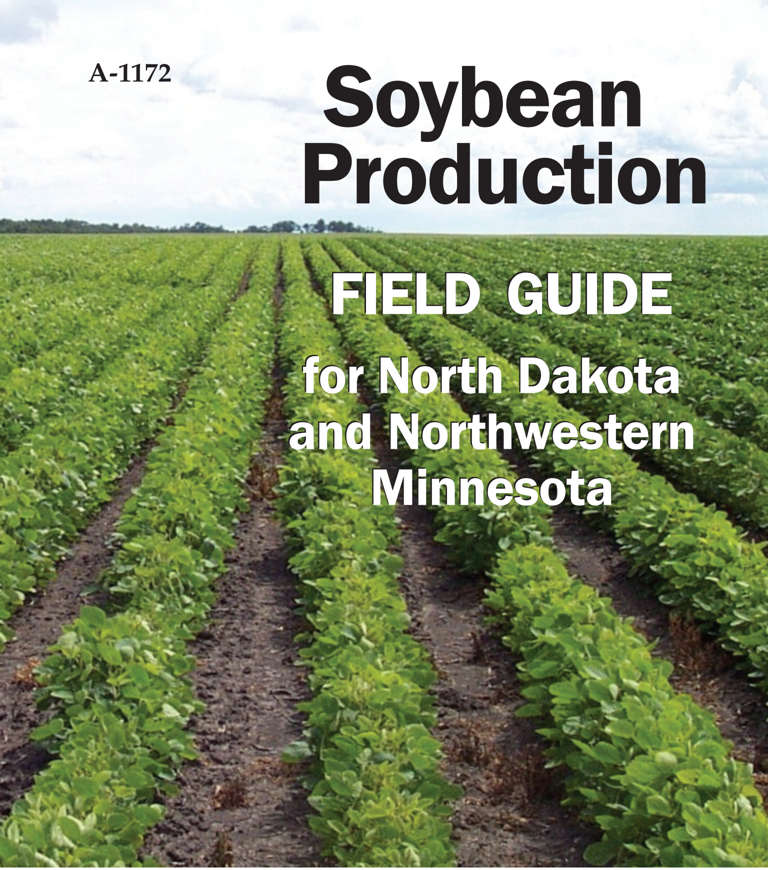
A-1172

# Soybean Production

## FIELD GUIDE for North Dakota and Northwestern Minnesota



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# Index

# Introduction

**Hans Kandel,**
Extension Agronomist

Changing weather conditions with varied rainfall amounts and stored soil water require soybean [*Glycine max* (L.) Merr.] growers to make careful decisions regarding tillage system, fertility management, variety selection, seedbed preparation, weed control strategies, crop rotations, water management and pest management practices.

This field guide has been developed to help you make timely management decisions. However, detailed and extensive information on any one area is not provided because of limited space. Complete discussions of soil fertility; weed, disease and insect control; variety performance; harvesting; and storage are available in other Extension publications listed in the back pages.

The pesticide use suggestions in this guide are based on federal label clearances and some state labels in North Dakota. Also, suggestions are based on research information collected in North Dakota State University experiments or trials in other states. All pesticides listed had a federal or state label at the time of publication of this guide. Check all pesticide labels at time of use for the most current label registration.

Modern technology, fluctuating export markets, changing USDA farm policies and environmental regulations all contribute to soybean growers' needs for careful planning and management to assure high yields and profitable production.

The publishers and contributors do not assume any responsibility, make any guarantees or offer any warranties in regard to the results obtained from use of the recommendations appearing in this guide.

## Soybean Growth and Development

The soybean is a dicotyledonous plant that has epigeal emergence, meaning that during germination, the cotyledons are pulled through the soil surface by an elongating hypocotyl. The soil-penetrating structure is the hypocotyl arch. Once emerged (VE stage), the green cotyledons (seed halves) open and supply the new seedling with stored energy while capturing a small amount of light energy. The growing point is between the two cotyledons, and because it is above the ground, it could be killed by a spring frost or physical damage. This is in contrast with corn, in which the growing point is below the surface during the early development stages. The first true vegetative leaves formed are the unifoliolate leaves. These two single leaves form directly opposite one another above the cotyledonary node (VC stage). All other leaves are trifoliolates and consist of three leaflets (V1-n stages).

# Soybean Emergence

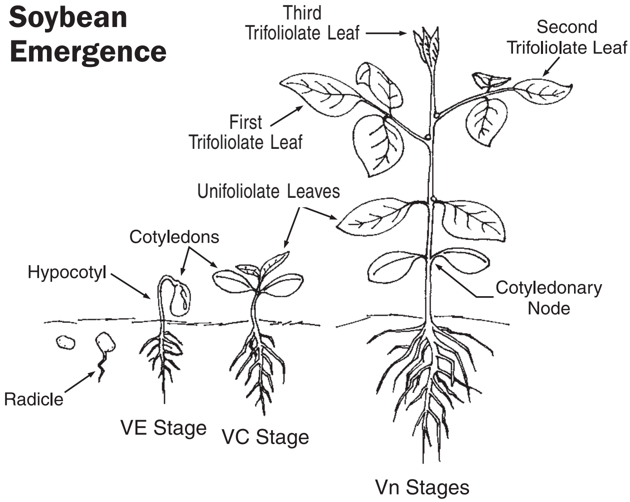


**Figure 1. Soybean Emergence.**

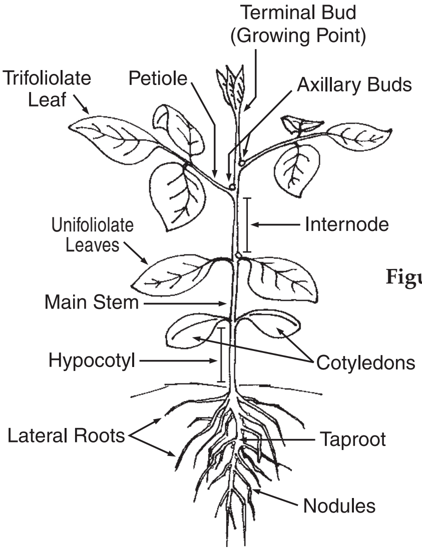


**Figure 2. The soybean plant in V2 stage of development.**

# Growth Stages

Soybean development is characterized by two distinct growth phases. The first is the vegetative (V) stages that cover growth from emergence to flowering. The reproductive (R) stages cover growth from flowering through maturation.

Plant stages are determined by classifying leaf, flower, pod and seed development. Staging also requires node identification. A node is the part of the stem where a leaf is (or has been) attached.

A leaf is considered fully developed when the leaf at the node directly above it (the next younger leaf) has expanded enough so that the two lateral edges on each of the leaflets have partially unrolled and are no longer touching.

## Vegetative stages (V)

| Stage | Description |
|---|---|
| VE | **Emergence** – Cotyledons above the soil surface. |
| VC | **Cotyledon** – Unifoliolate leaves unrolled sufficiently so that the leaf edges are not touching. |
| V1 | **First-node** – Fully developed leaves at unifoliolate node. |
| V(n) | **nth-node** – The "n" represents the number of nodes on the main stem with fully developed leaves beginning with the unifoliolate leaves. |

From *Fehr and Caviness*[1]

## Reproductive stages (R)

| Stage | Description |
|---|---|
| R1 | **Beginning bloom** – One open flower at any node on the main stem. |
| R2 | **Full bloom** – Open flower at one of the two uppermost nodes on the main stem with a fully developed leaf. |
| R3 | **Beginning pod** – Pod 3/16 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf. |
| R4 | **Full pod** – Pod 3/4 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf. |

R5 **Beginning seed** – Seed 1/8 inch long in a pod at one of the four uppermost nodes on the main stem with a fully developed leaf.

R6 **Full seed** – Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed leaf.

R7 **Beginning maturity** – One normal pod on the main stem that has reached its mature pod color.

R8 **Full maturity** – Ninety-five percent of the pods have reached their mature pod color. Five to 10 days of drying weather are required after R8 for the soybean moisture levels to be reduced to less than 15 percent.

From *Fehr and Caviness*[1]

## Number of days between stages.

| Stages | Average Days Fehr | Range in Days Fehr |
|---|---|---|
| Planting to VE | 10 | 5-15 |
| VE to VC | 5 | 3-10 |
| VC to V1 | 5 | 3-10 |
| V1 to V2 | 5 | 3-10 |
| V2 to V3 | 5 | 3-10 |
| V3 to V4 | 5 | 3-8 |
| V4 to V5 | 5 | 3-8 |
| beyond V5 | 3 | 2-5 |
| R1 to R2 | 3 | 0-7 |
| R2 to R3 | 10 | 5-15 |
| R3 to R4 | 9 | 5-15 |
| R4 to R5 | 9 | 4-26 |
| R5 to R6 | 15 | 11-20 |
| R6 to R7 | 18 | 9-30 |
| R7 to R8 | 9 | 7-18 |

From *Fehr and Caviness*[1]

[1] Fehr, W.R., and C.E. Caviness. 1977. Stages of soybean development. Spec. Rep. 80. Iowa State Univ. Coop. Ext. Serv., Ames.

**Number of days between stages (0.0-0.5 relative maturity; 2004-07).**

| Stages | Average Days Carrington | Range in Days Carrington |
|---|---|---|
| Planting to VE | 18 | 11-26 |
| VE to V1 | 13 | 11-15 |
| V1 to V3 | 10 | 8-12 |
| V3-R1 | 13 | 8-16 |
| R1 to R3 | 16 | 12-20 |
| R3 to R5 | 11 | 6-14 |
| R5 to R7 | 36 | 32-44 |
| R7 to R8 | 6 | 5-10 |

From *Endres et al.* Carrington Research Extension Center Annual Reports.

Extremes in growing conditions, such as temperature, rainfall and soils, can greatly alter the development of soybean. Many post-applied herbicides are labeled for application at certain soybean growth stages. To avoid herbicide injury (some herbicides), we highly recommend you identify development by growth stage and not use plant height, planting dates or row closure as a basis for application timing.

## Variety Selection and Adaptation

Soybean variety selection should be based on maturity, yield, seed quality, lodging resistance, iron-deficiency chlorosis tolerance and disease reaction. Comparative maturity and yield of public and private soybean varieties can be obtained from a current copy of Extension publication A-843, "North Dakota Soybean Variety Performance Testing."

Later-maturing varieties tend to yield more than early maturing varieties when evaluated at the same location. After determining a suitable maturity for the field, comparing yields of varieties that are of similar maturity is important. Although late maturity increases yield potential, later-maturing varieties are more risky to grow than earlier-maturing varieties because an early fall frost may kill a late-maturing variety before the beans have completely filled in the pods, which impacts yield and quality.

## Soybean Maturity

Soybean respond to both day length and heat units, so the actual calendar date a variety will mature is highly influenced by latitude; each variety has a narrow range of north to south adaptation. Soybean yield and quality are affected if a season-ending freeze occurs before a variety reaches physiological maturity. Dates of maturity are listed in performance tables and indicate when varieties were physiologically mature. Usually harvest can commence approximately seven to 14 days after the soybean crop is physiologically mature. Relative maturity ratings also are provided for many of the varieties entered in the trials at various locations. Relative maturity ratings for private varieties were provided by the companies entering the variety in the trial.

Varieties of maturity groups 00 (double zero), 0 (zero) and 1 are suitable for eastern North Dakota and northwestern Minnesota. These maturity groups are further subdivided. For example, a 0.1 maturity group is an early group 0 variety and a 0.9 is a late maturity group 0 variety.

Generalized areas of adaptation in North Dakota are indicated by zones in Figure 3. Minnesota maturity zones are indicated in Figure 4.

The best way to select a high-yielding variety is to use data averaged across several locations and years. Because weather conditions are unknown in advance, averaging across several years' data will identify a variety that likely will yield well across different weather conditions. Selecting a variety that has performed relatively well in both dry and moist conditions is the best way to pinpoint a variety that does well, regardless of weather fluctuations.

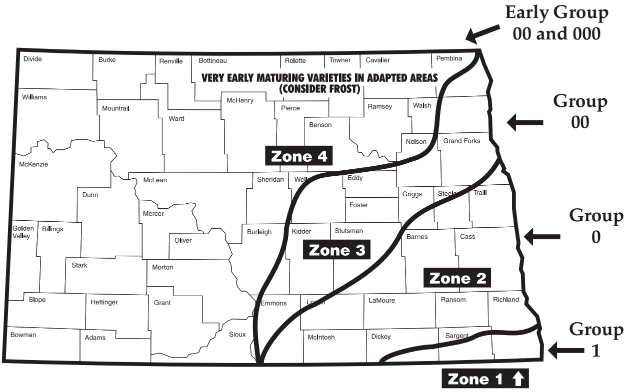


**Figure 3. North Dakota soybean maturity zones.**

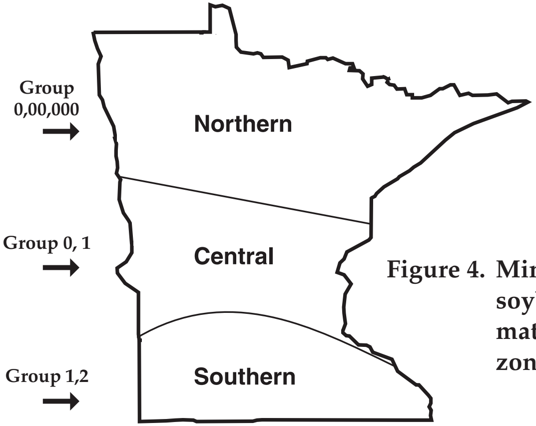


**Figure 4. Minnesota soybean maturity zones.**

## Phytophthora

Phytophthora root rot caused by the soilborne-fungus *Phytophthora sojae* is the No. 1 disease problem of soybean in North Dakota. Phytophthora root rot tends to be more of a problem in the Red River Valley and on poorly drained, heavy-textured soils, but the disease can cause significant stand reduction and yield loss in other areas when conditions are favorable. Most varieties have phytophthora root rot-resistance genes. Each gene for resistance confers resistance to a different race (or races) of phytophthora. For example, a gene that may confer resistance to Race 3 may not confer resistance to Race 4 and vice versa. According to a survey of phytophthora races done by NDSU's soybean pathologist, Berlin Nelson, Races 3 and 4 are most common in North Dakota. However, numerous other races are found in the state. Based on these findings, resistance genes *Rps6* and *Rps1k* (commonly called the k gene) are the most likely genes to provide resistance against the races common in North Dakota. Although use of a soybean variety with the genes *Rps6* or *Rps1k* does not guarantee control, deploying one of these two resistance genes will maximize the likelihood of some protection against phytophthora root rot.

## Iron-deficiency Chlorosis

Iron-deficiency chlorosis (IDC) is a major problem in the eastern part of North Dakota and western Minnesota and is caused by iron being less available as soil pH increases. Iron-chlorosis symptoms are most common during the two- to seven-trifoliolate leaf stages. Plants tend to recover and start to turn green again during the flowering and pod-filling stages. However, IDC during the early vegetative stages can reduce yield severely. Some varieties are more tolerant to IDC than others. For high pH soils with known IDC problems, select an IDC-tolerant variety of suitable maturity that is high yielding. Variety IDC sores are posted on Jay Goos' website at *www.yellowsoybeans.com*. Data on genetic differences for IDC tolerance are available in publication A-843.

## Soybean Cyst Nematode

The soybean cyst nematode (SCN), *Heterodera glycines*, is a small parasitic roundworm that attacks the roots of soybean plants. Soybean cyst nematode has been found and verified in Cass and Richland counties of North Dakota and up to Red Lake County in northwestern Minnesota. Unverified reports indicate SCN also has been found in fields in adjacent counties. Soybean cyst nematode causes yield losses in infested fields. Crop rotation and resistance are the most important management practices growers can use to control nematodes. Growers may want to consider testing their soils for SCN. If a nematode problem is in the field, only resistant soybean varieties should be planted.

# Specialty Soybean

### Food soybean

Some soybean varieties have been developed for human consumption and have special food-processing characteristics. Tofu is a white curd that primarily is consumed in Asian countries. Special varieties have been developed that are high in protein and make smooth-textured tofu. These high-protein tofu types are lower yielding than the oilseed varieties sold to the elevator. Natto is another human food product made from soybean. Natto is a fermented product made from whole soybeans that are cooked. Natto cultivars are very small seeded and tend to yield even less than the specialty cultivars developed for the tofu market. Growers should consult university publications on soybean variety performance to determine how much less these specialty varieties yield compared with oilseed soybean. Based on the lower yield, a higher price per bushel needs to be obtained to economically justify growing these specialty soybean types. A contract should be arranged prior to growing these special types so a market will be available.

**Oil modified**

Soybean cultivars with modified oil content are being developed. Different fatty acid compositions modify the type of oil the soybean plant produces in the seed. Low saturated fats are desirable because this type of oil is better for human health. High oleic, low palmitic, low stearic and low linolenic acid content are all genetic modifications that produce healthier oil for human consumption. We have not seen any indication that these modifications reduce yield. However, yield of specific cultivars with modified oil content should be evaluated to determine whether high yield has been incorporated with the modified oil content. These specialty cultivars are commercially available and will be produced using identity-preserved (IP) marketing.

## Seedbed Preparation

Soybean can be grown on a wide range of soil types under various cultural practices. Because of seed size and physiology, soybean seeds require about 50 percent of the seed weight in moisture to germinate. Also, soybean is seeded only 1 to 1.5 inches deep. These factors explain why preparation of a firm, uniform seedbed is important for optimum stand establishment. Shallow spring tillage to kill weeds before planting is effective on fall-tilled fields. Spring tillage usually is done just before planting. Several reduced-tillage programs can be followed. Many farmers are growing soybean under a no-till program. Special planters or drills may be required to handle surface residue in no-till and some reduced-tillage systems. Soybean, like other legume crops, has difficulty emerging through compacted layers and surface crusts.

### Planting Date

Soybean is susceptible to frost and prolonged exposure to near-freezing conditions in the spring and fall. Plant soybean after the soil has warmed to 50 F and air temperatures are favorable. Soybean generally should not be planted earlier than five days before the average last killing frost. This provides less than a 50 percent chance of frost killing the soybean plant. Very early planting in cool, wet soil may result in low germination, increased incidence of seedling diseases and poor stands.

Planting dates during the first half of May are favorable for highest yields with a reduced risk of frost injury. Earlier seeding allows the use of full-season varieties, which typically yield more than shorter-season varieties.

Data from date-of-planting studies at the NDSU Fargo Experiment Station indicated that late plantings had lower seed yields, poorer seed quality, lower oil content, shorter plant height and pods set closer to the ground compared with optimum planting dates. Some early maturing varieties have had acceptable yields when weather factors such as hail, late spring frost, floods, etc., necessitate late planting or replanting.

Soybean stands with poor emergence often are replanted without considering the yield-compensating ability of the plants in the initial stand. The yield of an initial planting at less than full stand must be compared with the yield of the replanted crop to determine whether replanting is justified. Replanting costs include seed, tillage, replanting and labor. The yield of a replanted crop must be sufficiently greater than the yield of the initial planting to cover the expenses associated with replanting. Risk of fall freeze damage to the replanted crop must be considered when deciding the maturity of the variety selected for replanting.

Plan to plant seed 1 to 1¾ inches deep and place the seed in moist soil. Planting deeper than 2 inches or in a soil that crusts may result in poor emergence and plant stand. Seeding in rows permits cultivation for weed control.

## Planting Rate

Soybean yields have not varied significantly over a wide range of plant populations. A plant population of approximately 150,000 plants per acre is desirable regardless of row spacing. Seeds per pound in available varieties range from 2,200 to 3,400, with an average of 3,000 seeds per pound. High planting rates may cause yields to decrease in low rainfall environments because of drought stress, and in a good rainfall year, high plant populations may lodge more than low populations. Low plant populations reduce lodging but contribute to low pod set and excessive branching. Extremely low seed number per foot of row may result in erratic stands due to lack of seedling energy necessary to break the soil surface. This may be critical in solid-seeded stands where soils are prone to crusting.

Seeding rates should be increased (around 10 percent) to compensate for natural occurring factors that cause some live seeds not to develop into established plants. Slightly higher seeding rates also may be advantageous with late planting dates or in no-till, where soil temperatures are lower. If planting in narrow row spacings (less than 10 inches), we suggest soybean seeding rates be adjusted upward. We recommend seeding rates of 175,000 seeds per acre in 12- to 15-inch row spacings and 200,000 seeds per acre when drill seeding. To ensure planting enough soybean seed, the planting rate should be based on a seed count. You will need to know the following to calculate the rate:

1. Desired population at harvest
2. Average stand loss for your farm
3. Germination value of your seed
4. Number of seeds per pound of seed

The following is an example for calculating planting rate:

1. Desired population at harvest is 150,000 plants per acre.
2. Normal stand loss is 10 percent.
3. Seed germination is 95 percent.
4. Soybean seed has a seed count of 3,000 seeds per pound or 180,000 seeds per bushel.

The seeding rate (SR), expressed as number of seeds per acre, can be calculated from the following equation: SR = D*[100/(M1)]*[100/(100-M2)], where D is the desired plant density per acre (150,000), M1 (germination percent = 95 percent) and M2 (average percent stand loss on the farm = 10 percent).

SR = 150,000*[100/(95)]*[100/(100-10)] =
175,450 seeds per acre

175,450 seeds ÷ 3,000 seeds per pound = 58.5 pounds/acre (lb/a) of soybean seed needs to be planted.

## Row Spacing

Midwest research demonstrates that higher yields of soybean can be obtained in rows of less than 30-inch spacing if stands are well-established and weeds are controlled adequately. NDSU research indicates that 12- to 18-inch row soybean outyields wider-spaced soybean by an average of 5 percent. The advantages for narrow-row soybean are increased yield, reduced soil erosion, increased harvesting efficiency, early crop canopy closure to help control weeds, and the convenience of using existing small-grain equipment for some planting and harvesting operations. The primary disadvantages of narrow row production (solid seeding) are increased potential disease problems and seedling emergence problems if the soil crusts easily.

# Planting Guide

To determine the number of seeds per acre planted, add seed to your planter or drill and operate it on a firm soil surface so seed is visible on the surface. Operate it for a short distance close to your normal operating speed. Then go back and count the number of seeds dropped in 1 linear foot of planter row. Make several counts and determine an average. Refer to one of the following charts to see that you are planting the number of seeds that you calculated in the earlier section.

**Soybean seeds per linear foot of row (seed count of 2,500 seeds per pound).**

| Approx. pounds seed per acre | Seeds per acre | Seeds per foot of row with row spacing (inch) of: | | | |
|---|---|---|---|---|---|
| | | 6 | 12 | 22 | 30 |
| 40 | 100,000 | 1.2 | 2.3 | 4.2 | 5.7 |
| 50 | 125,000 | 1.4 | 2.7 | 5.3 | 7.2 |
| 60 | 150,000 | 1.7 | 3.4 | 6.3 | 8.6 |
| 70 | 175,000 | 2.0 | 4.0 | 7.4 | 10.0 |
| 80 | 200,000 | 2.3 | 4.6 | 8.4 | 11.5 |

**Soybean seeds per linear foot of row (seed count of 3,000 seeds per pound).**

| Approx. pounds seed per acre | Seeds per acre | Seeds per foot of row with row spacing (inch) of: | | | |
|---|---|---|---|---|---|
| | | 6 | 12 | 22 | 30 |
| 40 | 120,000 | 1.4 | 2.8 | 5.0 | 6.9 |
| 50 | 150,000 | 1.7 | 3.5 | 6.3 | 8.7 |
| 60 | 180,000 | 2.1 | 4.2 | 7.5 | 10.4 |
| 70 | 210,000 | 2.5 | 4.9 | 8.8 | 12.1 |
| 80 | 240,000 | 2.8 | 5.6 | 10.0 | 13.8 |

# Air Seeder Calibration

Calibrating an air seeder usually is done by following the directions listed in the operators manual. It usually will tell you to hand turn the seed metering system a number of turns for a predetermined area. This often is listed for one-tenth or one-fourth of an acre. Then the metered seed needs to be weighed on a scale. Sometimes these scales are provided with the air seeder. The weights need to be multiplied by 10 for one-tenth of an acre or multiplied by 4 for one-fourth of an acre, and then adjustments can be made based on the previous calculated amounts.

