	**9**	**9**	N	**9**
Ryegrass, annual	**8+**	N	**9**	**8+**	7	8	N	N	N	8	N	**9**	6	6	8	**9**	7
Shepherdspurse	N	6	7	6	**9**	6+	**9**	**9**	**9**	**9**	**9**	N	**8+**	**9**	**9**	N	**9**
Summer Annuals																	
Amaranth, spiny	**9**	**9**	**9**	6	**9**	**9**	**8+**	8	**8+**	**9**	8	N	**9**	**9+**	**9**	N	**9**
Barnyardgrass	**9**	6	**9**	8	6	**8+**	6	N	N	8	N	**9**	8	8	**9+**	**9**	7
Crabgrass	**9**	6	**9**	8	6	**9**	7	N	N	6	N	**9**	8	8	**9**	**9**	7
Foxtails (annual spp.)	**9**	6	**9**	8	6	**9**	7	N	N	**9**	N	**9**	**8+**	**8+**	**9+**	**9+**	7
Goosegrass	**9**	6	**9**	8	6	**9**	7	N	N	**9**	N	**9**	8	6	**9+**	**9+**	7
Lambsquarters	**9**	**9**	**9**	6	**9**	**9**	**9**	**9**	**8+**	8	**10**	N	7	**8+**	**9**	N	**9**
Nightshade, eastern black	6	**8+**	**9**	N	6	N	**8+**	8	**8+**	**9**	**9**	N	7+	7+	**9**	N	7
Panicum, fall	**9**	6	**9**	6	6+	**9**	6+	N	N	**9**	N	**9**	8	**8+**	**9+**	**9**	6+
Pigweed spp.	**9**	**9**	**9**	6	**9****	**9**	**8+**	8	**8+**	**9**	8	N	**9+**	**9+**	**9**	N	**9**
Ragweed, common	N	7	N	N	8	N	8	7	**9**	**9**	**9**	N	7	8	**9**	N	**8+**
Smartweed spp.	N	7	N	N	**8+**	8	**8+**	8	6	**9**	**9**	N	**8+**	8	**9**	N	**8+**
Velvetleaf	N	7	N	N	8	**8+**	8	**9**	**9**	**9**	8	N	**9**	**9**	**9**	N	**8+**
Biennials																	
Carrot, wild	N	N	N	N	6	N	N	N	6	8	6	N	6	7	7	N	L
Perennials																	
Aster spp.	N	N	N	N	6	N	6	N	6	6	N	N	7	7	**8+**	N	6
Bedstraw, smooth	N	N	N	N	N	N	N	6	N	6	N	N	7	7	8	N	N
Bermudagrass	N	N	7	N	N	N	6	N	N	6	N	8	N	N	8	8	N

Table 2.6-5. Relative effectiveness of herbicides on weeds and crop tolerance in legume forages (continued).

	Preemergence							*Postemergence*									
Trade Name	**Balan**	**Chateau**	**Eptam**	**Kerb**	**Metribuzin**	**Prowl H2O**	**Sinbar**	**Aim**	**Butyrac/2,4-DB**	**Gramoxone**	**Maestro**	**Poast**	**Pursuit**	**Raptor**	**Roundup/Glyphosate**	**Select/Clethodim**	**Velpar**
Bluegrass, roughstalk	N	N	N	N	N	N	N	N	N	7+	N	8	6+	8	**9**	**8+**	8
Cockle, white	N	N	N	N	7	N	7	6	7	6	N	N	6	6	**9**	N	7
Dandelion	N	7+	N	N	7	N	6	6	7+	N	N	N	7	6	8	N	8
Dock spp.	N	N	N	N	6	N	6	6	6	N	N	N	7	7+	8	N	7
Dogbane, hemp	N	N	N	N	N	N	6	N	N	6	N	N	N	N	**8+**	N	6
Fescue, tall	N	N	N	8	N	N	7	N	N	6	N	6	N	N	**9**	7	7
Horsenettle	N	N	N	N	6	N	6	N	N	6	N	N	N	N	7	N	6
Johnsongrass	6	N	7	N	N	N	N	N	N	6	N	8	8	8	**9**	**9**	N
Milkweed, common	N	N	N	N	N	N	6	N	N	N	N	N	N	N	7	N	6
Nutsedge, yellow	N	N	8	N	N	6	N	N	N	N	N	N	7	6	7	N	N
Orchardgrass	N	N	6	7	N	N	6	N	N	6	N	6	N	N	8	7+	7
Plantain spp.	N	N	N	N	7	N	7	6	7	N	N	N	6	6	8	N	7
Quackgrass	N	N	8	8	N	N	6	N	N	6	N	7	6	N	**9**	8	6
Thistle, Canada	N	N	N	N	N	N	N	N	N	N	N	N	6	6	**9**	N	N

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage. Results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH. Crop tolerance rating of VG or less is rarely significant.
Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65%; N = less than 55% or no control.
Crop tolerance rating: E = excellent (almost never any crop injury observed); VG = very good (on rare occasion is crop injury observed); G = good (crop injury is seldom observed or is transient); FG = fair to good (occasionally is crop injury observed); F = fair (transient crop injury can be expected).
*Crop tolerance ratings are for forage crops listed under each herbicide in Table 2.6-6.
**Triazine-resistant biotypes exist in the region and are not controlled by metribuzin.

Table 2.6-6. Comments on herbicides for legume forages.

Trade Name*	Common Name	Crop(s)	Application Timing	Product/A	lb ai/A
Preplant					
Balan 60DF	benefin	alfalfa, birdsfoot trefoil, red clover, ladino clover, alsike clover	preplant incorporated	2 lb	1.2
• Balan provides approximately 1 month of soil residual control of many annual grass weeds and some annual broadleaf weeds. • Apply in 5 to 40 gal/A of water or liquid fertilizer to clean, dry soil within 3 weeks of planting. • Soil incorporation must occur within 8 hours after application. Uniformly incorporate into the top 2 to 3 inches of soil; see product label. • Do not use with companion seedings of small grains or forage grasses. • Forage grasses, small grains, sorghum, and corn can be planted 10 months after application.					
Eptam 7E	EPTC	alfalfa, birdsfoot trefoil, clovers, lespedeza; not white Dutch clover	preplant incorporated	3.5–4.5 pt	3–4
• Eptam provides approximately 1 month of soil residual control of many annual grass weeds, some annual broadleaf weeds, and yellow nutsedge. • Apply in 10 to 50 gal/A of water or liquid fertilizer to clean, dry soil just before planting and incorporate immediately. Operate equipment to uniformly incorporate into the top 2 to 3 inches of soil. Refer to the product label for specific instructions on soil incorporation equipment and methods. • Do not use if atrazine was applied within 12 months of planting. • Do not use on white Dutch clover. • Do not use on soils with greater than 10% organic matter. • Forage grasses, small grains, sorghum, and corn can be planted after normal harvest of the legume forage.					
Postemergence					
Aim 2EC	carfentrazone	alfalfa, clover, and alfalfa or clover-grass mixtures	established: POST	1 fl oz	0.016
• Aim only controls small, emerged weeds (no residual activity). It is not a rescue treatment. • Apply in spring or summer immediately after cutting but before 3 inches of new growth. • A 5- to 8-day or 10- to 14-day delay in cutting may be observed with applications made to 3- and 6-inch alfalfa, respectively. • Apply when weeds are actively growing and no more than 3 inches in height or rosettes are less than 2 inches across. • Aim may be applied when a crop, such as alfalfa, is in dormancy fall through early spring applications. • There are no crop rotation or overseeding restrictions for labeled crops; see label. • Water quality advisory.					
Butyrac 200 2E (2,4-DB)	2,4-DB	alfalfa, birdsfoot trefoil, CRP	seedling: POST; established: POST	1–3 qt	0.5–1.5 ae
• Butyrac 200 controls a relatively narrow spectrum of emerged broadleaf weeds and is particularly effective on morningglory species. • Apply in spring or summer when seedling legumes have 2 to 4 trifoliate leaves. • Apply by ground in a minimum of 10 gal/A or by air in 5 to 40 gal/A of water. • Apply when weeds are actively growing and no more than 3 inches in height, or rosettes are less than 2 inches across. • Do not apply if temperatures above 90°F or below 40°F are expected during or shortly after application. • 2,4-DB labels vary concerning overseeding or crop rotation restrictions or do not mention them. Unless specified on the label, most crops can be safely planted 3 months after application under normal environmental conditions. • *Water quality advisory.*					
Chateau 51WDG Chateau 41.4 EZ	flumioxazin	Alfalfa	established: dormant; between cuttings	2–4 oz	0.064–0.128 0.054–0.108
• Chateau provides 1 to 2 months of residual control of many annual broadleaf weeds and suppression of some annual grasses as they germinate. • It will not control weeds that have already emerged at the time of application. • Apply by ground in 10 to 30 gal/A or by air in 5 to 10 gal/A of water. • Dormant applications can be made in the fall after the last cutting, during winter dormancy, or anytime in the spring prior to 6 inches of alfalfa regrowth. • Postcutting applications should be made prior to 6 inches of regrowth, or unacceptable crop injury may occur. • Wait a minimum of 60 days between applications. • Do not apply with any adjuvant or tank-mix with any products formulated as an emulsifiable concentrate (EC) unless the application follows the last cutting of the season. • Application with paraquat can be used to burndown winter annuals prior to the winter dormant period. • Do not apply to mixed alfalfa-grass stands. • When applied at the 3 to 4 oz/A rate, forage grasses can be planted 6 months after application if soil is tilled or 12 months after application if planted no-tillage; at the 2 oz/A rate it is 4 months (tilled) and 8 months (no-till); see label for more details.					

Table 2.6-6. Comments on herbicides for legume forages (continued).

Trade Name*	Common Name	Crop(s)	Application Timing	Product/A	lb ai/A
Extreme 2.17L	imazethapyr + glyphosate	Roundup Ready alfalfa	seedling: POST; established: dormant; established: POST	2.2–4.4 pt/A	0.41–0.81(ae) + 0.05–0.1
• Extreme controls or suppresses many annual and some perennial broadleaf and grass weeds. • Extreme also provides 1 to 2 months of residual control of many emerging weeds. • Apply over-the-top to Roundup Ready alfalfa varieties only. • Apply to seedling Roundup Ready alfalfa at the second trifoliate stage or larger. • Apply to established Roundup Ready alfalfa in the fall, spring, or between cuttings before alfalfa regrowth reaches 3 inches. • Apply when the majority of weeds are 1 to 3 inches (height or rosette diameter). • Typical application rate is 3 pt/A. • Due to breeding constraints, some alfalfa plants may not contain the glyphosate-resistant gene; thus, some seedlings may not survive the application. • Do not apply more than 3 pt/A Extreme during the last year of the stand, or crop rotation options will be very limited. • Forage grasses are not listed on the Extreme label in crop rotation section; small grains can be planted 4 months after application; see label. • If replanting is necessary, do not plant alfalfa for 4 months following an Extreme application.					
Gramoxone SL 2S	paraquat	alfalfa, clover, or trefoil	seedling: dormant	1–2 pt	0.25–0.5
			established: dormant	2–3 pt	0.5–0.75
			between cuttings	1 pt	0.25
			spot treatment	0.2–0.7 fl oz/gal	0.15–0.5% solution
• Gramoxone SL controls emerged weeds only (no residual activity). • Dormant applications provide control of many winter annual weeds, and some seedling biennial and perennial weeds. • Apply only one dormant application per year by ground in a minimum of 10 gal/A or by air in a minimum of 5 gal/A of water. • To avoid injury, use only on seedling alfalfa or clover stands that are completely dormant, established clover stands with less than 2 inches of remaining fall regrowth that are completely dormant, or established alfalfa stands with less than 6 inches of remaining fall regrowth or 2 inches of new spring regrowth. • On seedling alfalfa (first year), 2 between-cutting applications may be made. First-year alfalfa stands and yields may be reduced if alfalfa is allowed to regrow more than 2 inches after cutting and before application. • On established alfalfa, 3 between-cutting applications may be made. Do not make between-cutting applications more than 5 days after cutting. • Between-cutting applications are not allowed on other legumes or alfalfa-grass mixtures. • There are no crop rotation restrictions when applying Gramoxone in legume forages. • Spot spraying with Gramoxone SL is recommended when only small areas are to be sprayed with labeled applications. Refer to weed rate tables of the herbicide label for the recommended herbicide concentration and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Always add a nonionic surfactant at 0.5 fl oz/gal (15 ml/gal). • 0.5 lb paraquat = 2 pt Gramoxone SL2.0 or 1.33 pt Gramoxone SL 3.0. • *Restricted-use pesticide.*					
Kerb 50W	pronamide	alfalfa, birdsfoot trefoil, crown vetch, clovers	seedling: dormant; established: dormant	1–3 lb	0.5–1.5
• Kerb provides 1 to 2 months of residual control or suppression of several annual grass and some broadleaf weeds, and also has postemergence activity on several small annual grass weeds. • Apply by ground in 20 to 50 gal/A of water. Make applications in fall or winter when temperatures fall below 55°F but before soil freeze-up. • Kerb may be applied to fall-seeded legumes after they reach the trifoliate leaf stage. • Do not apply to spring-seeded legumes until the following fall or early winter. • Do not use on alfalfa-grass mixtures. • Rainfall or overhead irrigation is required after application to activate the herbicide. • Do not use on soils with greater than 4% organic matter. • Forage grasses, as well as most other crops, can be planted 12 months after application; see label. • *Restricted-use pesticide.*					
Maestro 2EC	bromoxynil	alfalfa and alfalfa/small grain companion seedings, CRP	seedling: POST	1–1.5 pt	0.25–0.375
• Maestro controls emerged weeds only (no residual activity). • Apply in spring or fall to seedling alfalfa with at least 4 trifoliate leaves. • May be applied to a small grain companion seeding up to the boot stage. • Apply by ground in 10 to 20 gal/A or by air in a minimum of 5 gal/A of water or liquid fertilizer. Applications in liquid fertilizer may increase leaf burn to alfalfa.					

Table 2.6-6. Comments on herbicides for legume forages (continued).

Trade Name*	Common Name	Crop(s)	Application Timing	Product/A	lb ai/A
• Weeds should not exceed the 4-leaf stage, 2 inches in height, or 1 inch in diameter (whichever comes first). • Maestro application where temperatures are expected to exceed 70°F at or 3 days following application can result in unacceptable crop injury. • Any crop can be planted 30 days after application. • Do not use an adjuvant unless a tank-mix partner requires it; see Table 2.6-7.					
MCPA amine 4S	MCPA	alfalfa, clovers, or trefoil with small grain or forage grass companion seeding, CRP	seedling: POST	0.25–0.5 pt	0.125–0.25
• MCPA controls or aids in control of some emerged annual, biennial, or perennial weeds. • Treat after the grain is tillered and legumes are 2 to 3 inches tall. • Do not use more than 5 to 10 gal/A of water; higher volumes may result in injury to legumes. • Do not spray when grain is in the boot to dough stage. • Do not use on sweet clover or vetch. • Some MCPA labels allow application to newly seeded clover and grass pastures; treat seedling stands after they have 2 or more true leaves (trifoliate stage). • Follow all label recommendations to reduce the potential for spray drift. • MCPA labels vary concerning overseeding or crop rotation restrictions or do not mention them. Unless specified on the label, most crops can be safely planted 3 months after application under normal environmental conditions. • *Water quality advisory.*					
Metribuzin 75DF	metribuzin	alfalfa and alfalfa-grass mixtures	established: dormant	0.5–1.3 lb	0.38–1
• Metribuzin provides both postemergence and 1 to 2 months of residual control of several annual broadleaf weeds and a few grasses (brome species, annual bluegrass, green foxtail, and barnyardgrass). • Apply by ground in 10 to 40 gal/A or by air in a minimum of 2 to 10 gal/A of water or liquid fertilizer. • Apply in fall after alfalfa goes dormant or in the spring before new growth starts. Alfalfa may be severely injured if new growth is present at spring application. • May be applied after dormancy is broken, but before 3 inches of new growth, if impregnated on dry fertilizer. • Apply the appropriate rate from the label when weeds are less than 2 inches tall or 2 inches in diameter. • May be used on alfalfa-grass mixtures. Orchardgrass in mixed stands will generally tolerate metribuzin at rates of up to 0.67 lb/A. Rates of 0.67 to 1 lb/A can be used in mixed stands of alfalfa and grass to reduce grass stands and prevent crowding out of alfalfa. • Do not use metribuzin on sandy soils or serious crop injury can occur. Crop injury can also occur on loamy sand soils. Forage grasses and corn can be planted 4 months, small grains 8 months, and sorghum 12 months after application. • Tripzin 4 ZC is a premix of pendimethalin + metribuzin labeled for alfalfa • *Water quality advisory.*					
Poast 1.5E	sethoxydim	alfalfa, clovers, and birdsfoot trefoil	seedling: POST	1–2.5 pt	0.19–0.47
			established: POST	1–2.5 pt	0.19–0.47
			spot treatment	1.3–1.9 fl oz/gal	1–1.5% v/v solution
• Poast controls many annual and perennial grass weeds (emerged weeds only). • Apply to actively growing grasses by ground in 5 to 20 gal/A or by air in a minimum of 5 gal/A of water. • Refer to the herbicide label for the recommended herbicide concentration based on grass species and size (generally less than 8 inches tall) and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. • Repeated applications may be needed for complete control of perennial species. • Any crop can be planted 30 days after application. • Spot applications are allowed, but do not make spot treatments in addition to broadcast treatments. • Apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. • Spot applications are allowed, but do not make spot treatments in addition to broadcast treatments. Apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Always add a crop oil concentrate at 1.3 fl oz/gal (38 ml/gal).					
Prowl H2O/Satellite Hydro-Cap 3.8AS	pendimethalin	alfalfa	seedling: POST	0.5–1 qt	0.5–0.95
			seedling: dormant	0.5–1 qt	0.5–0.95
			established: dormant	1.1–4.2 qt	1–4
			between cuttings	1.1–4.2 qt	1–4
• Prowl H2O provides 1 to 2 months of residual control of most annual grasses and some annual broadleaf weeds as they germinate. It will not control any weeds that have already emerged at the time of application. • Apply by ground in a minimum of 10 gal/A or by air in a minimum of 5 gal/A of water. • Adequate rainfall or overhead irrigation is required after application to activate Prowl H2O.					

Table 2.6-6. Comments on herbicides for legume forages (continued).

Trade Name*	Common Name	Crop(s)	Application Timing	Product/A	lb ai/A
• Apply to seedling alfalfa after the legume has 2 fully expanded trifoliate leaves but before it reaches 6 inches in height. • Established alfalfa is defined by the label as alfalfa planted in the fall or spring that has gone through a first cutting/mowing. • Apply to established alfalfa before weed emergence. Applications can be made in the fall after the last cutting, during winter dormancy, in the spring, or between cuttings. Applications should be made prior to the alfalfa reaching 6 inches in regrowth. • Some stunting and yellowing of the alfalfa may occur with postemergence applications. • Rotation restrictions are based on Prowl rate used, rainfall received, and time of year applied; see label. • Tripzin 4 ZC is a premix of pendimethalin + metribuzin labeled for alfalfa					
Pursuit 2S	imazethapyr	alfalfa and alfalfa-grass mixtures, birdsfoot trefoil, clover, CRP	seedling: POST; seedling: dormant; established: POST; established: dormant; between cuttings	3–6 fl oz	0.047–0.094
• Pursuit controls or suppresses many annual and some perennial broadleaf weeds, as well as several grasses when they are small. • Pursuit also provides 1 to 2 months of residual control of many emerging weeds. • Apply by ground in a minimum of 10 gal/A or by air in a minimum of 5 gal/A of water. • Seedling applications are for pure seeded alfalfa or clover only. Apply when legume has 2 fully expanded trifoliate leaves or larger. • Dormant applications can be made in the fall after the last cutting or anytime in the spring prior to 3 inches of alfalfa or clover regrowth. • Between cutting applications should also be made prior to 3 inches of regrowth. • Apply when weeds are 1 to 3 inches in height or in the rosette growth stage. • Do not apply Pursuit to alfalfa-grass mixtures during the establishment year. • Do not apply more than 4 oz/A to alfalfa or clover in the last year of the stand (crop rotation considerations). • Forage grasses are not listed on the Pursuit label in crop rotation section; small grains can be planted 4 months after application; see label. • Water quality advisory.					
Raptor 1AS	imazamox	alfalfa	seedling: POST; seedling: dormant; established: dormant; between cuttings	4–6 fl oz	0.031–0.047
• Raptor controls or suppresses many annual and some perennial broadleaf weeds, as well as several grasses when they are small. • Raptor also provides approximately 1 month of residual control of many emerging weeds. • Apply by ground in a minimum of 10 gal/A or by air in a minimum of 5 gal/A of water. • Do not apply Raptor in liquid fertilizer as a carrier. • Apply when seedling alfalfa has 2 fully expanded trifoliate leaves or larger. • Seedling alfalfa may experience a temporary reduction in growth. • Apply when weeds are 1 to 3 inches in height or rosette width. • Apply to established alfalfa in the fall, winter, or spring to dormant or semi-dormant alfalfa or between cuttings. • Any application should be made before significant alfalfa growth or regrowth (3 inches). • Forage grasses can be planted 18 months, small grains 3 to 18 months (see label), and sorghum 9 months after application.					
Roundup 3S2 or	glyphosate	alfalfa, clover, and alfalfa or clover-grass mixtures	spot treatment	2% solution	
Roundup WeatherMAX 4.5S2			wiper applicator	33–77% solution	
• Make applications with hand-held equipment or wiper applicator. • Apply only to weed-infested areas of the field, and do not treat more than one-tenth of the total area at any one time. • Refer to weed rate tables of the herbicide label for the recommended herbicide concentration and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Apply to actively growing susceptible weeds. • Avoid contact with desirable species as severe injury or death can occur. • Further application may be made at 30-day intervals if necessary. • Consult the herbicide label for specific wiper applicator recommendations. • For best results, do not graze or harvest forage for 7 days after application, and make applications at least 7 days before a killing frost. • There are no crop rotation restrictions when applying glyphosate in legume forages.					
Roundup 3S or	glyphosate	alfalfa or alfalfa-grass mixtures	preharvest	32–63 fl oz	0.77–1.5
Roundup WeatherMAX 4.5S**				22–44 fl oz	
• For use on declining alfalfa stands prior to crop rotation. • Apply before last cutting in fall or spring to control certain perennials such as quackgrass. • Can be grazed or harvested in 36 hours. However, harvest should be delayed for 7 to 10 days after application to allow herbicide to have full effect. • Deep tillage after harvest improves control. • Fall applications are more effective on perennial grasses relative to spring applications. • Refer to herbicide label for additional application information and use restrictions. • There are no crop rotation restrictions when applying glyphosate in legume forages.					

Table 2.6-6. Comments on herbicides for legume forages (continued).

Trade Name*	Common Name	Crop(s)	Application Timing	Product/A	lb ai/A
Roundup PowerMAX or	glyphosate	Roundup Ready alfalfa only	seedling: POST	22–44 fl oz	0.77–1.9
Roundup WeatherMAX 5.5L			established: POST		

• Roundup provides broad-spectrum control of existing grass and broadleaf weeds but has no effect on weeds emerging after application.
• Some species of weeds may require retreatment for complete control, as will species with multiple germination flushes.
• Apply by ground in 3 to 40 gal/A or by air in 3 to 15 gal/A of water.
• Two applications may be made to seedling stands prior to the first cutting. The first application is from emergence up to the 4-trifoliate leaf stage and is necessary to remove the small percentage of glyphosate-susceptible alfalfa plants that are present in the new seeding. The second application is from the 5-trifoliate leaf stage to 5 days before the first cutting.
• The second application is from the 5-trifoliate leaf stage to 5 days before the first cutting.
• After the first cutting, a single application per cutting may be made up to 5 days before cutting.
• In established stands, a single application per cutting may be made up to 5 days before cutting.
• The highest level of control is achieved when annual weeds are less than 4 inches tall.
• For perennial weed problems, glyphosate should be applied during early fall.
• Sequential applications of glyphosate should be at least 7 days apart.
• The combined total for all in-crop applications cannot exceed 4.1 qt/A per year. The combined total for all applications (in-crop and establishment) cannot exceed 5.3 qt/A per year.
• There are no crop rotation restrictions when applying glyphosate in legume forages.
• The Roundup Ready system in alfalfa is easy to use and very effective on most weeds common to alfalfa plantings. However, herbicide-resistant weeds are selected for by repeated use of the same or similar herbicide over a period of time. Weed species with a very high amount of seed production and a variable genetic pool are more likely to develop resistant populations—for example, horseweed, common lambsquarters, ragweed species, and pigweed species. Therefore, it is recommended that the Roundup Ready system be used during the establishment year when the most benefit can be recognized, and then rotate between Roundup and other herbicides with different modes of action through subsequent seasons.