Another method for calibrating an air seeder requires collecting seed from the seed openers. Probably the easiest method is to place a tarp under the openers, collect seed over an area or distance (one-tenth of an acre) and weigh the pounds of seed collected.

First, determine the pounds of seed to plant as calculated in the planting rate section of this publication.

Then, (1) determine the circumference (feet) of the seed meter drive wheel on your seeder using the following formula:

$$c_{(ft)} = \frac{\text{diameter in inches x 3.14}}{\text{12 inches per foot}}$$

(2) Determine the drive wheel revolutions required to equal one-tenth of an acre. Use the following chart to calculate this number, which is based on the width of your air seeder.

**Travel distance to equal 1/10 acre.**

| Drill width | Distance |
|---|---|
| (feet) | (feet) |
| 16 | 272 |
| 20 | 218 |
| 24 | 181 |
| 28 | 156 |
| 32 | 136 |
| 36 | 121 |
| 40 | 109 |
| 44 | 99 |
| 48 | 91 |

(3) Next, calculate the metering wheel revolutions to cover this distance:

$$\text{Metering wheel revolutions} = \frac{\text{distance to cover 1/10 acre (feet)}}{\text{Circumference of drive wheel (feet)}}$$

(4) Place seed in the air seeder bin and start the air delivery system. Manually turn the metering wheel the number of revolutions that were calculated to cover one-tenth of an acre.

(5) Weigh the seed collected on the tarp and multiply times 10. This number should equal the pounds of seed you want to plant.

Drill calibration is becoming extremely important so you can be sure you are planting the correct amount of seed. If the amount of seed determined with either method is not equal to the amount of seed you desire, make an adjustment to the feed rate and recheck your seeder.

This method also works for determining the pounds of fertilizer to be applied.

**Hula Hoop method for determining population of drilled soybean[1].**

| | Inside diameter of Hula Hoop (inches) | | | | |
|---|---|---|---|---|---|
| **No. of Plants** | **30** | **32** | **34** | **36** | **38** |
| | —— Population x 1,000 —— | | | | |
| 10 | 89 | 78 | 69 | 62 | 55 |
| 12 | 107 | 94 | 83 | 74 | 66 |
| 14 | 124 | 109 | 97 | 86 | 77 |
| 16 | 142 | 125 | 110 | 99 | 89 |
| 18 | 160 | 140 | 124 | 111 | 100 |
| 20 | 178 | 156 | 138 | 123 | 111 |
| 22 | 196 | 172 | 152 | 136 | 122 |
| 24 | 213 | 187 | 166 | 148 | 133 |
| 26 | 231 | 203 | 179 | 160 | 144 |
| 28 | 249 | 218 | 193 | 173 | 155 |
| 30 | 266 | 234 | 207 | 185 | 166 |
| 32 | 284 | 250 | 221 | 197 | 177 |
| 34 | 302 | 265 | 235 | 209 | 188 |
| 36 | — | 281 | 249 | 222 | 199 |
| 38 | — | 297 | 362 | 234 | 210 |
| 40 | — | — | 277 | 247 | 221 |
| 42 | — | — | 290 | 259 | 232 |
| 44 | — | — | 304 | 271 | 243 |
| 46 | — | — | — | 284 | 255 |

[1] Example: If you count 24 plants inside a 32-inch Hula Hoop, your plant population is 187,000 per acre. Make at least 10 random counts in representative areas per field.

# Soybean Soil Fertility

**Dave Franzen,**
Extension Soil Science Specialist

Soybean has a need, as do most crops, for the 14 mineral nutrients: nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), boron (B), chloride (Cl), nickel (Ni) and molybdenum (Mo). Of these, North Dakota soils provide adequate amounts except for nitrogen, phosphorus, potassium, sulfur and iron.

## Nitrogen Fixation

Although the atmosphere is 78 percent nitrogen gas, plants cannot use it directly. Plants can use only ammonium-N or nitrate-N. Soybean is a legume and normally should provide itself N through a symbiotic relationship with N-fixing bacteria of the species *Bradyrhizobium japonicum*. In this symbiotic relationship, carbohydrates and minerals are supplied to the bacteria, and the bacteria transform nitrogen gas from the atmosphere into ammonium-N for use by the plant. This process also is called $N_2$ fixation.

The process of soybean infection by N-fixing bacteria and symbiotic N fixation is a complex process between the bacteria and the plant. The right species of N-fixing bacteria must be present in the soil either through residual populations from inoculation of previous soybean crops or through inoculation of the seed or seed zone at planting.

N-fixing bacteria are attracted to the roots by chemical signals from the soybean root. Once in contact with the root hairs, a root compound binds the bacteria to the root hair cell wall. The bacteria release a chemical that causes curling and cracking of the root hair, allowing the bacteria to invade the interior of the cells and begin to change the plant cell structure to form nodules. The bacteria live in compartments called "bacteroids;" a nodule may have up to 10,000 bacteroids. Each bacteroid is bathed in nutrients from the host plant, and the bacteroid takes $N_2$ gas from the soil air and converts it to ammonium-N using the enzyme nitrogenase. Nitrogenase consists of one Fe-Mo (iron-molybdenum)-based protein and two Fe (iron)-based proteins. Fe and Mo deficiencies, therefore, are a problem for N fixation in certain soybean-growing areas.

N fixation by nitrogenase must take place in an environment without oxygen. However, bacteria and roots have to respire, which requires oxygen. To get around this problem, nodules use the same strategy humans do in oxygen transfer in our blood. The transfer compound is leghemoglobin (closely related to our hemoglobin). It results in a pink-red color of active nodule interiors. N fixation is very energy intensive and does not come without cost to the soybean plant. Ten pounds of carbohydrate are needed for each pound of N produced.

Some researchers refer to carbohydrate movement in soybean plants as the "source-sink" relationship. Early in the growing season, the source of carbohydrates is leaves and the main sink is the nodule, in addition to the growing points of the plant. After flowering, the activity of nodules decreases rapidly and eventually stops due to lack of nutrient supply. The plant changes the sink from the nodules to the seed. Nodules disintegrate and bacteria are released once again into the soil.

These environmental conditions limit N fixation:

**Cold and heat** – A temperature of 60 to 80 F is ideal, while levels above or below this reduce bacterial activity.

**N levels too high** – When that occurs, nodule number and activity decrease. Roots do not attract bacteria or allow infection, so N fixation is limited or nonexistent.

**Drought** – Poor plant growth does not allow the plants to sustain nodules and plant growth, therefore nodule activity is sacrificed.

**Excessive wetness** – If soil pores are filled with water, not air, no N is available to fix.

**Compaction** – Compaction has been shown to affect nodulation of soybean plants more than N fertilization. If no air is available, no N-gas is available to fix.

In the soil, competition is possible between *Bradyrhizobium japonicum* bacteria found in inoculum and native strains of Rhizobium bacteria, which are less efficient than bacteria in inoculum. Nodules from initial inoculation tend to be on the main tap root near the surface, while native strains tend to grow on the branches away from the seed zone. Native strains are sometimes much better at infecting roots and can limit inoculation effectiveness. Native strains also siphon off nutrients from the host, lowering the N-fixing ability of more efficient strains.

## Using Inoculants

Inoculation is the application of specific bacteria (Rhizobia) to the soybean seed prior to planting. Brands of inoculants can be purchased in various formulations, including liquids, frozen prep, peat-based, dry powder-based and granular.

Proper storage is critical. Make certain the inoculant is fresh and has been stored in a manner recommended by the manufacturer. Inoculation ahead of seeding is possible, but check with the manufacturer to see if the shelf life of the product will allow it. Some seed treatments are toxic to inoculum. For example, Captan and PCNB are very toxic to inoculum. Vitavax is relatively safe up to 24 hours before seeding. Thiram produces effects in between these two groups. Planter box treatments using dry materials or auger treatments with liquids, fresh or frozen are all acceptable if they give good coverage of all seed. Granular treatments applied separately in a band at seeding also work well but are more expensive than planter box or auger treatments.

Follow product instructions and get uniform coverage on the seed. Use the high side of the application rate, especially for new growers and first-time fields. For first-time inoculum use, the granular form is most foolproof, particularly if the granular applicator is calibrated before use. On Conservation Rerserve Program breakout or previously flooded lands, we highly recommend growers inoculate soybean seed. Plant seed as soon as possible after inoculation (four hours for liquids and 24 hours for dry material). Always keep the inoculant and inoculated seed out of the sun in a cool place by tarping the truck or keeping it in a shaded area.

# Nutrients

**Nitrogen Recommendations for Soybean**

Nitrogen is not recommended for soybean, even first-year soybean. Elevated soil nitrate may increase the likelihood and severity of iron-deficiency chlorosis. The economics of late-season N application also is not justified.

**Phosphorus**

Soybean reacts better to broadcast applications of P than to banded applications with or near the seed. Soybean plants appear to prefer their entire rooting zone bathed in nutrients rather than having nutrients concentrated in a small area of the root zone. Several recent studies confirm that broadcast application of P is better than banded P.

If soil test levels are low to very low, then a separate application of broadcast P is justified. However, if soil test levels are medium or higher, the level of response of soybean to P fertilizer is small, not justifying a separate P application. Soybean roots are excellent scavengers of P at medium or higher soil test levels. At medium or higher soil test levels, front-loading the crop prior to soybean or applying more to the crop following soybean would be better than applying P to that soybean crop. The most common fertilizer application in the central soybean belt is applying extra P to the previous corn crop and allowing soybean plants to scavenge what is left. The practice has been successful for more than 40 years.

Even though a broadcast application of P may result in several more bushels of soybeans than a banded application, some producers will elect to apply P with the seed. **NO** fertilizer of any kind is recommended with soybean seed in a 15-inch row or wider. However, using a double-disk drill with 6-inch spacings, up to 10 pounds of N/acre may be applied to soybean as a P fertilizer (do not use urea). With air seeders, risk to soybean plants with fertilizer spread across the seed zone will be decreased. Even though applying up to 10 pounds of N/acre with a 6-inch row spacing is possible, dry weather at planting will increase the risk of injury. Therefore, the prudent action for the producer is not to push rates too hard toward the limit because of the variability within fields in both sand and soil water content. Sandier textures and low available soil-water soils may show more stand injury than other areas of the field. Again, the best recommendation for P application is to broadcast it.

**Potassium**

Testing the soil for K is important. After many years of soybean production, some soils may have been mined of K. Sandier-textured soils in the beach ridges west or east of the Red River Valley have been low in K for many years. Some sandier hilltops in the glacial till plain or in residual materials west of the Missouri River also may be lower in K. Some limited soil testing based on general landscape will show whether K is needed in these areas. Generally, coarser-textured soils are more at risk for K deficiency than heavier soils. However, with continuous soybean production, even heavy soils may be at risk. Potassium either should be broadcast or banded, with the seed and fertilizer separated. Do not apply potassium fertilizers with the seed.

**Sulfur**

Deficiencies are most possible on sandier hilltops and eroded areas with low organic matter. The risk of S deficiency is increased after wet falls and/or above-normal snowmelt and early spring rains. Coarser-textured, low-organic matter soils are then at risk and should receive a S application under those climatic circumstances.

## Soil pH

Soybean grows best around a pH of 6.5. Lowering the pH from 8 to 6.5 usually is not an option because of the cost of amendments and the formation of salt if the application is successful. However, low pH levels have been found in North Dakota. Sampling by landscape position reveals much better pH information than composite testing. Application of ground limestone or sugarbeet lime would be justified if the soil pH is lower than 6.

## Zinc

Soybean is usually not sensitive to low soil zinc levels in North Dakota and grow well at zinc test levels much lower than sensitive crops such as dry beans and corn. In a recent North Dakota study with 10 locations, nine varieties with and without zinc revealed no significant differences, even at soil test levels as low as 0.2 parts per million.

## Iron

Soybean plants are susceptible to low soil iron availability. Iron-deficiency chlorosis (IDC) is expressed as yellowing in between veins on younger leaves. Iron chlorosis is not seen until the first trifoliolate leaf emerges because before that time, iron from the seed is translocated to new growth. At emergence of the first true leaves, iron becomes an immobile nutrient and the plant must rely on soil availability to supply iron needs. This yellowing is called "chlorosis."

Iron deficiency chlorosis in this region is different than chlorosis historically reported in the central soybean growing belt. High soil carbonates, increased solubility of bicarbonate caused by soil wetness, and the presence of high levels of soluble salts have been shown to influence the presence and severity of iron chlorosis in soybean in North Dakota and northwestern Minnesota. Cold temperatures also aggravate the problem in some spring seasons. Application of harsh contact herbicides and systemic residual herbicides postemergence are discouraged on severely stressed soybean plants.

Application of iron-EDDHA chelate appears to be most helpful in correcting chlorosis. New formulations may be cost effective. An iron-EDDHA seed-applied fertilizer also should be used in conjunction with an IDC-tolerant variety.

Recent research in North Dakota and Minnesota has shown that in fields susceptible to IDC, seeding an oat cover crop at the same time as glyphosate-resistant soybeans decreases the IDC effect. The oat plants serve to dry the soil and take up some residual soil nitrate. In a dry spring, the oat plants should be killed earlier, and in a wet spring, they should remain until the five-leaf stage if practical.

To combat chlorosis, plant the most iron chlorosis-tolerant varieties available in your maturity range. See *www.yellowsoybeans.com* for the latest updates on varietal screening in our area.

**Nutrient recommendations for soybean.**

| | Soil test P, ppm (Olsen) | | | | | Soil test K, ppm | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | VL | L | M | H | VH | VL | L | M | H | VH |
| Yield potential | 0-3 | 4-7 | 8-11 | 12-15 | 16+ | 0-40 | 41-80 | 81-120 | 121-160 | 160+ |
| bu/a | lb $P_2O_5$/acre | | | | | lb $K_2O$/acre | | | | |
| 30 | 35 | 20 | 10 | 0 | 0 | 55 | 35 | 10 | 0 | 0 |
| 40 | 50 | 30 | 10 | 0 | 0 | 75 | 45 | 15 | 0 | 0 |
| 50 | 60 | 35 | 10 | 0 | 0 | 90 | 55 | 20 | 0 | 0 |
| 60 | 70 | 40 | 10 | 0 | 0 | 110 | 65 | 20 | 0 | 0 |

Olsen P recommendation = (1.55- 0.14 STP)YP.

Potassium recommendations = (2.2-0.0183 STK)YP.

The abbreviations used in the equation are as follows:

YP = yield potential.
STP = soil test phosphorus.
STK = soil test potassium.
ppm = parts per million.

# Soybean Weed Control

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The weed control suggestions in this production guide are based on the assumption that all herbicides mentioned will have a registered label with the Environmental Protection Agency. Soybeans treated with a nonregistered herbicide may have an illegal residue which, if detected, could cause condemnation of the crop. Federal law makes liable for seizure any raw agricultural commodity that possesses a pesticide residue for which no exemption or tolerance has been established or that exceeds the tolerances established by the Food and Drug Administration. People using herbicides in a manner contrary to label instructions are subject to penalty under federal and state laws. North Dakota State University or its officers or employees makes no claims or representations that the chemicals discussed will or will not result in residues on agricultural commodities and assume no responsibility for results from using herbicides.

Instructions for registered uses of herbicides are given on container labels. Read and follow label instructions carefully. USE PESTICIDES ONLY AS LABELED.

Herbicide labels also can be found on the Web at *www.cdms.net/Home.aspx.*

## Soybean fall or spring early pre-plant herbicides.

| | Rate/a | Before planting |
|---|---|---|
| 2,4-D amine[1] | 0.5 lb ai<br>1 lb ai | 15 days<br>1 month |
| 2,4-D ester[1] | 0.5 lb ai<br>1 lb ai | 7 days<br>1 month |
| E-99 | 1 lb ai | 15 days |
| Weedone 650 | 1 lb ai | 15 days |
| Aim EC | 2 fl oz | 0 |
| Affinity/thifensulfuron & tribenuron[1]<br>All formulations | Label rates | 14 days |
| Banvel/dicamba[1] | 4 fl oz<br>1 pt | 14 days<br>1.5 months |
| Express/tribenuron[1]<br>All formulations | Label rates | 1.5 months |
| Harmony/thifensulfuron[1]<br>All formulations | Label rates | 0 |
| Ignite 280 | 29 - 36 fl oz | 0 |
| Paraquat[1] - **RUP** | Label rates | 0 |
| Pre-Pare | 0.3 oz | 9 months |
| Rage D-Tech | 9-16 fl oz<br>17-24 fl oz<br>25-32 fl oz | 7 days<br>14 days<br>1 month |
| Roundup/generic[1] | 0.75-3 lb ae | 0 |
| Sequence | 2.5-3.5 pt | 0 |
| Sharpen | 1-2 fl oz | 0-2 months |
| Spartan | 3-8 fl oz | 0 |
| Spartan Advance | 16-36 fl oz | 0 |
| Spartan Charge | 3-8.5 fl oz | 0 |
| Valor[2] + tillage<br>- tillage<br>+ tillage<br>- tillage | 2 oz<br>2 oz<br>3 oz<br>3 oz | 0<br>0<br>0<br>0 |

[1] or generic brand equivalentd
[2] Valor = refer to label for rates >3 oz/a.

## Soil-applied herbicides in soybean

| Herbicide | Product/a (ai/a) | Weeds | When to apply | Remarks and paragraphs |
|---|---|---|---|---|
| **Prowl**<br>**Prowl H2O**<br>(pendimethalin) | **2.4 to 3.6 pt EC**<br>**2.1 to 3 pt ACS**<br>(1 to 1.5 lb) | Annual grass and some broadleaf weeds. | PPI. Fall or spring. | Adjust rate for soil type. Do not apply PRE. Poor wild oat and no wild mustard control. Green foxtail has become resistant to dinitroaniline (DNA) herbicides in North Dakota. |
| **Sonalan**<br>**Sonalan 10G**<br>(ethalfluralin) | **1.5 to 3 pt**<br>**5.5 to 11.5 10G**<br>(0.55 to 1.15 lb) | | | |
| Treflan/generic trifluralin | **1 to 2 pt**<br>(0.5 to 1 lb) | | | |
| Sencor/generic metribuzin | Soil pH >7.5 = **0.25 lb DF**<br>Soil pH <7.5 = **0.33 to 0.5 lb DF** | Broadleaf weeds including wild mustard. | PPI. | Sencor may injure certain soybean varieties. |
| Dual/<br>generic metolachlor | **1 to 2 pt**<br>(0.95 to 1.9 lb) | Grass and some broadleaf weeds. | PPI or PRE. | Dual may give greater weed control than generic metolachlor at equal product rates. Poor wild oat control and wild mustard control. Shallow PPI gives more consistent control than PRE. PRE requires precipitation for herbicide activation. Adjust rate for soil type and OM. Outlook gives greater nightshade or EPOST. control. |
| Intrro/generic alachlor **RUP** | **2 to 3 qt**<br>(2 to 3 lb) | | | |
| Outlook/generic dimethenamid | **16 to 21 fl oz**<br>(0.75 to 1 lb) | | PPI, PRE | |

| | | | | |
|---|---|---|---|---|
| **Valor** (flumioxazin) | **2 to 3 oz WDG** (1 to 1.5 oz) | Small-seeded broadleaf weeds including pigweed, nightshade, kochia lambsquarters, and B. wormwood. | EPP, Shallow PPI, and PRE. | PRE requires precipitation for herbicide activation. Refer to label for tank-mix options, application information, and rate structure. |
| **Spartan** (sulfentrazone) | **3 to 8 fl oz F** (1.5 to 4 oz) | | | |
| **Python** (flumetsulam) *No aerial application* | **0.8 to 1.33 oz DG or 5 to 3 a/pack** (0.64 to 1.06 oz) | Python does not control ALS resistant kochia. | | |
| **Sharpen** (saflufenacil) | **1 fl oz** (0.36 oz) | Broadleaf weeds. | | Sharpen has no grass activity. Provides burndown control of emerged broadleaf weeds. Planting interval is dependent on soil texture and OM. Refer to label for tank-mix options. |

## POST-applied herbicides in soybean

| | | | | |
|---|---|---|---|---|
| Basagran/ generic bentazon | **0.5 to 2 pt applied 1 to 4 times.** (0.25 to 1 lb) | Some broadleaf weeds. | POST. Soybean: After emergence. Broadleaf weeds: **Small.** | Non-residual, contact herbicide requiring thorough coverage. Most active in hot and sunny conditions. Add oil adjuvant at 1 to 2 pt/a. Allow a 30 day PHI. |

| Herbicide | Product/a (ai/a) | Weeds | When to apply | Remarks and paragraphs |
|---|---|---|---|---|
| **Rezult + MSO oil** adjuvant (bentazon & sethoxydim) | **1.6 + 1.6 pt or 0.8 + 0.8 pt 2X or 0.56 + 0.56 pt 3X or 0.4 + 0.4 pt 4X + 1.25 pt/a** (1 + 1 lb or 0.5 + 0.5 lb or 0.38 + 0.38 lb or 0.25 + 0.25 lb) | Small grass and broadleaf weeds including pigweed, ragweed, kochia, lambsquarters, wild buckwheat, biennial wormwood and Canada thistle. | First application: Weeds: **1 inch or less.** Make consecutive applications 7 to 10 days later. | Weeds must be small at application. MSO enhances weed control more than petroleum oil adjuvants. Sequential applications at 7 to 10 day intervals improve overall weed control. Tank-mix with Raptor at 2 fl oz/a for improved weed control. Allow 30 day PHI. |
| **Ultra Blazer** (acifluorfen) | **0.5 to 1.5 pt** (0.125 to 0.375 lb) | Small broadleaf weeds including pigweed and common lambsquarters. | POST. Soybean: 1 to 2 trifoliolates.<br><br>Weeds: Small. | Contact, non-residual herbicides requiring thorough coverage. Most active in hot and sunny conditions. May cause speckling on soybean leaves. Refer to label for crop response, adjuvant type and rate, and tank-mix options. |
| **Cadet** (fluthiacet) | **0.4 to 0.9 fl oz EC** (0.045 to 0.1 oz) | | | |
| **Cobra** (lactofen) | **6 to 12.5 fl oz** (1.5 to 3.2 oz) | | | |
| **Resource** (flumiclorac) | **2 to 3 fl oz EC** (0.215 to 0.32 oz) | | | |
| **Flexstar** (fomesafen + adjuvants) | **0.75 to 1 pt** (0.176 to 0.24 lb) | Broadleaf weeds including pigweed, cocklebur, Venice mallow, mustard, ragweed, kochia, smartweed, EB nightshade. Poor hairy nightshade control. | POST. Soybean: Prior to flowering.<br><br>Weeds: Small. | Contact herbicide requiring thorough coverage. Most active in hot and sunny conditions.Apply at 1 pt/a in N.D. east of I-29 and south of I-94 and in Minn. south of I-94. Use 0.75 pt/a in N.D. east of Hwy 281 and in Minn. south of US Hwy 2. Add MSO at 1% v/v + AMS at 10 lb/100 gal water. Refer to label for crop rotation restrictions and |

| | | | | |
|---|---|---|---|---|
| | | | | restrictions for each geographic region. Refer to narrative for improved broadleaf weed control. |
| **FirstRate** (cloransulam) | **0.3 oz WDG or 10 a/pack** (0.25 oz) | Venice mallow, cocklebur, horseweed, ragweed, sunflower, and wild mustard. | POST. Soybean: Up to 50% of plants flowering. Weeds: Up to 10 inches tall. | Add NIS at 0.125% v/v or oil adjuvant at 1.25% v/v + 28% UAN at 2.5% v/v. Refer to label for weed size, and tank-mix options. |
| Harmony/ generic thifensulfuron | **0.083 (1/12) oz DF0.125 (1/8) oz SG** (0.062 oz) | Wild mustard, pigweed and lambsquarters. No ALS-resistant weed control. | POST. Soybean: Fully expanded first trifoliolate leaf until 60 days PHI. | Add NIS at 0.25% v/v or oil additive at 1 to 2 pt/a+ 28% UAN or AMS. Refer to label for tank-mix options. |
| **Pursuit** (imazethapyr) | **3 fl oz** (0.75 oz ae) | Annual broadleaf weeds. Poor common lambsquarters, ragweed, wild buckwheat and biennial wormwood control. No control of ALS-resistant weeds. | POST. Soybean: Fully expanded first trifoliolate leaf but prior to flowering. Weeds: Small and actively growing. | Add NIS at 0.25% v/v or oil adjuvant at 1 to 2 pt/a + 28% UAN at 2.5% v/v. MSO adjuvants enhance weed control more than petroleum oil or NIS. Refer to label for weed size and application information. Raptor has less soil residual carryover than Pursuit. |
| **Raptor** (imazamox) | **4 to 5 fl oz** (0.5 to 0.625 oz ae) | | | |

| Herbicide | Product/a (ai/a) | Weeds | When to apply | Remarks and paragraphs |
|---|---|---|---|---|
| **Assure II Targa** (quizalofop) | **4 to 10 fl oz** (0.44 to 1.1 oz) | Annual grasses and quackgrass. | Soybean: Prior to pod set. Grass weeds: Refer to table below. | Add oil adjuvant at 1% v/v but not less than 1.25 pt/a. Oil adjuvant at more than 1 qt/a is not needed. See Select Max label for detailed adjuvant recommendations. Use highest rate of Assure II for yellow foxtail control. Grass control is reduced by tank mixtures or close interval application of POST broadleaf control herbicides. Antagonism generally can be avoided by applying a higher rate of grass herbicide or applying the grass control herbicide 1 or more days before or 7 days after the broadleaf control herbicide. Do not cultivate prior to 5 days before or 7 days after application. Refer to label for tank-mix options. |
| **Fusilade DX** (fluazifop) | **5 to 12 fl oz** (1.25 to 3 oz) | | | |
| **Fusion** (fluazifop & fenoxaprop) | **4 to 12 fl oz** (1 to 3 oz & 0.32 to 0.96 oz) | | Soybean: All stages. Grass weeds: Refer to table below. | |
| **Poast** (sethoxydim) | **0.5 to 1.5 pt** (0.1 to 0.3 lb) | Annual grasses. | | |
| Select/generic clethodim | **4 to 16 fl oz** (1 to 4 oz) | Annual grasses and quackgrass. | | |
| **Select Max** (clethodim) | **9 to 32 fl oz** (1.125 to 4 oz) | | | |

## NDSU soybean micro-rate

| | | | | |
|---|---|---|---|---|
| **Rezult B &**<br>**Rezult G +**<br>**Raptor +**<br>**Flexstar +**<br>Select/clethodim +<br>MSO adjuvant | **0.5 to 0.6 pt &**<br>**0.5 to 0.6 pt +**<br>**1 fl oz +**<br>**2 to 4 fl oz +**<br>**2 fl oz (optional) +**<br>**1.25 pt/a** | Grass and broadleaf weeds, including kochia, pigweed and nightshade. May not control wild buckwheat. | POST. Weeds. Small. Must be less than 1 to 2 inches tall. | **User assumes all risk of inadequate weed control when using this reduced-rate treatment.** Must be applied with MSO or MSO and basic pH blend adjuvants. Select/clethodim can be excluded if grass infestation is low. Refer to narrative and Rezult section above. |

**Grass control with post serbicides in soybean.**

| Herbicide | Grass size | Rate |
|---|---|---|
| | (inches) | (fl oz/a) |
| **Green and yellow foxtail** | | |
| Assure II/Targa | 2 to 4 | 7 to 8 |
| Fusilade DX | 2 to 4 | 10 to 12 |
| Fusion | 2 to 4 | 8 |
| Poast | 1 to 8 | 1 pt |
| Select/ | 2 to 8 | 4 to 6 |
| Select Max | 2 to 6 | 9 |
| | 6 to 8 | 12 |
| **Wild-proso millet** | | |
| Assure II/Targa | 2 to 6 | 5 to 8 |
| Fusilade DX | 4 to 8 | 6 |
| Fusion | 4 to 8 | 6 |
| Poast | 4 to 10 | 0.5 pt |
| Select | 1 to 10 | 4 to 6 |
| Select Max | 2 to 6 | 9 |
| | 6 to 8 | 12 |
| **Volunteer corn** | | |
| Assure II/Targa | 6 to 30 | 5 to 8 |
| Fusilade DX | 12 to 24 | 4 to 8 |
| Fusion | 12 to 24 | 6 |
| Poast | 1 to 20 | 1 pt |
| Select | 4 to 12 | 4 |
| | 12 to 24 | 6 |
| Select Max | 1 to 12 | 6 |
| | 12 to 24 | 9 |
| | 24 to 36 | 12 |
| **Wild oat, vol. small grains, sandbur** | | |
| Assure II/Targa | 2 to 6 | 7 to 8 |
| Fusilade DX | 2 to 6 | 8 |
| Fusion | 2 to 6 | 8 |
| Poast | 1 to 4 | 1 pt |
| Select | 2 to 6 | 6 |
| Select Max | 2 to 6 | 9 |
| | 6 to 8 | 12 |
| **Quackgrass** | | |
| Assure II/Targa | 6 to 10 | 12 |
| Fusilade DX | 6 to 10 | 12 |
| Fusion | 6 to 10 | 12 |
| Poast | 6 to 8 | 2 pt |
| Select | 4 to 12 | 8 |
| Select Max | 4 to 12 | 12 |

| Herbicide | Product/a (ai/a) | Weeds | When to apply | Remarks and paragraphs |
|---|---|---|---|---|
| **Preharvest application in soybean** | | | | |
| Roundup/ generic glyphosate | Up to 1.5 lb ae **See Remarks.** | Preharvest weed control. | Prior to harvest. Apply after pods have set and lost all green color. Allow a 7 day PHI. | Add AMS fertilizer at 4 lb/100 gal, or more for hard water. Refer to label adjuvant use. **Do not apply on soybean grown for seed because reduced germination/vigor may occur.** |
| Paraquat **RUP** | **8 to 12 fl oz 2SL** **5.6 to 8.4 fl oz 3SL** (0.13 to 0.188 lb) | Desiccant. | Prior to harvest. Paraquat – Allow a 15 day PHI. | Add NIS at 0.125% v/v. Most active in hot and sunny conditions. Apply when at least 65% of seed pods are a mature brown color or when seed moisture is 30% or less. |
| **Aim** (carfentrazone) | **1 to 1.5 oz** (0.256 to 0.384) | | Aim – Allow a 3 day PHI. | |
| **LibertyLink soybean** | | | | |
| **Ignite 280** (glufosinate) | **22 fl oz** (0.4 lb) | Annual grass and broadleaf weeds including ALS and glyphosate resistant weeds. | POST. Soybean: Emergence up to bloom. Weeds: Up to 3 inches tall. | **Apply only to LibertyLink soybean varieties.** Non-selective, contact, non-residual herbicide requiring thorough coverage. Add AMS at 3 lb/a. Apply with a registered grass herbicide. Refer to label for tank-mix options and restrictions. Most active in hot and sunny conditions. Controls weeds resistant to other herbicides. |

| Herbicide | Product/a(ae/a) | Weeds | When to apply | Remarks and paragraphs |
|---|---|---|---|---|
| **Roundup Ready and Roundup Ready 2 Yield soybean** | | | | |
| Roundup/ generic glyphosate | **Maximum single application =** 1.5 lb ae<br><br>**Maximum in-crop** = 2.25 lb ae<br>**See Remarks.** | Annual and perennial grass and broadleaf weeds. | POST. Soybean: Emergence through R2 of full flowering. The R2 stage when a pod 3/16 inch long at one of the four uppermost nodes appears on the main stem along with a fully developed leaf (R3 stage). Allow a 14 day PHI. | **Apply only to Roundup Ready/RR 2 Yield soybean varieties.**<br>lb ae/gal — lb ai/gal — Maximum single appl. 1.5 ae — Maximum in-crop 2.25 ae<br>3 — 4 — = 64 fl oz — 96 fl oz<br>4/4.17 — 5.4/5.1 — = 48 fl oz — 72 fl oz<br>4.5 — 5.5 — = 44 fl oz — 66 fl oz<br>5 — 6.1 — = 40 fl oz — 60 fl oz<br>Add AMS fertilizer at 4 lb/100 gal, or more for hard water. Multiple applications may be necessary for weed flushes. Drift and off-site movement may cause injury or death to other plants and crops. Refer to label for weeds controlled, application information, adjuvant use, tank-mix options with residual herbicides and restrictions. **Cannot plant harvested patented soybean seed.** |

| Herbicide | Product/a(ae/a) | Weeds | When to apply | Remarks and paragraphs |
|---|---|---|---|---|
| **Roundup Ready/STS (sulfonylurea-tolerant) soybean** | | | | |
| Harmony/ generic thifensulfuron | **0.33 oz DF**<br>**0.5 oz SG**<br>(0.25 oz) | Annual broadleaf weeds including, wild buckwheat, lambsquarters, mustard species, and volunteer RR canola. | POST. RR/STS soybean: First fully expanded trifoliolate to 60 days PHI. | **Apply only to RUR/STS soybean varieties.** Apply with glyphosate at 0.38 to 1.125 lb ae/a.Add NIS at 0.125 to 0.25% v/v to non-loaded glyphosate. Refer to label for adjuvant use. Apply with AMS at 4 lb/100 gal water, or more for hard water. Refer to label for weeds controlled and application information. |

*Refer to Roundup Ready soybean above for use of glyphosate in RR/STS soybean.*

## Weed Management in Roundup Ready Soybean

NDSU recommends using herbicides with different modes of action and different weed control management practices in Roundup Ready soybean production to delay development of glyphosate-resistant weeds.

**COMMANDMENT 1 – Control weeds BEFORE 2 to 4 inches tall to avoid yield loss.**

Remove weeds early, especially when grass weed populations are high. Some data from the Midwest indicate that soybean yield may not be reduced by delaying Roundup/generic glyphosate application until weeds are up to 6 inches tall. However, data from the northern Plains show that, especially under dry conditions, soybean yield loss will occur if weeds become greater than 4 inches tall prior to Roundup/glyphosate application.

Roundup/glyphosate – at 1.5 oz ae/a controls foxtail, 2.25 oz ae/a controls volunteer small grain and 3 oz ae/a controls wild oat and downy brome. Use higher rates on broadleaf weeds, larger weeds and tolerant weeds, or if weeds are under environmental stress.

## Three Systems of Weed Control in RR Soybean

1. PRE followed by glyphosate POST: **All PRE herbicides require rain for activation.**

   Tables list many registered PRE soybean herbicides that can be used in herbicide-resistant soybean. PRE herbicides at 2/3 to the full labeled rate may give 60 to 99 percent control of some grass and broadleaf weeds, will reduce weed infestations emerging with soybean, will allow more flexibility in application of POST herbicides and will help protect yield from early season weed competition.

2. Roundup/generic glyphosate + POST broadleaf herbicide (different mode of action):

   Several herbicides listed in the following table will improve control of weeds not controlled by Roundup/glyphosate. Roundup/glyphosate has no soil residual and will not control weeds emerging after application. Roundup/glyphosate may not control some weed species or biotypes. Many POST herbicides listed will give residual weed control. Follow label directions for tank-mix and application information.

3. Roundup/generic glyphosate (EPOST = 2- to 4-inch-tall weeds) followed by Roundup/glyphosate (POST = 14 to 21 days later):

   This program will increase the risk of weed resistance unless other strategies are used in rotational crops.

The following table shows herbicides to apply in tank-mix or sequentially with Roundup/glyphosate in RR soybean for control of weeds not controlled by Roundup/glyphosate. Weed ratings are control without Roundup/glyphosate. Refer to label for tank-mix and specific application information. Residual weed control listed in the table refers to control of subsequent flushes of weeds after herbicide application.

**Herbicides to apply in tank-mix or sequentially with Roundup/generic glyphosate in RR soybean for control of weeds not controlled by Roundup/glyphosate.** Refer to previous tables for additional herbicides.

| | | Rate/a | Buckwheat, Wild | Canola, Vol. RR[1] | Horseweed (Marestail) | Kochia | Lambsquarters | Mallow, Common | Nightshade species | Prickly lettuce | Ragweed, Common | Smartweed, Annual | Waterhemp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Preplant or PRE herbicides – no residual weed control** | | | | | | | | **Weed ControlRatings[3]** | | | | | |
| 2,4-D ester | Plant >7 d | 0.5-1 pt | P | P-G | E | P | E | P | N | E | E | F | G |
| Aim | | 0.5-1 fl oz | P | N-P | N | F-E | F-G | – | N | F | N | N | E |
| Harmony/thifen. | | See label | E | G-E | F | E[4] | E | G-E | N | E[4] | G | E[4] | E[4] |
| Sharpen | | 1 fl oz | G-E | G-E | G-E | G-E | G-E | – | G-E | – | G-E | G-E | G-E |
| **Preplant or PRE herbicides – with residual weed control. See Combination herbicides for soybean**. | | | | | | | | | | | | | |
| Prowl, Sonalan, Treflan[2] - PPI | | See label | N | N | N | P | F-E | N | N | N | N | P | F-E |
| Python[2] | | 0.8-1 oz DG | F-G | E | E | E[4] | E | – | E | – | P | G-E | E[4] |
| Spartan[2] | | 3-4.5 fl oz | P-F | P | E | E | E | – | F-E | P | P | E | E |
| Valor | | 2-2.5 oz WDG | P-F | G-E | E | E | E | E | E | E | P | F | E |
| **POST herbicides – See Combination herbicides for soybean**. | | | | | | | | | | | | | |
| FirstRate[2] | <50% flowr | 0.3 oz WDG | P-F | P-G | E[4] | P[4] | P | – | N | – | E | E | N |
| Flexstar[2] | < Flowering | 0.5-0.75 pt | P | E | N | G-E | P-F | G-E | F-E | – | G-E | G-E | E |
| Harmony SG | 60 day PHI | 1/8 oz SG | P | P-F | P | N | G | N | N | P[4] | N | G-E | N |
| Harmony DF | 60 day PHI | 1/12 oz DF | P | P-F | P | N | G | N | N | P[4] | N | G-E | N |
| Pursuit[2] | <Flowering | 2-3 fl oz | P | E | N | E[4] | P-F | P | E | E[4] | P | G | N |
| Raptor[2] | <Flowering | 2-3 fl oz | P | E | N | E[4] | F | P | E | G[4] | P | G-E | N |

[1] See table: Control of volunteer Roundup Ready crops (page 52).
[2] May carry over more than one cropping season. Follow labeled crop rotation restrictions.
[3] E = Excellent (90-99%), G = Good (80-90%), F = Fair (65-80%), P = Poor (40-65%), N = None.
[4] Except where resistant populations have developed.

**Combination herbicides (partial list) for conventional and herbicide-resistant soybean.**

| Trade Name | Manu-facturer | Applied at (Prod/a)... | Gives the equivalent product rates of: |
|---|---|---|---|
| Authority Assist | FMC | 4 fl oz | 3.33 fl oz Spartan + 1.33 fl oz Pursuit |
| | | 6 fl oz | 5 fl oz Spartan + 2 fl oz Pursuit |
| Authority First/Sonic | FMC | 2.4 oz | 3 fl oz Spartan + 0.2 oz FirstRate |
| | | 3.2 oz | 4 fl oz Spartan + 0.3 oz FirstRate |
| Authority MTZ | FMC | 8 oz | 3.6 fl oz Spartan + 3.6 oz Sencor |
| | | 12 oz | 4.33 fl oz Spartan + 4.33 oz Sencor |
| Boundary | Syngenta | 1.2 pt | 0.83 pt Dual Magnum + 4 oz Sencor |
| Domain | Bayer | 9 oz | 4.33 fl oz Define + 4.33 oz Sencor |
| Extreme | BASF | 1.5 pt | 2 fl oz Pursuit + 12 fl oz glyphosate-ipa (3 lb ae/gal) |
| | | 2.25 pt | 3 fl oz Pursuit + 18 fl oz glyphosate-ipa (3 lb ae/gal) |
| Gangster (co-pack) | Valent | 1.8 oz | 1.5 oz Valor + 0.3 oz FirstRate |
| Pursuit Plus | BASF | 20 fl oz | 0.88 pt Prowl $H_2O$ + 2 fl oz Pursuit |
| | | 1.8 pt | 1.28 pt Prowl $H_2O$ + 2.9 fl oz Pursuit |
| Rage D-Tech* | FMC | 8 fl oz | 0.5 fl oz Aim + 0.5 pt 2,4-D ester – apply at least 14 days prior to planting. |
| | | 16 fl oz | 1 fl oz Aim + 1 pt 2,4-D ester – apply at least 14 days prior to planting. |
| Sequence | Syngenta | 1.5 pt | 18 fl oz glyphosate-ipa (3 lb ae/gal) + 0.6 pt Dual II Magnum |
| Spartan Advance | FMC | 24 fl oz | 3.4 fl oz Spartan + 24 fl oz glyphosate-ipa (3 lb ae/gal) |
| Spartan Charge[5] | FMC | 5.75 fl oz | 4.5 fl oz Spartan + 1 fl oz Aim |

* Plant no earlier than 14 days after application.

## Control of volunteer Roundup Ready crops.

| | Rate | Canola Pre | Canola 3-leaf | Canola 6-leaf | Corn 10-18 inches | Corn 18-24 inches | Corn 24-40 inches | Soy-bean V2-V3 | Soy-bean V4-V6 |
|---|---|---|---|---|---|---|---|---|---|
| **POST Grass Herbicides** | | | | | | | | | |
| Assure II | 4-5 fl oz | N | N | N | E | E | G-E | N | N |
| Fusilade DX | 4-6 fl oz | N | N | N | E | E | G-E | N | N |
| Select/generic clethodim | 3-4 fl oz | N | N | N | G-E | P-F | P | N | N |
| | 6 fl oz | N | N | N | E | G | F | N | N |
| Select Max | 4-6 fl oz | N | N | N | F-G | P | N-P | N | N |
| | 8 fl oz | N | N | N | E | F | P | N | N |
| **Broadleaf Herbicides** | | | | | | | | | |
| Aim | 0.5 fl oz | – | P | N | N | N | N | P | P |
| atrazine | 0.38 lb ai | E | N-P | N | N | N | N | E | P |
| | 0.5 lb ai | E | P | N | N | N | N | E | F |
| Balance Flexx | 3 fl oz | E | – | – | N | N | N | – | – |
| Basagran/generics | 0.5 pt | – | G-E | F | N | N | N | N | N |
| Bronate/generics | 0.8 pt | – | E | F-G | N | N | N | E | E |
| Callisto | 3 fl oz | E | E | G | N | N | N | P | P |
| Stinger/generic clopyralid | 1.3 fl oz | N | N | N | N | N | N | G | F-G |
| | 2.6 fl oz | N | N | N | N | N | N | E | G-E |
| Curtail/generics | 0.25-0.5 pt | – | G-E | F-G | N | N | N | F-G | P-F |
| Banvel/generic dicamba | 2 fl oz | – | P | N | N | N | N | G | G |
| | 4-5 fl oz | – | P | P | N | N | N | E | E |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Extreme | 1.5 pt | E | E | G-E | F-G | F | P | N | N |
| Flexstar | 0.38-0.75 pt | – | E | E | N | N | N | N | N |
| FirstRate | 0.1-0.3 oz | E | E | F-E | – | – | – | N | N |
| Hornet | 1-2 oz | P-F | G-E | F-E | N | N | N | E | F |
| Huskie | 11 fl oz | - | E | G-E | N | N | N | G | G |
| MCPA | 0.5 pt | P | G-E | P | N | N | N | P | P |
| Sencor/generics | 0.25 lb | E | G-E | F | N | N | N | P-F | P-F |
| Laudis | 3 fl oz | – | E | G-E | N | N | N | G | G |
| Option | 1.5 oz | – | E | E | N | N | N | P | P |
| Progress + UpBeet + MSO | 1.5 pt + 0.25 oz | – | P-F | N-P | F | N-P | N-P | F | N-P |
| Pursuit | 2 fl oz | G-E | E | G-E | G | F | P | N | N |
| Raptor | 1-2 fl oz | – | E | G-E | P-F | P | N-P | N | N |
| | 4 fl oz | – | E | E | G-E | F | P | N | N |
| Spartan | 4 oz | P-F | – | – | – | – | – | – | – |
| Status | 1-2 oz | – | F-G | P-F | N | N | N | E | G-E |
| | 4 oz | – | G | F | N | N | N | E | E |
| Steadfast | 0.75 oz | – | E | E | N | N | N | P | P |
| Harmony/generics | 1/12 oz DF / 1/8 oz SG | – | P-F | P | N | N | N | N | N |
| | 0.33 oz DF / 0.5 oz SG | – | E | G-E | N | N | N | N | N |
| Express/generics | 0.167 oz DF/0.25 oz SG | – | E | G-E | P | P | P | P | P |
| Valor | 2.5 oz | E | – | – | – | – | – | – | – |
| WideMatch | 0.13-0.25 pt | – | P | P | N | N | N | F-E | P-G |
| UpBeet + MSO | 0.25 oz | – | P-F | N-P | F | N-P | N-P | F | N-P |
| Wolverine | 1.7 pt | – | E | G-E | E | E | E | G | G |
| 2,4-D | 0.25-0.5 pt | – | G | P | N | P | P | P | P |

## Herbicide Comments

Soybean is a poor competitor with weeds when cool soil temperatures cause slow germination and growth, but soybean does compete effectively in warm soils when germination and growth are rapid. Soybean production requires good cultural practices. Prepare the seedbed prior to planting to kill germinating weeds. Management practices such as thorough seedbed preparation, adequate soil fertility, choice of a well-adapted variety and use of good-quality seed all contribute to conditions of good competition with weeds. A rotary hoe or harrow may be used to control weeds after planting but before the soybean emerges or after emergence when soybean is in the one- to two-trifoliolate leaf stage. A rotary hoe or harrow helps activate PRE herbicides under dry conditions and increase weed control. The rotary hoe is an effective and economical weed control method when a field is not trashy, lumpy or wet, and when weeds are emerging. Cultivation is most effective when soybean is slightly wilted during the warm part of the day because the crop is less susceptible to breakage and weeds will desiccate quickly.

**Poast** (sethoxydim) plus petroleum oil adjuvant or applied POST controls annual grasses. **Assure II** (quizalofop), **clethodim**, **Fusilade DX** (fluazifopP), **Fusion** (fluazifop-P & fenoxaprop-P) plus petroleum oil adjuvant or **Select Max** (clethodim) applied POST controls annual grasses and quackgrass. Methylated seed oils (MSO) have performed equally to petroleum-based oil additives. Refer to Select Max label for adjuvant information. Retreat quackgrass when regrowth is 4 to 8 inches tall. Poast only suppresses quackgrass. Most broadleaf herbicides tank-mixed with POST grass herbicides often will reduce grass control compared with the grass herbicide applied alone. Reduced grass control can be avoided by applying the grass herbicide at least one day before or seven days after application of a broadleaf herbicide.