Select 2EC or Select Max 1EC	clethodim	alfalfa, birdsfoot trefoil	seedling: POST	6–16 fl oz or 12–32 fl oz	0.09–0.25
			established: POST	6–16 fl oz or12–32 fl oz	0.09–0.25
			spot treatment	0.33–0.65 fl oz/gal	0.25–0.5% v/v solution

• Select Max controls many annual and perennial grass weeds (emerged weeds only).
• Apply to actively growing grasses by ground in 10 to 40 gal/A or by air in a minimum of 10 gal/A of water.
• Apply to grasses at the size recommended on herbicide label (generally less than 6 inches tall).
• Repeated applications are required for complete control of perennial grasses. Allow a minimum interval of 14 days between repeat applications.
• For annual bluegrass control, apply 6 to 16 fl oz Select or 12 to 32 fl oz Select Max before the 4-leaf stage of bluegrass.
• Any crop can be planted 30 days after application.
• Select 2EC and Select Max 1EC require different adjuvants; see Table 2.6-7.
• Spot treatments are allowed but do not exceed a total of 32 fl oz/A per season for Select or 64 fl oz/A per season for Select Max for spot treatments and broadcast treatments combined. Refer to weed rate tables of the herbicide label for the recommended herbicide concentration and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff.
• Always add a crop oil concentrate at 1.3 fl oz/gal (38 ml/gal).

Sinbar 80WG	terbacil	alfalfa	established: dormant; between cuttings	0.75–1.5 lb	0.6–1.2

• Sinbar provides postemergence control (small weeds) and 1 to 2 months of soil residual control of many annual weeds and some biennial and perennial weeds.
• Use only on alfalfa established for 1 year or more.
• Apply by ground in water with sufficient spray volume for uniform coverage.
• Dormant applications can be made in the fall through winter to dormant alfalfa or in the spring prior to 2 inches of alfalfa regrowth. Spring between-cutting applications should also be made prior to 2 inches of regrowth.
• Two applications per year are allowed, but they must be separated by 60 days, and the total amount of Sinbar cannot exceed 1.5 lb/A per year.
• Apply before weeds germinate or before they exceed 2 inches in height or width.
• Do not use on alfalfa-grass mixtures.
• Do not use on sand, loamy sand, or gravel soils, or on soils with less than 1% organic matter or serious crop injury can occur.
• No other crops can be planted for 2 years following an application of Sinbar.
• Do not use any spray adjuvants. See Table 2.6-7.
• *Water quality advisory.*

Table 2.6-6. Comments on herbicides for legume forages (continued).

Trade Name*	Common Name	Crop(s)	Application Timing	Product/A	lb ai/A
Velpar 2L or	hexazinone	alfalfa	established: dormant; between cuttings	2–6 pt	0.5–1.5
Velpar 75DF				0.67–2 lb	

• Velpar provides postemergence control (small weeds) and 1 to 2 months of soil residual control of many annual, biennial, and perennial weeds as well as suppression of some woody species.
• Use only on alfalfa established for 1 year or more.
• Apply by ground in a minimum of 20 gal/A or by air in a minimum of 5 gal/A of water.
• Make a single application after alfalfa becomes dormant and before new growth begins in the spring. Where weeds have emerged, include a surfactant. Weeds should be less than 2 inches tall or 2 inches in diameter.
• If no dormant application is made, a between-cuttings treatment may be made; apply before 2 inches of alfalfa regrowth. Severe injury may result with between-cutting applications if significant alfalfa foliage is present at application or air temperature exceeds 90°F.
• Do not use an adjuvant with between-cutting applications.
• Do not use on gravelly or rocky soils, exposed subsoils, or hardpan, sand, or poorly drained soils, or serious crop injury can occur.
• Unacceptable weed control may occur on soils with greater than 5% organic matter.
• When applied at 3 pt/A or less, corn can be planted 12 months after application.
• Other crops may be planted 24 months after application.
• *Water quality advisory.*

Warrant 3 SL	acetochlor	alfalfa	established: dormant; between cuttings	1.25–2 qt	0.94–1.5

• Warrant can be applied after alfalfa after emergence to control of several grass and broadleaf weeds prior to their emergence, but it will not control weeds that are present at the time of application.
• Can be used on newly established and established alfalfa stands.
• Do not use this product on alfalfa grown for seed production.
• Remove domestic livestock from alfalfa stands before making applications of this product.
• Allow a minimum of 20 days between an application and subsequent cutting for forage or hay, or before open grazing of forage and livestock.
• Do not exceed a total of 3 applications or a combined total of 4 qt (3 lb ai) per acre per year.
• *Water quality advisory.*

See specific product label to determine correct rate for the soil type and weed species found in individual fields.
*See Table 2.6-1 for additional formulations or trade names containing these same active ingredients.
**Various formulations of this product are available. Refer to current product label for active ingredient concentration, application rate, and other restrictions. Adjust application rate if using Roundup.

herbicides at or during establishment is included in Table 2.6-5. Herbicides available for use during the establishment year are included in Table 2.6-6.

Control in an Established Stand

The best weed control in an established forage stand is achieved by maintaining a dense healthy stand through proper fertilization, cutting management, and insect control. Controlling weeds in established forages is normally of greatest benefit in the first cutting. Weeds generally contribute much less to yield in the second and succeeding harvests. Before using an herbicide in established stands, evaluate the forage to ensure it is worth the cost of the herbicide.

Below are some general rules to follow before using an herbicide in established forage stands:

- Thin or irregular stands do not thicken once weeds are removed. Be sure there are sufficient desirable species to fill in the gaps. A minimum of five alfalfa plants per square foot should be present.
- Weeds tolerant of the herbicide may invade the space left by susceptible species, ultimately creating a new or more severe weed problem.
- Treat only well-established, vigorous stands with herbicides.
- If the forage stand is at least two years old and 25 percent to 30 percent of the plants are weeds, removing them with an herbicide application is of questionable value. Renovation is likely more economical.
- If 50 percent or more of the plants are weeds, it is time to rotate to a different crop or renovate the existing crop.

If weeds become a problem in established forages, several herbicide options are available (see Table 2.6-6). Chemical control in established forage legumes is often limited to late fall or early spring applications. Many herbicides require the addition of adjuvants for effective control (Table 2.6-7). Also, many products have harvesting, feeding, or grazing restrictions on their use (Table 2.6-8).

Grass Forages, Including Pastures and Hayfields

Without proper management, broadleaf weeds can directly compete with forage grasses to reduce their nutritional value and longevity. Weeds can replace desirable grass species, filling in gaps or voids and reducing yield and overall quality of the hay or pasture. In addition, certain plants such as poison hemlock, white snakeroot, or black locust have toxic properties that can cause livestock injury or loss under certain circumstances (see Poisonous Weeds below).

Biennial and perennial weeds are considered especially troublesome by grass hay and pasture producers. Both biennials and perennials produce seed each year, potentially starting new infestations. In addition, perennial weeds such as hemp dogbane, Canada thistle, and multiflora rose reproduce from underground roots or rhizomes. Perennial rooting structures can survive for several years in the soil and are often unaffected by occasional mowing or livestock grazing.

Good cultural practices such as maintaining optimum soil fertility, using a competitive cutting schedule for forages, rotationally grazing pastures, and periodic clipping and/or coring pastures can help keep the crop competitive with weeds. The most critical time for weed control is during the establishment year. If a no-till seeding is desired, be sure the preplant vegetation is adequately controlled. See Tables 2.6-2 and 2.6-3 for information on burndown herbicides in controlling vegetation prior to planting.

In general, use preplant tillage or herbicides, companion seedings, mowing, and/or a postemergence herbicide to ensure that weeds are not a problem in the seeding year. To reduce weed shading, mow at a height above the grass seedlings when weeds are 8 to 10 inches tall. For warm-season grasses, do not mow after early August.

Certain application methods used in forage crops, including spot spraying and wiper applications, are not commonplace in row crops. With spot spraying, the herbicide is applied to weed-infested areas of the field, typically less than one-tenth of the total area. Spot applications are accomplished using a hand-held sprayer or a spray gun. Refer to the spot treatment section of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gallon per 1,000 square feet), avoiding spray dripping or runoff, to provide thorough coverage. Most backpack sprayers hold only 1 to 3 gallons of spray solution. Specialized equipment capable of measuring a small volume or weight (e.g., syringes, gram scales) is recommended to accurately dispense the desired quantity of herbicide product into small volumes of spray solutions (see Table 2.6-18). Apply all herbicides at least seven days before crop harvest, or harvest around weed patches, leaving them standing to be treated later. Apply all herbicides at least seven days before a killing frost. Spot treatment may kill desirable vegetation that is contacted by the herbicide. Select an herbicide based on its effectiveness on the target weed, safety to existing desirable vegetation, and grazing, overseeding, or rotational crop intervals.

Wiper applicators (weed wipers) are devices that physically wipe a concentrated solution of herbicide directly onto weeds by taking advantage of sufficient height difference between the weeds and crop canopy. The height difference in pasture can be increased by grazing the forage prior to wiper application and allowing some days for trampled weeds to recover. Sufficient contact from the wiper applicator while preventing contact with the crop controls weeds selectively is the goal. Since only the top several inches of the weeds are contacted with herbicide solution, a translocated herbicide such as dicamba or glyphosate is usually required for effective

Table 2.6-7. Adjuvants and rainfastness for postemergence herbicides in legume forages.

Trade Name	Adjuvant(s)	Rate	Rainfastness (hours)
Aim 2EC	non-ionic surfactant or	1 qt/100 gal	not specified
	crop oil concentrate	0.5–1 gal/100 gal	
Butyrac 200 2L/2,4-DB 2L	none		not specified
Glyphosate preplant or spot treatment	varies by product, check label	see label	1–6
	ammonium sulfate (optional)	8.5–17 lb/100gal	
Gramoxone 2SL	non-ionic surfactant or	1 qt/100 gal	0.5
	crop oil concentrate	1 gal/100 gal	
Kerb 50W	none		not specified
Maestro 2EC	not recommended (see label for instructions when tank-mixing)	1	
MCPA 3.7L	none		not specified
Metribuzin 75DF	none		not specified
Poast 1.5EC	crop oil concentrate or	2 pt/A	1
	methylated seed oil	1.5 pt/A	
	plus nitrogen solution or	2–4 qt/A	
	ammonium sulfate (optional)	2.5 lb/A	
Pursuit 2AS	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate or	1 gal/100 gal	
	methylated seed oil	1.25 gal/100 gal	
	plus nitrogen solution or	1.25–2.5 gal/100 gal	
	ammonium sulfate (required)	12–15 lb/100 gal	
Raptor 1AS	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate or	1–2 gal/100 gal	
	methylated seed oil	1–2 gal/100 gal	
	plus nitrogen solution or	2.5 gal/100 gal	
	ammonium sulfate (required)	12–15 lb/100 gal	
Roundup PowerMAX or WeatherMAX 5.5L in RR alfalfa	ammonium sulfate (optional)	8.5–17 lb/100 gal	not specified
Select 2EC	crop oil concentrate	1 gal/100 gal	1
	plus nitrogen solution or	1–2 qt/A	
	ammonium sulfate (optional)	2.5–4 lb/A	
Select Max 1EC	non-ionic surfactant or	1 qt/100 gal	1
	crop oil concentrate or	1 gal/100 gal	
	methylated seed oil	1 gal/100 gal	
Sinbar 80WP	do not use		not specified
Velpar 2L	non-ionic surfactant on dormant alfalfa	1 qt/100 gal	not specified
	none on nondormant alfalfa		
Warrant 3L	none	not specified	

Adjuvants are products included in the spray tank to improve the performance of herbicides. These include non-ionic surfactant (NIS), crop oil concentrate (COC), methylated seed oil (MSO), or nitrogen solutions. In general, NIS should contain at least 80% active ingredient, and COC should contain at least 15% emulsifier. Nitrogen solutions can be 28, 30, or 32% ammonium-based fertilizer solutions; ammonium sulfate should be spray-grade dry ammonium sulfate (21-0-0). Crop injury can occur with the use of adjuvants. Adding additional adjuvants other than what is labeled can increase the chance or severity of crop injury. Following are recommended adjuvants for broadcast postemergence applications; refer to herbicide labels for adjuvant recommendations with other application types. Rainfastness is number of hours needed between time of application and rainfall or irrigation to ensure sufficient absorption in the plant.

Table 2.6-8. Grazing, harvest, haying, and slaughter restrictions for herbicides in legume forages.

Trade Name	Type	Length	Comments
Aim (carfentrazone)	Grazing (forage) and haying (harvest)	21 days	May be used in established, mixed grass-clover stands as well as established pure forage legume stands
Butyrac (2,4-DB)	Grazing or feeding	60 days	Seedling alfalfa
		30 days	Established alfalfa
Chateau (flumioxazin)	Grazing or harvest	25 days	Established alfalfa; less than 6 inches of regrowth
Gramoxone (paraquat)	Grazing or harvest	60 days	Fall or spring dormant application alfalfa or clover
	Grazing or harvest	30 days	Between-cutting application alfalfa only
Kerb (pronamide)	Grazing or harvest	120 days	Fall or dormant application alfalfa or clover
Maestro (bromoxynil)	Grazing or harvest	30 days	After spring application
		60 days	After fall or winter application
MCPA	Forage or grazing	7 days	Do not forage or graze meat animals within 7 days of slaughter or dairy animals within 7 days of treatment; alfalfa or clover
Metribuzin	Grazing or harvest	28 days	Dormant application
Poast (sethoxydim)	Forage (grazing)	7/20 days	On the label, forage refers to green, undried alfalfa; Poast has 20-day restriction for clover hay only
	Hay (harvest)	14/20 days	Hay is dried alfalfa; Poast has 20-day restriction for clover hay only
Prowl H2O (pendimethalin)	Forage or hay harvest	28 days	Apply before 6 inches of alfalfa regrowth; has a 28-day restriction for 2.1 qt/A or less, 50-day restriction for more than 2.1 qt/A
Pursuit (imazethapyr)	Feeding, grazing, or harvest	30 days	Alfalfa or clover; be cautious of rotational crop restrictions
Raptor (imazamox)	Feeding, grazing, or harvest	N/A	Not specified on the label
Roundup/glyphosate	Grazing or harvest (preplant)	0 days	Alfalfa or clover may be grazed or cut for hay immediately following preplant application
	RR alfalfa only	5 days	In Roundup Ready alfalfa varieties, apply glyphosate up to 5 days before cutting
	Grazing or harvest (spot treatment)	3–14 days	Spot treatment on alfalfa or clover depends on glyphosate product used
Select (clethodim)	Feeding, grazing, or harvest	15 days	Increases when tank-mix with 2,4-DB (60 days)
Sharpen (saflufenacil)	Feeding, grazing, or harvest	28 days	
Velpar (hexazinone)	Grazing or feeding	30 days	Plant only corn for 12 months following application of Velpar
Warrant (acetochlor)	Grazing or feeding	20 days	Postemergence application

control. Repeat applications may be required to manage certain perennial weeds. A healthy actively growing crop that can develop a canopy over suppressed weeds is important to the success of wiper applications. There are several types of wiper applicators on the market. Wiper applicators must be designed and operated so that the rope, roller, sponge, or panel remains moist enough to transfer a sufficient amount of herbicide to the weed while not allowing drips to contact the crop. The two most common types are wick and roller applicators. Wick applicators use short braided ropes or appropriate fabric to "wick" the herbicide solution from inside a pipe to the plants that are wiped. With roller applicators, herbicide is manually sprayed intermittently onto a carpet-covered roller that is rotated with a motor or a ground-driven shaft. The main advantage of the roller applicator is that more herbicide solution can be maintained on the roller because the centripetal force from the rotation inhibits dripping. Compared to wick applicators, roller applicators provide consistent weed control. Bidirectional application is recommended to provide thorough control. Herbicides labeled for wiper application will usually provide specific application instructions on the label. In addition, research trials have indicated that a 5 percent solution applied in a wiper applicator is somewhat comparable to a broadcast application rate of 1 quart per acre.

Controlling woody perennial species (brush) or vines can be very difficult with standard broadcast herbicide applications. Achieving acceptable weed control can require multiple years of intensive and persistent management. Product labels often have specific recommendations concerning herbicide rate, spray volume, seasonal application, retreatment, and growth stage. Recommendations are often species-specific, and tank-mixes with other herbicides or alternative application methods may be required. Application methods may include basal bark, cut stump, dormant stem, oil-water emulsions, or high-volume foliar applications. Carefully read and follow all herbicide label recommendations.

Several herbicides are labeled for broadleaf weed control in grass pasture, hay, and CRP grassland. Tables 2.6-9 and 2.6-10 list herbicides that can be used in grass pasture, hay, and CRP grassland and labeled application timings. See Tables 2.6-11 through 2.6-14 for specific information about herbicides used in grass pasture, hay, and CRP grassland, including effectiveness, use, adjuvant requirements, rainfastness, and grazing and haying restrictions. Table 2.6-15 lists herbicides labeled for use in conservation reserve program (CRP) acres. Table 2.6-16 lists herbicides labeled for summer annual grass crops, and Table 2.6-17 shows the optimum time of year to treat selected weeds. Table 2.6-19 lists herbicides labeled for farmstead use.

Weed management in summer annual grasses begins with a clean seedbed obtained by either tillage close to planting or preplant herbicides such as glyphosate. Use fields with fewer perennial and annual grass weeds. Successful establishment begins with properly amended soils (pH and fertility) and appropriate seeding rate, depth, and equipment. When moisture is adequate, annual forage grasses emerge and grow quickly and compete well with weeds. There is often no need for additional weed control. Chemical weed control may be warranted when establishment is slow, weed populations are high, potentially toxic weeds are present, or high-quality (weed-free) hay or forage is desired. Herbicide options are limited. 2,4-D and dicamba herbicides are labeled for use in annual grass forages. However, 2,4-D and dicamba herbicides are not recommended in many areas during the hot summer months due to potential injury to sensitive plants with physical or vapor drift.

Winter annual weeds should be treated in late fall to spring. Summer annual weeds should be treated in early to late summer soon after emergence. Biennial weeds should be treated in the fall or early spring while in the seedling or rosette stages or in the early spring prior to bolting. Herbaceous and woody perennial weeds can vary significantly by species for when best to apply herbicides. In general, apply systemic herbicides to perennials is when the source/sink movement of sugars is toward the underground structures, typically optimized when the perennial is in early bloom stage or in the fall when temperatures begin to cool. Applications of these herbicides made in earlier growth stages, when movement is upward from underground structures to shoots and foliage, provide only control of top growth, with essentially no effect on the perennial structures. The addition of mechanical weed control techniques can substantially improve herbicide efficacy on perennials. Mowing or clipping the weed one or more times causes significant reductions in underground food reserves because the plant is forced to produce new top growth. When the weed reaches the early bloom stage following clipping, relatively less of the systemic herbicide is required to produce a lethal concentration in the depleted perennial structure.

Management of Autumn Olive

Autumn olive (*Elaeagnus umbellata*) is most easily managed through a proactive approach. Once plants become large, they are less easily and affordably controlled. Efficacy of broadcast applications is unknown; individual plant treatment is highly effective. For stems less than 1 inch in diameter at the base, apply a high-volume foliar treatment of Remedy Ultra at 2 quarts per 100 gallons of water after autumn olive leaves are fully expanded until prior to fall color. Apply to all foliage until wet, but avoid dripping or runoff. For stems 1 to 6 inches in diameter, a basal bark treatment is most effective. Apply Remedy Ultra in bark oil in a 25 percent herbicide, 75 percent oil mixture to all sides of every stem and exposed roots from the soil line up 12 to 18 inches on the stem. Apply at any time of the year except during spring. For stems greater

Table 2.6-9. Application timings for herbicides used in grass pasture, hay, and CRP grassland.

Trade Name	Use Only in	Establishment	Seedling Stand POST	Established Stand POST	Spot-Spray or Wiper Applicator	Grazed Fencerows
2,4-D amine[1]				L[2]	—[3]	Yes
2,4-D ester[1]				L	—[3]	Yes
2,4-D + dicamba tank mix				L		Yes
Aim			L	L		Yes
Arsenal						Yes
Chaparral (aminopyralid + metsulfuron)	PA, VA, WV			After tillering[4]	Spot	Yes
Clarity			1 pt/A max[5]	L	Spot and wiper	Yes
Crossbow (triclopyr + 2,4-D)				After tillering[4]	Spot	Yes
DuraCor SC (aminopyralid + florpyrauxifen		Prelant	20 fl oz/A max	After tillering[4]	Spot	Yes
Facet L				L	Spot	Yes
Freelexx				L	Spot	Yes
Glyphosate		Preplant renovation			Spot and wiper	Yes
Gramoxone SL		Preplant				No
GrazonNext HL (aminopyralid + 2,4-D)	PA, VA, WV			After tillering[4]	Spot	Yes
Grazon P+D (picloram + 2,4-D)	VA, WV			After tillering[4]		Yes
MCPA			0.5 pt/A max[6]	L		Yes
Metsulfuron				6–24 months[7]	Spot	Yes
Milestone	PA, VA, WV			After tillering[4]	Spot	Yes
PastureGard HL (triclopyr + fluroxypyr)				After tillering[4]	Spot	Yes
Permit/Sandea				L	Spot and wiper	Yes
Prowl H2O				≥6 tillers		Yes
Remedy Ultra				After tillering[4]		Yes
Sharpen				L		Yes
Spike 20P (pelleted)[8]				L	Spot	Yes
Stinger				L	Spot	Yes
Surmount (picloram + fluroxypyr)	VA, WV			After tillering[4]	Spot	Yes
Tordon				L	Spot	Yes
Vastlan				After tillering[4]	Spot	Yes
Weedmaster (dicamba + 2,4-D)			2 pt/A max[5]	L	Spot	Yes
Yukon			L	L	Spot	Yes

Use only in: If left blank, these products are available in Delaware, Maryland, New Jersey, Pennsylvania, Virginia, and West Virginia.
Establishment: Herbicide is applied preplant in no-till establishment to control existing weeds. There are currently no herbicides registered for preplant incorporated (PPI) or preemergence (PRE) applications in grass forage for residual weed control.
Seedling stand POST: Herbicide is applied postemergence (POST) to seedling grass that has reached a specific growth stage and is actively growing, or at a maximum allowable rate.
Established stand POST: Herbicide is applied POST to grass that has been established for a minimum length of time and is actively growing.
Spot-spray application: Herbicide is applied only to weed-infested areas of the field, usually with hand-held equipment. If the herbicide is labeled for seedling or established stands postemergence, then herbicide use rates, application timing, and minimum establishment periods should be observed unless otherwise stated on the label. Grazing, harvest, slaughter, and transfer restrictions still apply for all spot-spray applications.
Grazed fencerows: Herbicide is applied along a grazed fencerow to control emerged weeds and/or prevent seedling emergence. Use postemergence broadcast rates and timings unless grazed fencerows are specifically mentioned on the label. If the herbicide is labeled for spot applications, and the total area of the fencerows being treated is less than 10% of the total area inside the fencerows, spot application recommendations can be used. Grazing, harvest, slaughter, and transfer restrictions still apply for all applications to grazed fencerows.
[1] 2,4-D is manufactured by various companies; labels may vary among manufacturers.
[2] L = allowed on herbicide label with no specific grass size or establishment period restrictions.

Table 2.6-9. Application timings for herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Use Only in	Establishment	Seedling Stand POST	Established Stand POST	Spot-Spray or Wiper Applicator	Grazed Fencerows

[3] Most 2,4-D labels do not include spot-spray applications, while some do.
[4] Grasses should be tillering and have developed a good secondary root system.
[5] Labels state that "newly seeded areas" may be severely injured if rates greater than 1 pt/A (Clarity), 2 pt/A (Weedmaster), or 22 fl oz/A (FeXapan and XtendiMax) is applied, but no minimum size or growth stage is given. In practice, these products should not be applied until seedling grasses have attained the 3- to 4-leaf stage, have reached a minimum height of 6 inches, and are healthy and actively growing.
[6] This is labeled for mixed clover/grass stands after 2-trifoliate clover.
[7] Six months after establishment for bluegrass, bromegrass, and orchardgrass; 12 months for Timothy; 24 months for fescue.
[8] Spike is labeled for broadcast applications, but because it can persist for several years in the soil, it is generally only recommended for hand treatment of single plants, multistem clumps, or small stands of woody vegetation in land (including fencerows) dedicated to long-term grass pasture.

Table 2.6-10. Grass pasture, hay, and CRP grassland herbicide prepackaged mixes or co-packs and equivalents.

Trade Name	Components (lb ai/gal or lb ae/gal)	Site of Action Number	If You Apply (per acre)	You Have Applied (ai or ae)	An Equivalent Tank Mixture of
Chaparral 71.6WG	0.6213 lb aminopyralid	4	2.5 oz	0.098 lb aminopyralid	6.25 fl oz Milestone 2L
	0.0945 lb metsulfuron	2		0.015 lb metsulfuron	0.4 oz Metsulfuron 60DF
Cimarron Max (co-pack 60DF and 2.87L)	dry: 0.6 lb metsulfuron	2	dry: 0.4 oz	0.015 lb metsulfuron	0.4 oz Metsulfuron 60DF
	liquid: 1.87 lb 2,4-D	4	liquid: 1.6 pt	0.57 lb 2,4-D	1.2 pt 2,4-D amine 3.8L
	+ 1 lb dicamba	4		0.2 lb dicamba	6.4 fl oz Banvel 4S
Cimarron Plus 63WDG	0.48 lb metsulfuron	2	0.5 oz	0.015 lb metsulfuron	0.4 oz Metsulfuron 60DF
	0.15 lb chlorsulfuron	2		0.0047 chlorsulfuron	0.1 oz Telar 75DF
Crossbow 3L	2 lb 2,4-D	4	4 qt	2 lb 2,4-D	2 qt 2,4-D ester
	1 lb triclopyr	4		1 lb triclopyr	2 pt Remedy Ultra 4L
Curtail 2.38L	0.38 lb clopyralid	4	3 qt	0.285 lb clopyralid	12 fl oz Stinger 3L
	2 lb 2,4-D	4		1.5 lb 2,4-D	1.5 qt 2,4-D amine 3.8L
GrazonNext HL 3.74E	0.41 lb aminopyralid	4	2.1 pt	0.108 lb aminopyralid	6.9 fl oz Milestone 2L
	3.33 lb 2,4-D	4		0.9 lb 2,4-D	1 qt 2,4-D amine 3.8L
Grazon P+D 2.54SL	0.54 lb picloram	4	4 pt	0.27 lb picloram	1 qt Tordon 2L
	2 lb 2,4-D	4		1 lb 2,4-D	1 qt 2,4-D amine 3.8L
Huskie 2.06 EC	0.31 lb pyrasulfotole	27	15 fl oz	0.036 lb pyrasulfotole	0.31 lb pyrasulfotole
	1.75 lb bromoxynil	6		0.2 lb bromoxynil	13 fl oz Maestro 2EC
PastureGard HL 4SL	3 lb triclopyr	4	1.5 pt	0.75 lb triclopyr	1.5 pt Remedy Ultra 4L
	1 lb fluroxypyr	4		0.25 lb fluroxypyr	11 fl oz Vista XRT 2.8L
Prescott 3E	2.25 lb triclopyr	4	1.5 pt	0.42 lb triclopyr	0.84 pt Remedy Ultra 4L
	0.75 lb clopyralid	4		0.14 lb clopyralid	0.37 pt Stinger 3S
Surmount 1.34E	0.67 lb picloram	4	3 pt	0.34 lb picloram	1.4 pt Tordon 2L
	0.67 lb fluroxypyr	4		0.34 lb fluroxypyr	1 pt Vista XRT 2.8L
Weedmaster 3.87L	1 lb dicamba	4	4 pt	0.5 lb dicamba	1 pt Banvel 4S
	2.87 lb 2,4-D	4		1.44 lb 2,4-D	3 pt 2,4-D amine 3.8L
Yukon 67.5WDG	0.125 lb halosulfuron	2	6 oz	0.047 lb halosulfuron	1 oz Permit 75WG
	0.55 lb dicamba	4		0.206 lb dicamba	6.6 fl oz Clarity 4S

Table 2.6-11. Relative effectiveness of herbicides used in grass pasture, hay, and CRP grassland.

Trade Name (rate/acre)	2,4-D1 (2–3 pt)	2,4-D + dicamba1 (1 qt + 1 pt)	Aim (1–2 oz)	Chaparral (2–3 oz) (VA,WV)	Dicamba (1 pt)	Crossbow1 (2–4 qt)	DuraCor (12 to 20 fl oz/a) (PA, VA, WV)	GrazonNext HL (1.5–2.6 pt) (PA,VA,WV)	Grazon P+D (3–4 pt) (VA,WV)	Metsulfuron 60DF (0.1–0.3 oz)	Milestone (5–7 oz)	PastureGard HL (1–1.5 pt)	Remedy Ultra (2–4 pt)	Roundup/glyphosate (1–2 qt) (spot treatment)	Stinger (0.66–1.33 pt)	Surmount (1.5–3 pt) (VA, WV)
Site of Action Number	4	4	14	4/2	4	4/4	4/4	4/4	4/4	2	4	4/4	4	9	4	4/4
Winter Annuals																
Chamomile, mayweed	7	**10**	6	L	**8+**	8	—	7+	—	**10**	—	—	—	**9**	**9**	—
Chickweed, common	7	8	**8+**	**10**	7	**9**	**9**	**9**	8	**10**	7	8	7+	**10**	6	**9**
Cockle, corn	8	**10**	**9**	L	**10**	**8+**	—	—	—	L	—	—	—	**10**	N	—
Cockle, cow	8	**10**	**9**	**9+**	**10**	**8+**	—	—	—	**9**	—	—	—	**10**	N	—
Fleabane spp.	**9**	**10**	7	**9**	8	**9+**	L	8	**9**	**9**	L	—	—	**8+**	**9**	—
Henbit/deadnettle	6	**8+**	N	**9**	7+	**9+**	**9**	8	**9+**	**9**	**8+**	**8+**	7+	**9+**	—	**9**
Horseweed/marestail	**9**	**9**	N	**9**	**9**	**10**	L	**9**	**10**	**9**	**9+**	6	6	**9+**	**9+**	**9**
Mustard, garlic	N	8	7	8	7	8	—	—	—	8	—	—	8	8	N	—
Mustard spp.	**9**	**10**	**8+**	8	8	**10**	—	7+	7	**8+**	N	8	8	**10**	N	—
Pennycress, field	**9**	**10**	**8+**	**10**	8	**9+**	—	8	**10**	**9**	—	L	—	**10**	N	**9+**
Pepperweed spp.	**9**	**10**	**8+**	8	8	**9+**	L	8	7	**10**	N	8	8	**10**	N	—
Rocket, yellow	**9**	**10**	**9**	**8+**	**9**	**10**	—	8	—	**9**	—	—	—	**9**	6	—
Shepherdspurse	**8+**	**10**	**9**	**10**	8	**9**	—	8	—	**10**	—	—	—	**10**	N	—
Summer Annuals																
Amaranth, spiny	**9**	**10**	**9**	**8+**	**9**	**9**	L	8	7+	8	8	N	N	**9**	6	**9**
Cocklebur, common	**9**	**10**	8	**10**	**10**	**10**	L	**9**	**10**	**8+**	L	**8+**	**8+**	**9**	**9**	**9**
Groundsel, common	7	7	8	**9**	6	8	—	7	—	**9+**	—	—	—	**9**	**9**	L
Jimsonweed	8	**10**	**9**	**8+**	**10**	**9**	L	**9**	7	**9**	**8+**	—	—	**9**	8	7+
Lambsquarters, common	**10**	**10**	**9**	**9+**	**10**	**10**	**10**	**9**	**9+**	**9**	**9+**	**9**	**9**	**9**	6	**10**
Lettuce, wild/prickly	**9+**	**10**	**9**	**10**	**8+**	**9**	L	**9**	**10**	**9**	**9+**	**9**	—	**9**	**9**	**9**
Nightshade, eastern black	7+	**8+**	**9**	**8+**	**8+**	**8+**	—	7	6	8	**9**	6	—	**9**	8	L
Pigweed spp.	**9**	**10**	**9**	**9**	**9**	**9**	L	8	7	**10**	**9**	**9**	8	**9**	6	**9+**
Ragweed, common	**9**	**10**	7	**9**	**9**	**10**	**9**	**9**	**9+**	N	**9**	**9**	**8+**	**10**	**9+**	**9**
Ragweed, giant	**8+**	**10**	N	**9**	**9**	**10**	—	**9**	**9+**	N	**9**	**9**	**8+**	**10**	**9+**	**9**
Smartweed spp.	7	**9**	N	**9**	8	**9**	L	**9**	**9**	7	**8+**	N	—	**9**	**8+**	**9+**
Stiltgrass, Japanese[1]	N	N	N	N	N	N	7	7	N	N	7	N	N	**9**	N	N
Velvetleaf	**8+**	**10**	**9**	8	**10**	**9**	—	8	**8+**	8	—	**9**	—	**9**	6	**9**
Biennials																
Burdock, common	**9**	**10**	N	**8+**	8	**9**	L	8	**9+**	7	**9**	**9**	**9**	**9**	**9**	8
Carrot, wild	**9**	**10**	N	**10**	8	**9+**	**10**	8	**9+**	**9**	N	7	7	**9**	6	**8+**
Evening primrose, common	**9**	**10**	7+	**9**	8	**9+**	—	**9**	—	—	**9**	—	—	**10**	—	—

Table 2.6-11. Relative effectiveness of herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name (rate/acre)	2,4-D1 (2–3 pt)	2,4-D + dicamba1 (1 qt + 1 pt)	Aim (1–2 oz)	Chaparral (2–3 oz) (VA,WV)	Dicamba (1 pt)	Crossbow1 (2–4 qt)	DuraCor (12 to 20 fl oz/a) (PA, VA, WV)	GrazonNext HL (1.5–2.6 pt) (PA,VA,WV)	Grazon P+D (3–4 pt) (VA,WV)	Metsulfuron 60DF (0.1–0.3 oz)	Milestone (5–7 oz)	PastureGard HL (1–1.5 pt)	Remedy Ultra (2–4 pt)	Roundup/glyphosate (1–2 qt) (spot treatment)	Stinger (0.66–1.33 pt)	Surmount (1.5–3 pt) (VA, WV)
Evening primrose, cutleaf	**9**	**10**	N	**8+**	7	8	L	**9**	**9**	7+	**9**	8	8	6	—	—
Hemlock, poison	7+	**9**	7+	N	8	**9**	L	8	**8+**	N	N	N	N	**9**	N	8
Mullein, common	N	6	N	**9+**	N	N	L	—	7+	8	—	N	N	—	N	7+
Parsnip, wild	**9**	**10**	N	**9**	**9**	**10**	L	**8+**	**8+**	7	7	—	—	**9**	N	—
Teasel	7+	**10**	8	**9**	**9**	**8+**	L	**8+**	**8+**	6	**9**	—	—	**9**	**9**	—
Thistle, bull	**9+**	**10**	N	**9+**	**9**	**9+**	L	**9**	**9**	6	**9**	6	7	**9**	**9+**	**9**
Thistle, musk	**8+**	**10**	N	**9+**	**9**	**9+**	L	**9**	**9**	8	**9+**	6	7	**9**	**9+**	**8+**
Thistle, plumeless	**8+**	**10**	N	**9+**	**9**	**9+**	**10**	**9**	**9**	8	**9**	6	7	**9**	**9+**	**8+**
Herbaceous Perennials																
Aster spp.	**9**	**10**	N	**9**	**8+**	**9**	L	7	8	7	—	—	—	**9**	**9+**	—
Bedstraw, smooth	7	7	6	**9**	N	8	L	**9**	7	N	**9**	L	—	**9**	7	L
Bindweed, field	8	**8+**	6	—	**8+**	8	—	7	6	N	—	7	7	8	N	8
Bindweed, hedge	**9**	**10**	N	—	**9**	**9**	—	8	**8+**	N	—	7+	8	8	N	**8+**
Brackenfern	7	7	N	7	N	7+	—	7	—	7	—	—	—	6	—	—
Buttercup spp.	**8+**	**9**	7	**8+**	8	**10**	**10**	**9**	**10**	**9**	**8+**	8	8	**9**	8	**8+**
Catsear, common	7	**9**	N	**9**	7+	—	—	**9**	—	—	**9**	—	—	**8+**	—	—
Chickweed, mouseear	6	8	6	**10**	7+	**8+**	**9**	7	**9**	**10**	8	8	**8+**	**9**	6	**9**
Chicory	**9**	**10**	7	**9**	8	**9**	**9**	**9**	**9+**	7+	**9**	**9**	**8+**	**9**	**9**	**8+**
Clover spp.	7	**8+**	N	**10**	**8+**	**8+**	**9**	**9+**	**10**	**8+**	**9+**	**8+**	**9**	**10**	**9**	**10**
Cockle, white	7	**9**	6	8	**8+**	**9**	—	N	—	8	—	L	—	**9+**	**9**	L
Daisy spp.	**9**	**10**	N	**9**	**8+**	**9+**	L	**9**	8	6	**9**	—	—	**8+**	**8+**	—
Dandelion	**9+**	**10**	6	**8+**	7	**9+**	L	**9**	**9**	7+	**9**	8	7+	7	7	**9**
Dock spp.	8	**10**	7	**9**	8	**9**	**9**	**9**	**9**	**8+**	**9**	8	8	**9**	7+	**9**
Dogbane, hemp	6	7	N	N	7	8	—	6	7	N	N	7	7	8	6	**8+**
Dogfennel	7	7+	N	N	7	7	—	7	7+	6	N	**9**	8	8	6	**9**
Garlic or onion, wild	8	**8+**	N	**9**	7	8	—	6	N	**9+**	N	N	N	**9**	N	N
Goldenrod spp.	8	**8+**	N	8	7	8	—	8	**9**	8	6	7	7+	**9**	6	**9**
Groundcherry spp.	7	7+	7	**9**	7	**8+**	—	7	—	—	**9**	—	—	8	N	—
Hawkweed spp.	8	**9**	6	L	7+	**9**	L	8	6	7	L	—	—	**9**	8	—
Horsenettle	6	7+	N	**9**	7	8	**9**	**8+**	**9**	7	**9**	6	6	8	N	**8+**
Ironweed, tall	8	**9**	N	**8+**	**8+**	**9**	L	**9**	**9+**	N	8	7	6	**9**	6	**8+**
Knapweed, spotted	7	8	N	**8+**	7	7	L	**9**	**9**	6	**8+**	6	6	**9**	**9**	**8+**
Knotweed, Japanese	7	7+	6	7+	7+	7	—	7	N	—	7+	N	—	8	8	L
Lespedeza, sericea	N	N	N	6	N	7+	—	N	6	6	N	8	8	7	N	7
Milkweed, common	6	7	N	N	6	7	—	6	7	N	N	6	6+	7+	N	**8+**

Table 2.6-11. Relative effectiveness of herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name (rate/acre)	2,4-D1 (2–3 pt)	2,4-D + dicamba1 (1 qt + 1 pt)	Aim (1–2 oz)	Chaparral (2–3 oz) (VA,WV)	Dicamba (1 pt)	Crossbow1 (2–4 qt)	DuraCor (12 to 20 fl oz/a) (PA, VA, WV)	GrazonNext HL (1.5–2.6 pt) (PA,VA,WV)	Grazon P+D (3–4 pt) (VA,WV)	Metsulfuron 60DF (0.1–0.3 oz)	Milestone (5–7 oz)	PastureGard HL (1–1.5 pt)	Remedy Ultra (2–4 pt)	Roundup/glyphosate (1–2 qt) (spot treatment)	Stinger (0.66–1.33 pt)	Surmount (1.5–3 pt) (VA, WV)
Mugwort	6	7	6	8	7	8	L	8	7	7	8	—	—	7	**8+**	—
Nettle, stinging	8	**9**	6	8	8	**9**	—	**9**	**9**	6	**9**	**9**	**9**	**9**	7	**9**
Nightshade, bitter	7	**8+**	6	—	7	—	—	7	7	—	—	—	—	**9**	8	—
Plantain spp.	8	**10**	7	**9**	8	**9**	**10**	7+	**9**	**9**	N	**9**	8	**9**	N	**8+**
Pokeweed, common	7	7	N	6	7	**9**	L	8	7+	N	7+	N	N	8	N	**8+**
Snakeroot, white	8	**9**	7	—	**9**	**9**	—	8	8	N	—	—	—	8	N	—
Sorrel, red	6	**10**	**8+**	8	**8+**	—	—	—	**9**	**8+**	—	6	—	**9**	8	—
Sowthistle, perennial	7	**9**	N	**8+**	8	8	L	**9**	**9+**	7	**9**	8	8	**9**	8	—
Star-of-Bethlehem	N	N	**8+**	—	N	—	—	—	—	—	—	—	—	8	—	—
Thistle, Canada	7	7+	N	**9+**	7	8	**9**	**9**	**9**	7	**9**	8	6	8	**9**	7
Toadflax, yellow	7	8	**8+**	—	7+	—	—	7	—	—	—	—	—	8	N	—
Waterhemlock, spotted	7+	**9**	N	—	8	**9**	—	7	—	N	—	—	—	**9**	N	—
Wingstem	**8+**	**8+**	N	**9**	6	7+	L	**9**	**9**	N	**9**	6	7+	—	6	**8+**
Woodsorrel, yellow	7	7+	7	L	7	8	—	**8+**	—	**9**	—	—	—	**9**	8	—
Yarrow, common	7	**9**	N	L	**9**	**8+**	L	7	—	8	L	L	L	**9**	7	L
Woody Perennials																
Blackberry spp.	6	6+	N	L	6	8	—	N	7+	7	N	L	7+	8	7	8
Creeper, trumpet	6	7+	N	—	6	8	—	—	7	N	—	—	L	7+	N	7
Creeper, Virginia	7	**9**	N	—	8	**8+**	—	7	—	—	—	L	L	8	N	—
Dewberry spp.	6	7	N	L	6	7+	—	N	—	**8+**	—	—	—	7	7	7
Grape, wild	8	**9**	N	—	8	**9**	—	8	—	—	—	L	—	8	N	L
Honeysuckle spp.	7	7+	N	L	N	**8+**	—	7	8	**10**	—	L	—	8	N	L
Kudzu	N	6	N	8	6	6	L	8	**9**	N	8	7	7	—	—	—
Locust, black	7	**8+**	N	L	8	8	—	L	—	7	L	L	L	8	N	**9+**
Olive, autumn	7	8	N	—	7+	8	—	7	—	—	—	—	**9**	8	N	—
Poison-ivy, oak	7	**8+**	N	6	7+	**8+**	—	7	**8+**	6	—	L	L	8	N	7
Rose, multiflora	6	7+	N	8	6	**8+**	—	—	**8+**	**8+**	—	6	**8+**	8	N	7
Sumac spp.	6	7+	N	—	7	**8+**	—	L	7	N	—	L	L	8	7	8

Weed control rating: 10 = 95–100%; 9 = 85–95%; 8 = 75–85%; 7 = 65–75%; 6 = 55–65% ; L = weed is listed as control on herbicide label, but local data is limited; N = less than 55% or no control ; — = not applicable or no local data available

*Herbicide contains multiple active ingredients. See Table 2.6-10 for prepackaged mixture, or co-packs, and their constituents.

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rates and weed size or growth stage and proper timing of application (see Table 2.6-17). Results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH. Spike 20P also is available for control of problem woody perennials as well as some herbaceous perennials. See a Spike label for additional information. Some products show for which states they are registered under the rate. These products should only be used in the listed states.

[1] Japanese stiltgrass control in grass forages is inconsistent. Prowl H2O or Satellite HydroCap can be applied to established forage grasses in early spring to control germinating Japanese stiltgrass seedlings. Aminopyralid-containing products can provide some residual control when applied in the early spring. Currently there are no labeled, POST herbicides that effectively and selectively control stiltgrass without injuring the desirable forage grasses. Facet L (quinclorac) is labeled in grass forages and has activity on foxtails, crabgrass, barnyardgrass (<2" tall); but it has poor activity on Japanese stiltgrass and kills clover. Acclaim Extra (fenoxaprop) is not labeled in forages. Plateau controls stiltgrass but some cool season forages grasses are sensitive to it (see label for details). Pursuit also controls stiltgrass, but the label is ambiguous about its utility in grass forage settings.

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland.

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
2,4-D LVE 3.8L or	2,4-D	established: POST	1.5–3 qt	1.4–2.8 ae	yes
2,4-D amine 3.8L			1–2 qt	0.95–1.9 ae	

• 2,4-D is marketed by various companies with various trade names. Refer to the label provided with the product for specific recommendations and restrictions.
• Make application when grasses are well established, usually 4 to 5 inches tall with a good root system and tiller development.
• Make applications by ground in a minimum of 10 gal/A or by air in a minimum of 2 gal/A of water or liquid fertilizer.
• Do not make applications when the temperature is expected to exceed 80°F that day as drift is more likely to occur.
• Treat susceptible woody perennials in the spring after leaves are fully expanded.
• Ester formulations are slightly more effective (more leaf-absorbed) than amine formulations, but also slightly more volatile.
• 2,4-D labels vary concerning overseeding or crop rotation restrictions. Unless specified on the label, most crops can be safely planted 3 months after application under normal environmental conditions.
• *Water quality advisory.*

Aim 2EC	carfentrazone	seedling: POST	1–2 fl oz	0.016–0.032	yes
		established: POST			

• For new seedings apply to grasses that have at least 3 or 4 leaves.
• Aim is safe to legumes and clovers, but temporary injury may occur.
• Significant crop response may occur, but is temporary.
• Apply in a minimum of 10 gal/A of water or liquid fertilizer. Applying Aim in liquid fertilizer may increase the level of crop response.
• Applications made within 8 hours of rainfall or irrigation or when heavy dew is present may cause significant crop response.
• Aim has a relatively narrow spectrum of weed control and is primarily used for control of winter or summer annual broadleaf weeds up to 4 inches tall (emerged weeds only).
• Aim has activity on Star-of-Bethlehem, dayflower species, and speedwell species. Star-of-Bethlehem may require additional application at least 10 days after the first.
• Three applications per season are allowed, but do not make applications less than 7 days apart.
• There are no crop rotation or overseeding restrictions for labeled crops; see label.

Arsenal 2AS	imazapyr	grazed fencerows	1–3 pt	0.25–0.75	no
			0.4–1.2 fl oz/gal	0.3–0.9% v/v solution	

• Arsenal is labeled for spot treatment in grass pasture. However, due to its length of residual activity on cool-season grass species, bare spots in the pasture could persist for several months. Therefore, it is only recommended for use along permanent or long-term fencerows.
• This use falls under the spot treatment part of the label, so grazed fencerows can be treated so long as the total area to be treated is no more than 10% of the total pasture and fencerow areas combined.
• Arsenal provides postemergence and 3 to 6 months of soil residual control of many annual, biennial, and perennial grass and broadleaf weeds as well as several vine and brush species. DO NOT apply where Arsenal may contact the roots of desirable trees or other plants.
• Make applications with handheld equipment.
• Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff.
• Rotation crops can be planted 12 months after application and completion of a successful field bioassay.