Assure II may provide excellent green foxtail control but less yellow foxtail control. Lower yellow foxtail control may result from applying Assure II at reduced rates, with broadleaf herbicides or to large or stressed plants. Addition of fertilizer may enhance yellow foxtail control and control of stressed grasses.

Clethodim is an ACCase mode of action herbicide similar to Assure II, Fusilade and Poast. However, in NDSU research, clethodim controls many grasses documented resistant to other ACCase herbicides and is antagonized less by tank-mixes with broadleaf herbicides. We recommend that clethodim be used in rotation with herbicides of different modes of action and in a resistant weed management program.

Several generic brands of clethodim are available, but not all formulations are identical to the original Select formulation. Select, Clethodim, Trigger and Volunteer are the same, but Arrow, Prism, Section and Select Max all have different formulations.

Select Max is a 1 lb/gal formulation, contains activating adjuvants in the formulation, and allows use of NIS, PO or MSO depending on tank-mix partner.

**Basagran** (bentazon) at 0.5 to 1 qt/a applied POST controls many annual broadleaf weeds and suppresses Canada thistle. NDSU research has shown greater broadleaf weed control, especially in kochia, lambsquarters, redroot pigweed and wild buckwheat, by applying Basagran as split treatments either twice each at 1 pt/a, three times each at 0.67 pt/a or four times each at 0.5 pt/a, compared with one application at 2 pt/a. Make applications seven to 10 days apart depending on weed growth rate, growing conditions, size of weeds at application, degree of weed control from first application and sequential flushes. The first application must be made to small weeds (1 inch).

For Canada thistle control, apply Basagran at 1 qt/a when plants are 8 inches tall to bud stage, and make a second application at 1 qt/a seven to 10 days later.

**The NDSU soybean micro-rate** concept is based on the sugarbeet micro-rate and substitutes additional weed management for reduced herbicide rates. Application to small weeds is essential for success. The micro-rate can be applied more than once in dry bean to control emerging weed flushes, but applying a foundation herbicide treatment (DNA or acetanilide) may require only one POST application. MSO adjuvant is required for optimum weed control.

The POST grass herbicide can be excluded if grass populations are low. Preliminary data show weed control can be improved by increasing spray volume. The first application can be made at 10 gallons per acre (gpa) when weeds are small and less than 3 inches tall. Increase spray volume by 10 gpa for every 3 inches in weed height. The addition of AMS at 1 lb/a also increases weed control. Weed control from the micro-rate is best when temperature plus humidity is greater than 140. Increasing spray volume and using AMS may help improve weed control when the value is below 140.

**Sequential micro-rate applications** will provide greater broadleaf weed control than a single application at full rates and can be used in all crops where Basagran is labeled. Apply with oil additive at 1qt/a (1pt/a by air). Do not reduce the amount of oil adjuvant with the micro-rate. MSO adjuvant has shown greater enhancement of Basagran than petroleum oil (COC) adjuvants, but the cost of MSO is higher. Basagran is safe to soybean at all stages. The total maximum seasonal use rate is 4 pt/a, so the rate of the micro-rate can be increased if weeds are large at application or if sequential applications are delayed due to rain or wind.

**Weed control from Basagran applied one to four times, NDSU data.**

| Basagran + | Rate | Colq | Koch | Rrpw |
|---|---|---|---|---|
| | (pt/a) | —— percent control —— | | |
| Petroleum oil at 1 qt/a | 2 pt x 1 application | 8 | 38 | 51 |
| | 1 pt x 2 | 31 | 64 | 90 |
| | 0.67 pt x 3 | 34 | 79 | 95 |
| | 0.5 pt x 4 | 76 | 98 | 99 |
| MSO at 1.5 pt/a | 2 pt x 1 application | 5 | 86 | 92 |
| | 1 pt x 2 | 76 | 98 | 95 |
| | 0.67 pt x 3 | 79 | 98 | 98 |
| | 0.5 pt x 4 | 99 | 99 | 99 |

Basagran commonly is combined with fertilizer micronutrients that may cause incompatibility problems resulting in zinc precipitation. Chelated zinc materials (black) have greater incompatibility problems than unchelated material (clear). Recommendations to prevent precipitation are to fill the sprayer with water, add Basagran and thoroughly agitate, then add zinc fertilizer material.

**Rezult B and Rezult G** (bentazon and sethoxydim) applied POST at equal product amounts controls some grass and broadleaf weeds. Apply with oil adjuvants at 1 to 2 pt/a. Refer to the label or narrative for tank-mix options. Rezult is priced economically compared with other POST herbicide programs. Rezult may be more economical than Basagran for grass and broadleaf weed control. If so, use the following chart.

| Bentazon | Basagran | Rezult |
|---|---|---|
| (lb ai/a) | (product/a) | (product/a) |
| 0.25 | 0.5 pt | 0.4 pt |
| 0.33 | 0.67 pt | 0.56 pt |
| 0.5 | 1 pt | 0.8 pt |
| 1 | 2 pt | 1.6 pt |

**Flexstar** (fomesafen + adjuvants) applied POST controls many small broadleaf weeds. Apply with NIS at 0.25 to 0.5 percent v/v or oil adjuvant at 0.5 to 1 percent v/v. Oil adjuvants increase weed control but also increase risk of soybean injury. NDSU research has shown good to excellent kochia control when Flexstar is applied at high spray volumes (>17 gpa) with oil adjuvants (especially MSO type) at labeled rates and to kochia less than 2 inches tall.

Soybean injury may result when Flexstar is tank-mixed with EC formulation herbicides that act as an additional oil adjuvant. Activity of fomesafen and risk of crop injury increase as temperature and humidity increase. A maximum of 0.75 pt/a is allowed in most of North Dakota, while 1 pt/a is allowed through the Midwest. The reduced fomesafen rate reduces carryover and crop rotation restrictions.

Flexstar is labeled on soybean and Reflex is labeled on dry bean. Flexstar contains adjuvants lacking in the Reflex formulation. Reflex may give less consistent weed control than Flexstar and will require better management strategies to achieve adequate weed control. See label or crop rotation restriction section for additional information.

**Alachlor,- dimethenamid, metolachlor or S-metolachlor** applied PPI or PRE controls annual grass and some broad-leaf weeds and does not control wild oat. Apply the higher rate on clay soils high in organic matter. Soybean has good tolerance and incorporation improves consistency of weed control. Dual products may be surface applied or incorporated in the fall after Oct. 15 but before the ground freezes or applied in the spring.

**Metribuzin** controls some annual broadleaf weeds, including wild mustard. Adjust the rate according to soil type, pH and percentage of organic matter. Some soybean varieties are susceptible to metribuzin; consult the label for a list of susceptible varieties. Soybean injury can be reduced by using herbicide combinations with lower rates of metribuzin.

**Pursuit** (imazethapyr) applied POST controls or suppress many broadleaf weeds, except ALS-resistant weeds. Pursuit has controlled marshelder, Russian thistle, common cocklebur, sunflower, smartweed and lanceleaf sage in NDSU field trials. Pursuit may not control Venice mallow, horseweed, wild buckwheat, lambsquarters and common ragweed. POST application may not provide adequate soil residual to control subsequent flushes of nightshade due to plant foliage intercepting most of the spray. However, even a small amount of Pursuit may give a reduction in number and intensity of flushes of other weeds. Pursuit is enhanced greatest by MSO (1.5 pt/a) and basic pH blend (1 percent v/v) adjuvants. UAN fertilizer (a solution of urea and ammonium nitrate in water) improves weed control, especially lambsquarters.

Crop injury may result if either Pursuit or thifensulfuron is applied sequentially or tank-mixed together. In sequential application, the first herbicide reduces the ability of soybean to metabolize the second herbicide. Weeds not controlled by the first herbicide may not be controlled after the second herbicide is applied. This is particularly important for lambsquarters. Weeds that escape control from the first herbicide may be larger than labeled size by the time soybean can be treated safely with the second herbicide. Delay cultivation for 14 days after application to avoid reduction in weed control.

Tank-mixtures of Pursuit with Assure II, clethodim or Fusilade DX may result in reduced grass control. Reduced grass control can be avoided by applying the POST grass herbicide either one or more days prior to or seven days after Pursuit.

**Pursuit Plus** (imazethapyr and pendimethalin) at 1.8 pt/a applied PPI controls most annual grass and broadleaf weeds, including wild buckwheat. North Dakota state labeling allows use in the state only south of U.S. Highway 2 at a reduced rate of 1.8 pt/a, which is 75 percent of the full labeled rate. Pursuit Plus at 1.8 pt/a contains the equivalent of Pursuit at 3 fl oz/a plus 1.75 pt/a of Prowl EC. Add additional pendimethalin at 1.75 pt/a for more consistent weed control. Thoroughly incorporate it into the top 1 to 2 inches of soil. Refer to paragraphs on Pursuit and Prowl for additional information on use and restrictions.

**Python** (flumetsulam) applied PPI or PRE will control many annual small-seeded broadleaf weeds in soybean. Python does not control large-seeded broadleaf weeds such as common and giant ragweed and common cocklebur. Python requires soil water for optimum weed control. Python also is strongly affected by soil pH. High soil pH increases herbicide activity and the speed of herbicide degradation, but it also increases risk of crop injury.

Excellent broad-spectrum weed control may occur when applied on soils with above 7.5 pH when significant precipitation occurs after application, when rates are based on soil texture and organic matter content, and under light to moderate weed infestations. Some stunting may occur under poor growing conditions on soils with pH greater than 8.0.

**Raptor** (imazamox) applied POST controls nearly all annual grass and broadleaf weeds in soybean except wild buckwheat, lambsquarters, common and giant ragweed, Venice mallow, horseweed, biennial wormwood and ALS-resistant weeds. In NDSU field trials, Raptor has controlled marshelder, Russian thistle and lanceleaf sage less than 1 inch tall. Soil residue of Raptor will not control late-germinating weeds or weed flushes later in the growing season after rain events. Raptor, as compared with Pursuit, has greater grass and broadleaf weed control, provides improved lambsquarters control and has less carryover and crop rotation restrictions.

Apply **Raptor** with a basic pH blend adjuvant at 1 percent v/v or MSO-type adjuvants at 1.25 pt/a. Alternatively, apply with NIS at 0.125 to 0.25 percent v/v or oil concentrate at 0.5 percent v/v plus 28 percent UAN liquid fertilizer at 4 percent v/v. Use of 28 percent UAN improves control of some weeds such as lambsquarters. MSO-type oil additives should be used when weeds are large and/or stressed. MSO or basic pH blend adjuvants enhance weed control more than NIS or some petroleum oil additives with or without 28 percent UAN. However, Raptor applied with MSO + UAN may result in crop injury at temperatures greater than 88 F and greater than 80 percent relative humidity.

Refer to the label and paragraph on Pursuit and Raptor for information and restrictions when applying Raptor before or after thifensulfuron or tank-mixing with thifensulfuron or other POST grass herbicides. Raptor has fewer crop rotation restrictions than Pursuit. However, like Pursuit, Raptor carryover is affected by soil pH. As the soil pH increases, the rate of Raptor degradation increases. At soil pHs less than 6.5, the rate of breakdown is slow and injury to sugarbeet and other sensitive crops may occur if planted before the allowed time interval. See label or information on crop rotation restrictions.

**Sonalan** (ethalfluralin), **trifluralin** or **Prowl/H20** (pendimethalin) applied PPI controls most annual grasses and some small-seeded broad-leaf weeds but provides no wild mustard, common cocklebur and sunflower control. Requirements for proper timing and depth of incorporation differ for each herbicide. Adjust the rate according to soil type. Trifluralin must be incorporated in the top 2 to 3 inches of soil within 24 hours of application. Trifluralin incorporation may be delayed up to two days if applied to a cool, dry soil. Incorporation of Sonalan 10G can be delayed three to five days after application. Herbicides can be applied with most soil PPI herbicides labeled in soybean. Sonalan has less soil residue than trifluralin or Prowl and may be more active at comparable rates.

**Spartan** (sulfentrazone) applied shallowly PPI or PRE controls most annual small-seeded broadleaf weeds and partially may control wild buckwheat, marshelder, wild mustard, common ragweed, hairy nightshade, Venice mallow and foxtail but provides no perennial weed control. The rate must be adjusted for soil texture, soil pH and organic matter content. Apply 3 to 6 fl oz/a for coarse- and medium-textured soils and 4 to 8 fl oz/a for fine-textured soils. Herbicide solubility, activity and phytotoxicity increase as soil pH increases. The user must read and follow the label for rate information to ensure adequate weed control. Spartan provides excellent burndown weed control and may be applied up to 30 days prior to planting, but use the higher rate in the appropriate rate range. Spartan can be tank-mixed with most PPI/PRE herbicides registered in soybean.

NDSU research has shown that consistent control of susceptible broadleaf weeds and suppression of foxtail and marginally susceptible broadleaf weeds depends on at least 0.5 to 0.75 inch of rainfall shortly after application and before weeds emerge. Spartan will leave a residue in the soil for more than one year. Refer to the label for crop rotation restrictions.

**Harmony GT (**thifensulfuron**)** has activity on wild mustard, lambsquarters, pigweed species, annual smartweed and wild buckwheat. Apply with NIS at 0.125 to 0.25 percent v/v or oil adjuvants at 0.5 percent v/v plus liquid fertilizer at 4 percent v/v. DO NOT apply with oil adjuvants when tank-mixing with any other herbicide or severe crop injury may occur. See the label or Pursuit paragraph for precautions when tank-mixing with Pursuit and other herbicides. Thifensulfuron as spray drift or sprayer contamination may cause severe injury to susceptible crops such as sugarbeet and sunflower. Thoroughly clean sprayer to prevent contamination of subsequent spray mixtures and injury to susceptible crops. Follow the label for improved cleanout procedure.

**Valor** (flumioxazin) applied EPP or PRE controls most small-seeded broadleaf weeds and may suppress foxtail, common and giant ragweed, annual smartweed, Russian thistle and wild buckwheat. **Gangster** (flumioxazin and cloransulam), a co-pack of Valor and FirstRate applied EPP or PRE, controls most broadleaf weeds. Valor and Gangster does not control perennial weeds. Apply from 14 days prior to seeding to just before soybean emergence. Valor can be applied with glyphosate in early burndown programs in soybean. Valor requires a minimum of 0.25 inch of rain for activation and requires a bioassay prior to planting sensitive crops. Refer to the label for weeds controlled, rates and crop rotation restrictions.

## Soybean Herbicide Injury/Symptomology

**Acetanilide (Lasso, Dual, etc)**

Leaf stunting, puckering and the "drawstring" effect on the central vein or leaf midrib.

**DNA (Trifluralin, Sonalan, Prowl)**

Excessive rates with stress conditions may cause pruned roots and swollen or cracked hypocotyls.

**Plant Growth Regulators**

Leaf puckering along with stem and branch twisting and epinasty.

**ALS Inhibitors**

Misapplication, drift or carryover of some ALS herbicides not registered on soybean may stunt soybean plants and cause yellow or chlorotic blotches on leaves. Labeled herbicides such as Raptor and Pursuit may intensify the symptoms of iron chlorosis. Tank-mixes of Harmony GT with Pursuit or Raptor are not recommended due to severe soybean stunting and leaf burn.

**Contact – Soil applied(Authority and Valor)**

Authority: Some soybean varieties are susceptible to injury. See your seed dealer for a list. Symptoms are stunting and yellowing of soybean leaves. Valor may cause localized speckling from a "splash effect" after a rainstorm. Speckling may occur only on bare soil where no crop residue exists.

**Contact – POST (Aim, Blazer, Cobra, Flexstar)**

Aim, Blazer and Flexstar may show localized speckling of soybean leaves. More serious injury may result if Aim is applied in wet or dewy conditions. Injury from Cobra may vary from speckling to severe leaf burn. New soybean growth after contact herbicide application is unaffected.

**Contact – POST (Basagran)**

Yellow chlorotic mottling in small patches on leaves. Areas of leaf burn may occur under stress conditions or hot temperatures. Injury is cosmetic and new growth is unaffected.

**Triazine**

Symptoms of atrazine carryover from high rates and high soil pH may be visible as leaf burn and desiccation from the bottom leaves progressing up the plant and from leaf tips inward. Symptoms from metribuzin may be similar to atrazine where high rates are used.

**Glyphosate (Conventional soybean)**

Symptoms from drift are expressed early on new growth as stunting and leaf yellowing. Symptoms will progress to older plant tissue. Plants may remain stunted, and affected plant tissue may die within seven to 14 days after exposure depending on herbicide concentration and growing conditions.

# Insect Management in Soybean

**Janet J. Knodel**
Extension Entomologist

Producers should scout soybean fields on a regular basis to minimize insect pest damage and adopt integrated pest management (IPM) strategies, such as the use of economic thresholds and combining various control strategies (cultural control, host plant resistance, biological control).

Prior to the first detection of soybean aphid in the U.S. in 2000, soybean grown in the north-central U.S. rarely was damaged by insects; indeed, it was considered to be a low-risk crop when grown in rotation with corn or wheat. Since soybean aphid has become a chronic major insect pest of soybean, inputs for control of insect pests have increased dramatically.

Other insect pests that occasionally impact soybean include armyworms, bean leaf beetles, cutworms, foliage-feeding caterpillars, grasshoppers, potato leaf-hoppers, seed corn maggots, spider mites and wire-worms. Significant progress with soybean IPM has been made and will continue into the future to aid successful soybean production. A growing-season calendar shows the soybean insect pest problems and the time of occurrence in the northern production area of North Dakota and Minnesota (Figure 5). Pictures of insects can be found in the photo section of this publication.

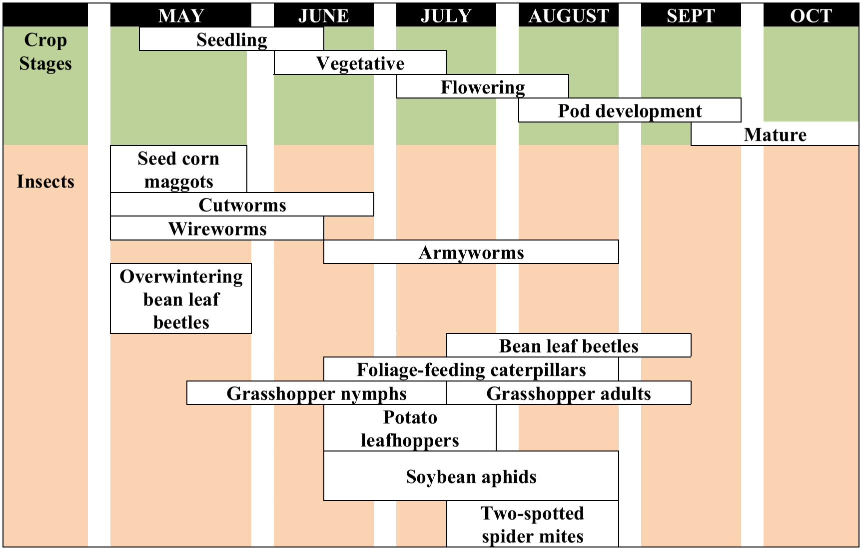


Figure 5. A growing season calendar indicating the time of occurrence of soybean insect pests.

# Estimating Defoliation Damage

In soybean, field scouting to assess insect populations is based on the number of insects per foot of row, insects per plant, sweep net samples, or the level of defoliation. To determine the number of insects per foot of row, lay a strip of cloth in the inter-row space and shake plants over the cloth. Count the total number of insect pests per foot of row that fall on the cloth. If sampling narrow-row or drilled soybean, consider using a "Texas vertical beat sheet." The vertical beat sheet is made from a piece of galvanized metal flashing or similar stiff material 36 inches wide, 32 inches tall and crimped at the bottom to form a collecting trough 4 inches wide. Place the device next to the row and shake the plants against the vertical surface. Insects dislodged from plants collect in the trough, where they can be counted or collected.

The percent of defoliation is determined by estimating the amount of leaf tissue loss based on visual inspection of randomly selected plants. Examples provided (Figure 6) are guidelines for estimating loss for individual leaflets. Actual defoliation estimates made for pest management decisions are based on estimated leaf area lost over the entire plant.

The growth stage of the soybean plant is important when making pest management decisions. Under most conditions, moderate defoliation early in the season has little effect on final soybean yield.

As plants reach the flowering and pod-filling stages, defoliation poses a greater threat to yield. For example, research indicates that the soybean plant can sustain a 35 percent leaf loss prior to the pre-bloom period. From pod set to maturity, the plant can tolerate only a 20 percent defoliation level.

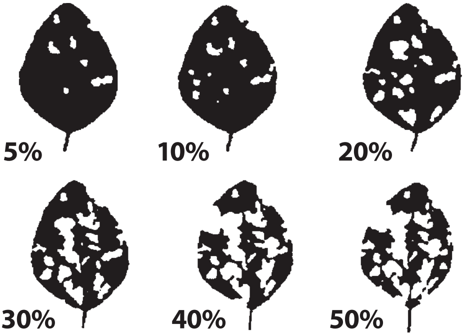


**Figure 6. Soybean defoliation levels.**

## Armyworms [Lepidoptera: Noctuidae: *Pseudaletia unipuncta* (Haworth)]

Armyworms are greenish brown with longitudinal stripes. Full-grown larvae are smooth, striped and almost hairless. Armyworms feed for three to four weeks. When full grown, larvae are 1½ to 2 inches long. Armyworm larvae have six growth stages or instars. The final instar lasts about 10 days, and they consume large amounts of plant material during that time. Armyworms are inactive during the day, resting under plant trash, clumps of grass or lodged plants. They feed at night or on cloudy days, crawling up on plants and consuming foliage. Due to their habit of feeding at night, armyworms may go undetected until significant damage has occurred.

Armyworms do not overwinter in the region. The moths migrate from southern states in late spring and early summer. This helps explain the sporadic infestations that occur. When moths arrive, they prefer to lay their eggs in moist, shady areas, usually where grasses have lodged. Infestations that develop within soybean fields often are due to grass weed problems.

Armyworms are more of a problem in small grains and corn. Damage to soybean can occur when the armyworms' usual host plants become exhausted due to feeding or dry conditions. When their food is depleted in the hatching site, the armyworms may move in large numbers or "armies," eating and destroying plants or crops in their path.

**Threshold**

Control of armyworms is recommended when 25 to 30 percent of the foliage is destroyed or if significant injury to pods is evident. Most often in soybean, infestations are due to migrating armyworms. Under these circumstances, treatment of a couple of swaths ahead of the migrating armyworms to establish a barrier strip and prevent further migration and injury may be all that is needed.

## Bean Leaf Beetle [Coleoptera: Chrysomelidae: *Cerotoma trifurcata* (Förster)]

This beetle can vary in color from yellow to reddish brown and may have three to four black spots with a black border on the wing covers. Adults emerge from overwintering and move into bean fields as the seedlings emerge. The white larvae develop in the soil, feeding on the roots and nodules. New adults emerging from mid-July to August feed on foliage and pods.

Feeding injury to leaves appears as small round holes between the leaf veins. Late-season feeding on the foliage and pods by the new adults that emerge in August can be more important than early season feeding, especially if viruses are present. This may increase the risk of virus transmission and cause secondary fungal and bacterial infections (rotting and discoloration).

Bean leaf beetles are the vector of Bean Pod Mottle Virus. In 2007, Bean Pod Mottle Virus was detected in 6 percent of soybean fields sampled in southeastern North Dakota *(Source: B. Nelson, Department of Plant Pathology, NDSU)*.

### Threshold

Due to low incidence of this insect in North Dakota, no local control guidelines have been developed. Based on information from other regions where these insects are a common pest, a sweep net is used to determine if bean leaf beetles are present. Treatment would be recommended when three to seven beetles per sweep are found. Treatment thresholds based on defoliation are 50 percent defoliation during early vegetative, 40 percent defoliation during pre-bloom, 35 percent defoliation during bloom and 20 to 25 percent defoliation during pod set to fill.