Chaparral 71.6WG (VA and WV only)	aminopyralid + metsulfuron	established: POST	2–3.3 oz	0.078–0.128 + 0.012–0.019	yes
		seed head suppression	2–2.5 oz	0.078–0.098 + 0.012–0.015	
		spot treatment	0.025–0.033 oz/gal	0.02–0.026% w/v solution	

• Chaparral provides postemergence control and 2 to 3 months of soil residual control of many annual, biennial, and perennial weed species and suppression of blackberry and multiflora rose in permanent grass pasture.
• Apply by ground in a minimum of 10 gal/A or by air in a minimum of 2 gal/A of water or liquid fertilizer.
• High-volume foliar applications for brush control (volume not specified) are allowed; consult herbicide label for details.
• In general, Chaparral may be applied in the spring or early summer, depending on the target weed species, as a broadcast application over grass that was planted at least 4 months prior to the application and growing under favorable conditions for establishment. Grasses should have well-established root systems and be tillering.
• Smooth bromegrass may be more sensitive to applications of Chaparral than other perennial grasses, and temporary growth suppression may occur.
• Special precautions are provided on the label for applications to tall fescue to minimize injury and stunting. Make application later in spring after new growth is 5 to 6 inches tall or in the fall. Do not use more than 2 oz/A of Chaparral and tank-mix with 2,4-D. Use only a non-ionic surfactant (0.5 to 1 pt/100 gal) when mixing with water; do not use any adjuvant when mixing with liquid fertilizer. Adhere strictly to these precautions, or severe injury may occur. Even when these precautions are followed, some stunting, yellowing, or seed head suppression of fescue may occur.
• Do not use Chaparral on timothy, annual (Italian) ryegrass, or perennial ryegrass, or severe injury will occur.

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
• With fall applications, do not plant grasses the following spring; do not overseed ryegrass for 4 months after application. • Do not rotate to any crop within 1 year following treatment, or to any broadleaf crop until an adequately sensitive field bioassay shows that the aminopyralid level in soil will not adversely affect that broadleaf crop. Cereals and corn can be planted 1 year after treatment; most broadleaf crops require at least a 2-year wait until planting. • The Chaparral label has restrictions concerning the use and management of plant residues (hay, straw, mulch, compost) and manure that may contain aminopyralid residues. These include important restrictions concerning the movement and sale of hay products treated with aminopyralid. Be certain you understand and are able to follow these label restrictions before using this product. • For tall fescue seed head suppression and broadleaf weed control: Chaparral may be used to reduce the number of seed heads of tall fescue when applied prior to flower emergence. For best results apply 2 to 2.5 oz/A after initial greenup when grass height is approximately 6 inches. Later applications may still be effective; however, the seed head suppression will be less effective and the number of seed heads could be noticeably higher. Many weed species can be controlled with this application timing in addition to the suppression of seed head development. • Make spot applications with hand-held equipment. Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Spot treatments may be applied at equivalent broadcast rates of up to 6.6 oz/A (0.066 oz/gal), but no more than 50% of the acreage may be treated, and the total amount of Chaparral applied from all applications must not exceed 3.3 oz per acre per year. • A non-ionic surfactant should be added. • Repeat treatments may be made, but the total amount of Chaparral applied from all applications must not exceed 3.3 oz per acre per year. • *Water quality advisory.*					
Clarity 4S or dicamba	dicamba	seedling: POST	0.5–1 pt	0.25–0.5 ae	yes
		established: POST	0.5–2 pt	0.25–1 ae	
		spot treatment	0.2–1.6 fl oz/gal	0.16–1.25% v/v solution	
• Application to seedling grasses should not exceed 1 pt/A, and grasses should be actively growing, unstressed, and have attained the 3- to 4-leaf stage and 6 inches tall. For higher rates delay application until grasses are well established, usually 4–5 inches tall with a good root system and tiller development. • Apply in a minimum of 10 gal/A of water or liquid fertilizer, or by air in 2 to 40 gal/A of water. • High-volume foliar applications for brush control (up to 600 gal/A) are allowed; consult herbicide label for details. • Do not make applications when the temperature is expected to exceed 80°F that day as drift is more likely to occur. • Forage grasses or small grains can be overseeded after 30 days per pint of dicamba applied. • Legumes and other broadleaf crops may be planted 4 months after application. • Make spot applications with hand-held equipment. Do not treat more than one-tenth of the total area at any one time. • Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Clarity is also labeled for wiper applications. Consult the herbicide label for specific recommendations. • *Water quality advisory.*					
Crossbow 3E	triclopyr + 2,4-D	established: POST	1–6 qt	0.25–1.5 ae + 0.5–3 ae	yes
		spot treatment	1.5–2 fl oz/gal	1.2–1.6% v/v solution	
• Crossbow provides postemergence control and 1 to 2 months of soil residual control of many annual, biennial, and perennial weeds as well as many woody plants. • Apply only to grasses with well-established root systems that are tillering. • Apply to actively growing weeds or brush by ground or air (helicopter only) in 10 to 30 gal/A of water or liquid fertilizer. • For best results, treat biennial or winter annual weeds in the rosette stage. • Some hard-to-control perennial weeds and woody species may require retreatment. Use higher rates for less susceptible species. • High-volume foliar applications for brush control (100–200 gal/A) are allowed; consult herbicide label for details. • Follow all label recommendations to reduce the potential for spray drift or volatility to sensitive plants. • Crossbow will severely injure alfalfa, clover, and other legumes. • Forage grasses may be overseeded 21 days after application. Other crops can be planted the next growing season. • Make spot applications with hand-held equipment. • Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 ft2) to provide thorough coverage. • For best results, do not graze or harvest for 7 days after application, and make applications at least 7 days before a killing frost. • Do not spray to the point of runoff. • Water quality advisory.					
DuraCor SC (PA, VA, and WV only)	aminopyralid + florpyrauxifen-benzyl	seedling: POST; established: POST	12–20 fl oz	0.063–0.104 ae + 0.006–0.0105 ae	yes
		spot treatment	40 fl oz	1.46 v/v solution	
• Spot treatments may be applied at an equivalent broadcast rate of up to 40 fl oz of DuraCor (0.208 lb aminopyralid and 0.0209 lb florpyrauxifen-benzyl) per acre per annual growing season; however, not more than 50% of an acre may be treated at this rate.					

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
• Repeat treatments may be made, but the total amount of DuraCor applied must not exceed 20 fl oz per acre per year. • DuraCor can be applied at 12 fl oz of product per acre in early to mid-spring when weeds are less than 2 inches tall. Applications in this range are most effective when conditions are favorable to plant growth. • For longer residual control of susceptible late spring and early summer weed emergence, apply up to 20 fl oz of product per acre. Increasing application rate to the high end of the rate range specified will extend the period of residual control.					
Facet L 1.5SL	quinclorac	established: POST	12–64 fl oz	0.14–0.75 ae	no
		spot treatment	0.55–1.6 fl oz/gal	0.4–1.25% v/v solution	
• Facet L (formerly Paramount 75WDG) provides postemergence control and 1 to 2 months of soil residual control or suppression of several annual grass weeds, a few annual broadleaf weeds, and field or hedge bindweed. • Facet L is the only herbicide labeled for postemergence control of grass weeds in grass forage crops. Labeled grass weeds are barnyardgrass, large crabgrass, giant, green, and yellow foxtails, junglerice, and broadleaf signalgrass. • Rates greater than 32 fl oz/A and less than 22 fl oz/A are for leafy spurge control and bindweed maintenance, respectively. For broadleaf control apply 22 to 32 fl oz/A. For grass control apply at 32 fl oz/A with MSO at 1% v/v. • Use only on labeled established grasses (timothy and reed canarygrass not included) that have developed a good root system and are tillering. • Local experience indicates that Facet may cause more injury to orchardgrass than to the other labeled cool-season grasses. • Apply to actively growing plants by ground in a minimum of 5 gal/A of water. Aerial applications are not allowed in the Northeast region. • For best results apply to labeled grass and broadleaf weeds up to 2 inches tall and prior to grass tiller development. • Do not apply Facet when air temperature is more than 90°F. • Forage grasses can be overseeded 10 months after application. • Legume crops can be planted 24 months after application and completion of a successful field bioassay. • For spot applications, do not exceed the maximum per-area rates for broadcast application. Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • *Water quality advisory.*					
GrazonNext HL 3.74E (PA, VA, WV only)	aminopyralid + 2,4-D	established: POST	1.2–2.1 pt	0.062–0.108 + 0.5–0.9	yes
		spot treatment	0.5–0.9 fl oz/gal	0.4–0.7% v/v solution	
• GrazonNext provides postemergence control and 2 to 3 months of soil residual control of many annual, biennial, and perennial weed species in permanent grass pasture. • In general, it is best to wait 45 to 60 days after grass planting before applying GrazonNext. • Smooth bromegrass may be more sensitive to applications of GrazonNext than other perennial grasses, and temporary growth suppression may occur. • Apply by ground in a minimum of 10 gal/A or by air in a minimum of 2 gal/A of water or liquid fertilizer. • High-volume foliar applications for brush control (volume not specified) are allowed; consult herbicide label for details. • Grass can be overseeded in the fall after a spring or early summer application. • Do not rotate to any crop within 1 year following treatment or to any broadleaf crop until an adequately sensitive field bioassay shows that the aminopyralid level in soil will not adversely affect that broadleaf crop. Cereals and corn can be planted 1 year after treatment; most broadleaf crops require at least a 2-year wait until planting. • The GrazonNext label has restrictions concerning the use and management of plant residues (hay, straw, mulch, compost) and manure that may contain aminopyralid residues. These include important restrictions concerning the movement and sale of hay products treated with aminopyralid. Be certain you understand and are able to follow these label restrictions before using this product. • Make spot applications with hand-held equipment. Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Spot treatments may be applied at equivalent broadcast rates of up to 4.2 pt/A (1.7 fl oz/gal), but no more than 50% of the acreage may be treated, and the total amount of GrazonNext applied from all applications must not exceed 2.1 pints per acre per year. • A non-ionic surfactant should be added. • Repeat treatments may be made, but the total amount of GrazonNext applied from all applications must not exceed 2.1 pints per acre per year. • *Water quality advisory.*					
Grazon P+D 2.54SL (VA and WV only)	picloram + 2,4-D	established: POST	2–8 pt	0.14–0.54 + 0.5–2	yes
• Grazon P+D provides postemergence control and 2 to 3 months of soil residual control of many annual, biennial, and perennial weed species in permanent grass pasture. • The distribution of Grazon P+D may be further restricted within Virginia and West Virginia due to the picloram content of the product and sensitivity of certain broadleaf crops. • Apply to grasses that are well established as indicated by tillering, development of secondary root system, and vigorous growth. • Smooth bromegrass may be more sensitive to applications of Grazon P+D than other perennial grasses, and temporary growth suppression may occur. • Apply by ground in 10 to 40 gal/A or by air in a minimum of 2 gal/A of water, an oil-water emulsion, or liquid fertilizer. • High-volume foliar applications for brush control (100 gal/A) are allowed; consult herbicide label for details. • Cool-season grasses can be seeded a minimum of 21 days after application (60 days for smooth bromegrass).					

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
• Do not rotate to food or feed crops on treated land if they are not registered for use with picloram until an adequately sensitive field bioassay or chemical test shows that no detectable picloram is present in soil.• The Grazon P+D label has restrictions concerning the use and management of plant residues (hay, straw, mulch, compost) and manure that may contain picloram residues. Be certain you understand and are able to follow these label restrictions before using this product. • *Water quality advisory.* • *Restricted-use pesticide.*					
Metsulfuron 60DF	metsulfuron	established: POST	0.1–0.4 oz	0.004–0.015	yes
		seed head suppression	0.3–0.4 oz	0.011–0.015	
		spot treatment	0.01 oz/gal	0.008% w/v solution	
• Metsulfuron provides both postemergence control and 2 to 3 months of soil residual control of many annual, biennial, and perennial weed species, and suppression of blackberry and multiflora rose in permanent grass pasture. • Apply by ground in a minimum of 10 gal/A or by air in 2 to 5 gal/A of water or liquid fertilizer. • Postemergence applications are rainfast in 4 hours, after which rainfall or overhead irrigation is required to activate the herbicide in the soil. • Applications up to 0.4 oz/A may be made to grasses that have been established for a minimum amount of time as follows: bermudagrass (2 months); bluegrass, bromegrass, and orchardgrass (6 months); timothy (12 months); and fescue (24 months). • Special precautions are provided on the label for applications to fescue or timothy. Apply to fescue in late spring or fall or to timothy in late summer or fall. Either species should be at least 6 inches tall and actively growing. Use the lowest recommended rate of metsulfuron (up to 0.4 oz/A) for the target weeds and tank-mix with 2,4-D for added safety. Use only a non-ionic surfactant at 0.5 pt/100 gal when mixing with water; do not use any adjuvant when mixing with liquid fertilizer. Adhere strictly to these precautions, or severe injury may occur. Even when these precautions are followed, some stunting or yellowing of timothy or fescue may occur. • Do not use metsulfuron on annual (Italian) or perennial ryegrass, or severe injury will occur. • Overseeding intervals for grasses are specific to region, soil pH, metsulfuron rate, and grass species. In our region with soils of pH 7.5 or less, the interval range is from 6 to 34 months (see label). • Metsulfuron is persistent in soil; rotation to most broadleaf crops is 34 months or completion of a successful field bioassay. • Cimarron Max is a co-pack that contains the active ingredients of metsulfuron and 2,4-D plus dicamba. • Cimarron Plus is a premix with the active ingredients metsulfuron and chlorsulfuron (Glean or Telar). • For tall fescue seed head suppression and broadleaf weed control: Metsulfuron may be used to reduce the number of seed heads of tall fescue when applied prior to flower emergence. For best results apply 0.3 to 0.4 oz/A after initial greenup when grass height is approximately 6 inches. Later applications may still be effective; however, the seed head suppression will be less effective and the number of seed heads could be noticeably higher. • Spot treatment with metsulfuron is effective for suppression or control of multiflora rose, blackberry, and Canada thistle. Make applications with hand-held equipment. Apply 1 oz/100 gal (0.28 gr/gal) on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff, but dense stands of brush may need to be treated form both sides to achieve adequate coverage. • A non-ionic surfactant at 2 to 4 pt/100 gal should be added. • Make applications after plants are fully leafed in the spring up through late summer.					
Milestone 2E	aminopyralid	established: POST	3–7 fl oz	0.047–0.109 ae	yes
		spot treatment	0.13–0.36 fl oz/gal	0.1–0.3% v/v solution	
• Milestone provides postemergence control and 2 to 3 months of soil residual control of many annual, biennial, and perennial weed species in permanent grass pasture. • In general, it is best to wait 45 to 60 days after grass planting before applying Milestone. • Smooth bromegrass may be more sensitive to applications of Milestone than other perennial grasses, and temporary growth suppression may occur. • Apply by ground in a minimum of 10 gal/A or by air in a minimum of 2 gal/A of water or liquid fertilizer. • High-volume foliar applications for brush control (volume not specified) are allowed; consult herbicide label for details. • Grass can be overseeded the fall after a spring treatment. • Do not rotate to any crop within 1 year following treatment or to any broadleaf crop until an adequately sensitive field bioassay shows that the aminopyralid level in soil will not adversely affect that broadleaf crop. Cereals and corn can be planted 1 year after treatment; most broadleaf crops require at least a 2-year wait until planting. • The Milestone label has restrictions concerning the use and management of plant residues (hay, straw, mulch, compost) and manure that may contain aminopyralid residues. Follow the label restrictions carefully. • Make spot applications with handheld equipment. Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • Spot treatments may be applied at equivalent broadcast rates of up to 14 fl oz/A (0.32 fl oz/gal), but no more than 50% of the acreage may be treated, and the total amount of Milestone applied from all applications must not exceed 7 fl oz per acre per year. • A non-ionic surfactant should be added. • Repeat treatments may be made, but the total amount of Milestone applied from all applications must not exceed 7 fl oz per acre per year. • *Water quality advisory.*					

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
PastureGard HL 4L	triclopyr + fluroxypyr	established: POST	0.75–4 pt	0.28–1.5 ae + 0.094–0.5 ae	not recommended
		spot treatment	0.2–1.5 fl oz/gal	0.16–1.2% v/v solution	

• PastureGard provides postemergence control and 1 to 2 months of soil residual control of many annual, biennial, and perennial weeds as well as many woody plants.
• Apply to actively growing weeds or brush by ground in a minimum of 5 gal/A or by air in a minimum of 3 gal/A (nonwoody broadleaf weeds) or 4 gal/A (woody plants) of water.
• For brush control, high-volume foliar applications (50 to 100 gal/A), basal methods, and cut stump methods are allowed; consult herbicide label for details.
• For best results treat blackberry either before first flower or after fruit drop.
• Some hard-to-control woody species may require retreatment.
• Apply only to grasses with well-established root systems that are tillering.
• Forage grasses or small grains can be overseeded 21 days after application.
• Other crops can be planted 4 months after application.
• For spot treatments apply at rates equivalent to broadcast application rates. Refer to weed rate tables of the herbicide label and apply the recommended per gallon concentration above on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff.
• *Water quality advisory.*

Permit/Sandea 75WDG	halosulfuron	established: POST	0.67–1.3 oz	0.031–0.063	no
		spot treatment	0.019 oz/gal	0.016% w/v solution	

• Sandea provides excellent postemergence control of yellow nutsedge and has both preemergence (3 to 4 weeks soil residual) and/or postemergence activity on several annual broadleaf weeds.
• Apply by ground in a minimum of 10 gal/A water or by air in 3–15 gal/A water.
• For best results, spray actively growing nutsedge plants at the 3- to 5-leaf stage and susceptible broadleaf plants that are 1 to 3 inches tall.
• Heavy nutsedge infestations may require additional applications.
• Wait at least 48 hours after application before irrigation.
• Yukon is a premix of Sandea and dicamba.
• Forage grasses, small grains, sorghum, and corn can be overseeded 2 months after application.
• Legume forages can be planted 9 months after application; see label for other broadleaf crops.
• Apply Sandea as a postemergence spot treatment only to those areas of emerged nutsedge. Do not exceed a rate of 0.75 oz/A (0.019 oz/gal). Apply on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. A second postemergence spot application at 0.75 oz/A is allowed where nutsedge has emerged or regrown. Follow the same procedures as first application. The potential for injury to desirable broadleaf and grass plants is increased with a second application.
• *Water quality advisory.*

Prowl H2O 3.8AS/ Satellite HydroCap	pendimethalin	established POST (fall, winter, spring); between cuttings	1.1–4.2 qt	1–4	yes

• Prowl H2O will not control any weeds that have already emerged at the time of application.
• Provides 1 to 2 months of residual control of most annual grass weeds and a few broadleaf weeds as they germinate (refer to label for weeds controlled).
• An early April application may be required to control annual grasses such as foxtails (annual species only), jointhead arthraxon, crabgrass, and others as well as suppression of Japanese stiltgrass
• Applications may be made in fall after last cutting/grazing, in winter, spring, or between cuttings (but before weed emergence).
• Apply to solid (established) stands of perennial forage grasses with a minimum of 6 tillers.
• Apply by ground in a minimum of 10 gal/A or by air in a minimum of 5 gal/A of water or liquid fertilizer.
• Adequate rainfall or overhead irrigation is required to activate Prowl H2O.
• Multiple applications are allowed; however, maximum use rate of Prowl H2O is 4.2 qt/A per year with 30 days between sequential applications.
• Adverse environmental conditions or weak stands of grass may cause temporarily injury.
• Do not apply to mixed stands with forage legumes other than alfalfa.
• Crop rotation restrictions are based on Prowl rate used, precipitation, and application timing; see label.

Remedy Ultra 4L	triclopyr	established: POST	0.5–4 pt	0.25–2 ae	yes

• Remedy Ultra provides postemergence control and 1 to 2 months of soil residual control of many annual, biennial, and perennial weeds as well as many woody plants.
• Apply to actively growing weeds or brush by ground in a minimum of 10 gal/A or by air in a minimum of 2 gal/A (non-woody broadleaf weeds) or 4 gal/A (woody plants) of water or liquid fertilizer.
• Do not use liquid fertilizer as the carrier when treating woody plants (brush).

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
• For brush control, high-volume foliar applications (100 to 200 gal/A), basal methods, and cut stump methods are allowed; consult herbicide label for details. • Biennial or winter annual weeds are most susceptible while in the rosette stage. • For best results treat blackberry during or after bloom. • Some hard-to-control woody species may require retreatment. • Apply only to grasses with well-established root systems that are tillering. • Forage grasses can be overseeded 21 days after application. • Other crops can be planted the next season after application. • *Water quality advisory.*					
Roundup 3S or Roundup Weather-MAX4.5S	glyphosate	spot treatment	2.5 fl oz/gal	2% v/v solution	no
• Glyphosate controls emerged weeds only (no residual activity). • Make applications with hand-held equipment or wiper applicators. Avoid contact with desirable vegetation. Consult the herbicide label for specific wiper applicator recommendations. • At rates up to 2 qt/A, any portion up to the entire field may be treated. For rates above 2 qt/A, apply only to weed-infested areas of the field, and do not treat more than one-tenth of the total area at any one time. • Subsequent applications to the same areas can be made at 30-day intervals. • Refer to weed rate tables of the herbicide label for the recommended herbicide concentration. • For spot treatment, apply on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. • There are no overseeding restrictions for spot treatment with glyphosate.					
Sharpen 2.85SC	saflufenacil	established: dormant; established: POST	1–2 fl oz	0.022–0.044	yes
• Sharpen has a relatively narrow spectrum of weed control and is primarily used for control of winter or summer annual broadleaf weeds up to 6 inches tall. It primarily controls emerged weeds but has some very short (1 to 2 weeks at the labeled rates) residual activity. • Apply by ground in a minimum of 5 gal/A water or 20 gal/A liquid fertilizer, or by air in a minimum of 3 gal/A water. • Make dormant applications in the fall, during the winter, or in early spring before greenup. • Make in-season applications before weeds reach the maximum size (usually 3 to 6 inches) listed on the weed table of the label. • Sharpen may cause transitory injury to forage grasses. • There are no replant restrictions for forage grasses, small grains, or sorghum at the 2 fl oz/A rate. • For other crops, rotation restrictions are up to 5 months at the 2 fl oz/A rate; see label. • *Water quality advisory.*					
Spike 20P	tebuthiuron	established: POST	10–20 lb	2–4	n/a
		individual plant	0.4–0.7 oz/100 sq ft	2–4	
• Spike 20P is a pelleted formulation for control of woody plants (trees, shrubs, etc.) and vines. • Apply by hand evenly over the area occupied by individual plants, multistem clumps, or small stands of woody vegetation. • For multiflora rose control, apply Spike in early spring after ground thaw and before multiflora rose growth. • Requires rainfall to move herbicide to root zone. • Make only one application per year. • Desirable grasses or legumes in the treated area may be injured or killed. Dormant season application is recommended to minimize herbicidal activity on forage grasses. • For best results, do not disturb treated plants by wood cutting or removal for 2 years after application. • Poor or erratic results are likely to occur in soils containing more than 5% organic matter or more than 30% clay, and in areas where woody plants are rooted directly in a shallow water table. • Spike can persist in the soil for several years, and should therefore only be used on land dedicated to long-term grass forage production unless severe herbicide injury to legumes, row crops, shrubs, or trees can be tolerated in treated areas for several years. A field bioassay is required before planting sensitive crops. • Do not apply Spike 20P in the vicinity of desirable plants. Exposure of even a small part of a plant root system to Spike may cause severe plant injury or death. Treatment setback distance from desirable plants should be one to two times the height or width of adjacent non-target vegetation, whichever is greater. Avoid applications on slopes where surface water or groundwater flow toward desirable vegetation. • Do not apply more than 10 lb/A on "vulnerable sites" as described on the herbicide label under "Use Restrictions for Groundwater Protection." Do not apply in areas where the water table is predominately shallow (5 feet or less), to interior ditch banks, or to ditches used to transport irrigation water or potable water. Do not apply within areas identified by state or local authorities as protected groundwater recharge zones. • *Water quality advisory.*					