## Cutworms (Lepidoptera: Noctuidae)

Several cutworm species affect regional crops. The dingy cutworm, *Feltia jaculifera* (Guenée), overwinters as a partially grown larva and is one of the first cutworm species to cause problems during crop emergence from early to mid-May. The moth of the dingy cutworm is known to lay her eggs on sunflower heads from mid-July through September. Soybean and other crops following sunflower in rotation are at greatest risk of injury by this cutworm. Other cutworms, the redbacked, *Euxoa ochrogaster* (Guenée), and the darksided, *Euxoa messoria* (Harris), overwinter as eggs, which hatch in mid to late May. Eggs are laid in the fall and survive in weedy, wet and reduced- tillage areas. Feeding injury by these cutworms normally occurs in late May to early June.

Most damage by cutworms occurs when soybean plants are in the early stages of development. Damage consists of young plants being chewed off slightly below or at ground level. Some cutworm feeding injury may occur on foliage. Cutworms feed primarily at night. When checking soybean fields for cutworms during the day, dig into the soil an inch or two around recently damaged plants; there you can find the gray to gray-brown larvae.

### Threshold

Economic thresholds for cutworm treatment decisions are not well-established. Treatment guidelines used through the years include this one: Treatment should occur when one cutworm or more is found per 3 feet of row and the larvae are small (less than ¾ inch long). Another guideline is treatment should occur when 20 percent of plants are cut or when gaps of 1 foot or more exist in the plant row. When making a final decision, consider that surviving soybean plants are able to compensate for early stand reductions because of the plant's long growth period and branching ability.

## Foliage-feeding Caterpillars (Lepidoptera)

### Green Cloverworm, Cabbage Looper, Velvetbean Caterpillar, Thistle Caterpillar and Alfalfa Webworm

Populations of these caterpillars have been negligible in North Dakota and little treatment to control them has been required. Sampling for these insects is accomplished through the use of a drop cloth or a vertical beat sheet placed between two rows of plants. The larvae are dislodged from the plants and counted on the cloth or collection tray to arrive at an estimate of the number per row feet.

## Green cloverworm [Nymphalidae: *Vanessa cardui* (Linnaeus)]

These caterpillars are green with two narrow white stripes down the side. When mature, the worms are 1¼ inches long. These caterpillars have only three pairs of fleshy prolegs on the abdomen, plus the pair on the back tip. When moving, the worms arch the middle of the body, or "loop." Young worms scrape leaf tissue, creating a transparent skin, or "window," on the leaf surface. Older cloverworms eat holes in the leaves.

## Cabbage looper [Noctuidae: *Trichoplusia ni* (Hübner)]

These caterpillars are light to dark green with lighter-colored stripes along the side and on the top, running the length of the body. When mature, the worms are 1½ inches long. These caterpillars have only two pairs of fleshy prolegs on the abdomen, plus the pair on the back tip. When moving, the caterpillars also arch the middle of the body, or "loop." These worms feed on leaves on the interior and lower portion of the plant. As defoliation occurs, worms feed higher in the plant. Feeding injury is similar to the cloverworm.

## Velvetbean caterpillar [Noctuidae: *Anticarsia gemmatalis* (Hübner)]

This insect does not overwinter in the region. Instead, moths migrate from southern locations.

These caterpillars have dark lines bordered by lighter-colored, narrower lines running the length of the body. The background color ranges from a pale yellow-green to brown or black. These larvae have four pairs of fleshy prolegs to distinguish them from the cloverworm and the looper. Young velvetbean caterpillars feed on the underside of leaves in the upper portion of the plant. Older larvae consume the entire leaf except for the leaf veins.

## Thistle caterpillar [Nymphalidae: *Vanessa cardui* (Linnaeus)]

This insect is the larva of the butterfly known as the painted lady. This butterfly does not overwinter in the region but migrates from southern locations each spring. These caterpillars are brown to black with yellow stripes along each side of the body. They are covered with spiny scoli (fleshy structures) that give the caterpillar a prickly appearance. Full-grown larvae are about 1½ inches long. The caterpillars feed on the leaves, webbing them together at the feeding site.

## Alfalfa webworm [Crambidae: *Loxostege cereralis* (Zeller)]

These larvae are 1 inch long when fully grown. They are greenish to nearly black with a light stripe that runs down the middle of the back. They have three dark spots, each with hairs, on the side of each segment. These larvae feed for about three-plus weeks. Infestations are characterized by light webbing over the leaves. Beneath the web is where the larvae feed, consuming the leaves. These larvae move very rapidly, forward or backward, when disturbed.

**Threshold**

Control of these different caterpillars normally is not warranted until greater than 30 percent of the foliage is destroyed prior to bloom, or when 20 percent of the foliage is destroyed after bloom, pod set or fill has been reached. This usually requires an average infestation of four to eight larvae per row foot.

## Grasshoppers (Orthoptera: Acrididae)

In the northern Great Plains, grasshopper egg hatch normally begins in late April to early May. Most grasshoppers emerge from eggs deposited in uncultivated ground. Soybean growers should expect to find grasshoppers feeding first along soybean field margins adjacent to noncrop sites where the nymphs are hatching. Later infestations may develop when grasshopper adults migrate from harvested small-grain fields. Grasshoppers will feed upon leaves and pods, chewing holes in them. A result of these migrations is soybean fields becoming sites for significant egg laying.

**Threshold**

The threatening rating is considered the action threshold for grasshoppers. For example, grasshopper control is advised whenever 50 or more small nymphs per square yard can be found in adjacent, noncrop areas, or when 30 or more nymphs per square yard can be found within the field. When 20 or more adults per square yard are found in field margins or eight to 14 adults per square yard are occurring in the crop, treatment would be justified. Because estimating the number of grasshoppers per square yard is difficult when population densities are high, pest managers can count grasshoppers collected from four 180-degree sweeps when using a 15-inch sweep net and use that value as an estimate for the number of adult (or nymph) grasshoppers per square yard. Many of the grasshopper infestations in soybean will be heaviest on field margins. Treating these areas early may lessen the total number of grasshoppers successfully entering a field.

Soybean plants are most sensitive to defoliation during pod development (growth stages R4 to R6). During this time, plants can tolerate only up to 20 percent defoliation. Of greater concern is direct feeding damage to pods and seeds. Grasshoppers are able to chew directly through the pod walls and damage seed. If more than 5 to 10 percent of the pods are injured by grasshoppers, an insecticide application is recommended.

**Grasshopper thresholds.**

| | Nymphs (young grasshoppers) | | Adults | |
|---|---|---|---|---|
| Rating | Margin | Field | Margin | Field |
| | per square yard | | | |
| Light | 25-35 | 15-23 | 10-20 | 3-7 |
| Threatening | 50-75 | 30-45 | 21-40 | 8-14 |
| Severe | 100-150 | 60-90 | 41-80 | 15-28 |
| Very severe | 200+ | 120 | 80+ | 28+ |

## Potato Leafhopper [Hemiptera: Cicadellidae: *Empoasca fabae* (Harris)]

The adult is wedge-shaped and pale green. Adults are very active, jumping or flying when disturbed. Nymphs are wingless. Both adults and nymphs run backwards or sideways rapidly when disturbed. Nymphs feed on the underside of the leaf, usually completing their growth on the leaves near where they hatched. Large numbers of adults may appear early in the season, but their presence is dependent on migration from the south and east.

Soybean plants with moderate to dense pubescence, or plant hairs, are tolerant to leafhopper infestations. The short plant hairs form a barrier that discourages leafhoppers from feeding and laying eggs on plant tissue. When feeding does occur, damage by leafhoppers is referred to as “hopper-burn.” Foliage becomes dwarfed, crinkled and curled. Small triangular brown areas appear at the tips of leaves, gradually spreading around the entire leaf margin. Potential damage to soybean by potato leafhopper is not fully understood. Damage is more likely when drier growing conditions occur.

### Threshold

The threshold for spray decisions is based on an average of five leafhoppers per plant in the vegetative stages and nine leafhoppers per plant in early bloom stages.

## Soybean Aphid [Hemiptera: Aphididae: *Aphis glycines* (Matsumura)]

Soybean aphid first was detected in the U.S. in 2000 and spread through soybean production areas in the north-central U.S., including North Dakota, in 2001. Since its introduction, soybean aphid has become a major insect pest of soybean throughout the Midwest.

Foliar insecticides are the primary management tactic for aphid control. However, multiple years of research have shown that natural enemies often can keep soybean aphids below the economic threshold in nonoutbreak years. Another nonchemical management tactic that shows promise for controlling soybean aphid is the use of genetically based aphid-resistant soybean lines.

Soybean aphid is light yellow with black cornicles (tail pipes) and a pale-colored cauda (tail projection). As with other aphids, soybean aphid is small, about 1/8 inch. Nymphs (or young) are smaller yet.

Aphids suck plant sap. When infestations are large, infested leaves are wilted or curled. Aphids excrete honeydew, a sweet substance that accumulates on surfaces of lower leaves and promotes the growth of sooty mold. Soybean aphid colonizes tender leaves and branches from early vegetative through reproductive plant stages. Later, as vegetative plant growth slows, the aphids slow their reproductive rate, move down to the middle and lower part of the plant and feed on the undersides of leaves. Toward the end of the season, the colonies again begin to increase in number rapidly. These increases are followed by a migration to the overwintering host, buckthorn.

**Threshold**

The guidelines for making soybean aphid treatment decisions are:

- Begin scouting soybean fields at the V3 to V4 stage to determine if soybean aphids are present in fields. No treatment is recommended at this time and is discouraged so that insecticides do not reduce the presence of predators and parasites.
- The critical growth stages for making most soybean aphid treatment decisions are the late vegetative to early reproductive stages (V*n* to R3). Assessing aphid populations at these stages is critical.
- **Economic threshold from R1 (first flower) to R5 (beginning seed) is 250 aphids/plant AND when populations are increasing actively in 80 percent**

**of the field.** At R6 (full seed), no insecticide treatment is recommended. Research trials throughout the north-central states have not demonstrated a yield benefit for soybean aphid management at the R6 and later stages.

## Seedcorn Maggot [Diptera: Anthomyiidae: *Delia platura* (Meigen)]

Seedcorn maggots attack soybean seed, preventing sprouting or weakening the seedlings. The yellowish-white maggot is found burrowing in the seed, emerging stem or the cotyledon leaves. Damage to the seedlings results in a condition called "snakeheads," or plants without cotyledon leaves.

Adult flies emerge in the spring when soil temperatures reach 50 F. They deposit eggs in soil with abundant organic matter and decaying crop residue or on the seed or seedling. Injury from seedcorn maggots is usually most severe during wet, cold springs and in fields with high organic matter soils. When cool, wet conditions occur during planting, the slow germination and emergence of the seedling extends the period of time it is vulnerable to feeding by the maggot.

### Threshold

When conditions are wet and cool or when planting into high crop residue conditions, insecticide seed treatments provide the best defense against injury.

## Two-spotted Spider Mites (Acari: Tetranychidae: *Tetranychus urticae* Koch)

Adult spider mites are small (less than 0.2 inch) and greenish white to orange-red, and have two dorsal spots and four pairs of legs. Nymphs are smaller than adults and have three to four pairs of legs. Magnification is necessary to see mites. Host plants for spider mites include soybean, dry bean, alfalfa, corn, vegetables, ornamentals and trees. Mites overwinter as eggs on vegetation. The life cycle of spider mites can be completed in only five to 14 days, with fastest development rates occurring above 91 F. Each female lives for 30 days, and she produces about 300 eggs during her lifetime. In hot, dry weather, natural fungal diseases of mites are slowed and populations can increase from a few individuals to millions within a few generations. Mites thrive on stressed plants that are nutrient rich.

Leaf injury symptoms appear as stippling first and then progress to yellowing, browning or bronzing as feeding injury increases and eventually leaf drop. Feeding injury causes water loss from the plant and reduces the photosynthetic ability of the plant. In severe cases, premature leaf senescence and pod shattering, and even plant death, can occur. When severe mite infestations occur during late vegetative and early reproductive growth, a 40 to 60 percent yield loss between treated and untreated soybean has been demonstrated in other north-central states. Be sure to scout during full-pod (R4) through beginning-seed (R5) stages because these crop stages are the most important contributors to soybean yield. Spider mites can cause yield reduction as long as green pods are present.

When scouting for spider mites, look on the underside of leaves and lower foliage at the field edges first for tiny mites and fine spiderlike webbing. A quick sampling procedure to determine whether mites are present is to hold a piece of white paper below leaves, then tap them to dislodge the mites. The mites appear as tiny dust specks; however, they will move slowly after being knocked off the leaf. Dislodged predatory mites will move faster than the two-spotted spider mite.

Another sampling measure involves pulling up plants and examining the underside of the leaves from the bottom of the plants upward. When spider mites need to move due to diminishing food supply, they climb to the top of plants and are dispersed by the wind through "ballooning," so they can spread quickly within a field or to adjacent fields.

Infestations typically are first noted near field edges and fields near alfalfa (a preferred host). Products labeled for mite control often do not give adequate control and the population of mites may rebound quickly to pretreatment levels or higher. When rain and humidity are present, natural reductions in mite populations occur due to infection by a fungal pathogen. Conditions that are good for the development of the pathogen are temperatures cooler than 85 F, with at least 90 percent relative humidity for 12 to 24 hours. Mites usually become a problem when hot, dry weather occurs. When a production area has low rainfall, the region can become a "hot spot" for mite injury and a source of mites migrating to neighboring areas.

**Threshold**

Deciding whether to treat is difficult. No specific threshold has been developed for two-spotted spider mite in soybean. Sample plants at least 100 feet into the field and walk in a "U" pattern, sampling two plants per location at 20 different locations. Assess mite damage using the following scale from the University of Minnesota:

0 - No spider mites or injury observed.

1 - Minor stippling on lower leaves, no premature yellowing observed.

2 - Stippling common on lower leaves, small areas or scattered plants with yellowing.

3 - Heavy stippling on lower leaves with some stippling progressing into middle canopy. Mites present in middle canopy with scattered colonies in upper canopy. Lower leaf yellowing is common. Small areas with lower leaf loss may occur **(Spray Threshold)**.

4 - Lower leaf yellowing readily apparent. Leaf drop common. Stippling, webbing and mites common in middle canopy. Mites and minor stippling present in upper canopy **(Economic Loss)**.

5 - Lower leaf loss common, yellowing or browning moving up plant into middle canopy, stippling and distortion of upper leaves common. Mites present in high levels in middle and lower canopy.

If spider mites are above the threshold while significant pod or seed fill still needs to occur, we recommend an organophosphate insecticide (for example, Lorsban, Dimethoate) instead of a pyrethroid insecticide. Pyrethroids for example, Asana, Baythroid, Decis, Mustang Max, Proaxis, Warrior) tend to flare (increase) mite populations seven to 10 days after application. Reasons for an increase in mite populations include disruption of the natural enemies that control spider mites (predatory mites), increased movement of mites out of fields and increased reproductive rates of female mites.

Early detection facilitates timely and effective rescue treatments. Current insecticides for soybean provide short-term protection, about seven days, from mites and do not kill mite eggs. Fields will need to be monitored continually for resurging populations.

The efficacy of an insecticide can be improved significantly with sufficient coverage (greater than 18 gallons/acre of water) and application at high pressure to penetrate foliage. However, under dry conditions, mites usually will occur throughout the field, and spot treatments are not effective in controlling mites and unlikely to prevent the infestation from spreading. Insecticides labeled for mite control have a

21- (Dimethoate) to 30-day (Cobalt) harvest interval. Consequently, if infested fields still have green seeds but seeds are filling, accepting some yield loss from mites and not treating may be better than treating and being unable to meet the labeled harvest interval.

**IPM for soybean aphids and spider mites**

When scouting soybean fields, consider which insect pests (soybean aphid and spider mites) are present and their population levels. If the heat and drought stress continues, soybean has an increased risk for spider mites and reduced risk for soybean aphids (increased mortality and decreased reproductive rate due to hot temperatures greater than 90 F). If heavy rains occur, mite and aphid populations can collapse. Mite infestations often are concentrated early in field edges, and spot treatment can be feasible and more economical. However, under dry conditions, mites usually will occur throughout the field, and spot treatments are unlikely to prevent the infestation from spreading. Early detection facilitates timely and effective rescue treatments.

## Wireworms (Coleoptera: Elateridae)

Wireworms are most likely to be problems when soybean follows pasture or grassland. Infestations often are found in coarse-textured soils (sandy loam) where moisture is abundant, perhaps in low spots of fields.

## Thresholds

Producers have no easy way to estimate wireworm infestations. Two methods are used:

### Soil Sampling

Sample 20 well-spaced, 1-square-foot sites to a depth of 4 to 6 inches for every 40 acres being planted. If you find an average of one wireworm per square foot, treatment would be justified.

### Solar Bait Trap

In September, establish bait trap stations for two to three weeks before a freeze. Place bait stations randomly through the field, making sure you represent all areas of the field. You should have 10 to 12 stations per 40-acre field. Place 1 cup of wheat and 1 cup of shelled corn in a 4- to 6-inch-deep hole. Cover the grain with soil and then an 18-inch-square piece of clear plastic. Dig up the grain. If you find an average of one or more wireworm larvae per station, treatment would be justified.

## Seed Treatment

Insecticide seed treatments should be applied either as commercial or on-farm application for managing wireworms in soybean.

**Insecticides labeled for soybean insects pest in North Dakota (sorted by insecticide class and active ingredient).**

| Insecticide class | Active ingredient | Product[1] | Preharvest interval | Targeted insects |
|---|---|---|---|---|
| | | | (days) | |
| Carbamate | carbaryl | Sevin | 21 | armyworm, cutworms, bean leaf beetle, foliage feeding caterpillars, grasshoppers, potato leafhopper |
| | methomyl | Lannate LV+ | 14 | bean leaf beetle, foliage feeding caterpillars, soybean aphid |
| | thiodicarb | Larvin brand 3.2+ | 28 | armyworm, cutworms, bean leaf beetle, foliage feeding caterpillars |
| Insect growth regulator | diflubenzuron | Dimilin | 21 | armyworm, foliage feeding caterpillars, grasshoppers |
| | methoxyfenozide | Inteprid | 14 | armyworm, foliage feeding caterpillars |
| Microbial | *Bacillus thuringiensis* | Dipel DF | None | armyworm, foliage feeding caterpillars |
| | spinetoram | Radiant SC | 28 | armyworm, foliage feeding caterpillars |
| | spinosad | Tracer | 28 | armyworm, foliage feeding caterpillars |

| | | | | |
|---|---|---|---|---|
| Neonicotinoid | imidacloprid | Nuprid 1.6 F, MANA Alias 4F | 7 | bean leaf beetle, potato leafhopper, soybean aphid |
| | imidacloprid seed treatment | Gaucho 600 and generics | — | bean leaf beetle, seed corn maggot, wireworms |
| | thiamethoxam seed treatment | Cruiser seed treatment | — | seed corn maggot, wireworms, bean leaf beetle |
| Neonicotinoid + pyrethroid | imidacloprid + cyfluthrin | Leverage+ | 45 | bean leaf beetle, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |
| Organophosphate | acephate | Orthene | 14 | armyworm, bean leaf beetle, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |
| | chlorpyrifos | Lorsban 4E+, Lorsban Advanced+, Advanced Chlorpyrifos 4E+, XNufos 4E+, Hatchet 4E+, Nufos 4E+, Warhawk 4E+, Yuma 4E+, and generics | 28 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid, spider mites |
| | dimethoate | Digon 400, Dimethoate 4E, 4EC, 400, Dimethoate 2.67 EC, Dimate 4E,4EC | 21 | bean leaf beetle, grasshoppers, potato leafhopper, spider mites |
| | methyl parathion | Penncap M+ | 30 | bean leaf beetle, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |

| Insecticide class | Active ingredient | Product[1] | Preharvest interval (days) | Targeted insects |
|---|---|---|---|---|
| Organophosphate + pyrethroid | chlorphyrifos + gamma-cyhalothrin | Cobalt$^{+}$ | 30 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid, spider mites |
| Pyrethroid | beta-cyfluthrin | Baythroid XL$^{+}$ | 45 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |
| | bifenthrin | Bifenture 2E$^{+}$, Brigade 2E$^{+}$, Discipline 2E$^{+}$, Fanfare 2E$^{+}$, Sniper 2E$^{+}$, Tundra EC$^{+}$, and generics | 18 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid, spider mites |
| | bifenthrin + zeta-cypermethrin | Hero$^{+}$ | 21 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid, spider mites |
| | deltamethrin | Delta Gold$^{+}$ | 21 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |
| | esfenvalerate | Asana$^{+}$, Adjourn$^{+}$ and generics | 21 | bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |

| | | | | |
|---|---|---|---|---|
| | gamma-cyhalothin | Proaxis$^{+}$ | 45 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |
| | lambda-cyhalothrin | Warrior II$^{+}$, Silencer$^{+}$, Grizzly Z$^{+}$, Kaiso 24 WG$^{+}$ and generics | 30 (Kaiso = 45) | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid, spider mites |
| | permethrin | Pounce 3.2 EC$^{+}$, Ambush$^{+}$, Arctic 3.2 EC$^{+}$, and generics | 60 | cutworms, bean leaf beetle, foliage feeding caterpillars, potato leafhopper |
| | zeta-cypermethrin | Mustang Max EC$^{+}$, Respect$^{+}$ | 21 | armyworm, bean leaf beetle, cutworms, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |
| Pyrethroid + neonicotinoid | lambda-cyhalothrin + thiamethoxam | Endigo ZC$^{+}$ | 30 | armyworm, bean leaf beetle, foliage feeding caterpillars, grasshoppers, potato leafhopper, soybean aphid |

$^{+}$Restricted-use insecticide.

[1] Always read and follow the manufacturer's directions before using the product and always use the labeled rates. Mention of any trade names does not imply the North Dakota State University Extension Service's or author' endorsement of one product versus another or discrimination against any other product not listed. Please consult the current edition of the "North Dakota Field Crop Insect Management Guide," NDSU Extension Service publication E-1143, for more information and restrictions on insecticides labeled in soybeans (*www.ag.ndsu.edu/pubs/plantsci/pests/e1143w1.htm*).

# Disease Management and Identification

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Problematic diseases of soybean in the North Dakota and northern Minnesota region may affect yield and quality of the crop. Accurate identification of the problem is the first step in managing these diseases. Once identified, specific management techniques to address the problem may benefit soybean growers. The information in this chapter is designed to aid in identification, prevention and management of soybean diseases. Pictures can be found in the photo section of this publication. Below are general guidelines for managing soybean diseases.

- **Use high-quality seed.** Certified seed will minimize the introduction of soybean pathogens. Avoid using seed produced on fields with diseases that can be seed-borne.
- **Use crop rotation.** Soybean diseases, especially root and stem diseases and soybean cyst nematodes, build up when soybean crops are grown in close rotations. Lengthening rotations to three or four

years between soybean crops allows natural processes to reduce pathogen populations. Some crops such as dry bean and sugarbeet may be infected by some pathogens that attack soybean. Have diseases accurately identified so you can make sound decisions on the use of rotation crops.

- **Scout fields for disease.** Record the incidence of disease; such information can be used to make good decisions on management practices.
- **Strengthen the soybean plant.** Use good cultivation practices to promote growth of soybean. Provide adequate soil fertility, avoid soil compaction, enhance drainage, control weeds and avoid herbicide damage.

Two websites that provide information on diseases in this region are:

- *www.extension.umn.edu/cropdiseases/soybean/index.html*
- *www.ndsu.edu/pubweb/~bernelso/soydiseases/*

# Below Ground

The most significant diseases in our region, such as root rots, and pests, such as soybean cyst nematode, are found underground. An independent section on seed treatments follows discussion of all diseases.