Table 2.6-12. Comments on herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Common Name	Application Timing	Product/A	lb ai/A	Apply in Liquid Fertilizer as a Carrier
Stinger 3S	clopyralid	established: POST	0.66–1.3 pt	0.25–0.50 ae	no
		spot treatment	0.13–0.5 fl oz/gal	0.1–0.4% v/v solution	

• Stinger provides postemergence control and 1 to 3 months of soil residual control of some annual, biennial, and perennial broadleaf weeds, but it is primarily used for Canada thistle control.
• Apply to actively growing weeds by ground in a minimum of 10 gal/A of water. Do not apply by aircraft.
• For Canada thistle, apply in rosette stage or after thistle is at least 4 inches tall, but before the bud stage.
• Multiple treatments are allowed as long as all treatments do not exceed 1.33 pt/A during a growing season.
• Apply only to actively growing well-established grasses that are tillering and have developed secondary roots.
• The Stinger label has restrictions concerning the use and management of plant residues (hay, straw, mulch, compost) and manure that may contain herbicide residues. Follow the label recommendations carefully.
• There are no overseeding restrictions for forage grasses, small grains, or field corn.
• Most broadleaf crops can be planted 10.5 to 18 months after application; see label.
• Spot treatment with Stinger is primarily for Canada thistle control. Refer to weed rate table of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff.
• *Water quality advisory.*

Surmount 1.33L (VA and WV only)	picloram + fluroxypyr	established: POST	3–6 pt	0.25–0.5 + 0.25–0.5	yes
		spot treatment	0.6–1.1 fl oz/gal	0.5–0.85% v/v solution	

• Surmount provides postemergence control and 2 to 3 months of soil residual control of many annual, biennial, and perennial weed species in permanent grass pasture. It may provide improved control of hemp dogbane, milkweed, dewberry, or sumac species over Grazon P+D.
• The distribution of Surmount may be further restricted within Virginia and West Virginia due to the picloram content of the product and sensitivity of certain broadleaf crops.
• Apply to grasses that are well established as indicated by tillering, development of secondary root system, and vigorous growth.
• Apply by ground in a minimum of 10 gal/A or by air in a minimum of 5 gal/A of water, an oil-water emulsion, or liquid fertilizer.
• High-volume foliar applications for brush control (100 gal/A) are allowed; consult herbicide label for details.
• Cool-season grasses can be seeded a minimum of 21 days after application.
• Do not rotate to any crop within 1 year following treatment other than range or pasture grasses, grasses for hay or silage, barley, oats, rye, or grain sorghum. Thereafter, other crops may be planted after an adequately sensitive field bioassay shows that the risk of crop injury is within acceptable limits.
• The Surmount label has restrictions concerning the use and management of plant residues (hay, straw, mulch, compost) and manure that may contain picloram residues. Be certain you understand and are able to follow these label restrictions before using this product.
• Spot treatment with hand-held sprayers should be applied at a rate equivalent to a broadcast application. Refer to weed rate table of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff.
• Make applications at least 7 days before a killing frost.
• *Water quality advisory.*
• *Restricted-use pesticide.*

Weedmaster 3.87L	dicamba + 2,4-D	seedling: POST	0.5–2 pt	0.06-0.25 + 0.18–0.72	yes
		established: POST	1–4 pt	0.125–0.5 + 0.36–1.4	
		spot treatment	0.4–1.6 fl oz/gal	0.3–1.25% v/v solution	

• For broadcast applications, apply by ground in 5–40 gal/A of water or liquid fertilizer or by air in 3–10 gal/A of water.
• For brush control, foliar and basal applications in oil and water emulsions and cut surface applications are allowed; consult herbicide label for details.
• Applications to newly seeded areas should not exceed 2 pt/A and should only be applied to actively growing unstressed grasses that have attained the 3- to 4-leaf stage and have reached a minimum height of 6 inches.
• Multiple applications are allowed on established grasses as long as all treatments do not exceed 8 pt/A during a growing season.
• Do not make applications when the temperature is expected to exceed 80°F that day, as drift is more likely to occur.
• Forage grasses and small grains can be overseeded after 10 days per pint of Weedmaster applied.
• Legumes and other broadleaf crops may be planted 4 months after application.
• Make spot applications with hand-held equipment. Refer to weed rate tables of the herbicide label and apply the recommended concentration on a spray-to-wet basis (1 gal/1,000 sq ft) to provide thorough coverage. Do not spray to the point of runoff. Do not make spot treatments in addition to broadcast treatments.
• Weedmaster is effective on many woody species as a spot spray at the higher rates.
• Add a surfactant at 0.5% v/v for improved control.
• *Water quality advisory.*

The following comments apply to all herbicides, unless otherwise noted in the table: Apply postemergence to actively growing broadleaf weeds. Treat biennials in the rosette stage of growth. Higher rates or repeat treatments may be required for less susceptible species, perennial weeds, and woody plants. For maximum efficacy, do not mow, graze, hay, or disturb the treated area for 7 days after application. Make applications at least 7 days before a killing frost. These herbicides will severely injure alfalfa, clover, and other legumes. Do not use if loss of desirable legume species cannot be tolerated. Follow label recommendations to reduce the potential for spray drift or volatility to sensitive plants.

Table 2.6-13. Adjuvants and rainfastness for postemergence herbicides used in grass pasture, hay, and CRP grassland.

Trade Name	Adjuvant(s)	Rate	Apply in Liquid Fertilizer as a Carrier	Rainfastness (hours)
2,4-D amine 3.8L	none recommended[1] or	1 qt/100 gal	yes	1
	non-ionic surfactant[2] or	1–2 qt/A		
	crop oil concentrate[2]			
2,4-D ester 3.8L	none recommended[1] or	1 qt/100 gal	yes	1
	non-ionic surfactant[2] or	1–2 qt/A		
	crop oil concentrate[2]			
Aim 2EC	non-ionic surfactant or	1 qt/100 gal	yes	not specified
	crop oil concentrate or	1 gal/100 gal		
	methylated seed oil plus	1 gal/100 gal		
	nitrogen solution or	2–4 gal/100 gal		
	ammonium sulfate (optional)	2–4 lb/A		
Arsenal 2AS	non-ionic surfactant or	1 qt/100 gal	N/A	1
	methylated seed oil	1.5–2 pt/A		
Chaparral 71.6WG[3]	crop oil concentrate or	1 gal/100 gal	yes	not specified
	methylated seed oil or	0.5–1 gal/100 gal		
	non-ionic surfactant plus	1 qt/100 gal		
	nitrogen solution or	2 qt/A		
	ammonium sulfate (optional)	2 lb/A		
Clarity	non-ionic surfactant or	1–2 pt/100 gal	yes	4
	crop oil concentrate plus	1 qt/A		
	nitrogen solution or	2–4 qt/A		
	ammonium sulfate (optional)	2.5 lb/A		
Crossbow 3L	none recommended		yes	not specified
DuraCor SC	methylated seed oil or	1 %v/v	yes	2
	non-ionic surfactant	0.25-0.5 v/v		
Facet 1.5L	crop oil concentrate or	2 pt/A	no	6
	methylated seed oil plus	1–2 pt/A		
	nitrogen solution or	2–4 qt/A		
	ammonium sulfate (optional)	8.5 lb/100 gal		
Glyphosate preplant or spot treatment	varies by product; check label	see label	no	1–6
	ammonium sulfate (optional)	8.5–17 lb/100gal		
Gramoxone SL 2.0 Gramoxone SL 3.0	non-ionic surfactant or	1 qt/100 gal	yes	0.5
	crop oil concentrate	1 gal/100 gal		
GrazonNext HL 3.74E	non-ionic surfactant	1–2 qt/100 gal	yes	not specified
Grazon P+D 2.54SL	non-ionic surfactant[1]	1 qt/100 gal	yes	not specified
MCPA 3.7L	none recommended		yes	not specified
Metsulfuron 60DF	non-ionic surfactant or	1–2 qt/100 gal	yes	4
	non-ionic surfactant (on fescue)	0.5–1 pt/100 gal		
	non-ionic surfactant (on timothy)	0.5 pt/100 gal		

Table 2.6-13. Adjuvants and rainfastness for postemergence herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Adjuvant(s)	Rate	Apply in Liquid Fertilizer as a Carrier	Rainfastness (hours)
Milestone 2L	non-ionic surfactant	1–2 qt/100 gal	yes	not specified
PastureGard HL 4L	non-ionic surfactant[4] or	1–2 qt/100 gal	not recommended	not specified
	nitrogen solution[4]	1–2 qt/100 gal		
Permit/Sandea 75DF	non-ionic surfactant	1–2 qt/100 gal	no	4
Prowl H2O 3.8AS	none recommended		yes	not applicable
Remedy Ultra 4L	non-ionic surfactant[1]	1 qt/100 gal	yes	not specified
Sharpen 2.85SC	methylated seed oil	1 gal/100 gal	yes	1
	plus ammonium sulfate (dormant only)	8.5–17 lb/100 gal		
Stinger 3S	not recommended[5]		no	6
Surmount 1.33L	non-ionic surfactant[2] or	1–2 qt/100 gal	yes	not specified
	nitrogen solution[2]	1–2 qt/100 gal		
Weedmaster 3.87L	non-ionic surfactant plus	2–4 pt/100 gal	yes	4
	nitrogen solution (optional)	2–4 qt/A		

Adjuvants are products included in the spray tank to improve the performance of herbicides. These include non-ionic surfactant (NIS), crop oil concentrate (COC), methylated seed oil (MSO), or nitrogen solutions. In general, NIS should contain at least 80% active ingredient, and COC should contain at least 15% emulsifier. Nitrogen solutions can be 28, 30, or 32% ammonium-based fertilizer solutions; ammonium sulfate should be spray-grade dry ammonium sulfate (21-0-0). Crop injury can occur with the use of adjuvants. Adding additional adjuvants other than what is labeled can increase the chance or severity of crop injury. Following are recommended adjuvants for broadcast postemergence applications; refer to herbicide labels for adjuvant recommendations with other application types. Rainfastness is number of hours needed between time of application and rainfall or irrigation to ensure sufficient absorption in the plant.

[1] An adjuvant is allowed, but not required, in water dilutions to provide improved wetting of the foliage.

[2] An adjuvant is recommended for control of woody plants only.

[3] See fescue precautions on herbicide label for specific adjuvant recommendations.

[4] An adjuvant is allowed for improved weed or woody plant control, especially when plants are drought stressed.

[5] The label states that the addition of adjuvants is not usually necessary and that adding a surfactant to the spray mixture may increase effectiveness on weeds but may reduce selectivity to the crop, particularly under situations of plant stress.

Table 2.6-14. Grazing, harvest, haying, and slaughter restrictions for herbicides used in grass pasture, hay, and CRP grassland.

Trade Name	Type of Animal	Interval between Application and Grazing	Interval between Application and Green Harvest[1]	Interval between Application and Haying	Comments
2,4-D amine or	Lactating dairy	7 days	—[2]	7 days	Remove meat animals from treated area 3 days before slaughter; 2,4-D labels vary; see specific label of product used
2,4-D LVE	Other livestock	0	—	7 days	
Aim (carfentrazone)	All	0	0	0	Slaughter restrictions are not mentioned on label
Chaparral (aminopyralid + metsulfuron)	All	0	—	0	No slaughter restrictions
Cimarron Plus (metsulfuron + chlorsulfuron)	All	0	0	0	Be cautious of crop rotation restrictions; see label for details
Clarity (dicamba)	Lactating dairy	7 days if < 1 pt		37 days if < 1 pt	Remove meat animals from treated areas 30 days prior to slaughter
		21 days if 1–2 pt	—	51 days if 1–2 pt	
		40 days if 2–4 pt		70 days if 2–4 pt	
	Other livestock	0	—	7 days	
Crossbow (2,4-D + triclopyr)	Lactating dairy	Do not graze until next season	—	14 days	Remove meat animals from treated areas or dried hay 3 days prior to slaughter
	Other livestock	0	—	14 days	
DuraCor SC (aminopyralid + florpyrauxifen-benzyl	All	14 days	18 months	14 days	Do not move hay or silage made from grass treated with DuraCor within the preceding 18 months off farm unless allowed by supplemental labeling.
Facet L (quinclorac)	All	0	—	7 days	No slaughter restrictions on the label
GrazonNext HL (aminopyralid + 2,4-D)	All	0	—	7 days	Do not transfer grazing animals for 3 days from treated areas to areas with Milestone-sensitive species; do not spread manure to areas where sensitive species are or will be grown
Grazon P+D (picloram + 2,4-D)	Lactating dairy	7 days	—	30 days	Remove meat animals from treated area 3 days before slaughter
	Other livestock	0	—	30 days	
Metsulfuron	All	0	0	0	Do not seed to other crops for 1 or more years; see label for restrictions
Milestone (aminopyralid)	All	0	0	0	Do not transfer grazing animals for 3 days from treated areas to areas with Milestone-sensitive species; do not spread manure to areas where sensitive species are or will be grown
PastureGard HL (triclopyr + fluroxypyr)	All	0	0	14 days	Remove meat animals from treated areas at least 3 days before slaughter

Table 2.6-14. Grazing, harvest, haying, and slaughter restrictions for herbicides used in grass pasture, hay, and CRP grassland (continued).

Trade Name	Type of Animal	Interval between Application and Grazing	Interval between Application and Green Harvest[1]	Interval between Application and Haying	Comments
Permit/Sandea (halo-sulfuron)	All	0	37	37	0-day preslaughter interval
Prowl H2O (pendimethalin)	All	0	0	0	Mixed-stand alfalfa/cool-season forage grasses may be grazed or harvested for forage or hay 14 or more days after applying Prowl H2O
Remedy Ultra (triclopyr)	All	0	0	14 days	Remove meat animals from treated areas at least 3 days before slaughter
Roundup/glyphosate	All	Spot: 7 days	Spot: 7 days	Spot: 7 days	Use as spot treatment; do not treat more than one-tenth of any acre; leaves no soil residue
		Renovate: 56 days	Renovate: 56 days	Renovate: 56 days	
Sharpen (saflufenacil)	All	0	0	0	No slaughter restrictions on the label
Spike (tebuthiuron)	All	0 if < 20 lb/A	—	1 year	Leaves soil residue up to 2 years
Stinger (clopyralid)	All	0	0	0	Do not use hay or straw from treated areas for compost or mulch on susceptible broad-leaved crops
Surmount (picloram + fluroxypyr)	Lactating dairy	14	14	14	Remove meat animals from treated areas at least 3 days before slaughter
	Other livestock	0	0	0	
Weedmaster (dicamba + 2,4-D)	Lactating dairy	7	37	37	Remove meat animals from treated areas 30 days prior to slaughter
	Other livestock	0	37	37	

[1] Green harvest includes harvest for silage, green-chop, or haylage.
[2] — = interval not specified on the label.

Table 2.6-15. Herbicides labeled for use in CRP acres.

Trade Name	CRP Grass Same as Forage (use guide)	Specific CRP Grass Section (see label)	Labeled for CRP Grass, Not Forage (see label)	Specific CRP Legume Section (see label)	Labeled for CRP Legume, Not Forage (see label)
2,4-D amine/ester	POST				
2,4-DB/Butyrac 200			POST	POST	
Aim	POST				
Chaparral[1]	POST				
Cimarron Max		POST			
Cimarron Plus		POST			
Clarity/dicamba		POST			
Crossbow	POST				
DuraCor[2]	POST				
Facet	POST				
Glyphosate		Preplant, renovation, or dormant POST		Preplant or renovation	
Gramoxone SL		Preplant		Preplant	
GrazonNext HL[2]	POST				
Grazon P+D[1]	POST				
Huskie	POST				
Journey			preplant[3]		Preplant
Kerb			POST		
MCPA		POST		POST	
Maestro			POST	POST	
Metsulfuron	POST[4]				
Milestone	POST				
PastureGard		POST			
Plateau			PRE[3] or POST[3]		PRE or POST
Permit/Sandea	POST				
Poast				POST	
Prowl EC/pendimethalin					PPI or PRE
Pursuit			POST	POST	
Remedy Ultra	POST				
Starane Ultra			POST		
Stinger		POST			
Telar XP			POST		
Weedmaster		POST			

This table contains herbicides that are available for use on Conservation Reserve Program (CRP) acres seeded to grasses or legumes. Many products labeled for use on grass forage have the same label requirements for CRP grasses. These uses are listed in the first column of the table, and the grass forage section of this guide also applies to use on CRP acres. Some products labeled for use on grass or legume forage can be used on CRP acres but have specific label recommendations or supplemental labels for CRP acres (columns 2 and 4). Other products are not labeled for use on forages grown in Delaware, but their use is allowed on CRP acres (columns 3 and 5). When choosing products for CRP acres, it is very important to consult the herbicide labels to determine non-target plant, environmental, and human risks, grass or legume species tolerance, weed species susceptibility, use rates, rotational crop or overseeding restrictions, and adjuvant requirements.

[1] For Virginia and West Virginia only.

[2] For Pennsylvania, Virginia, and West Virginia only.

[3] Primarily for use on warm-season grasses.

[4] Not on all metsulfuron labels.

Table 2.6-16. Herbicides labeled for summer annual grass crops.

Herbicide	Labeled Annual Grasses	Timing*/Weed Type	Use Rate per Acre	Crop Stage	Season Maximum Rate	Grazing/Harvest Interval (days)	Rotation to Grasses (months)	Rotation to Small Grains (months)	Rotation to Alfalfa/Clover (months)
2,4-D	Forage sorghum, sorghum-sudan hybrid	POST/broadleaf	0.5 to 2.1 pt	At least 6 leaves and 5 to 10 inches tall	2.1 pt (1 appl.)	30	1	after harvest	after harvest
Aim[1]	Teff, crabgrass	POST/broadleaf	0.5 to 2 fl oz	Any	5.9 fl oz (3 appl.)	0	0	0	12/12
Aim[1]	Millets	POST/broadleaf	0.5 to 2 fl oz	Up to jointing	2 fl oz	7	0	0	12/12
Aim[1]	Forage sorghum	POST/broadleaf	0.5 to 1 fl oz	Up to 6-leaf	1 fl oz	After 6-leaf	0	0	12/12
Atrazine 4L[1]	Forage sorghum, sorghum-sudan hybrid	PPI, PRE, POST/ broadleaf	3.2 to 4 pt (see label)	Up to 12 inches	5 pt	PPI/PRE: 60; POST: 45	Second year	Next year to second year[2]	Second year
Basagran[1]	Forage sorghum	POST/broadleaf	1 to 2 pt	Before heading	2 pt	12	0	0	0
Callisto[1]	Pearl millet	PRE/broadleaf	up to 6 fl oz	N/a	6 fl oz (1 appl.)	n/a	18	4	10/18
Dicamba	Forage sorghum, sudangrass	POST/broadleaf	8 to 32 fl oz	At least 3-leaf	64 fl oz	7	1	0.5 to 1.5 (see label)	4
Dual II Magnum[3,4]	Forage sorghum	PRE/grass	1 to 1.67 pt5	N/a	1 appl.	n/a	Next spring	4.5	4/9
Huskie[1]	Forage sorghum	POST/broadleaf	12.8 to 16 fl oz	3-leaf but prior to flag leaf or 30 inches	32 fl oz	7/7	1 (9 for timothy)	1 week	4/bioassay
Maestro 2EC (Buctril) (for 4EC formulation reduce rates by half)[3]	Forage sorghum, sudangrass, sorghum-sudan hybrid	POST/broadleaf	1 to 1.5 pt	3-leaf but prior to preboot/4-leaf but prior to preboot	2 pt	45	1	1	1
Permit/Sandea[1]	Pearl millet	POST/broadleaf and nutsedge	0.5 to 0.67 oz	2-leaf but prior to head	0.67 oz	0/0 (forage); 37 (hay)	2	2	9
Permit/Sandea[1]	Sorghum	POST/broadleaf and nutsedge	0.67 to 1 oz	2-leaf but prior to head	1 oz	30/30	2	2	9
Yukon	Sorghum, proso millet	POST/broadleaf and nutsedge	3 to 6 oz	3- to 5-leaf	6 oz (1 appl.)	0/0; 30/30	2	2	9

Pay particular attention to rotational crop restrictions; consult labels for crops not listed. Check labels for weeds controlled. The listed postemergence herbicides typically control only small annual broadleaf weeds, so check labels for maximum weed size or growth stage.

*Application timing: POST = postemergence; PPI = preplant incorporated; PRE = preemergence.

[1] Check label for adjuvant recommendations.

[2] Next year if applied before June 10; second year if applied after June 10.

[3] No adjuvant recommended.

[4] Requires the use of Concep-treated seed.

[5] Coarse soils, 1 to 1.33 pt; medium soils, 1.33 to 1.5 pt; fine soils, 1.33 to 1.67 pt.

Table 2.6-17. Optimum time of year for foliar application of systemic herbicides to selected weeds.

Weeds	March	April	May	June	July	August	September	October	November
Winter annual weeds (chickweed, henbit, horseweed, etc.)	■	▒						■	■
Summer annual weeds (fleabane, pigweed, ragweed, perilla mint, etc.)		■	■	■					
Spiny pigweed			■	■	▒				
Biennial weeds (burdock, wild carrot, poison hemlock, bull thistle, spotted knapweed etc.)	■	▒						■	■
Musk thistle		■	■					■	■
Herbaceous Perennials									
Buttercup spp., plantains		■	■				■	■	
Dandelion	■	■	■					■	■
Dock spp.	■	■							
Dogfennel				■	■	■			
Garlic, wild	■	■							■
Horsenettle, Carolina					■	■			
Dogbane, hemp					▒	■	■	■	
Milkweed, common					▒	■	■	■	
Pokeweed	■			■	■	■			
Star-of-Bethlehem	■								
Thistle, Canada			■	■				■	■
Woody Perennials									
Barberry, Japanese		■	■				■	■	
Brambles (*Rubus* spp.)			■				■	■	
Olive, autumn		■	■				■	■	
Rose, multiflora		■	■	▒	▒	▒	■	■	
Sumac		■	■	▒	▒	▒	■	■	

□ Do not apply

▒ Less than optimal but potentially effective depending on your specific geography and weather

■ Optimum timing of application

Table 2.6-17. Optimum time of year for foliar application of systemic herbicides to selected weeds (Continued).

These timings are based on adequate soil moisture and climate of the Eastern Shore area. Across the Mid-Atlantic region (north to south or east to west) these timings could vary by 1 to 3 weeks either way. Consult this table for general guidelines but herbicide labels for specific application information.

Winter annual weeds should be treated in late fall to spring. Summer annual weeds should be treated in early to late summer soon after emergence. Biennial weeds should be treated in the fall or early spring while in the seedling or rosette stages or in the early spring prior to bolting. Herbaceous and woody perennial weeds can vary significantly by species for when best to apply herbicides. In general, apply systemic herbicides to perennials when the source/sink movement of sugars is toward the underground structures, typically optimized when the perennial is in early bloom stage or in the fall when temperature begin to cool. Applications of these herbicides made in earlier growth stages, when movement is upward from underground structures to shoots and foliage, provides only control of top growth, with essentially no effect on the perennial structures. The addition of mechanical weed control techniques can substantially improve herbicide efficacy on perennials. Mowing or clipping the weed one or more times causes significant reductions in underground food reserves because the plant is forced to produce new top growth. When the weed reaches the early bloom stage following clipping, relatively less of the systemic herbicide is required to produce a lethal concentration in the depleted perennial structure.

Table 2.6-18. Accurate herbicide volume and weight measurements for small-volume applications.

Common Conversion Factors							
Liquid Products							
	Quart (qt)	Pint (pt)	Cup	Fluid Ounces (fl oz)	Tablespoon (tbsp)	Teaspoon (tsp)	Milliliter (ml)
1 gallon	4	8	16	128	256	768	3785
1 quart	—	2	4	32	64	192	946
1 pint	—	—	2	16	32	96	473
1 cup	—	—	—	8	16	48	237
1 fl oz	—	—	—	—	2	6	29.57
1 tbsp	—	—	—	—	—	3	14.8
1 tsp	—	—	—	—	—	—	4.9
Dry Products							
1 pound (lb) = 16 oz wt = 453.6 grams (gr)							
1 oz wt = 28.35 grams (gr)							

Spot-spray, wiper bar, or other small-area applications often require preparation of a small volume of spray solution. Backpack sprayers usually have a 1- to 3-gallon capacity. Spray concentrations for liquid herbicide formulations can be as low as 0.05 fl oz (1.5 ml) per gallon, and concentrations for dry herbicide formulations as low as 0.01 oz wt (0.28 gr) per gallon. Inaccurate measurement of these very small concentrations can cause large deviations above or below the intended application rate, resulting in possible crop damage, carryover, or poor weed control. For example, when measuring a pint of liquid herbicide, a deviation of 0.5 ml, which is equivalent to 6 drops from a dropper, would result in a negligible increase or decrease of 0.1% from the intended rate. However, the same 6 drop deviation when measuring 1.5 ml of a liquid herbicide would result in an unacceptable rate increase or decrease of 33%.

Most liquid measuring devices intended for use with agricultural products are good for measuring large volumes (pints, quarts, gallons), but they are usually not accurate below a volume of 10 fl oz (296 ml). Two types of measuring devices are available for low volumes that are accurate and easy to use. Graduated cylinders are tall, narrow cylinders with milliliter graduations along the outside of the tube. They are available in durable polypropylene material that can be washed and reused. They are available in sizes ranging from 10 ml (0.34 fl oz) with 0.2-ml increments to 4,000 ml (1.06 gal) with 50-ml increments. Pouring liquid herbicides into small graduated cylinders from large containers can be difficult. Disposable syringes are probably the cleanest and most accurate way to measure small volumes of liquid herbicide. Although they are termed disposable, they can be easily dismantled, washed, and reused several times. Buy syringes without the needles if possible, or remove and dispose of needles before use to avoid possible injury or exposure to the herbicide through a skin puncture. A syringe is essential for measuring volumes of less than 0.17 fl oz (5 ml) and can be purchased in sizes ranging from 3 ml with 0.1-ml increments up to 60 ml with 1-ml increments. A good arrangement of measuring devices to have for medium- to small-volume measurements includes a 250-ml graduated cylinder with 2-ml graduations, and 3-ml, 10-ml, and 60-ml syringes.

For dry products, postal scales measuring to 0.1 oz wt are adequate for weights above 1 oz wt (28.4 gr). A gram scale accurate to 1/100 of a gram (0.01 gr) should be used for measuring weights of less than 1 oz wt . Converting products measured by mass (oz wt or grams) into volume (teaspoons, tablespoons, or milliliters) is not practical because of the variability in the density (weight per given volume) of individual products. If sufficiently accurate weighing devices are not available, dry products requiring low concentrations should not be used for small-volume applications.

Table 2.6-19. Herbicides labeled for farmstead use.

Trade Name	Components (ai or ae/gal or lb)	Soil Residual[1]	Grass Control	Broadleaf Control	Woody Plant and Vine Control	Grazing Restriction (days)	Haying Restriction (days)
2,4-D (various formulations)	(varies) 2,4-D	No	No	Yes	Few	0–7	7
Arsenal 2AS	2 lb imazapyr	Yes	Yes	Yes	Yes	0	7
Cimarron Max Co-Pack	Part A (dry): 0.6 lb metsulfuron	Yes	No	Yes	Several	0–7	37
	Part B (liquid): 1 lb dicamba						
	2.87 lb 2, 4-D						
Cimarron Plus 63WG	0.48 lb metsulfuron	Yes	No	Yes	Several	0	0
	0.15 lb chlorsulfuron						
Crossbow 3L	2 lb 2,4-D	Limited	No	Yes	Several	0–NS[2]	14
	1 lb triclopyr						
Dicamba	4 lb dicamba	No	No	Yes	Several	0–40	0–70
Escort/Metsulfuron 60WG[3]	0.6 lb metsulfuron	Yes	No	Yes	Few	0	0
EsplAnade 200SC	1.67 lb indaziflam	Yes	Yes	Yes	No	Do not	Do not
Glyphosate (various formulations)	(varies) glyphosate	No	Yes	Yes	Several	0–56	0–56
Karmex 80DF/Direx 4L	0.8 lb diuron	Yes	Yes	Yes	No	Not specified	Not specified
PastureGard HL 4L	3 lb triclopyr	Limited	No	Yes	Several	0–NS	14
	1 lb fluroxypyr						
Payload 51WG	0.51 lb flumioxazin	Yes	Yes	Yes	No	Do not	Do not
Pramitol 25E	2 lb prometon	Yes	Yes	Yes	No	Not specified	Not specified
Prowl 3.3EC	3.3 lb pendimethalin	Yes	Yes	Yes	No	Do not	Do not
Prowl H2O	3.87 lb pendimethalin	Yes	Yes	Yes	No	See label	See label
Sahara 70DG	0.078 lb imazapyr	Yes	Yes	Yes	Many	Not specified	Not specified
	0.62 lb diuron						
Solicam 78.6DF	0.79 lb norflurazon	Yes	Yes	Yes	No	Do not	Do not
Spike 20P	0.2 lb tebuthiuron	Yes	No	Yes	Many	0	365
Starane Ultra/Vista 2.8L	2.8 lb fluroxypyr	Limited	No	Yes	No	7	14
Stinger 3L	3 lb clopyralid	Limited	No	Yes	No	0	0
Velpar 2L or 75DF	2 lb hexazinone	Yes	Yes	Yes	Several	0–7	60–365
Weedmaster 3.87L	2.87 lb 2,4-D	No	No	Yes	Several	0–7	37
	1 lb dicamba						

Table 2.6-19. Herbicides labeled for farmstead use (continued).

Trade Name	Components (ai or ae/gal or lb)	Soil Residual[1]	Grass Control	Broadleaf Control	Woody Plant and Vine Control	Grazing Restriction (days)	Haying Restriction (days)

This table lists several herbicides available for use in farmstead areas. Farmstead areas may include areas around buildings (storage buildings, poultry houses, greenhouses, etc.), nongrazed fencerows, non-irrigation ditch banks, unpaved lanes, or other non-cropped agricultural areas where selective weed control or bare ground is desired. Some herbicide labels allow grazing or haying of treated areas within or around these sites, while others do not. Many of these herbicides are toxic to desirable plants when spray particles contact either aboveground plant parts, bare roots, and/or the soil where plant roots have penetrated. Most of these products should not be used on impervious surfaces such as paved or highly compacted areas. Runoff from treated impervious surfaces or transport of treated soils by erosion can severely injure or kill susceptible non-target plants. Do not apply these products directly to water, and exercise caution when using these products near irrigation or domestic water supplies. Many of these products are not recommended for use on highly permeable soils and/or soils with groundwater near the soil surface. Read herbicide labels carefully to determine allowed uses, environmental risks, human risks, desirable plant species tolerance, weed species susceptibility, application types, use rates, adjuvant requirements, and specific grazing or haying restrictions.

[1] Herbicides listed as having limited soil residual activity may, for a short time, provide residual control or suppression of some species and can injure or kill susceptible desirable plants through soil activity.

[2] NS = next season after application.

[3] Not on all metsulfuron labels.

than 6 inches in diameter, a cut-stump treatment is most effective. Cut the plant with a chain-saw and apply Remedy Ultra in bark oil in a 25 percent herbicide, 75 percent oil mixture less than 10 minutes after cutting. Cut-stump treatment is effective at any time of year except during spring. For all treatment types, autumn olive wood is very brittle after death, making removal from fences much easier. Similarly, animals can trample small stems once dead. See Table 2.6-17 for additional information on timing of application. Mowing does not control autumn olive. For more information on basal bark applications, go to https://plantscience.psu.edu/research/projects/wildland-weed-management/publications/invasive-species-quicksheets/exotic-shrubs.

Management of Brambles and Multiflora Rose

Brambles (*Rubus* spp.) and multiflora rose (*Rosa multiflora*) can be very difficult and generally require an herbicide application in two consecutive years for eradication. Goats are an effective option to graze out brambles, but be prepared to graze for two to three years for complete control. Mowing is a waste of time and money and can lead to decreased herbicide efficacy when conducted up to one year preceding application as well as six months following application. Triclopyr-containing herbicides (Remedy Ultra, PastureGard, and Crossbow) and metsulfuron-containing herbicides (metsulfuron, Chaparral, and Cimarron) are most effective, and a combination of triclopyr and metsulfuron are recommended. Apply a high-volume foliar treatment of Remedy Ultra at 2 quarts and metsulfuron 60DF at 1 ounce per 100 gallons of water in mid- to late September. Apply to all foliage until wet but avoid dripping or runoff. See Table 2.6-17 for additional information on timing of application. A second application is generally required for complete control of brambles. Application of metsulfuron in two consecutive years is not recommended due to tall fescue injury and stand thinning. In the second year, replace metsulfuron with GrazonNext at 7 fluid ounces per 100 gallons of water.

Management of Weedy Grasses in Pasture and Hay

There are no selective postemergence grass herbicides labeled for use in cool-season grass pastures or hayfields. Therefore, management practices that provide optimal growing conditions for desirable forages or minimizing bare spots that provide opportunities for weedy grasses could prevent their incidence and invasion. Some of these practices are discussed in earlier sections of this chapter. Scouting pastures to detect aggressive grasses such as Johnsongrass, Japanese stiltgrass, joint-head grass, etc., and taking appropriate steps is recommended to prevent their spread. Perennial grasses such as Johnsongrass may be controlled by applying a glyphosate product as a spot application (to provide 2 lb ae/A) or by applying glyphosate using a weed-wiper (solution strength vary with equipment; approximate 5 percent strength is required for rotary weed wiper and 1:3 ratio with water required for rope and other types of wipers). Late summer is a good time to apply so that the treated parts of the field can be reseeded in the fall. For controlling annual grasses such as Japanese stiltgrass, joint-head grass, foxtails, barnyard grass, etc., application of a preemergence herbicide may be considered. In established pastures and hayfields, pendimethalin (Prowl H2O) is effective to control most annual weedy grasses when applied prior to weed germination. Split application is recommended in hayfields (spring application followed by application after first cut). Quinclorac (Facet L) is also effective to control certain annual grasses such as foxtails. For more information, go to https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/spes/spes-58/SPES-58.pdf.

Poisonous Weeds

Health effects ranging from none to sickness or occasional death can occur when grazing animals contact or consume toxic plants. To protect animals, it is important to be aware of how toxic plant poisoning occurs commonly. Toxicity is usually derived from certain compounds synthesized by the plant to deter pests, to tolerate extreme soil or other environmental conditions, etc. The toxic potential (the ability to cause detrimental effects) of a given weed on a given day is dependent on many factors, including the species, age, reproductive status, size, or health of animals consuming it; the plant part, growth stage, condition, and amount of the plant consumed; and the season or environmental conditions when consumed. Discrepancies in the poisonous attributes of weeds noted by different sources may be attributed to these variables. Since most of the poisonous substances emit a repulsive odor or are inherently distasteful, the animals typically stay away from plants or plant parts that are poisonous. This is especially true if other more desirable forage species are available. Occasional cases of poisoning, however, do occur when the stand of desirable species is significantly lower than the harmful plants, when extreme weather conditions such as drought occur, with excessive soil fertility, when livestock are contained for extended periods where poisonous plants are prevalent, or when accidental ingestion is followed by lactation and subsequent poisoning of the offspring. Lastly, poisonous weeds are known to affect forage and hay quality as noted above.

With some weeds, the toxic compound remains in harvested hay or silage (poison hemlock), while in others it is reduced (hairy vetch) or eliminated (buttercup). Some tree leaves are more toxic after wilting (red maple, wild cherry). Some toxic compounds occur naturally in plants, while others are released by fungi (fungal endophytes) growing in association with a living host forage plant (tall fescue toxicosis,

ryegrass staggers, red clover slobbers); by fungi in molded hay or clippings (aflatoxin, botulism, sweet clover poisoning); or by undesirable bacteria in silage (listeriosis). Applications of some herbicides may increase the palatability of certain poisonous plants. Blister beetle poisoning in horses results from consuming a toxin in dead beetles that are bailed into alfalfa hay. Certain weeds such as wild garlic or wild onion, while not toxic, may impart a disagreeable flavor to the milk of lactating animals.

About 200 to 300 plant species have been listed as poisonous to animals. While a complete list of poisonous plants is beyond the scope of this publication, below is a sampling of plant families and species with toxic potential:

- Beech family: oak species
- Boxwood family (highly toxic): boxwood, pachysandra
- Buckwheat family: buckwheat, dock species, rhubarb
- Buttercup family: buttercup species, baneberry, larkspur species
- Heath family (highly toxic): azalea, rhododendron, mountain laurel
- Legume family: black locust, crown or hairy vetch, golden chain tree, lupine species, pea species, alsike clover, sweet clover, red and white clover
- Lily family: autumn crocus, lily-of-the-valley,
- Star-of-Bethlehem, hyacinth species, skunk cabbage, onion and garlic (both wild and cultivated), tulip, asparagus
- Maple family: red maple
- Nightshade family: nightshade species, jimsonweed, ground cherry, horsenettle, tomato, potato
- Rose family: wild black cherry, chokecherry
- Yew family (highly toxic): English or American yew
- Other species: black walnut (shavings used as bedding), bleeding heart, bouncing bet, bracken fern, burning bush, cocklebur, dogbane species, foxglove, ground-ivy, hemp dogbane, horse chestnut species, horsetail, Johnsongrass, milkweed species, oleander, pigweed (*Amaranthus* species), poison hemlock, pokeweed, privet, ryegrass species, shattercane, St. Johnswort, tall fescue, water hemlock species, white snakeroot, and others

Toxic weed consumption most often occurs when animals are undernourished, they are introduced to new grazing areas, toxic plants are fed directly to them, or they escape enclosures and feed on toxic plants. It can also occur when the forage provided is not suitable for the species or grazed at the wrong growth stage (prussic acid poisoning), while experiencing environmental stress (nitrate poisoning), or during rapid growth with imbalanced fertility (grass tetany). In addition, otherwise suitable feed, hay, or forage can have toxic effects when animals are transitioned to the new source too quickly.

Provide grazing animals with adequate pasture to meet their nutrient and energy requirements or supplement their diets with a balanced ration to reduce the chance that they will consume toxic plants. Make gradual transitions to new food sources. Be aware of environmental, seasonal, and fertility conditions that may cause forages to accumulate toxic compounds and test if necessary. Scout for toxic plants (inside and outside the fence), implement good forage and weed management practices, spray for weed control when needed, wait after herbicide treatment until plants are no longer palatable, and remove dangerous plants from your property. Minimize the potential for accidental introductions of toxic plants via downed tree limbs, yard cuttings (especially ornamentals), or others feeding your animals. Provide animals with safe bedding materials.

If you suspect plant poisoning has occurred, call a veterinarian immediately. Remove all animals from the area. Identify the suspected plants. Remove accidentally introduced plant material or eradicate toxic plant species by hand-weeding, herbicide applications, pasture renovation, or other recommended practices. Monitor the grazing area over time to ensure the toxic species has been eradicated. Remove animals from herbicide-treated infestations of toxic plant species until dead and unpalatable, as herbicide treatment may increase palatability.

Discussion of toxic ingredients within plants, their specific effects on grazing animals, or toxic dosages (amount required to cause toxicity symptoms) is beyond the scope of this publication. More information can be found in the following sources:

- Burrows, G. E., and R. J. Tyrl, *Handbook of Toxic Plants of North America* (Oxford: Blackwell Publishing, 2006)
- Cornell University Animal Science: http://poisonousplants.ansci.cornell.edu/index.html
- Knight, A. P., and R. G. Walter, A *Guide to Plant Poisoning of Animals in North America* (Wyoming: Teton NewMedia, 2001)

Insects

Alfalfa

New Seeding

Potato leafhoppers are the most destructive insect pest species on new seedings of alfalfa in the state. Stress to alfalfa seedlings caused by this pest species can affect the vigor and later performance of the plants and can influence stand longevity. To obtain optimum stands, yields, and quality, it is essential to use sound control measures for potato leafhopper on new seedings.

In most years, leafhopper populations are high enough in some fields to cause appreciable losses to newly established stands. Two methods of reducing this damage exist, seeding

Figure 2.6-1. Key periods of forage insect pests in Pennsylvania.

glandular-haired, potato-leafhopper-resistant alfalfa varieties and monitoring leafhopper populations by periodic sweeping followed by insecticide applications if counts exceed the economic threshold.

When alfalfa is typically seeded in spring, there are no insect pest species that influence yield, with the possible exception of cutworms. Clover root curculio do not lay eggs in spring-seeded alfalfa because they already have moved into established stands when new seedings are seeded. The same is true for alfalfa weevils, which migrates into established stands to lay their eggs in late March and early April. Regrowth after the first cut must be monitored closely for insects, starting when the regrowth is 2 to 3 inches tall. See Tables 2.6-20 and 2.6-21 for materials and rates.

Currently, malathion is the only control method for potato leafhoppers on seedling alfalfa established in spring grains such as oats. This compound has a very short residual, however, and application requires driving over the alfalfa and small grain.

Glandular-haired potato leafhopper–resistant alfalfa is a newer pest management tool for farmers. This technology provides season-long protection against the pest. These varieties provide resistance through glandular hairs, which produce a sticky substance that prevents the nymphs from feeding and may contain a toxin. Expression of these hairs, however, is increased after the first cutting. It also should be noted that not all plants express the glandular hairs. In the newest varieties, approximately 70 to 80 percent of plants have the hairs. The remaining plants are still susceptible to injury. Therefore, although the first cutting of a new seeding is most susceptible to injury, some crop injury can occur during any cutting when leafhopper pressure is high. In some situations, it still may pay to apply an insecticide for the pest. During the new seeding year, it would be best to continue to use the regular thresholds-resistant alfalfa. Following the first year, the thresholds can be tripled to three times the normal thresholds (see next section).

The economics of using these varieties is improving each year, as the percentage of plants expressing the glandular hairs increases, and other agronomic characteristics of the plant improve. This technology is a good alternative for farmers who typically do not treat for leafhopper or who would like to organically produce the crop. It should be recognized that this technology does not provide protection against alfalfa weevil or other alfalfa pests.

Established Stands

Management of forage insect pests is aimed primarily at the alfalfa weevil and the potato leafhopper in alfalfa. Other insect pests of forages are minor in comparison and must be dealt with on a field-by-field basis. Economic injury levels for the potato leafhopper and the alfalfa weevil are fairly well established. The economic injury level is the value of crop loss caused by the pests that is equal to the cost of a spray application. Thus, unless the value for the crop loss caused by the pests exceeds the cost of controlling them, it is not profitable to spray. On the other hand, some insect losses can be avoided if a spray is applied at the proper time.

Table 2.6-20. Summary of recommended insecticides for forage crop insect control.

Forage Crop Pest	AL	AZ	BT	CA	CL	CN	DI	FL	GC	IN	LC	LCC	MA	ME	MF	MT	PE	SU	ZE
Alfalfa blotch leafminer				▲		▲			▲		▲	▲		▲					
Alfalfa weevil	▲			▲		▲	▲		▲	▲	▲	▲	▲	▲			▲		▲
Armyworm	▲			▲	▲						▲	▲			▲				▲
Cereal rust mite*				▲															
Black cutworm	▲	▲	▲	▲	▲	▲			▲		▲	▲					▲		▲
Grasshopper	▲	▲		▲		▲	▲		▲		▲	▲	▲						▲
Lygus bug	▲	▲		▲		▲	▲		▲		▲	▲	▲	▲			▲	▲	▲
Meadow spittlebug	▲					▲			▲		▲	▲	▲				▲		▲
Pea aphid	▲					▲	▲	▲	▲		▲	▲	▲	▲			▲	▲	▲
Potato leafhopper	▲	▲		▲		▲	▲	▲	▲	▲	▲	▲	▲				▲		▲
Slug																▲			

*Sevin XLR has a label in Pennsylvania on timothy for cereal rust mite.
AL = alpha-cypermethrin (Fastac), AZ = azadirachtin, BT = Bacillus thuringiensis, CA = carbaryl (Sevin), CL = chlorantraniliprole (Prevathon), CN = cyfluthrin (Baythroid), DI = dimethoate, FL = flupyradifurone (Sivanto), GC = gamma-cyhalothrin (Proaxis), IN = indoxacarb (Steward), LC = lambda-cyhalothrin (Lambda Cy, Taiga, Warrior), LCC = lambda-cyhalothrin + chlorantraniliprole (Besiege), MA = malathion, ME = methomyl (Lannate), MF = methoxyfenozide (Intrepid), MT = metaldehyde (Deadline MPs), PE = permethrin (Ambush, Arctic, Perm-up, Pounce), SU = sulfoxaflor (Transform), ZE = zeta-cypermethrin (Mustang Max).

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects.

- "**R**" after the insecticide name indicates that the compound has a restricted-use label.
- "**O**" indicates that the pesticide is labeled for organic use. However, check with your organic certifier to be sure that the material is allowed for your organic system.
- For certified organic insect control materials, refer to the Organic Materials Review Institute materials list at https://www.omri.org/, call 514-343-7600, or check with your local certifier and see https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program.
- Pesticide use can many times be avoided by using a combination of pest management methods. See Part I, Section 11: Organic Crop Production and Part II, Section 1: Pest Management to learn about IPM programs and methods for organic production.
- Each year there is an increase in the number of products offering mixtures of two active ingredients. If growers are faced with an outbreak of a pest complex, the two-ingredient mixtures may be of value; however, these products tend to be more expensive, and single ingredients can be just as effective. In general, we feel that the value of these two-ingredient mixtures is questionable for managing above-threshold populations of a single pest species.
- **Most of these products are highly toxic to bees and many other beneficial insect species.** Try to minimize use when crop is blooming and bees are likely to be present. See labels for details.

Suggested insecticides, rates, and restrictions for ALFALFA BLOTCH LEAFMINER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: Control may be justified if 30% or more of the leaflets have a mine.					
Cabaryl (Sevin)	Various formulations available; see labels for rates and restrictions		7	12	Do not apply more than once per cutting. Highly toxic to bees.
Cyfluthrin **R** (Baythroid 2)	2 to 2.8 oz	0.031 to 0.044 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.
Gamma-cyhalothrin **R** (Proaxis)	3.84 oz	0.015 lb	1 (forage); 7 (hay)	24	Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.92 to 3.84 oz	0.03 lb	1 (forage); 7 (hay)	24	Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Highly toxic to bees. Avoid application when bees are actively foraging. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	9 fl oz	0.03 lb lambda-cyhalothrin; 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz of Besiege or 0.12 lb ai lambda-cyhalothrin or 0.2 lb ai chlorantraniliprole.
Methomyl **R** (Lannate 90SP) (Lannate LV)	0.5 to 1 lb 1.5 to 3 pt	0.45 to 0.9 lb	7	48	Do not graze livestock or use for livestock feed within 7 days of last application. Highly toxic to bees. Registered for alfalfa. See label for rates and restrictions.