## Soybean Cyst Nematode

The soybean cyst nematode (SCN), *Heterodera glycines*, is the most problematic pathogen of soybean in the

United States. This nematode is a microscopic roundworm that infects soybean roots. Extensive losses occur throughout infested areas. Losses greater than 50 percent have been measured in infested fields in North Dakota.

Nematodes easily spread from field to field by equipment contaminated with infested soil, wind-blown soil or overland flooding, or are carried by animals. In addition, SCN can be carried in soil "peds," which are small clumps of soil sometimes found associated with soybean seed. As of 2009, SCN has been confirmed in Cass, Dickey and Richland counties in North Dakota and Becker, Clay, Norman, Otter Tail, Red Lake and Wilkin counties in northwestern Minnesota. However, SCN is suspected in additional counties and likely will spread throughout the growing region.

**Symptoms**

Infection by SCN often will not result in obvious above-ground symptoms unless plants are stressed or the egg densities are high. Above-ground symptoms include stunting and yellowing, poor stands or just unthrifty plants. The roots can appear dark and decayed, and they have few, if any, nitrogen fixing nodules. A diagnostic characteristic is the presence of white to yellowish lemonshaped female nematode cysts (about 1 millimeter in diameter) on the roots. You can observe these if you carefully remove the plant from the soil with a shovel and gently wash or shake the soil off the roots. The severity of the symptoms is directly related to the amount of SCN in the soil. Warm, dry growing seasons tend to increase severity of the above-ground symptoms, while cool, wet years tend to decrease severity. Losses from SCN are usually much greater during droughts. Severity also tends to be higher in sandy soils than in heavy-textured soils.

**Management**

Maintain fields free of SCN by cleaning any equipment that previously was used in an infested area. Reduce the potential spread of SCN from infested fields to adjacent clean fields by reduced-tillage operations and practices that limit wind erosion and movement of soil. Also, use good-quality seed free of soil "peds."

Management begins by confirming the presence of *H. glycines* in the field. Economic thresholds for SCN levels in the soil have not been established for North Dakota or Minnesota. Growing a susceptible soybean in a field with low egg levels is possible, but you always have the chance of some yield loss. Unfortunately, SCN reproduces to high levels in this northern soybean-growing area, thus once a field is infested, growing susceptible cultivars will begin to increase egg levels relatively fast.

Growers can sample the soils in their fields and send the samples to public (for example, the University of Minnesota Southern Research and Outreach Center in Waseca or the NDSU Soil Testing Laboratory in Fargo) or private laboratories where egg counts can be determined. Soil tests are used to determine if a field is infested, an extended rotation is necessary or a resistant cultivar should be used. Soil testing is highly recommended if a potential for SCN infestation exists. Information on the correct soil-sampling procedures can be found on the websites of many universities or labs that process samples.

If a grower decides to plant a susceptible soybean on land infested with SCN at low egg densities, a fall soil sampling should be conducted to determine the egg density in the field. Those results will indicate the amount of reproduction during that season and can be used to decide if a rotation or use of a resistant cultivar is warranted.

Crop rotation is an effective method to reduce egg densities in soil. Rotation to nonhost crops for three to four years may reduce nematode populations, but many factors affect the reduction in egg densities, thus the results in each field will vary. Data from North Dakota indicates that in heavily infested fields following rotations to nonhost crops for four to five years, egg densities in some fields still were high. Nonhost crops are corn, sugarbeet, alfalfa, potato, small grains and sunflower. Dry edible bean, certain lupines and crambe are hosts of SCN. Consult a list of susceptible crops before growing specialty crops in SCN-infested fields. Weed control is important because SCN will reproduce on a wide variety of weeds.

Resistant cultivars are available to control SCN, but fewer are available in the early maturing varieties adapted to northern areas of North Dakota and Minnesota. Resistance usually is combined with crop rotation to manage SCN. Use cultural practices such as high fertility to help soybean plants become established and grow strongly to reduce the negative effects of SCN.

## Phytophthora Root Rot

Phytophthora root rot is a major disease of soybean, especially in areas where soybean has been cultivated for many years. The disease is caused by the fungallike pathogen *Phytophthora sojae*. Yield losses can be substantial; entire fields have been destroyed. The disease is common in the Red River Valley. The pathogen survives in soil as spores called oospores, which are produced in infected plants. When the soil water content is high, the spores germinate and infect the roots. Infection and disease development can occur at any stage of plant development, but are most commonly observed and damaging at the seedling or young plant stage.

Disease is most common in heavy, compacted clay soils and fields subject to flooding. Flooding rains, especially near planting, favor disease development. Reduced tillage, especially notill, is reported to increase damage. The pathogen does not infect other crops grown in this region naturally. Only three *Lupinis* spp. and soybean are natural hosts.

*P. sojae* has more than 70 races. The most prevalent races in North Dakota are 3 and 4, but many others are found in low frequency. As more acreage is cropped to soybean and more resistance genes are deployed, we expect the race frequency will change.

**Symptoms**

They include seed rot and pre and postemergence dampingoff and wilting of young plants. These are common in flooded soils and often are misidentified as water damage. On older plants, leaves may become yellow and plants will wilt, with wilted leaves remaining on the plant. The lateral and tap roots are destroyed. A dark brown discoloration often appears on the lower portion of the stem. The disease is usually patchy in the field, often occurring in low or flooded areas.

**Management**

Planting resistant cultivars is the best method to control Phytophthora root rot. Choose a resistant cultivar that contains a gene that controls races 3 and 4. Because these two races (3 and 4) were found to be the most prevalent races in the last survey. The resistance genes *Rps1k* and *Rps6* are commonly available genes and will manage both races.
We recommend you rotate these genes in a field (alternate *Rps6* and *Rps1k* in rotation) to avoid the potential increase in races that could overcome one or both genes. Races that can overcome both *Rps1k* and *Rps6* genes are known to exist in our region, and as more acreage is exposed to those genes, other races

will become more common. If a resistant cultivar is dying due to Phytophthora root rot, switch to a cultivar with a different gene the next time soybean is planted in that field.

Some cultivars are reported to have tolerance to Phytophthora root rot. This type of resistance can be effective against all races. These cultivars may not lose yield under low to moderate disease pressure but can be damaged severely under high disease pressure. Crop rotation is not an effective method to reduce disease because the oospores are very long-lived in soil. Metalaxyl and mefenoxam seed treatments will protect seedlings but not older plants.

## Rhizoctonia Dampingoff and Root Rot

The fungus *Rhizoctonia solani* causes pre and postemergence dampingoff and root rot of young and adult plants. When soil populations of Rhizoctonia are high, pre and postemergence dampingoff can reduce stands by 50 percent or greater. Generally, Rhizoctonia on soybean is a seedling disease, but damage has been observed on older plants. The pathogen survives in the soil and is common in this region.

### Symptoms

They consist of seed decay and brown to reddish lesions on seedling stems and roots just below the soil line. These lesions may girdle stems and kill the plant. On older plants, the pathogen causes a reddish-brown cortical root rot that may extend into the base of the stem. Plants may appear unthrifty or, less commonly, will die. Root rot can reduce nodulation greatly.

Damage from *Rhizoctonia solani* is observed commonly in areas with a long history of soybean production with close rotations or during weather conditions not favorable for seed germination and rapid growth of seedlings. *R. solani* has various anastomosis groups (AG). AG4 and AG5 are most common on soybean, but AG22 and AG3 are found occasionally. AG3, generally found on potato, is weakly pathogenic on soybean, but AG22 can be highly pathogenic, especially at high temperatures. AG4 and AG22 are common on sugarbeet. Because *R. solani* has a wide host range that includes many crops grown in this region, crop rotation practices may affect the severity of the disease. Disease severity appears greater in plants showing iron chlorosis.

**Management**

Crop rotation to nonsusceptible hosts such as small grains will reduce populations of *Rhizoctonia* in the soil. Avoid close rotations with sugarbeet if you see evidence of *Rhizoctonia* in the field. Close rotations with dry beans also may increase incidence of disease. Protective seed treatments and good seedbed preparation can reduce dampingoff. Cultivating soil to hill up around stems promotes lateral root growth and may lessen the effect of root rot on older plants.

## Fusarium Root Rot

Fusarium root rot caused by *Fusarium solani* and other *Fusarium* species can cause dampingoff of seedlings and root rot on older plants. Infected seedlings can result in poor stands, late emergence or stunted plants. Infected seedling roots will show reddish or dark-brown discoloration and decay. The disease at this stage may be misdiagnosed as Rhizoctonia because symptoms are similar.

**Symptoms**

On older plants, symptoms consist of reddish-brown lesions on lateral roots and the tap root. In advanced stages of disease, the cortex decays, the roots are black and fissures develop in the dead surface tissues of the tap root. A few nitrogen-fixing nodules may be on the roots. Plants may appear stunted or unthrifty, and you may see a yellowing of the leaves with the veins remaining green for a short time. The leaves eventually become completely yellow, then die from the edges inward and fall from the petioles.

Fusarium root rot often has been observed in association with stressed plants, such as in drought conditions or with herbicide damage. High populations of the pathogen in the soil, however, may result in disease development under good growing conditions. The pathogen may interact with other pathogens, such as *Rhizoctonia* or the soybean cyst nematode, to cause disease. Disease severity may be greater in plants showing iron chlorosis.

### Management

Crop rotation will lower populations of the pathogen in the soil. When you see evidence of this disease, avoid dry beans in close rotations because the pathogen can infect dry beans. Most cultivars appear to be susceptible to Fusarium root rot. Fungicide seed treatments can reduce dampingoff by *F. solani*. Damage to seedlings often occurs during weather conditions not conducive to rapid seed germination and plant emergence. Ridging soil around the base of the plants can promote root growth and reduce damage to root rot in older plants. Use high-quality seed; plant in warm, well-drained soils; reduce soil compaction; and provide good fertility.

## Sudden Death Syndrome

Sudden death syndrome (SDS) has not been reported in North Dakota or northern Minnesota but may appear in the near future. The disease is caused by *Fusarium virguliforme*. Yield losses from SDS can be severe when symptoms occur early during flowering.

### Symptoms

Indications of SDS generally begin on the leaves at or just after flowering. Symptoms at first are scattered circular to irregular-shaped interveinal yellow spots that produce a mottled appearance to the leaves. Eventually the yellow tissue dies and turns brown, and green tissue remains only along the major leaf veins. The upper leaves are the first to defoliate;

complete defoliation can occur when the disease is severe. Flower and pod abortion can occur. Plants showing severe leaf symptoms also will have extensive decay of roots and plants are pulled easily from the soil. The disease usually first appears in patches in fields and expands in subsequent years. Disease development is associated with wet, cool conditions early in the growth of soybean plants and warmer temperatures and heavy rainfalls during and after flowering. Foliar symptoms of SDS can be similar to those caused by brown stem rot.

**Management**

Cultivar susceptibility to SDS varies, but highly resistant cultivars adapted for North Dakota and northern Minnesota have not been identified yet. If the soybean cyst nematode is present in fields with SDS, control of the nematode will help reduce SDS severity. Some evidence indicates that some crop rotation will reduce populations of the SDS fungus in the soil. Dry bean are a host of the SDS pathogen. Because SDS develops when the soil has excess water content, practices that encourage drainage (including subsurface drainage) will help minimize disease development. Reducing soil compaction can reduce the severity of SDS.

# Above-ground Diseases

Many disease threats of soybean, including stem and foliar diseases, exist above ground. A survey of more than 120 fields in 2008 and 2009 identified the most common and/or economically problematic above-ground diseases in North Dakota.

The disease survey was conducted between R3 and R5, so diseases with symptoms that appear later in the season (such as White Mold and Brown Stem Rot) are underestimated significantly. Numerous diseases were identified in both years but disease severity was generally low.

**Frequency of fields in North Dakota with diseases between R3 and R5 soybean growth stages in 151 and 121 fields scouted in 2008 and 2009, respectively.**

| Disease | 2008 | 2009 |
|---|---|---|
| | —— Percent —— | |
| Bacterial Blight | 100 | 73 |
| Downy Mildew | 23 | 31 |
| Septoria Brown Spot | 54 | 29 |
| Charcoal Rot | 1 | 9 |
| Stem Canker | 1 | 7 |
| White Mold | 2 | 3 |
| Alternaria Leaf Spot | 24 | 2 |
| Anthracnose | 1 | 1 |
| Powdery Mildew | 1 | 1 |
| Brown Stem Rot | 1 | 1 |

## White Mold (Sclerotinia stem rot)

White mold of soybean is a common disease caused by the fungus *Sclerotinia sclerotiorum*. It can cause seed yield reductions, particularly when soybean is planted in infested soil and you have a dense plant canopy with prolonged periods of wet weather (a major factor in disease development). The disease is observed rarely when dry periods persist in July and August. Besides seed yield reductions, the disease results in reduced seed quality and seed contaminated with the black sclerotia of the fungus. *Sclerotinia* overwinters as sclerotia in soil. The sclerotia germinate to form small mushrooms called apothecia that produce spores termed ascospores. The ascospores utilize senescing flower tissue as a food base and then infect the stems of the plant; the disease is closely tied to flowering.

### Symptoms

They usually are observed after the canopy has closed. Dead plants are generally the first symptom observed. An inspection under the canopy will reveal a cottony, white mycelial (fungus threads) growth on stems, leaves or pods. Lesions develop on main stems and side branches. Stems appear bleached and sometimes shredded from advanced decay. Dark sclerotia form in and on diseased tissue. Seeds in diseased pods usually are shriveled and may be infected by the fungus or replaced by sclerotia. When a field with white mold is harvested, the seed almost always is contaminated with sclerotia.

Yield losses usually occur when incidence of disease is 15 percent or greater. In North Dakota, estimated yield loss per 10 percent disease incidence ranges from 1 to 3.4 bushels per acre.

The pathogen has an extensive host range of more than 370 plant species and causes diseases on a wide variety of crops, such as sunflower, dry bean, canola, alfalfa, buckwheat, lupine, mustard, potatoes, Jerusalem artichoke, safflower, lentil, flax, field pea and many vegetables. It also has many common broadleaf weed hosts, such as marsh elder, lambs-quarters, pigweed, Canada thistle and wild mustard.

**Management**

The most important controls for white mold of soybean are to choose less susceptible cultivars, avoid planting on soils heavily infested with *Sclerotinia* and maintain open rows so air movement through the crop reduces plant wetness. Cultural practices, such as reduced seeding rate and wider row spacing, that reduce environmental conditions favoring disease are helpful. Orienting the rows toward the prevailing wind, for example, may help dry the crop following precipitation. Under very prolonged rainy periods or in protected areas such as along shelterbelts where humidity is higher, disease may develop even in an open canopy. Fungicide applications have been shown to reduce disease in trials.

Soybean fields should be monitored for disease incidence. Check the seed hopper at harvest for the presence of sclerotia. As disease begins to increase in a field, the rotation time to nonsusceptible crops, such as small grains and corn, should be increased. Crop rotation will reduce populations of sclerotia in soil but will not eliminate the pathogen entirely. We recommend you not plant susceptible crops, such as dry edible bean and sunflower, during the rotation. If you rent land, find out the disease and cropping history before making planting decisions.

Although common soybean cultivars adapted for this region are susceptible to white mold, some cultivars are less susceptible than others. Information on cultivar susceptibility may be available from the NDSU Extension Service and seed companies. Do not use seed from a white mold-infected crop. Seed quality could be low, and sclerotia may be introduced into the field along with the seed. Also, maintain good control of broadleaf weeds because they can be hosts of Sclerotinia and can make the microclimate more favorable for white mold. When growing a susceptible crop under irrigation, avoid practices that favor a dense canopy and free water on the plant during flowering because these will create ideal conditions for disease development.

If fungicides are labeled for management of sclerotinia in the future, the most important aspects of management will be timing and penetration deep into the canopy. Applications must be made preventatively, preferably at the onset of bloom (R1).

## Septoria Brown Spot

Septoria brown spot, caused by *Septoria glycines*, is a common leaf disease that may develop throughout the season.

### Symptoms

This disease is noticed first as pinpoint brown spots that develop on the leaves on the lower parts of the plants. These spots may remain small or enlarge up to 3/16 inch, becoming irregular and angular in shape and reddish brown to dark brown with age. Severely diseased leaves turn yellow and fall off, with defoliation beginning on the lower leaves and progressing up the plant. Brown, irregularly shaped spots may develop on the stems, petioles and pods. Yield losses of 8 to 15 percent have been reported in other states.

Septoria brown spot develops in warm, humid weather. Hot, dry conditions will arrest disease development, but it may resume if conditions improve. Rainy weather is especially favorable since *Septoria* spreads by splashdispersed spores. Disease development also occurs in areas with poor drainage. The brown spot fungus survives on soybean crop refuse and may be seed-borne.

### Management

How frequently economic loss occurs in North Dakota and Minnesota is unclear, but in most of the Midwest,  little evidence is available to suggest that Septoria brown spot causes yield loss except under the most extreme circumstances. Given this, active management of this disease in most years is unnecessary, and management techniques utilized for other diseases (for example, crop rotation) likely are sufficient. Fungicides are available, but disease pressure warranting their use in our area is unlikely. Additionally, bacterial blight is much more common than brown spot (especially in the early part of the season), and the symptoms of both pathogens can be confused. Correct identification of the pathogen is essential.

## Bacterial Blight

Bacterial blight was the most commonly found disease in the 2008-09 disease survey. How frequently economic loss occurs from bacterial blight is unclear. Bacterial blight (caused by *Pseudomonas syringae* pv. g*lycinea)* develops in cool, humid weather. The bacteria blight pathogen can be seed-borne and also can survive on soybean crop residue. Bacteria readily enter wounds in the leaf, and rapid spread may occur following late spring or early summer rain storms, hail or cultivation when the plants are wet.

### Symptoms

The blight begins as small, greasy, green, angular, watersoaked spots; later they turn yellow and then reddish brown. The spots are surrounded by a narrow yellow border. As the spots coalesce, portions of the leaf tissue fall out, and the leaves become torn and ragged. Infected young leaves may be distorted and stunted. Severely diseased leaves may drop off.

Occasionally, large black spots may develop on stems, petioles and pods. Seeds in infected pods may become slimy. Hot, dry weather will stop the development of bacterial blight.

**Management**

Do not use seed from a diseased field. Use crop rotation and bury soybean crop residue with tillage. Do not cultivate when the plants are wet. Some cultivars are less susceptible. Because bacterial blight is caused by a *bacterial* pathogen, fungicides are not useful for control.

## Downy Mildew

Downy mildew, caused by *Peronospora manshurica,* develops primarily in years with extended periods of cool, humid weather.

**Symptoms**

They include yellowgreen to yellow spots on the upper leaf surface and a purplish or grayish downy fungal growth on the lower leaf surface opposite the yellowgreen patches on the upper leaf surface. The yellow spots turn brown later in the season. Pod infection may result in seeds that are dull white, cracked or covered with a white crust of overwintering oospores. If these white or encrusted seeds are planted, a small percentage of the emerging seedlings may be infected systemically with the downy mildew fungus, resulting in stunted plants. Leaves of systemically infected plants will have areas of greenyellow tissues along the main veins and the leaf edges will be curled downward. Downy mildew may cause losses up to 10 to 13 percent.

**Management**
Use crop rotation and bury infected crop residue by tillage. Use a seed treatment if planting seed from an infected field or the seed has a white crust on it.

## Pod and Stem Blight

This disease, caused by *Diaporthe* and *Phomopsis* fungal spp., is common in southern Minnesota but less so in North Dakota and northwestern Minnesota.

**Symptoms**
They include rows of raised black fruiting bodies that develop on the stem and a random pattern of raised fruiting bodies that develop on the pods. Infected stems often are killed. Infected seeds are shriveled and cracked and may be covered with white fungal growth.

The pod and stem blight fungus survives on infected soybean crop refuse and can be seed-borne. It develops in wet weather and results in crop injury as the crop nears maturity. If infected seeds are planted, plants may die on emergence.

**Management**
Use crop rotation. Also use tillage to bury infected soybean crop residues. Plant high-quality seed that is nearly free of the pod and stem blight pathogen or use a seed treatment. Harvest promptly at maturity. Maintain adequate potash levels.

## Stem Canker

Stem canker is relatively common in southern Minnesota and in South Dakota, but how frequently it occurs in North Dakota and northwestern Minnesota is unclear. Stem canker is caused by two different but related pathogens, each causing a distinct disease: *Diaporthe phaseolorum* var. *caulivora (Northern Stem Canker) and Diaporthe phaseolorum* var. *merdionalis (Southern Stem Canker).*

### Symptoms

Early symptoms of stem canker are reddish-brown lesions that appear at the base of the leaf petiole or branches. Lesions may develop into sunken dark-brown cankers with small black raised structures on the surface (perithecia). Plant parts above the lesion may die. Stem canker develops in wet weather, and symptoms most likely may be observed beginning in mid-July following wet springs.

### Management

Resistant varieties, tillage, foliar fungicides and crop rotation may be useful to mitigate stem canker where it has been a problem.

## Brown Stem Rot

The brown stem rot fungus *Phialophora gregata* was confirmed in North Dakota in 2008. Infection occurs through the roots and develops slowly until pods are filling.

## Symptoms

Symptoms usually do not appear until late in the season. The most reliable symptoms develop inside the lower stem. When the stem is split open with a knife, the pith (central tissues) is brown. The internal browning may extend several inches or more above the soil line. Leaf symptoms, which develop sporadically or may not occur, consist of a yellowing followed by browning of tissues between the main veins. The veins remain green. Foliar symptoms can be similar to those caused by sudden death syndrome. The best time to assess for brown stem rot is the R5 to R6 stage, when seeds are beginning to develop in pods at the four uppermost nodes. Any time that a field suddenly turns brown, rather than yellow green, late in the season, the lower stems should be split and examined for brown stem rot.

The brown stem rot fungus survives several years in soybean crop residue. The disease develops during cool or moderate temperatures. The greatest damage occurs when cool and wet weather occurs during the early reproductive stage and is followed by hot and dry weather.

## Management

At the time of this printing, resistant varieties with suitable maturity for North Dakota are unavailable. Use crop rotation, planting nonhost crops for three years. Small grains and corn are not hosts. Burying soybean crop residue to hasten its decomposition may reduce brown stem rot.

## Charcoal Rot

Charcoal rot is a relatively rare but problematic disease in North Dakota and northwestern Minnesota. Charcoal rot is caused by the fungal pathogen *Macrophomina phaseolina*. The pathogen has a very large host range, which includes corn and sunflower. Yield losses are most likely when plants are under water stress midway to late in the season. Hence, drought, high temperatures and sandy soils lead to the development of charcoal rot. In Iowa in 2003, incidence of charcoal rot ranged from 20 to 90 percent of all surveyed fields and high yield loss was suspected in some fields. This epidemic was correlated to the driest August on record in the state. Charcoal rot often is observed first as a general loss of vigor in maturing soybean plants.

### Symptoms

They include a light gray to silver discoloration at the base of the stem. If the epidemis is scraped off at the base of the stem, a fine black line (similar to a marker drawing) containing microsclerotia may be observed. The pathogen survives as microsclerotia.

### Management

Crop rotation and planting nonhost crops are important management tools. If irrigating, keep soil water content reasonably high at the end of the season. Encouragement of early canopy closure by increasing planting density may reduce risk of charcoal rot but also may increase risk of other diseases.

## Soybean Rust

The pathogen causing soybean rust (*Phakopsora pachyrhizi*) was detected first in the southern United States in the fall of 2004 and is the most significant foliar disease threat to U.S. soybean production. However, at the time of printing, the disease has not reached North Dakota or Minnesota. The annual risk of soybean rust in North Dakota and Minnesota is thought to be low.

The pathogen causing soybean rust has a relatively broad host range, of which the two most important alternative hosts are kudzu and dry edible bean. The soybean rust pathogen cannot survive freezing winter temperatures, so it overwinters in the Gulf Coast states and Mexico, surviving primarily on kudzu. The urediniospores produced by the pathogen are dispersed easily by wind and will cause infection readily on nearby soybean plants.

Conditions optimal for infection include moderately warm temperatures (60 to 75 F) and six hours of free moisture, which includes rain and/or dew, on leaves. Spores can be damaged by sunlight, so overcast skies are critical for pathogen spread, survival and infection. Under optimal conditions, soybean rust can spread rapidly, and in late 2007 infection, it was found as far north as northern Iowa.

For soybean rust to reach North Dakota and northern Minnesota, several events must occur. First, the pathogen must overwinter in Texas and/or Louisiana.

Second, conditions must be favorable near the overwintering site so ample spores are produced. Third, spores must be picked up by wind currents and blown north while skies are overcast. Lastly, the conditions where the spores are deposited must be favorable for infection to take place. Infection possibly could spread from the overwintering site to our region in one storm, but more likely, successive storm and infection events would be needed to bring the pathogen north in a stepwise progression (up to Oklahoma, then to Nebraska and finally to North Dakota or northern Minnesota).

**Symptoms**

The first symptoms of soybean rust begin as very small brick-red to brown spots on the upper leaf. The spots are very small (less than a leaf hair) and are observed more readily by holding the leaf up to the bright sky. On the underside of the leaf, opposite the brown spots, pustules will form. Pustules resemble miniature volcanoes, with spore masses erupting through the leaf tissue. Seeing these without a hand-held lens or magnifying glass with at least 20x in power is very difficult. The best way to observe the pustules is to roll the leaf around a finger and look through the hand-held lens at an angle perpendicular to the leaf. When pustules become numerous, the leaves will drop prematurely.

**Warning**

Soybean rust resembles many other soybean diseases, including bacterial pustule, brown spot, bacterial blight and downy mildew. Accurate confirmation of soybean rust is critical before any management action can be considered.

## Management

Rust-resistant varieties will be available in the future, but they likely will not be available in our maturity groups for many years. Rotation and tillage will have no bearing on soybean rust in North Dakota and Minnesota.

Early detection combined with fungicide applications, if necessary, can result in excellent management of soybean rust. Pathologists in southern states routinely scout for soybean rust and post the information online at www.sbrusa.net. Being the most northern soybean-growing region in the country, we benefit by watching the progression of soybean rust to our south. When rust is suspected and weather conditions are favorable for infection and spread, fungicide applications can mitigate potential damage.

Fungicides are most effective at the early stages of an epidemic, and by the time rust is detected *easily*, economic loss may be unavoidable. Data indicate that fungicides applied before R1 and after R6 are unlikely to be economically feasible. For information about specific chemicals and/or timing, consult www.sbrusa.net and the latest version of the "North Dakota Field Crop Fungicide Guide," NDSU Extension Service publication PP-622.

# Virus Diseases

Virus diseases have not been a serious problem in this area, but in soybean-producing areas to the south, viruses have become a problem in recent years. The recent introduction of the soybean aphid into this area may result in virus problems because aphids are virus victors. The two most common viruses that have been found in North Dakota and Minnesota are soybean mosaic virus (SMV) and bean pod mottle virus (BPMV). Numerous other viruses can be found in soybean but they have not been detected yet in this northern growing area. Identification of a virus disease requires special techniques. Identifying a virus based on symptoms is very difficult.

**Symptoms**

Virus symptoms vary greatly but may consist of stunting, fewer pods, leaf mosaic (light and dark green areas), puckering, blistering, distortion, chlorosis or necrosis. Plants can be infected without showing symptoms. Seed mottling can occur, which is detrimental to the quality of food beans.

The severity of the disease and the effect on yield are affected greatly by the plant stage at infection, the environmental conditions and the susceptibility of the cultivar. Yield losses can be substantial under heavy disease pressure. Seed can transmit SMV, and the virus is vectored by aphids (*Aphis glycines*). The vector of BPMV is the bean leaf beetle (*Cerotoma trifurcata*).

# Seed Treatment of Soybean

Soybean seeds may be treated with fungicides to improve stand, protect against seedling infection by some pathogens and reduce the spread of diseases that may be carried on or in the seeds. The use of seed treatments may not be necessary if healthy seed is planted under conditions favoring rapid emergence.

When planting into less than ideal conditions, such as cool, poorly drained or notill/reduced-tillage soil, seed treatments sometimes can provide a more uniform stand but often not a yield advantage. Seed treatments containing mefenoxam or metalaxyl are effective against downy mildew and seedling infection by *Phytophthora* and *Pythium*.

However, seasonlong management of *Phytophthora* can be obtained only through the use of resistant varieties. Products that contain carboxin, PCNB, fludioxonil or strobilurins may provide some protection for seeds and seedlings against *Rhizoctonia*. Biological seed treatments that contain spores of the bacteria *Bacillus subtilis* are labeled for suppression of *Fusarium* and *Rhizoctonia* infection. New seed treatment products frequently are being developed and sold. Many resources are available for more information on seed treatment products currently available. Please consult the latest version of the "North Dakota Field Crop Fungicide Guide," NDSU Extension Service publication PP-622, or other reliable sources for product information. Also consult and follow the product label when using any product.

White mold (Sclerotinia stem rot) may be spread through infected seed. Fludioxonil, thiram and captan + PCNB + TBZ have been shown to reduce disease spread by seeds. Avoiding “binrun” seed and planting certified diseasefree seed is most important in managing the spread of white mold through seeds.

## Seed Treatment Fungicides and *Bradyrhizobium japonicum* Inoculants

Some seed-treatment fungicides have an adverse effect on *Bradyrhizobium* inoculants. Captan and PCNB severely reduce survival of bacteria on treated seed and reduce nodulation compared with inoculated seed without these fungicides. Therefore, if captan- or PCNB-treated seed is to be planted, using an infurrow inoculant might be best. Carboxin has a moderate effect on *Rhizobium* and could be used if the seed is inoculated immediately before planting. Mefenoxam and metalaxyl have little or no adverse effect on *Rhizobium,* and thiram has no adverse effect.

# No-tillage or Minimum-tillage Soybean Production

Minimum or no-till production practices may create an environment favorable for pathogens to damage soybean seeds or young seedlings. The cool, moist soil conditions created by these practices can delay germination, decrease seedling vigor and slow seedling emergence. This is especially true during cool, wet springs and when soybean is planted early. In the first 14 days following planting, soybean plants are susceptible to stress from a variety of factors, such as high or low soil water content and temperatures, crusted soils, compaction, deep planting and reduced seed quality. Pathogens that become active and damage soybean plants in the seedling stages include *Rhizoctonia*, *Fusarium*, *Phytophthora*, *Pythium* and some of the seed-borne fungi. Seed treatments with a broad-spectrum fungicide will protect the crop during the critical seed germination and emergence period.

# Hail Damage

**Hans Kandel**
Extension Agronomist

A hailstorm can cause yield losses in soybean ranging from slight to total destruction of the crop. Extensive research has been conducted to predict the effects of hail damage on soybean yields accurately. Results from these studies are used by hail insurance companies to assess yield losses and determine adjustment payment made to clients.

**Yield loss predictions** are based on two factors: a) the growth stage at the time of damage and b) the degree of plant damage. Plant damage is classified as leaf defoliation, stand reduction, stem damage and pod damage.

**Stand reduction** is a measure of the number of plants killed by the storm. The pre-storm plant population is compared with the remaining stand seven to 10 days after the storm to determine the yield loss due to stand reduction.

To determine the pre-storm population, count the original number of plants (live plants and remnants of plants) in 10 feet of row. Repeat this step several times throughout the field to get a representative sample.

Now convert the average stand per 10 feet of row to plants per acre, using the following formula:

$$\frac{\text{(average number of plants in 10-foot row)}}{\text{(row spacing in inches)}} \times 52{,}250 = \text{number of plants per acre}$$

Using the same procedure, determine the remaining live plant population.

(stand before the storm – stand after the storm) = stand loss in plants

(stand loss in plants)/(stand before the storm/100) = percent stand loss

**Percent yield loss of soybean as affected by the amount of stand reduction (all stand counts x 1,000 plants/acre).**

| Original stand | Remaining stand (x 1,000) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (x 1,000) | 120 | 110 | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 |
| | Percent yield loss[1] | | | | | | | | | | | |
| 125 | 1 | 3 | 6 | 10 | 14 | 18 | 24 | 30 | 36 | 44 | 54 | 65 |
| 120 | 0 | 1 | 5 | 9 | 13 | 17 | 23 | 29 | 35 | 43 | 53 | 64 |
| 110 | – | 0 | 3 | 7 | 11 | 15 | 21 | 27 | 33 | 41 | 51 | 62 |
| 100 | – | – | 0 | 3 | 7 | 11 | 17 | 23 | 29 | 37 | 45 | 59 |
| 90 | – | – | – | 0 | 3 | 7 | 13 | 19 | 25 | 33 | 43 | 55 |
| 80 | – | – | – | – | 0 | 4 | 10 | 16 | 22 | 30 | 40 | 52 |
| 70 | – | – | – | – | – | 0 | 6 | 12 | 18 | 25 | 35 | 48 |
| 60 | – | – | – | – | – | – | 0 | 7 | 13 | 20 | 30 | 45 |
| 50 | – | – | – | – | – | – | – | 0 | 8 | 16 | 25 | 41 |
| 40 | – | – | – | – | – | – | – | – | 0 | 11 | 23 | 39 |

[1] Yield loss also will depend on the growth stage of the crop.

**Defoliation** is measured as a percentage of the leaf area destroyed by the storm. Leaf tissue that is green and still attached to the plant will continue to produce photosynthate and is **not** considered destroyed leaf area. Research has shown that leaf loss during vegetative stages has little effect on yield. Defoliation loss is measured only in the reproductive stages for indeterminate varieties.

**Percent yield loss of indeterminate soybean varieties as affected by degree of defoliation.**

| | **Defoliation (Percent leaf area destroyed)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stage** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| R1-2 | 0 | 2 | 3 | 5 | 6 | 7 | 9 | 12 | 16 | 23 |
| R3 | 2 | 3 | 4 | 6 | 8 | 11 | 14 | 18 | 24 | 33 |
| R4 | 3 | 5 | 7 | 9 | 12 | 16 | 22 | 30 | 39 | 56 |
| R5 | 4 | 7 | 10 | 13 | 17 | 23 | 31 | 43 | 58 | 75 |
| R6 | 1 | 6 | 9 | 11 | 14 | 18 | 23 | 31 | 41 | 53 |

These tables are intended only to provide general guidelines to soybean yield losses due to hail injury. The percentage of nodes cut off or broken were not included. Even though early season soybean defoliation appears to be very devastating, research has shown that soybean plants can recover and yield fairly well under good growing conditions. The pod-setting and pod-fill periods are very susceptible to severe injury. Hail adjusters usually will defer final yield loss determinations until later in the season. These tables and guides are being revised and updated continually as research becomes available. Specific loss predictions should be left to trained hail adjusters.

*Source: National Crop Insurance Association - Soybean Loss Instruction - Pub. No. 6302.*

# Frost Damage

Soybean plants are damaged easily by frost in the 28 to 32 F range. Temperatures of 28 F for any extended period of time can kill soybean plants (stems and leaves) completely. During the early seedling stage (VE to VC), soybean has some tolerance to temperatures of 29 to 30 F for short periods of time. If the seedlings have been somewhat hardened off by cool temperatures for several days, then temperatures as cool as 28 F can be tolerated. Once true leaves emerge, soybean plants become more susceptible to freezing temperatures below 32 F for any extended period of time. The unifoliolate leaf stage is slightly more frost tolerant than the first or second trifoliolate leaf stages.

# Late-season Frost Damage

Research information from Wisconsin has shown that all varieties tested had reduced yields when frost occurred at or before R6. Earlier-maturing varieties sustained economic yield losses from frost at more advanced growth stages than later-maturing varieties. The greatest yield losses occurred when frost occurred at stage R5. The number of beans per plant and reduced bean size contributed to overall yield loss. Maturity was hastened by some frost treatments and was not delayed in any of the trials studied.

Soybean seed on frost-damaged plants many mature and change color as early as or even earlier than nonfrosted soybean plants. The leaves tend to remain on the frost-damaged soybean plants. Seed moisture may be slightly higher and seed size usually is reduced as the soybeans dry and shrink. A frost will not hurt soybean yields if the soybean growth stage is beyond R7. A frost between R6 and R7 may or may not affect yield, depending on the temperature and duration of the freeze.

Beans that are still green and soft will shrivel. Stalks rapidly turn dark green to brown and will not recover. Beans in pods that have turned yellow will mature normally. Some green beans will turn yellow after 30 to 40 days of storage.

Growers and researchers through the years have tried to use color keys such as yellow soybean leaves, yellow pods and brown pods to estimate soybean maturity and safety from frost. Generally these methods didn't work because of differences in varieties regarding symptoms of maturity. However, studies do show that "yellow" pods sprinkled with brown are the best clue of physiological maturity.

Open pods and check shrinking of beans and look for separation of beans from the white membrane inside the pod. This indicates the soybean plants are physiological mature and fairly safe from frost injury. Pods do not all mature evenly. Note that if one or two pods on any of the upper four nodes have turned brown and other pods are light yellow to tan, the soybean plants are fairly tolerant to a killing frost. In the event of a leaf-killing frost when pods are still light green or yellow, wait until the pods are mature in color before combining. The most significant effect of an early frost on soybean may be in the reduction in their value as a future source of seed.

Generally speaking, soybean fields planted to narrow row spacings (6 or 7 to 12 inches) may have slightly more tolerance to light frosts than soybean planted in wider rows (30 to 36 inches). The heavy plant canopy of the solid-seeded, closely drilled beans tends to hold the soil heat better and therefore protects the plants to some degree.

# Estimating Soybean Yields

Soybean yield estimates are most accurate within three weeks of maturity but are still only estimates. Assume 2.3 beans per pod.

- Determine the number of feet of row needed to make 1/1,000 of an acre (table below).
- In the determined area, count the number of plants in 10 different randomly selected sample areas. Calculate the average.

  Avg. = ________________ = A (plants/acre)

- Count the number of pods per plant on 10 randomly selected sample areas. Calculate the average.

  Avg. = ________________ = B (pods/plant)

- Calculate pods/acre by multiplying plant population by pods/plant.

  A X B = ________________ = C (pods/acre)

- Calculate seeds/acre by multiplying pods per acre by an estimate of 2.3 seeds/pod.

  2.3 X C = ________________ = D (seeds/acre)

- Calculate pounds/acre by dividing seeds/acre by an estimate of 3,000 seeds/pound.

  D ÷ 3,000 = ________________= E (lbs/acre)

- Estimate yield by dividing pounds/acre by 60 pounds/bu.

  E ÷ 60 = ________________ = yield (bushels/acre)

## Row length equal to 1/1,000 acre

| Row width | Length of a single row equal to 1/1,000 of an acre |
|---|---|
| (inches) | |
| 6 | 87' 1" |
| 7 | 74' 8" |
| 8 | 65' 4" |
| 10 | 52' 3" |
| 15 | 34' 10" |
| 20 | 26' 2" |
| 28 | 18' 8" |
| 30 | 17' 5" |
| 32 | 16' 4" |
| 36 | 14' 6" |
| 38 | 13' 9" |
| 40 | 13' 1" |

# Harvesting Soybean

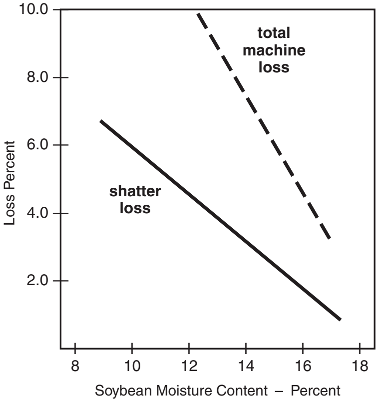
**John Nowatzki**
Extension Agricultural Machine Systems Specialist

Field studies in soybean harvesting have shown that a 10 percent or higher harvest loss is not uncommon, but studies also have shown that harvest loss can be reduced to 3 percent or less. To keep losses low, you need to know where harvest losses occur, how to measure loss, what is a reasonable level of loss, and the equipment adjustments and operating practices that will help reduce losses.

## Soybean Loss

Soybean should be harvested when bean moisture content reaches 13 percent on the first dry down (Figure 7). However, if beans are ready for harvest

**Figure 7. Shatter and machine loss related to moisture content at harvest.**



and then are subjected to alternating periods of wet and dry weather, preharvest or shatter loss can be high. Preharvest losses are influenced by the time of harvest and can be reduced by harvesting early. Preharvest losses are beans that have dropped on the ground prior to harvest.

Gathering or header losses can account for more than 80 percent of the total loss in soybean harvesting. These include all losses occurring at the header caused by actions of the cutter bar, reel and feeder auger, and losses from soybeans left on uncut stubble.

**Gathering losses are divided as follows:**

- **Shatter loss** – shelled beans and detached bean pods that are shattered from stalks by the header and fall to the ground
- **Stubble loss** – beans remaining on stubble
- **Stalk loss** – beans in pods attached to stalks that were cut, fell on the ground and did not run through the combine
- **Lodged stalks** – beans remaining in pods attached to stalks that are laying on the soil or, if cut, were cut at lengths larger than stubble height

Soybean is an easy crop to thresh, separate and clean. The beans are easy to remove from the pod, and their size and shape make them easy to clean. But small errors in adjustment can cause serious bean loss. Follow the settings recommended in the operators manual for cylinder speed and concave spacing, along with air flow and shoe settings. Then, operate the combine in the field and check for loss. Usually, only small adjustments need to be made in the field. Remember to run the cylinder at the slowest speed possible but fast enough to thresh the beans from the pods. Excessive cylinder or rotor speed is usually the main reason for cracked bean seeds.

## Gathering Equipment

Several machinery developments have occurred to improve the soybean gathering efficiency compared with a conventional rigid cutter-bar platform. These include the integral flexible-floating cutter bar, row-crop head, pickup finger reels, pickup guards, narrow-pitch knives (1½ vs. 3 inches) and combination pickup finger/air reels.

These attachments provide significant reductions in soybean loss. The flexible-floating cutter bar is able to follow soil slopes better and cut shorter stubble, reducing the number of pods left on the stalks. Pickup reels help lift lodged stalks so the cutter bar can slide under and retrieve them.

Narrow-pitch knives help reduce side movement of plants and the resulting shatter loss. Pickup guards ride on the soil surface, sliding under lodged bean stalks so they are cut and directed into the combine header. Combination finger/air reels help push cut stalks and pods back into the feeder housing to reduce bean pods and seed from building up on the cutter bar with the resulting shelling and bean loss.

All these attachments have been shown to reduce bean loss, but growers have a cost factor to consider before the equipment can be justified economically. For example, a grower needs to complete a cost-reduction estimate to determine how much money he or she can afford to spend on the attachments. A grower must estimate how many acres of beans will be harvested, crop yield and a loss level improvement regarding soybean harvesting.

For example, a producer may grow 500 acres of soybean and be able to reduce loss by 3 to 5 percent. With a 35 bushel per acre (bu/a) yield and a 3 to 5 percent reduction in loss, a grower could see a return of 1 to 1.75 bu/a more beans in the bin. Multiplied times 500 acres, an extra 500 to 875 bushels of soybeans could be saved. Spread the investment over five or more years, and a significant amount of money can be justified to reduce harvest loss of beans. Interest costs on the money should be included, along with repairs, insurance and resale value.

## Combine Adjustments

Reel speed and position are extremely important to reduce bean loss. Reels with pickup fingers will cause the least disturbance to the standing plants and, when positioned correctly, will place cut plants to convey smoothly along the header auger and into the feeder.

The proper reel speed is 25 to 50 percent faster than the forward travel speed. Faster reel speeds will rip bean pods off stalks and result in increased bean loss. The axis of the reel should be positioned 8 to 12 inches ahead of the cutter bar.

## Harvesting High-quality Seed

Cylinder or rotor speed has more effect on seed damage than cylinder-concave clearance (Figure 8). Operating the cylinder only fast enough to remove the beans from the pods and no faster is important. Slowing the cylinder speed during the day as beans dry also is important. This is more important for conventional combines than rotary because Illinois

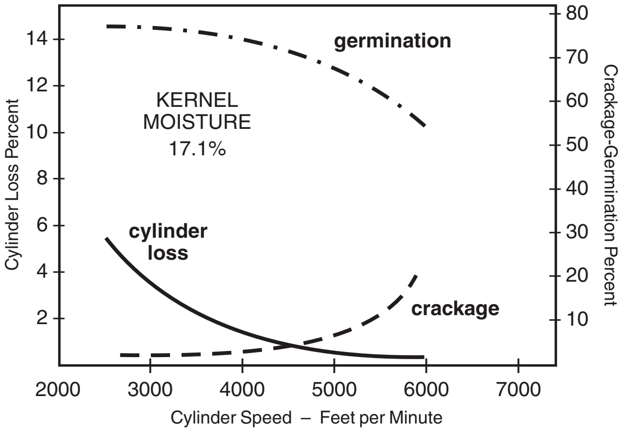



**Figure 8. Relationship of cylinder speed to cylinder loss, germination and soybean crackage.**

tests found that rotary combines produced significantly fewer splits than conventional cylinder concave-type machines. But both types of machines could produce high-quality soybeans easily. If cylinder or rotor speeds are too fast, damaged soybeans will result.

## Measuring Harvest Loss

Identifying where harvest losses are occurring is important so growers can take measures to eliminate or minimize the loss. Soybean seed loss from the various areas is determined by making several seed counts inside a measured area. The measured area is best completed by forming a 1-foot by 1-foot square. The best way to do this is to form a heavy piece of wire (No. 9 is good) into a square. Then this square is used in the field to make seed counts.

Refer to Figure 9 (page 141) and record your seed counts in the "Loss" table (see below).

**The procedure to use in the field is:**

1) Operate the combine in the field and stop. Back up the combine about 20 feet.

2) Using the 1-foot-square frame, count all beans in the frame as the frame is moved across the width of the cutter bar. Refer to Figure 9.

    a. Count beans in the uncut area to determine "preharvest shatter loss."

    *This is location 1 in Figure 9.*

b. Count beans behind the combine to find the "total crop loss."

*This is location 2 in Figure 9.*

3) Enter the bean counts for "preharvest losses" and "total crop loss" into the "Loss" table.

4) Divide that number by the number of frame counts that were completed across the cutting width of the combine. This number is the average number of beans per frame.

5) Divide No. 4 by 4 because approximately four beans per square foot equals 1 bushel per acre. If the beans you are raising are large, then three beans per square foot would equal 1 bushel per acre.

6) Subtract the preharvest loss from the total harvest loss. This is the machine loss due to combine operation. Then estimate your crop yield and divide the bu/a loss by the yield. For example:

35 bu/a yield and 1.2 bu/a loss

$$\text{percent loss} = \frac{1.2 \text{ bu/a}}{35 \text{ bu/a}} \times 100 = 3.4 \text{ percent}$$

If the machine loss is more than 3 percent of crop yield, growers may need to do further investigation into the source of loss.

7) Gathering loss is determined and measured between the combine header and the unharvested crop (location 3). Again, measurements should be made across the entire width of the header.

a. Shatter loss is determined by counting all loose beans and beans in loose pods on the ground.

Enter this number under shatter losses in the "Loss" table.

b. Loose stalk loss is determined by counting all beans on loose stalks that were cut and are lying on the ground. Add this to the table.

c. Lodged stalk loss is determined by counting all beans in pods on stalks still attached to the ground and lying flat. Add to the table. Pickup guards on the cutter bar may reduce this loss considerably.

d. Stubble loss is determined by counting all beans in pods still attached to the stubble. Add this to the table.