Suggested insecticides, rates, and restrictions for ALFALFA WEEVIL (LARVA).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: For stubble, two or more larvae per crown.					
Alpha-cypermethrin **R** (Fastac)	2.2 to 3.8 fl oz	0.014 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
Carbaryl (Sevin)	Many formulations available; see labels for rates		7	12	See label for specific uses, rates, and restrictions. Highly toxic to bees. Do not apply in bloom periods.
Cyfluthrin **R** (Baythroid 2)	1.6 to 2.8 oz	0.025 to 0.044 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for ALFALFA WEEVIL (LARVA); continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Dimethoate	Many formulations available; see labels for uses, rates, and restrictions				For reduction of larvae only. Do not apply to alfalfa in the bloom period. Make only one application per cutting. Highly toxic to bees if directly exposed to treatment. Registered for alfalfa.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	1 (forage); 7 (hay)	24	Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Indoxacarb (Steward EC)	6.7 to 11.3 oz	0.065 to 0.11 lb	7	12	Do not apply more than 45 oz (0.44 lb ai) per acre per season. Make no more than one application per cutting. Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	1 (forage); 7 (hay)	24	Highly toxic to bees. Avoid application when bees are actively foraging. Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz Besiege, 0.12 lb ai lambda-cyhalothrin, or 0.2 lb ai chlorantraniliprole.
Malathion	Many formulations available; see labels for uses, rates, and restrictions				Do not apply to alfalfa in bloom or to seed alfalfa. Malathion should be considered where very short-term control is needed. It is a relatively safe material. Registered for alfalfa, clover, and grass, among others. Can be used in new seedings of alfalfa sowed with small grains.
Methomyl **R** (Lannate 90SP) (Lannate LV)	 1 lb 3 pt	0.9 lb	7 (grazing)	48	Do not graze livestock or use for livestock feed within 7 days of last application. Highly toxic to bees. Registered for alfalfa. See label for details on further restrictions.
Permethrin **R** (Ambush 25WP) (Arctic 3.2) (Perm-up) (Pounce 25WP)	4 to 12.8 oz	0.1 to 0.2 lb	14	12	See label for specific rates. Do not apply more than 0.2 lb ai per cutting. Highly toxic to bees. Avoid applications when honey bees are foraging.
Zeta-cypermethrin **R** (Mustang Max)	2.24 to 4 oz	0.014 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

Suggested insecticides, rates, and restrictions for ARMYWORM.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for ARMYWORM; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Carbaryl (Sevin XLR plus)	1 to 1.5 pt		14	12	Do not make more than two applications per year or apply more than 3 pints per acre per year. Highly toxic to bees. Labeled for alfalfa, pasture, birdsfoot trefoil, and clovers; see label for details.
Chlorantraniliprole (Prevathon)	14 to 20 oz	0.047 to 0.067 lb	14 (grain); 1 (forage)	4	Registered for forage, fodder, and straw of cereal grains excluding corn and rice. Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply more than 60 fl oz or 0.2 lb ai per acre per crop.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	1 (forage); 7 (hay)	24	Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Highly toxic to bees; avoid application when bees are actively foraging. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz Besiege or 0.12 lb ai lambda-cyhalothrin or 0.2 lb ai chlorantraniliprole.
Methoxyfenozide (Intrepid 2F)	4 to 8 oz	0.06 to 0.12 lb	21	4	Controls only lepidopteran larvae (caterpillars). Does not have significant negative impact on beneficial arthropods. Not registered in NY. Labeled on alfalfa, clover, crownvetch, kudzu, lespedeza, lupin, milk vetch, sainfoin, trefoil, velvet bean, and vetch.
Spinosad (Blackhawk) (Tracer)	1 to 2.2 oz	0.031 to 0.062 lb	3 (hay or fodder); 0 (forage)	4	Does not harm beneficial insect complex in field. Do not apply Tracer within 3 days of harvest for hay or fodder; no preharvest interval for forage. Do not apply more than 6 oz of Tracer per acre per year.
Zeta-cypermethrin **R** (Mustang Max EC)	2.8 to 4 oz	0.0175 to 0.025 lb		12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa and other legumes, grasses, and a wide variety of other forages; useful for mixed stands; see label for details. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

Suggested insecticides, rates, and restrictions for BLACK AND CLIMBING CUTWORMS.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin **R** (Fastac)	2.2 to 3.8 fl oz	0.014 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)		0.25 to 1 pt		12	Use a minimum of 30 gallons of water per acre during application. The compound interferes with an insect's ability to molt and kills larvae. May repel or deter insect feeding. May require multiple applications to provide adequate control.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for BLACK AND CLIMBING CUTWORMS; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Bacillus thuringiensis **O**	Many formulations available; see labels for rates and restrictions				Most effective when larvae are still small. Do not enter the field without protective clothing until the spray has dried.
Carbaryl (Sevin)	Many formulations are available		7	12	See label for specific uses, rates, and restrictions. Highly toxic to bees. Do not apply in bloom periods.
Chlorantraniliprole (Prevathon)	14 to 20 oz	0.047 to 0.067 lb	14 (grain); 1 (forage)	4	Registered for forage, fodder, and straw of cereal grains excluding corn and rice. Make no more than four applications per acre per crop. Minimum interval between treatments is 7 days. Do not apply more than 60 fl oz or 0.2 lb ai per acre per crop.
Cyfluthrin **R** (Baythroid 2)	0.8 to 1.6 oz	0.013 to 0.025 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.
Gamma-cyhalothrin **R** (Proaxis)	1.92 to 3.2 oz	0.0075 to 0.0125 lb	1 (forage); 7 (hay)	24	Labeled for alfalfa, sorghum. Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	1 (forage); 7 (hay)	24	Highly toxic to bees. Avoid application when bees are actively foraging. Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz Besiege or 0.12 lb ai lambda-cyhalothrin or 0.2 lb ai chlorantraniliprole.
Permethrin **R** (Ambush 25WP) (Arctic 3.2 EC) (Perm-up) (Pounce 25WP)	2 to 12.8 oz	0.05 to 0.2 lb	14	12	See label for rates. Do not apply more than 0.2 lb ai per cutting. Avoid applications when honey bees are foraging; highly toxic to bees.
Spinosad (Blackhawk) (Tracer)	1 to 2.2 oz	0.031 to 0.062 lb	3 (hay or fodder); 0 (forage)	4	Does not harm beneficial insect complex in field. Do not apply Tracer within 3 days of harvest for hay or fodder; no preharvest interval for forage. Do not apply more than 6 oz of Tracer per acre per year.
Zeta-cypermethrin **R** (Mustang Max)	2.24 to 4 oz	014 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for CEREAL RUST MITE (TIMOTHY MITE).

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Carbaryl (Sevin XLR plus)	2 to 3 pt		30	12	Registered on timothy only for cereal rust mite. Only one application per season is allowed. Highly toxic to bees.

Suggested insecticides, rates, and restrictions for GRASSHOPPER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: Can be a problem under dry conditions; no threshold available.					
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	0.25 to 1 pt			12	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and kills larvae. May repel or deter insect feeding. May require multiple applications to provide adequate control.
Carbaryl (Sevin)	Many formulations are available.		7	12	See label for specific uses, rates, and restrictions. Highly toxic to bees; do not apply in bloom periods.
Cyfluthrin **R** (Baythroid 2)	2 to 2.8 oz	0.031 to 0.044 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.
Dimethoate	Many formulations and suppliers available; see labels for uses, rates, and restrictions				For reduction of nymphs only. Do not apply to alfalfa in the bloom period. Make only one application per cutting. Highly toxic to bees if directly exposed to treatment. Registered for alfalfa.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	1 (forage); 7 (hay)	24	Labeled for alfalfa and sorghum. Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	1 (forage); 7 (hay)	24	Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Highly toxic to bees. Avoid application when bees are actively foraging. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz of Besiege or 0.12 lb ai lambda-cyhalothrin or 0.2 lb ai chlorantraniliprole.
Malathion	Many formulations available; see labels for uses, rates, and restrictions				Do not apply to alfalfa in bloom or to seed alfalfa. Malathion should be considered where very short-term control is needed. It is a relatively safe material. Registered for alfalfa, clover, and grass, among others. Can be used in new seedings of alfalfa sowed with small grains.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for GRASSHOPPER; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Zeta-cypermethrin **R** (Mustang Max)	2.8 to 4 oz	0.0175 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

Suggested insecticides, rates, and restrictions for LYGUS BUG.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin **R** (Fastac)	2.8 to 3.8 fl oz	0.018 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
Azadirachtin **O** (Neemix 4.5)	0.25 to 1 pt			12	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and kills larvae. May repel or deter insect feeding. May require multiple applications to provide adequate control.
Carbaryl (Sevin)	Many formulations are available.		7	12	See label for specific uses, rates, and restrictions. Highly toxic to bees; do not apply in bloom periods.
Cyfluthrin **R** (Baythroid 2)	1.6 to 2.8 oz	0.025 to 0.044 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.
Dimethoate	Many formulations and suppliers are available. See individual labels.				For reduction of larvae only. Do not apply to alfalfa in the bloom period. Make only one application per cutting. Highly toxic to bees if directly exposed to treatment. Registered for alfalfa.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	1 (forage); 7 (hay)	24	Labeled for alfalfa and sorghum. Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	1 (forage); 7 (hay)	24	Highly toxic to bees. Avoid application when bees are actively foraging. Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz of Besiege or 0.12 lb ai lambda-cyhalothrin or 0.2 lb ai chlorantraniliprole.
Malathion	Many formulations available; see labels for rates and restrictions				Do not apply to alfalfa in bloom or to seed alfalfa. Malathion should be considered where very short-term control is needed. It is a relatively safe material. Registered for alfalfa, clover, and grass, among others. Can be used in new seedings of alfalfa sowed with small grains.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for LYGUS BUG; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Methomyl **R**		0.45 to 0.9 lb	7	48	Do not graze livestock or use for livestock feed within 7 days of last application. Highly toxic to bees. Registered for alfalfa. See labels for details on further restrictions.
(Lannate 90SP)	0.5 to 1 lb				
(Lannate LV)	1.5 to 3 pt				
Permethrin **R** (Ambush 25WP) (Arctic 3.2) (Perm-up) (Pounce 25WP)	4 to 12.8 oz	0.1 to 0.2 lb	14	12	See labels for specific rates. Do not apply more than 0.2 lb ai per cutting. Highly toxic to bees. Avoid applications when honey bees are foraging.
Sulfoxaflor (Transform WG)	1.5to 2.75 oz	0.047 to 0.086 lb	7	24	No more than two applications per cutting and 8.5 oz (0.27 lb) per year. Highly toxic to bees.
Zeta-cypermethrin **R** (Mustang Max)	2.24 to 4 oz	0.014 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

Suggested insecticides, rates, and restrictions for PEA APHID.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: control if 100 or more aphids per sweep.					
Alpha-cypermethrin **R** (Fastac)	2.2 to 3.8 fl oz	0.014 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
Cyfluthrin **R** (Baythroid 2)	2.8 oz	0.044 lb	7	12	Suppression only. Maximum application per cutting is 3.2 oz. Highly toxic to bees.
Dimethoate	Many formulations and suppliers available; see labels for rates and restrictions				For reduction of nymphs only. Do not apply to alfalfa in the bloom period. Make only one application per cutting. Highly toxic to bees if directly exposed to treatment. Registered for alfalfa.
Flupyradifurone (Sivanto)	7 to 10.5 fl oz	0.09 to 0.14 lb	7 (forage); 21 (grain)	4	Labeled on alfalfa. Maximum allowed per year is 28 fl oz per acre (0.365 lb ai per acre).
Gamma-cyhalothrin **R** (Proaxis)	3.84 oz	0.015 lb	1 (forage); 7 (hay)	24	Labeled for alfalfa. Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.92 to 3.84 oz	0.03 lb	1 (forage); 7 (hay)	24	Highly toxic to bees. Avoid application when bees are actively foraging. Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage);7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz Besiege, 0.12 lb ai lambda-cyhalothrin, or 0.2 lb ai chlorantraniliprole.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for PEA APHID; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Malathion	Many formulations available; see labels for uses, rates, and restrictions				Do not apply to alfalfa in bloom or to seed alfalfa. Malathion should be considered where very short-term control is needed. It is a relatively safe material. Registered for alfalfa, clover, and grass among others. Can be used in new seedings of alfalfa sowed with small grains.
Methomyl **R**		0.45 to 0.9 lb	7	48	Do not graze livestock or use for livestock feed within 7 days of last application. Highly toxic to bees. Registered for alfalfa. See labels for details on further restrictions.
(Lannate 90SP)	0.5 to 3 lb				
(Lannate LV)	1.5 to 3 pt				
Permethrin **R**	2 to 12.8 oz	0.1 to 0.2 lb	14	12	Do not apply more than 0.2 lb ai per cutting. Avoid applications when honey bees are foraging; highly toxic to bees. See labels for specific rates.
(Ambush 25WP)					
(Arctic 3.2)					
(Perm-up)					
(Pounce 25WP)					
Sulfoxaflor	0.75 to 1.0 oz	0.023 to 0.031 lb	7	24	No more than two applications per cutting and 8.5 oz (0.27 lb) per year. Highly toxic to bees.
(Transform WG)					
Zeta-cypermethrin **R**	2.24 to 4 oz	0.014 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.
(Mustang Max)					

Suggested insecticides, rates, and restrictions for POTATO LEAFHOPPER.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Alpha-cypermethrin **R**	2.2 to 3.8 fl oz	0.014 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
(Fastac)					
Azadirachtin **O**	0.25 to 1 pt			12	Use a minimum of 30 gal of water per acre during application. The compound interferes with an insect's ability to molt and kills larvae. May repel or deter insect feeding. May require multiple applications to provide adequate control.
(Neemix 4.5)					
Carbaryl	Many formulations available		7	12	See label for specific uses, rates, and restrictions. Highly toxic to bees; do not apply in bloom periods.
(Sevin)					
Cyfluthrin **R**	0.8 to 1.6 oz	0.013 to 0.025 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.
(Baythroid 2)					
Dimethoate	Many formulations and suppliers available; see labels for rates and restrictions				For reduction of nymphs only. Do not apply to alfalfa in the bloom period. Make only one application per cutting. Highly toxic to bees if directly exposed to treatment. Registered for alfalfa.
Flupyradifurone	7 to 10.5 fl oz	0.09 to 0.14 lb	7 (forage); 21 (grain)	4	Labeled on alfalfa. Maximum allowed per year is 28 fl oz per acre (0.365 lb ai per acre).
(Sivanto)					

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for POTATO LEAFHOPPER; continued.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Gamma-cyhalothrin **R** (Proaxis)	1.92 to 3.2 oz	0.0075 to 0.0125 lb	1 (forage); 7 (hay)	24	Labeled for alfalfa. Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Indoxacarb (Steward EC)	9.2 to 11.3 oz	0.09 to 0.11 lb	7	12	Suppression only. Do not apply more than 45 oz (0.44 lb ai) per acre per season. Make no more than one application per cutting. Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	0.96 to 3.2 oz	0.015 to 0.025 lb	1 (forage); 7 (hay)	24	Highly toxic to bees. Avoid application when bees are actively foraging. Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	5 to 8 fl oz	0.017 to 0.026 lb lambda-cyhalothrin; 0.03 to 0.05 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz Besiege, 0.12 lb ai lambda-cyhalothrin, or 0.2 lb ai chlorantraniliprole.
Malathion	Many formulations available; see labels for uses, rates, and restrictions				Do not apply to alfalfa in bloom or to seed alfalfa. Malathion should be considered where very short-term control is needed. It is a relatively safe material. Registered for alfalfa, clover, and grass, among others. Can be used in new seedings of alfalfa sowed with small grains.
Permethrin **R** (Ambush 25WP) (Arctic 3.2) (Perm-up) (Pounce 25WP)	3.2 to 12.8 oz	0.05 to 0.2 lb	14	12	Do not apply more than 0.2 lb ai per cutting. Highly toxic to bees. Avoid applications when honey bees are foraging. See labels for specific rates.
Zeta-cypermethrin **R** (Mustang Max)	2.24 to 4 oz	0.014 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

Suggested insecticides, rates, and restrictions for SLUGS.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Metaldehyde (Deadline M-Ps) (Metarex)	Different formulations available; see for uses, rates, and restrictions		0	12	See comments in Table 2.2-21 in corn section. Primarily a problem in no-till fall seedings but can occur in spring seedings.
Sodium Ferric EDTA (Ferroxx)	5 to 20 lb per acre or 0.11 to 0.44 lb per 1,000 square feet		0.25 to 1 lb	0	0

Slug notes: Slug damage is most severe during cool, wet weather, especially in fields under reduced tillage with a fairly heavy cover of organic matter. Small grain plants usually recover from slug feeding; however, extensive plant mortality may occur during periods of prolonged wet weather in May/June or September/October.

Table 2.6-21. Suggested insecticides, rates, and restrictions for corn insects (continued).

Suggested insecticides, rates, and restrictions for SPITTLEBUG.

	Rate per Acre		Restrictions		Comments
Insecticide	**Formulated**	**Active**	**Harvest (days)**	**Reentry (hours)**	**(Read the label for dosage, method, and limitations)**
Threshold: spray applications are not profitable unless there are one or more spittle masses per stem by mid-May.					
Alpha-cypermethrin **R** (Fastac)	2.2 to 3.8 fl oz	0.014 to 0.025 lb	30 (grain); 60 (forage)	12	Registered for alfalfa. A maximum of 3.8 fl oz of product (0.025 lb ai) per acre may be applied per cutting and a maximum of 11.4 fl oz of product (0.075 lb ai) per acre per season.
Cyfluthrin **R** (Baythroid 2)	0.8 to 1.6 oz	0.013 to 0.025 lb	7	12	Maximum application per cutting is 3.2 oz. Highly toxic to bees.
Gamma-cyhalothrin **R** (Proaxis)	2.56 to 3.84 oz	0.01 to 0.015 lb	1 (forage); 7 (hay)	24	Labeled for alfalfa. Do not apply more than 0.015 lb ai per cutting (0.06 lb ai per acre). Highly toxic to bees.
Lambda-cyhalothrin **R** (Lambda Cy) (Taiga Z) (Warrior and Warrior II)	1.28 to 3.84 oz	0.02 to 0.03 lb	1 (forage); 7 (hay)	24	Highly toxic to bees. Avoid application when bees are actively foraging. Do not apply more than 0.03 lb ai per acre per cutting or more than 0.12 lb ai per acre per season. Warrior II uses half the rate of Warrior.
Lambda-cyhalothrin + chlorantraniliprole **R** (Besiege)	6 to 9 fl oz	0.02 to 0.03 lb lambda-cyhalothrin; 0.04 to 0.06 lb chlorantraniliprole	1 (forage); 7 (hay)	24	Do not apply more than 9 fl oz per acre per cutting. Per acre per growing season, do not exceed a total of 31 fl oz Besiege, 0.12 lb ai lambda-cyhalothrin, and 0.2 lb ai chlorantraniliprole.
Malathion	Many formulations available; see the label for uses, rates, and restrictions				Do not apply to alfalfa in bloom or to seed alfalfa. Malathion should be considered where very short-term control is needed. It is a relatively safe material. Registered for alfalfa, clover, and grass, among others. Can be used in new seedings of alfalfa sowed with small grains.
Permethrin **R** (Ambush 25WP) (Arctic 3.2EC) (Perm-up) (Pounce 25WP)	4 to 12.8 oz	0.1 to 0.2 lb	14	12	Do not apply more than 0.2 lb ai per cutting. See label for specific rates. Highly toxic to bees. Avoid applications when honey bees are foraging.
Zeta-cypermethrin **R** (Mustang Max)	2.24 to 4 oz	0.014 to 0.025 lb	3	12	Highly toxic to bees, fish, and other aquatic organisms. Labeled for alfalfa, other legumes, and grass forages; useful for mixed stands. Maximum of 0.25 ai per acre per cutting or 0.075 lb ai per acre per season.

A good pest management program requires proper identification of the pest species causing crop injury and determination whether the economic threshold has been exceeded. How can you determine if and when a spray application will be profitable? Get a copy of the publication "A Pest Management Program for Alfalfa in Pennsylvania" from your local extension office. This publication will aid you in deciding when it is profitable to control potato leafhopper and alfalfa weevil. Pest identification requires knowing when and what to look for in the field. Figure 2.6-1 shows the key periods of forage insect occurrence in Pennsylvania.

Alfalfa Blotch Leafminer

Alfalfa blotch leafminer can be found in practically all alfalfa fields in the state; however, damage always looks worse than it actually is. The second cutting usually is most severely infested. Control may be justifiable if 30 percent or more of the leaflets have a mine present.

The adult fly is about 0.13 inch long and resembles a common housefly. The larvae (maggots) are pale-yellow, soft-bodied, shortened, and thickened. At least three generations per year occur in Pennsylvania. Adult females emerge in the spring, cut shallow holes through the lower leaf surface, and deposit eggs under the leaf epidermis. A female lays one to three eggs per leaflet. To feed, the female cuts a hole in the leaf with her ovipositor and laps up exposed sap and tissue, forming conspicuous pinholes in the leaves. After the eggs hatch, the larvae tunnel within the leaf, feeding on leaf tissue. The larval stage lasts approximately two weeks. Larval mining causes conspicuous white blotches on the leaflets, which typically are comma shaped. Blotches and punctures can cause deterioration of foliage quality, loss of photosynthetic area, and defoliation.

Alfalfa Weevil

Alfalfa weevil is a problem primarily in the first cutting of alfalfa in April and May. Larvae feed within the growing tips, on the upper leaves as they open, and later on the lower leaves. Plants become skeletonized from weevil feeding, and the leaves dry, giving the field a frosted appearance. After cutting, the larvae may feed on the new emerging shoots, severely retarding alfalfa regrowth. Adults also feed on the alfalfa plant. Conditions that favor pest development are excessive pesticide use (which destroys biological control agents), mild winters, and warm dry spring weather. Several species of parasitic wasp and a fungus help maintain alfalfa weevil populations. See "A Pest Management Program for Alfalfa in Pennsylvania" for information on the alfalfa weevil life cycle, identification, sampling techniques, and economic thresholds. Note: Recent higher values of hay have altered economic thresholds a bit, so see the recently revised alfalfa weevil fact sheet available online from the Penn State Department of Entomology for updated thresholds for this pest species.

Black Cutworm

Black cutworms can cause extensive damage to new seedings in late May and early June. See Part II, Section 2: Corn for information on cutworm biology.

Pea Aphid

Pea aphid control sometimes is needed, but natural controls usually suffice to keep aphid populations in check. In fact, large numbers of aphids are most commonly found in alfalfa fields that have been routinely sprayed with insecticides, which limit populations of all insects, including pests and natural enemies. Unfortunately, plant-feeding pest populations recover more quickly than natural-enemy populations; therefore, once aphid populations start growing in fields that had been sprayed with insecticides, aphid numbers increase rapidly without natural enemies that usually limit their abundance. Getting aphid populations under control in the longer term usually involved minimizing insecticide use by adopting integrated pest management, which involves scouting for pests and using insecticides only if pest populations exceed economic thresholds. Control of aphids may be warranted if populations reach 30 aphids per sweep of an insect net.

Pea aphids are small, green, long-legged insects about 0.19 inch long. They can be winged or wingless. Like other aphids, the pea aphid damages the plant by removing sap with its sucking mouthparts and possibly by poisoning the plant. The insect overwinters on alfalfa, clovers, and other perennial plants in either the egg stage or as adult females. In the spring, populations increase on the winter host and begin migrating to other hosts around May 1. Winged females start colonies on new plants by giving birth to live young, which are ready to reproduce in 12 days. A female commonly produces six to seven young per day. There are seven to 20 generations per year. Pea aphids may be found in forage fields during June and July.

Potato Leafhoppers

Potato leafhoppers are the most destructive insect pests of alfalfa in the state. Many poor stands and low yields can be attributed to these pests. New spring seedings are especially vulnerable to attack by leafhoppers. Regrowth of second and third cuttings of established stands also is damaged frequently.

Leafhopper populations often vary considerably from one field to the next. For this reason, it is advisable to make leafhopper checks with an insect net in each alfalfa field. Start checking new seedings in early June, and check the regrowth of established stands when the plants are about 3 inches high. The Penn State Extension publication "A Pest Management Program for Alfalfa in Pennsylvania" discusses economic

thresholds. For glandular-haired potato-leafhopper-resistant alfalfa, studies indicate that the thresholds can be tripled compared to the regularly used thresholds. Note: Recent higher values of hay have altered economic thresholds a bit, so see the recently revised potato leafhopper fact sheet available online from the Penn State Department of Entomology for updated thresholds for this pest species.

Adult potato leafhoppers are yellowish green and about 0.13 inch long and 0.03 inch wide. The nymphs are similar in appearance but lack wings. Damaging populations may be more likely when temperatures are between 70 and 90°F, when harvest is delayed, or when alfalfa is strip-cut or cut in blocks.

Spittlebug

Meadow spittlebug damage is most likely on legumes seeded in small-grain stubble. Spray applications are not profitable unless there are one or more spittle masses per stem by mid-May.

The adult spittlebug is 0.25 to 0.38 inch long and resembles a frog; its head is short and blunt with large eyes. Adults vary in color and marking, ranging from light gray to dark brown, with spots, strips, or bands on the wing covers. Adults walk with their front four legs and drag their back legs. The nymphal stage is found within the frothy spittle mass that they secrete. They are about 0.03 inch long and orange. As they develop, they become greenish-yellow and then green. Eggs are laid during August and September in small-grain stubble, alfalfa, or weeds, where they overwinter. They begin to hatch during April in Pennsylvania. The nymphal stage lasts approximately five to eight weeks. Adults appear in late May and early June to lay the next year's eggs.

Slugs

Slugs can damage new seedings of alfalfa, particularly fields seeded no-till in the fall. Spring seedings are less susceptible to slug injury.

Other Forages

Potato leafhoppers may be a problem on new seedings of birdsfoot trefoil. Potato leafhopper populations of ten nymphs and adults in ten sweeps of an insect net justify control measures on new seedings. On established stands, spittlebugs and potato leafhoppers are common but are usually not abundant enough to warrant control measures. Spray only when needed. An average of one spittlebug nymph per stem in early May justifies spray protection. A potato leafhopper population of 20 nymphs and adults in ten sweeps of an insect net justifies control measures on established stands.

Insects normally are not a problem on new seedings of clovers seeded in winter grains or on a prepared seedbed. Reduced or no-till seedings of clover in grain stubble are apt to need spray protection from spittlebugs, particularly on red, alsike, and ladino clovers. Be sure to monitor such seedings from late April on to determine if a spittlebug problem exists. Also, the clover cyst nematode attacks red clover roots and crowns. It has been found only in central Pennsylvania, and its distribution throughout the state is not known. Rotating fields out of clover for two or more years should keep this pest under control. Insects normally are not a problem in grasses or small grain crops.

See Table 2.6-20 for quick reference to recommended insecticides for control of each insect pest, and Table 2.6-21 for rates, restrictions, and other information.

Diseases

Alfalfa

The following management practices will help minimize disease losses in alfalfa. Most of these recommendations apply to other legumes as well.

- Use the best-adapted, disease-resistant varieties.
- Do not plant alfalfa in poorly drained fields. Red clover, birdsfoot trefoil, or grass species are better choices. In fields that are moderately to poorly drained, *Phytophthora*- and *Aphanomyces*-resistant varieties should be used along with fungicide-treated seed and/ or Ridomil Gold (mefenoxam) or MetaStar (metalaxyl) soil treatment.
- Use cereal, corn, or grass crops for at least two years in rotation with alfalfa.
- Keep soil pH, phosphorus, and potassium at optimal levels for crop growth.
- Because they interact with diseases, control potato leafhoppers with resistant varieties and/or insecticide applications.
- Clean all plant debris from equipment before storing it for the winter; some pathogens that do not survive well in the field survive well on equipment under shelter.
- Mow youngest stands first. This reduces the spread of pathogens by machinery from older, more diseased stands into healthier, younger stands. If this is not feasible, a thorough cleaning with a pressure washer between older stands and newer stands should help reduce pathogen spread.
- Mow after the dew has dried because many pathogens are spread easily in water films.
- When stands are hit hard by leaf spot diseases, mow a few days earlier than usual to retain more leaves and reduce inoculum levels in the field.
- Maintain a cutting schedule that ensures the recharging of root carbohydrates both during the growing season and before fall dormancy.
- To minimize Sclerotinia stem and crown rot outbreaks, avoid late summer plantings of alfalfa by conservation-tillage methods.

Anthracnose

Anthracnose is a fungal disease that occurs statewide and is particularly severe in southeastern Pennsylvania. This fungus often cannot overwinter in the field, but it does so in infected plant debris on equipment in storage. Therefore, cleaning equipment before storing it for the winter helps delay the introduction of this pathogen into young seedlings in the spring. Resistant varieties are available and should be used statewide.

Aphanomyces Root Rot

Aphanomyces root rot is a disease that causes establishment problems in some areas. To date, only trace amounts of the disease have been reported in Pennsylvania, although both pathogen strains are known to widely exist in Pennsylvania soils. This disease is likely to occur under the same wet soil conditions as does *Phytophthora*, so it is possible that losses caused by this fungus have been occurring but were attributed to *Phytophthora*. The fungicide treatments available against *Pythium* spp. and *Phytophthora* spp. are ineffective against *Aphanomyces* spp.; however, resistance to two races of the fungus is available in some newer varieties.

Crown and Root Rot Complex

Crown and root rot complex, caused by *Fusarium* spp. plus other fungi and bacteria, is common in alfalfa. Resistant varieties are not available; therefore, growers must use best management practices to minimize stress on the plants, which slows down the rate of root rot development. Root-rotting pathogens can align with root-feeding insects, and root deterioration progresses with increasing stand age.

Foliar Diseases

Foliar diseases are common in Pennsylvania throughout most of the growing season and can cause significant quality and yield loss through defoliation. When foliar diseases are severe, early mowing helps retain leaves and reduces inoculum in the field. Some of the current varieties have improved levels of resistance, but all become diseased if favorable moisture levels and temperatures prevail.

Nematodes

Nematodes generally do not cause serious problems on forages in Pennsylvania, as long as rotations with corn, cereal, or grass crops are used.

Phytophthora Root Rot

Phytophthora root rot can devastate young stands of alfalfa and can cause serious plant loss in older stands. This fungal pathogen lives in the soil, and soils saturated with water for three or more days can trigger a disease outbreak. In perennially wet sites, the use of alternative crops is recommended. The use of resistant varieties, seed treatment with Apron fungicide, and/or soil treatment with Ridomil Gold (mefenoxam) or MetaStar 2E (metalaxyl) fungicide are effective control measures.

Sclerotinia Crown and Stem Blight

Sclerotinia crown and stem blight can cause seeding failures. Late summer or early fall seedings using conservation tillage favor disease development. The infective stage for this disease usually occurs in October, and fall-seeded plants are very susceptible at this time. Because conservation tillage does not bury the survival structures of the fungus, disease severity in no-till plantings is often more severe than in conventionally tilled seedbeds. Infected seedlings often survive until spring when the plants die, and entire stands may be lost. Spring plantings, because of the plants' increased maturity in the fall, are not as likely to be devastated. Resistant varieties are not available.

Spring and Summer Blackstem

Spring and summer blackstem occur on alfalfa in Pennsylvania, with spring blackstem usually more severe. Leaves, petioles, and stems are attacked, with the spring blackstem fungus also causing crown and root rot. As with other foliar diseases, early harvesting of severely diseased stands can increase leaf retention and reduce inoculum in the field. A few current varieties have improved levels of resistance, but all become severely diseased if extended moist periods prevail.

Wilts

Wilt diseases can cause severe stand losses in Pennsylvania. Bacterial, Fusarium, and Verticillium wilts occur statewide; Fusarium wilt is worse in southern counties, and Verticillium wilt is worse in northern counties. Resistance to these wilts is available in current varieties and is necessary for maximum production.

Viruses

Virus diseases are not considered serious on alfalfa in Pennsylvania. Viruses may be present, however, without causing obvious symptoms, and it is possible that viruses contribute to premature stand decline. No virus-resistant varieties are available.

Birdsfoot Trefoil

Crown and Root Rots

Crown and root rots caused by fungi such as *Fusarium* spp., *Rhizoctonia* spp., and *Mycoleptodiscus* spp. severely damage birdsfoot trefoil, particularly in southeastern Pennsylvania. Economic production with varieties susceptible to these fungi is questionable in this region.

Fusarium Wilt

Fusarium wilt has been reported in Pennsylvania and may cause economic losses in birdsfoot trefoil in the northern parts of the state. Stemphylium leaf spot and stem canker may become severe in warm, humid environments. Symptoms include reddish-brown lesions on the leaflet and cankers on the stems. If the crop is close to harvest maturity, early cutting should aid in leaf retention (maintaining higher quality forage) and in reducing inoculum in the field.

Following good management practices that minimize stress on the plant and promote vigorous growth can reduce losses caused by these diseases.

Clovers

Bean Yellow Mosaic Virus

Bean yellow mosaic virus is the predominant virus in red clover, occurs generally throughout the state, and undoubtedly contributes to premature decline of red clover stands. Currently, no varieties are highly resistant to this disease.

Clover Cyst Nematode

The clover cyst nematode attacks red clover roots and crowns. It has been found only in central Pennsylvania, and its distribution throughout the state is unknown. Rotating fields out of clover for two or more years should keep this pest under control.

Crown and Root Rot Fungi

Crown and root rot fungi, especially *Fusarium* spp., may severely attack red clover. This problem, coupled with injury caused by root-feeding insects, limits red clover stand longevity. Insects feeding on the leaves and stems also stress the plants and favor rapid root rot. The development of root rot is slower when good management practices are used to minimize plant stress. Management practices that help slow down root rot include maintaining adequate potassium and phosphorus levels, maintaining optimal soil pH for vigorous plant growth, and following recommended harvesting schedules.

Fungi

Several fungi attack leaves and stems of red clover throughout the growing season. Although none of these is considered to be a major problem, they may become severe enough to stress the plant and reduce forage yield and quality. When leaf and stem problems are very severe, early harvest will be beneficial in retaining more leaves and reducing inoculum in the field.

Northern and Southern Anthracnose

Northern and southern anthracnose are diseases of red clover caused by different fungi, although their symptoms are quite similar. Leaf blotches, collapsed petioles, and wilted stems on the first harvest usually are the result of northern anthracnose. Similar symptoms later in the season usually are attributable to southern anthracnose. Current varieties have good resistance to one or both of these diseases and should be utilized.

Powdery Mildew

Powdery mildew is distributed throughout the state and, although not considered a serious disease problem, does place an undesirable stress on the plants. Several of the newer varieties have good resistance to this disease.

Sclerotinia Crown and Stem Blight

Sclerotinia crown and stem blight is a problem on red clover during cool, wet springs and particularly following late snow cover. White to grayish growth of the fungus may be seen on the outside of stems, and black reproductive structures (sclerotia) form on and in stems, crowns, and soil. Early spring growth can be delayed, and occasionally this disease kills plants in Pennsylvania. As soon as drier, warmer weather begins, the disease subsides. Rotation and deep plowing to bury sclerotia help reduce inoculum in the field.

Fungicide Applications for Forages

Quadris (azoxystrobin) has been labeled for use on alfalfa and clover in both pure and mixed-grass stands. Headline (pyraclostrobin) has been labeled for use on alfalfa for forage. Research is currently being done to determine the economic and yield benefits, if any, of using a fungicide on alfalfa.

Cool-Season Grasses: Established Stand Management

Depending on the species and variety, a number of fungal leaf diseases, including rusts and leaf spots, attack grasses. These generally are not of economic importance and can be minimized by using sound management practices that ensure balanced fertility, adequate pH, and resistant varieties when available.

Brown stripe of orchardgrass is an endemic disease of Pennsylvania that can be found on orchardgrass from emergence throughout the stand's life. Although this disease starts are small lesions on the leaf, the characteristic symptoms are seen as leaf tip dieback. This disease not only reduces the appearance of the hay but has some impact on the nutrient value of the hay. This disease overwinters in both debris and older leaves near the ground. Disease evaluations on currently available varieties have been conducted at Rock Springs, Pennsylvania, and some resistance to this disease has been found.

Appendix

Weights, Measurements, and Conversion Factions

Average Bushel Weights and Seed Per Pound

Below are average bushel weights and seed per pound for the major crops grown in Pennsylvania. This is presented as a guide for determining the amount of seed required to obtain a desired plant population. Seed per pound will vary from year to year depending on growing conditions.

	Bushel Weight (lb)	Average Seed (lb)
Grain Crops		
Barley	48	13,600
Corn	56	1,450
Oat	32	12,700
Rye	56	18,080
Sorghum	56	14,000
Soybean	60	2,500
Sunflower, oilseed	27	6,000
Wheat	60	12,000
Forage Crops		
Alfalfa	60	220,000
Birdsfoot trefoil	60	1,000,000
Bromegrass	14	137,000
Fescue, tall	20	226,800
Ladino clover	60	860,000
Orchardgrass	14	590,000
Red clover	60	270,000
Reed canarygrass	46	550,000
Sudan grass	40	50,000
Timothy	45	1,230,000
Vetch, hairy	60	20,000

Useful Weights and Measures

1 acre = 0.405 hectare
1 hectare = 2.47 acres
1 acre = 43,560 square feet
1 acre = 4,840 square yards
1 bushel (dry) = 1.244 cubic feet
1 bushel (dry) = 2,150 cubic inches
1 bushel (dry) = 35.24 liters
1 bushel (dry) = 4 pecks
1 bushel (dry) = 32 quarts

1 cubic foot = 0.804 bushel
1 cubic foot = 25.714 quarts (dry)
1 cubic foot = 29.922 quarts (liquid)
1 cubic foot = 1,728 cubic inches
1 cubic foot = 7.48 gallons

1 cubic inch = 16.39 cubic centimeters
1 cubic inch = 0.554 ounces (fluid)

1 cubic yard = 27 cubic feet
1 cubic yard = 46,656 cubic inches
1 cubic yard = 202 gallons
1 cubic yard = 764.5 liters

1 gallon = 3,785 cubic centimeters
1 gallon = 231 cubic inches
1 gallon = 0.1337 cubic feet
1 gallon = 3.785 liters
1 gallon = 128 fluid ounces

1 inch = 2.54 centimeters
1 kilogram = 35.274 ounces
1 kilogram = 2.205 pounds

1 liter = 33.81 ounces (fluid)
1 liter = 1.816 pints (dry)
1 liter = 2.11 pints (liquid)
1 liter = 61.025 cubic inches
1 liter = 0.264 gallons

1 meter = 39.37 inches

1 mile = 5,280 feet
1 mile = 1,760 yards

1 mile per hour = 1.467 feet per second

1 ounce (avoirdupois) = 28.349 grams
1 ounce (fluid) = 29.574 cubic centimeters
1 ounce (fluid) = 1.805 cubic inches

1 pound = 453.59 grams
1 pound = 16 ounces

1 quart (dry) = 67.20 cubic inches
1 quart (liquid) = 57.75 cubic inches

1 rod = 16.5 feet
1 rod = 5.029 meters
1 rod = 5.5 yards

1 square foot = 144 square inches
1 square yard = 9 square feet

1 ton (short) = 907.185 kilograms
1 ton (short) = 2,000 pounds
1 ton (long) = 2,240 pounds

1 yard = 3 feet
1 yard = 91.440 centimeters

Conversion Factors for English and Metric Units

All measurements in Part II: Pest Management are reported in English units (e.g., pounds per acre). However, if you may have access to some data reported in metric units, the conversions below may be of interest to you.

To convert column 1 into column 2, multiply by:	Column 1	Column 2	To convert column 2 into column 1, multiply by:
1.609	mile, mi	kilometer, km	0.621
0.914	yard, yd	meter, m	1.094
2.540	inch, in	centimeter, cm	0.394
2.590	mile^2, mi^2	kilometer^2, km^2	0.386
0.00405	acre, A	kilometer^2, km^2	247.1
0.405	acre, A	hectare, ha	2.471
102.8	acre-inch	meter^3, m^3	0.00973
0.2852	cubic foot, ft^3	hectoliter, hl	3.532
0.352	bushel, bu	hectoliter, hl	2.838
0.946	quart (liquid), qt	liter, L	1.057
0.9072	ton (English), T	T ton (metric)	1.102
0.00454	pound, lb	quintal, q	220.5
0.454	pound, lb	kilogram, kg	2.205
2.242	ton (English)/acre	ton (metric)/hectare	0.446
1.121	lb/acre	kg/ha	0.892
1.121	hundredweight/acre	quintal/hectare	0.892
0.0703	lb/in^2, psi	kg/cm^2	14.22
0.06895	lb/in^2, psi	bar	14.50
1.013	atmosphere, atm*	bar	0.9869
1.033	atmosphere, atm	kg/cm^2	0.9678
0.06805	lb/in^2, psi	atmosphere, atm	14.70
0.555	(F-32) Fahrenheit, F	Celsius, C	1.80C + 32
10.764	foot-candle, ft-c	lux	0.0929

*An atmosphere may be specified in metric or English units.

KEY FOR IDENTIFYING COMMON GRASSY WEED SEEDLINGS IN PENNSYLVANIA

A = annual, **P** = perennial, **WA** = winter annual

1. Stem triangular, solid, three ranked leaves ..... YELLOW NUTSEDGE, *Cyperus esculentus,* **P**
1. Stem flat to round, hollow, two ranked leaves ..... GRASSES, *Gramineae* spp.
  A. Auricles present ..... QUACKGRASS, *Agropyron repens,* **P**
  A. Auricles absent
    1. Ligule absent ..... BARNYARDGRASS, *Echinochloa crusgalli,* **A**
    1. Ligule present
      2. Ligule a fringe of hairs
        3. Sheath round with overlapping margins
          4. Sheath covered with long hairs ..... WITCHGRASS, *Panicum capillare,* **A**
          4. Sheath smooth
            5. Margins of the sheath hairy
              6. Leaf blade rough above, smooth to somewhat rough below ..... GREEN FOXTAIL, *Setaria viridis,* **A**
              6. Leaf blade covered with short hairs above, smooth and keeled below ..... GIANT FOXTAIL, *Setaria faberii,* **A**
            5. Margins of the sheath not hairy
              6. Collar hairy on the margins ..... STINKGRASS, *Erogrostis cilianensis,* **A**
              6. Collar not hairy on the margins ..... FALL PANICUM, *Panicum dichotomiflorum,* **A**
        3. Sheath distinctly flattened, smooth, with overlapping margins
          4. Collar divided, not hairy on the margins ..... BRISTLY FOXTAIL, *Setaria verticillata,* **A**
          4. Collar not divided, hairy on the margins
            5. Leaf blade has a few long hairs near the base ..... YELLOW FOXTAIL, *Setaria glauca,* **A**
            5. Leaf blade smooth ..... SANDBUR, *Cenchrus pauciflorus,* **A**
      2. Ligule membranous
        3. Sheath round to oval
          4. Sheath smooth, split with overlapping margins
            5. Leaf blade smooth above and below, midrib white above, prominent below
              6. Thick, white rhizomes just below soil surface ..... JOHNSONGRASS, *Sorghum halepenese,* **P**
              6. No rhizomes, fibrous root system like corn ..... SHATTERCANE, *Sorghum bicolor,* **A**
            5. Leaf blade rough above and below, midrib not white or prominent below
              6. Short, scaly rhizomes at or below soil surface ..... WIRESTEM MUHLY, *Muhlenbergia frondosa,* **P**
              6. No short, scaly rhizomes at or below soil surface ..... NIMBLEWILL, *Muhlenbergia schreberi,* **P**
          4. Sheath hairy, closed to near the top
            5. Sheath short, hairy ..... CHEAT, *Bromus secalinus,* **A** or **WA**
            5. Sheath densely soft, white, hairy, frequently purplish ..... DOWNY BROMEGRASS, *Bromus tectorum,* **A** or **WA**
        3. Sheath distinctly flattened, split with overlapping margins
          4. Sheath smooth or sparsely hairy
            5. Leaf blade smooth above, smooth and keeled below, tip boat-shaped ..... ANNUAL BLUEGRASS, *Poa annua,* **A** or **WA**
            5. Leaf blade smooth above, a few hairs near base; smooth, keeled below ..... SMALL CRABGRASS, *Digitaria ischaemum,* **A**
          4. Sheath hairy
            5. Leaf blade long, hairy near the base above, smooth below ..... GOOSEGRASS, *Eleusine indica,* **A**
            5. Leaf blade hairy above and below, ligule often reddish or purplish ..... LARGE CRABGRASS, *Digitaria sanguinalis,* **A**

KEY FOR IDENTIFYING COMMON BROADLEAVED WEED SEEDLINGS IN PENNSYLVANIA

1. First true leaves alternate
    1. True leaves heart shaped
        1. True leaves densely hairy
            1. Cotyledons oval to round ..... VELVETLEAF, *Abutilon theophrasti*
            2. True leaves hairless to sparsely hairy; cotyledons butterfly-wing shaped ..... TALL MORNINGGLORY, *Ipomea purpurea*
    2. True leaves lobed, spade, star, pentagon shaped
        1. True leaves lobed
            1. All leaves lobed (first leaf slightly), cotyledons butterfly-wing shaped ..... IVYLEAF MORNINGGLORY, *Ipomea hederacea*
        2. True leaves spade, arrowhead, star, pentagon shaped
            1. True leaves with ochrea
                1. Cotyledons lanceolate to elliptic ..... WILD BUCKWHEAT, *Polygonum convulvulus*
            2. True leaves without ochrea
                1. True leaves spade shaped; cotyledons kidney-bean shaped
                1. True leaf margins parallel; leaf tip blunt ..... FIELD BINDWEED, *Convulvulus arvensis*
                2. True leaf margins with distinct edges and not parallel; leaf tip pointed ..... HEDGE BINDWEED, *Calystegia sepium*
                2. True leaves star or pentagon shaped; cotyledons large, spoon shaped
                1. True leaves star shaped ..... WILD CUCUMBER, *Echinocystis lobata*
                2. True leaves pentagon shaped (five sided) ..... BURCUCUMBER, *Sicyos angulatus*
    3. True leaves oval, ovate, elliptic, lanceolate, spoon shaped
        1. True leaves spoon shaped; cotyledons kidney-bean shaped ..... MUSTARD species
        2. True leaves lanceolate to elliptic
            1. Distinctive odor when crushed
                1. Cotyledon midrib prominent ..... JIMSONWEED, *Datura stramonium*
                2. Plants with ochrea; no odor ..... PENNSYLVANIA SMARTWEED, *Polygomum pensylvanicum*
        3. True leaves ovate
                1. True leaves covered with mealy white granules or frost ..... COMMON LAMBSQUARTERS, *Chenopodium album*
                2. True leaves without white granules or frost
                1. True leaves with notched tip, reddish undersides ..... SMOOTH PIGWEED OR REDROOT PIGWEED, *Amaranthus* sp.
                2. True leaves without notched tip
                1. Spines or thorns present on petioles, midrib, and stems; perennial ..... HORSENETTLE, *Solanum carolinense*
                2. No spines or thorns present on petioles, midrib, or stem
                1. True leaves sparsely to densely hairy with pointed tip
                1. Leaf underside purple; cotyledons small and ovate ..... EASTERN BLACK NIGHTSHADE, *Solanum ptycanthum*
                2. True leaves smooth to sparsely hairy
                1. Stem purple; cotyledons if present small and ovate; perennial .. SMOOTH GROUND CHERRY, *Physalis subglabrata*

1. First true leaves opposite
    1. True leaves lobed
        1. True leaves with three to five major lobes; plants as large as a silver dollar at two-leaf stage GIANT RAGWEED, *Ambrosia trifida*
        2. True leaves with greater than five major lobes, lacy; plants as large as a quarter at two-leaf stage COMMON RAGWEED, *Ambrosia artimesiifolia*
    2. True leaves not lobed
        1. True leaves densely hairy, later leaves alternate ..... COMMON SUNFLOWER, *Helianthus annuus*
        2. True leaves hairless or sparsely hairy
            1. True leaves covered with white mealy granules ..... COMMON LAMBSQUARTERS, *Chenopodium album*
            2. True leaves without white granules or frost
                1. True leaves rough textured; leaves alternate after first true leaves; cotyledons thick and waxy ..... COMMON COCKLEBUR, *Xanthium strumarium*
                2. True leaves smooth, waxy, may be slightly hairy; sap milky
                1. Cotyledons, if present, lanceolate to elliptic ..... HEMP DOGBANE, *Apocynum cannabinum*
                2. Cotyledons, if present, oblong ..... COMMON MILKWEED, *Asclepias syriaca*

Parts of a plant

Leaf shapes

Ochrea

Ochrea: a papery, membrane-like structure surrounding the nodes of plants in the Polygonaceae (buckwheat or smartweed) family.

Leaf arrangement

Grass leaves

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