Add the four gathering unit losses and subtract the preharvest loss from the gathering unit loss. This figure will give the gathering unit loss. Subtract the gathering unit loss from the machine loss to give the cylinder and separation loss. Follow the step-by-step procedure in the "Loss" table.

| **Loss Table** | **No. of Beans** | **No. of Frames (counts)** | **Avg. No. of Beans Per Frame** | **Bu/acre** |
|---|---|---|---|---|
| A. Total crop loss | | | ÷ 4 | |
| B. Preharvest losses | | | ÷ 4 | |
| D. Gathering unit losses a+b+c+d – B | | | | |
| a. shatter loss | | | ÷ 4 | |
| b. loose stalk loss | | | ÷ 4 | |
| c. lodged stalk loss | | | ÷ 4 | |
| d. stubble loss | | | ÷ 4 | |
| E. Cylinder and separation losses (C-D) | | | | |

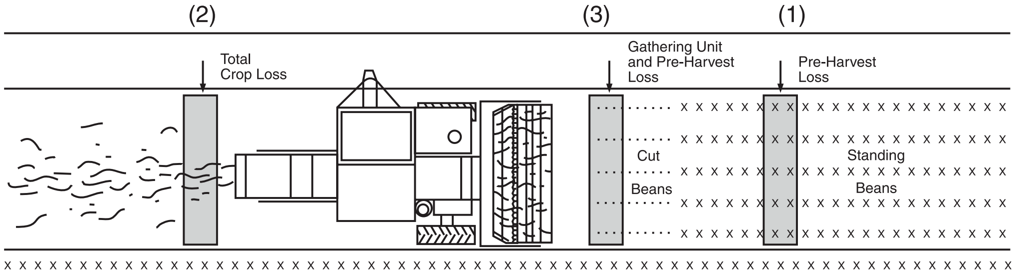



**Figure 9. Location of areas to make seed loss counts.**

# Soybean Drying, Handling and Storage

**Kenneth Hellevang**
Extension Engineer

Soybeans usually are traded on a 13 percent moisture basis, so harvesting, storing and selling soybean as close to 13 percent moisture (wet basis) as possible is to the farmer's advantage. Soybean that are wetter than 13 percent moisture are likely to mold under warm conditions, and buyers usually apply shrink factors and drying charges when wet beans are delivered.

On the other hand, soybeans that are drier than 13 percent moisture are more likely to split during handling and, since they weigh less, fewer bushels are available for sale. If the temperature of the stored beans is kept below about 60 F, soybeans usually can be held for at least six months at 13 percent moisture without mold problems. For storage under warmer temperatures or for storage times longer than six months, however, the recommended moisture content is 11 percent.

## Storage Management for 11 to 13 Percent Moisture Soybean

Soybean that are harvested at 11 to 13 percent moisture can be placed directly into ordinary storage bins equipped with simple aeration systems (perforated ducts or pads and relatively small fans). The suggested winter storage temperature for grains and oilseeds in the upper Midwest is 20 to 30 F. Since soybeans usually are harvested at temperatures well above 30 F, cooling them by operating aeration fans during cool weather is necessary.

Rather than waiting until outdoor temperatures drop to 20 to 30 F before cooling stored beans, cooling them in 10- to 20-degree stages as average temperatures drop in the fall is best. For example, if beans are harvested at 55 F, you could wait a few weeks until average outdoor temperatures drop to 40 F and run the fans long enough to cool all the beans in the bin to 40 F. Then shut the fan off for a few more weeks and repeat the cycle when average outdoor temperatures fall to about 25 F.

The airflow provided by aeration fans usually is expressed as cubic feet of air per minute per bushel of beans, or cfm/bu. You can estimate the amount of fan operation time to cool an entire bin of beans by dividing 15 by the airflow in cfm/bu.

For example, many on-farm storage bins have an airflow rate of about 0.2 cfm/bu, so the cooling time would be 15 divided by 0.2, or 75 hours, which is about three days. You can use this formula to estimate cooling time, but you should measure the bean temperature at several different points in the bin to make sure that cooling is complete.

When you are operating aeration fans to cool beans that are 11 to 13 percent moisture, you don't need to worry too much about relative humidity. Beans near the point where air enters the bin will rewet some during very humid weather, and some overdrying will occur during very dry weather, but if fans are operated no longer than necessary to cool the bin, the overall moisture change will be quite small.

Changing the moisture of a crop takes about 50 times as long as changing its temperature does, which means you can move a temperature front through 50 feet of beans by the time you've changed the moisture of a 1-foot layer. If you are concerned about operating the fan during weather that is too humid or too dry, however, you can install controls that will operate the fan only during weather conditions that do not cause drying or rewetting.

Keep in mind that these types of controls will limit the time that the fan operates, and cooling the entire bin will take longer than cooling would without the controls.

Once soybeans have been cooled to 20 to 30 F, check them every two to four weeks during winter months to make sure the temperature is stable and no mold, insect and crusting problems are developing. If you find problems, or if bean temperature has moved above or below the desired range, operate the aeration fan during 20 to 30 F weather to run a temperature front through the bin. If you need to hold the beans into spring and summer, increase your frequency of checking the bins to every two weeks. But unless a problem develops, operating the aeration fans is not necessary.

If you do need to aerate during spring or summer, do so during the coolest weather available and make sure that you keep bean temperature less than 60 F.

When spoilage problems develop in stored beans, they often start in pockets of accumulated fines (small pieces of broken seeds, weed seeds and stem material) and foreign material. This material is difficult to aerate and it is often wetter and more susceptible to mold growth than whole seeds.

Try to keep fines and foreign material out of the bin by setting combines for maximum cleaning or by running beans through a grain cleaner on the way into the bin. Or at least prevent the fines and material from accumulating in one spot by using grain spreaders to fill bins, frequently moving spouts during bin filling or coring bins (removing some beans through the center unloading sump) after they are full.

For more information about grain and oilseed storage, obtain "Management of Stored Grain with Aeration" (publication AG-FO-1327) from the University of Minnesota Distribution Center or "Crop Storage Management" (publicationAE-791) from the NDSU Distribution Center.

## Soybean Handling

Soybeans are subject to splitting during handling, so handle them gently. Belt conveyors, bucket elevators and drag or mass conveyors provide the gentlest handling. But normal grain augers can be used if they are operated slowly and at full capacity, and pneumatic or air-type conveyors can be used if the air-to-grain ratio is set properly and lines are laid out with a minimum number of very gradual curves.

Avoid long drop heights in bean handling by frequently adjusting the position of conveyors or using bean ladders or other devices that break long drops into a series of shorter drops. One handler of food-grade soybeans recommends 10 feet as the maximum height for any single drop.

## Artificial Drying

Most years, fall weather conditions in the upper Midwest will dry soybeans to 11 to 13 percent moisture in the field. But some years, weather conditions prevent soybeans from drying to 13 percent moisture, and sometimes growers harvest at moistures greater than 13 percent to avoid the harvest losses that can occur at lower moisture contents.

Soybeans can be harvested without too much damage up to about 18 percent moisture.
If soybean is harvested at a moisture content much above 13 percent, artificial drying is necessary.

Not much research has been published on soybean drying. Most drying recommendations are based on limited experience or are extrapolated from corn drying recommendations. In most cases, dryers that were designed for corn can be adapted for use with soybean.

**Natural-air drying**: Using unheated air to dry soybeans usually works well, but it is a slow process (four to six weeks, depending on initial moisture, airflow and weather). Bins used for natural-air drying should have fully perforated floors and fairly large drying fans. Fan power requirements depend on desired airflow and depth of beans. For example, delivery of 1 cfm/bu (cubic feet of air per minute per bushel of beans in the bin) through an 18-foot depth of soybeans would require about 0.6 horsepower (hp) per 1,000 bushels of beans in the bin, while delivery of 1.5 cfm/bu through 18 feet of beans would take about 1.6 hp/1,000 bu.

Management of natural-air soybean dryers is similar to that for natural-air corn dryers, except that soybean moisture values need to be about 2 percentage points lower than those recommended for corn.

In southern Minnesota, use an airflow rate of 1 cfm/bu to dry 17 to 18 percent moisture beans, 0.75 cfm/bu for 15 to 17 percent moisture beans and 0.5 cfm/bu for 13 to 15 percent moisture beans. In North Dakota and northern Minnesota, higher airflow is needed because fewer days are available for drying in the fall.

In northern areas, use 1 cfm/bu to dry soybeans that are 16 percent moisture or less, 1.25 cfm/bu for 17 percent moisture beans and 1.5 cfm/bu for 18 percent moisture beans. See “Natural-Air Corn Drying in the Upper Midwest” (publication BU-6577), which is available from the University of Minnesota Distribution Center, or “Natural-Air/Low-Temperature Crop Drying” (publication EB-35) from the NDSU Distribution Center for information on equipping and managing natural-air dryers.

Because natural-air drying is a slow process, using one bin to dry both beans and corn in the same year will be difficult. Don’t plan on having the beans dry before corn harvest unless the soybeans are only slightly wetter than 13 percent or unless you use a shallow drying depth.

**Low-temperature drying**: Early in the fall, especially in years with warm, dry weather, drying soybeans to less than 13 percent moisture is possible with no supplemental heat (see previous section on natural-air drying). However, late in the fall, or in years with cool, damp weather, soybeans might not dry to 13 percent and adding a small amount of supplemental heat to the air in natural-air dryers might be helpful. Do not heat the air more than 3 to 5 degrees, though, or you will overdry the beans and you might cause an increase in splitting. Research has shown that exposing soybeans to relative humidities of less than 40 percent can cause excessive splitting.

For every 20 degrees that you heat air, you cut its relative humidity approximately in half, so producing relative humidities less than 40 percent doesn't take very much heat.

Some alternatives to adding supplemental heat to natural-air drying bins include:

- Turning off the fan when the weather gets cold in the fall, keeping beans cold during winter and resuming drying when average temperatures climb above freezing in the spring.
- Installing bigger fans so you can finish drying earlier in the fall when weather is better.
- Using manual or automatic controls to turn off the fan during periods of high humidity. Fan control will increase the amount of time required for drying, but it will result in drier beans.

**High-temperature drying**: Many kinds of gas-fired corn dryers can be used to dry soybeans, but be careful. Soybeans split easily if they are dried too fast or are handled roughly. Set the drying air temperature lower than you would for corn and avoid dryers that re-circulate the crop during drying.

Column-type dryers often be can operated at 120 to 140 F without causing too much soybean damage, although some trial and error might be required to set dryers properly. Examine beans leaving the dryer carefully and reduce the temperature if you're getting too many splits.

If the soybeans will be saved for seed, keep drying temperatures under 110 F to avoid killing the embryo.

Don't forget that crops dried in gas-fired dryers must be cooled within a day or so to remove dryer heat. This can be done in the dryer or aerated storage bins. Stored beans should be aerated again later in the fall to cool them to 20 to 30 F for winter storage.

## Immature, Frosted or Green Beans

In years when frost kills soybean plants before the seeds are fully mature, make sure you remove as much chaff and green plant material as possible before binning the beans. Immature beans can be stored without significant molding, but concentrations of green chaff can lead to heating in storage.

Although producers have heard that green soybeans eventually will turn yellow in storage, the color change observed in a University of Minnesota laboratory study was minimal. Storing green soybeans for a few months after harvest still might be worthwhile to avoid the high discounts that are applied in years when large quantities of green beans are delivered during harvest. Just make sure that any green beans going into storage are clean, evenly distributed throughout the bin and cooled as soon as possible after harvest.

# Reconditioning Overly Dry Soybeans

In years with exceptionally warm, dry falls, soybean sometimes is harvested at moisture contents well under 13 percent moisture. Although adding water to increase soybean moisture is illegal, given enough time and a high enough airflow per bushel, increasing the moisture content of soybeans is possible by aerating them with humid air. But here are some practical concerns and limitations:

- The process is quite slow, even with the high airflow per bushel (0.75 to 1 cfm/bu) available on bins equipped for drying. It will be similar to the speed of drying. Accomplishing significant reconditioning would be difficult using the low airflow aeration systems common on storage bins.
- Fan control is tricky and some beans could end up too wet for safe storage.
- You are likely to end up with layers of wet and dry beans unless you can find some way to mix them in the bin or during unloading of the bin.
- Swelling that accompanies rewetting will increase stress on bin walls.

The table of equilibrium moisture values shows the moisture content that soybeans would reach if exposed to different combinations of temperature and relative humidity for long periods of time. If you continuously aerated a bin of beans, they would tend to lose moisture during periods of low humidity and gain moisture during periods of high humidity.

To recondition soybeans to 13 percent moisture during normal fall temperatures of 30 to 60 F, you would need to control the fan so it operates during weather that has an average relative humidity of 65 to 70 percent.

The table indicates that bean moisture increases sharply as relative humidity increases, which means that rewetting a layer of soybeans to a moisture content that is too high for safe storage is quite easy.

**Equilibrium moisture values (percent wet basis) for soybeans.**

| | Relative humidity (percent) | | | | |
|---|---|---|---|---|---|
| **Temperature** | **50** | **60** | **70** | **80** | **90** |
| **(F)** | | | | | |
| 32 | 10.0 | 11.8 | 13.7 | 16.2 | 19.8 |
| 40 | 9.8 | 11.5 | 13.5 | 16.0 | 19.6 |
| 50 | 9.5 | 11.2 | 13.2 | 15.7 | 19.4 |
| 60 | 9.2 | 11.0 | 13.0 | 15.4 | 19.1 |
| 70 | 8.9 | 10.7 | 12.7 | 15.2 | 18.9 |
| 80 | 8.6 | 10.4 | 12.5 | 15.0 | 18.7 |

During reconditioning, the moisture of the whole bin doesn’t change at once. A rewetting zone develops and moves slowly through the bin in the direction the airflow is moving. This is similar to the way a drying zone moves through a drying bin.

In most cases, not enough high-humidity hours are available in the fall to move a rewetting zone all the way through the bin. And in many cases, depending on how the fan is controlled, the parts of the bin that have been rewetted will be too wet for safe storage.

Mixing the wet layers with the dry layers would be best to reduce spoilage risk and avoid drying charges for the wet layers when the beans are sold.

Mixing can be accomplished to a limited extent by emptying the bin and moving the beans through a grain-handling system. The most effective way to mix the beans, though, would be to use an in-bin stirring system. In fact, bin dryers equipped with stirring augers are a good choice for reconditioning soybeans.

If the initial moisture content of the beans is 10 percent or less, controlling the fan so it only runs when the relative humidity of the air reaching the beans is greater than about 55 percent should result in rewetting. If you use a single humidistat to turn the fan on anytime humidity is greater than 55 percent, average humidity during the hours the fan operates should be well above 55 percent and the beans are likely to rewet to at least 13 percent.

Since humidity is almost always higher at night than it is during the day, an alternative to a humidistat would be a timer set to run the fan only during nighttime hours.

If you aren't equipped to mix beans after reconditioning, you need to avoid rewetting them to moisture levels that are too high for safe storage. Approaches to prevent excessive rewetting include:

- Reducing the humidity setting on the humidistat that controls the fan so the fan runs during drier conditions

- Adding a second humidistat that stops the fan when relative humidity reaches very high levels
- Installing a sophisticated microprocessor-based controller that monitors both temperature and humidity and only runs the fan when air conditions will bring the crop to the desired moisture content (for either drying or rewetting)

The disadvantage of the last two approaches is that the fan doesn't run as many hours as it would with a single-humidistat control and less total moisture would be added. Running the fan at high humidities and then mixing the wet and dry beans would result in greater average moisture content.

Reconditioning time depends primarily on airflow per bushel and weather conditions. It is fastest when airflow per bushel is high and air is warm and humid. Reconditioning will be most successful in a bin equipped as a drying bin – one that has a fully perforated floor and a fan that can deliver at least 0.75 cfm/bu.

Even with this airflow, moving a rewetting front all the way through the bin probably would take at least a month of fan operation. Keep in mind that you can't run the fan continuously because in a typical fall, continuous fan operation would result in drying rather than rewetting.

Soybeans swell when they absorb moisture, and experience during floods indicates that soaking the bottom few feet of beans in a bin can result in enough pressure to rupture bin walls. We don't have enough information on reconditioning soybeans through use of airflow to know whether this procedure can damage bins, but the process definitely will increase stress on the walls. Using a vertical-stirring auger to mix layers of dry and wet beans might be one way to reduce outward pressure generated during rewetting.

To increase chances of success in using airflow to recondition soybeans:

- Use a bin equipped with a fully perforated floor and a fan that can deliver at least 0.75 cfm/bu.
- Use a bin equipped with stirring equipment if it is available. If stirring equipment is not available, consider transferring the beans to another bin to mix the wet and dry layers.
- Use timers, humidistats, programmable controllers or some other type of automatic control to limit fan operation to weather conditions that will cause rewetting.
- Keep reconditioned beans cool (20 to 30 F is the suggested winter-storage temperature in the upper Midwest) to reduce chances of spoilage.
- Watch carefully for signs of moldy beans and excessive stress on the bin.

## Food or High-value Soybean

More care is required with high-value soybean primarily to minimize the amount of cracked skins and beans. The optimum moisture content for harvest is about 13 to 15 percent. At moisture contents below about 13 percent, more beans split, germination is reduced due to more damage during harvest and handling, field loss will be greater and producers see a loss of about 1.1 percent per point of moisture below 13 percent due to less weight.

To minimize damage during handling, belt conveyors are preferred to augers. If augers are used, they should be operated at a slow speed and be kept full. Pneumatic conveyors can be used if the proper air-to-grain ratio is maintained, gentle curves are used in the conveying tubes and a low conveying velocity is used. Drop heights should be minimized, so bean ladders are recommended in bins or other locations where the beans may fall during conveying. Cold beans are more susceptible to damage during handling.

Use care in drying beans because much of the damage that occurs during handling is due to stresses created during drying. Damage during drying occurs when the relative humidity of the drying air is below about 40 percent.

Generally, the drying air in a high-temperature dryer should not be heated more than 20 degrees to minimize the potential for damage to the seed coat. One study showed that with a 100 F drying temperature,10 to 60 percent of the skins cracked and 5 to 20 percent of the beans cracked. Another study showed about 15 percent of the seed coats cracked with the drying air at 40 percent relative humidity and 30 percent of the seed coats cracked with a 30 percent relative humidity.

## U.S. standards for soybean grades and grade requirements.

| Grading Factors | Grades U.S. Nos. 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| | Minimum pound limits | | | |
| Test weight (lb/bu) | 56.0 | 54.0 | 52.0 | 49.0 |
| | Maximum percent limits | | | |
| Damaged kernels | | | | |
| Heat (part of total) | 0.2 | 0.5 | 1.0 | 3.0 |
| Total | 2.0 | 3.0 | 5.0 | 8.0 |
| Foreign material | 1.0 | 2.0 | 3.0 | 5.0 |
| Splits | 10.0 | 20.0 | 30.0 | 40.0 |
| Soybeans of other colors[1] | 1.0 | 2.0 | 5.0 | 10.0 |
| | Maximum count limits | | | |
| Other materials | | | | |
| Animal filth | 9 | 9 | 9 | 9 |
| Castor beans | 1 | 1 | 1 | 1 |
| Crotalaria seeds | 2 | 2 | 2 | 2 |
| Glass | 0 | 0 | 0 | 0 |
| Stones[2] | 3 | 3 | 3 | 3 |
| Unknown foreign substance | 3 | 3 | 3 | 3 |
| Total[3] | 10 | 10 | 10 | 10 |

**U.S. sample grade** are soybeans that:

(a) Do not meet the requirements for U.S. Nos. 1, 2, 3 or 4; or

(b) Have a musty, sour or commercially objectionable foreign odor (except garlic odor); or

(c) Are heating or otherwise of distinctly low quality

[1] Disregard for mixed soybeans.

[2] In addition to the maximum count limit, stones must not exceed 0.1 percent of the sample weight.

[3] Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones and unknown foreign substances. The weight of stones is not applicable for total other material.

# Contributors to the Soybean Production Field Guide

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- **Dean Malvick**, Plant Pathologist, University of Minnesota Extension
- **Sam Markell**, Plant Pathologist, NDSU Extension Service
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- **John Nowatzki**, Agricultural Machine Systems Specialist, NDSU Extension Service
- **Richard Zollinger**, Weed Specialist, NDSU Extension Service

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- **Ted Helms**, NDSU Soybean Breeder
- **Dwain Meyer**, NDSU Plant Sciences
- **Joel Ransom**, Agronomist, NDSU Extension Service
- **Bill Wilcke**, Agricultural Engineer, University of Minnesota Extension

# Resource Publications

## North Dakota State University

- Soybean Production (A-250)
- North Dakota Soybean Performance Testing (current year) (A-843)
- Agricultural Weed Control Guide (current year) (W-253)
- Field Crop Fungicide Guide (current year) (PP-622)
- Crop Rotations for Increased Productivity (EB-48)
- Profitable Midwest No-Till Soybean Production (NCR-580)
- Soybean Soil Fertility (SF-1164)
- Crop Rotations for Managing Plant Disease (PP-705)
- Mechanical Weed Control with Harrow and Rotary Hoe (W-1134)
- Soybean Aphid, Aphis glycines, Management in North Dakota (E-1232)

## University of Minnesota

- The Minnesota Soybean Field Book
- Fertilizing Soybeans in Minnesota
- Minnesota Variety Trials Results
- Soybean Growth and Development Information for Replant Decisions
- Soybean Disease
- Tillage Best Management Practices for Corn-Soybean Rotations

# Resource Contact Information

**North Dakota State University**

| | |
|---|---|
| Agronomy | (701) 231-8135 |
| Economics – Markets and Budgets | (701) 231-7377 |
| Engineering | (701) 231-7261 |
| Entomology | (701) 231-7581 |
| Plant Pathology | (701) 231-7056 |
| Soils Sciences | (701) 231-8884 |
| Weeds Sciences | (701) 231-8157 |

**University of Minnesota**

| | |
|---|---|
| Agronomy | (612) 625-4298 |
| Economics – Markets and Budgets | (612) 625-8150 |
| Engineering | (612) 625-8205 |
| Entomology | (612) 625-8611 |
| Plant Pathology | (612) 625-5282 |
| Soil Sciences | (612) 624-3482 |
| Weeds Sciences | (612) 625-8130 |

**Ag Statistics Services, USDA**

**North Dakota Ag Statistics Service** (701) 239-5306
P.O. Box 3166
Fargo, ND 58108-3166

**Minnesota Ag Statistics Service** (612) 296-2230
8 4th St. E., Suite 500
St. Paul, MN 55101-1008

**Plant Diagnostic Labs**

**NDSU – Plant Diagnostic Lab** (701) 231-7854
206 Waldron Hall
NDSU Dept 7660, P.O. Box 6050
Fargo ND 58108-6050

**University of Minnesota** (612) 625-1275
Plant Disease Clinic
495 Borlaug Hall
1991 Buford Circle
St. Paul, MN 55108

**North Dakota State Seed Department** (701) 231-5400
Seed testing labs
1313 18th St. N.
P.O. Box 5257
Fargo, ND 58105

**Minnesota State Seed Lab** (651) 201-6649
Dept. of Agriculture
601 Robert St. N.
St. Paul, MN 55155-2531

**North Dakota Soybean Growers Association**
and
**North Dakota Soybean Council** (701) 239-7194
1411 32nd St. S.W., Suite 3 Fax: (701) 239-7195
Fargo, ND 58103
*Web: www.ndsoybean.org*

**Minnesota Soybean Growers Association** (507) 388-1635
and
**Minnesota Soybean Research and Promotion Council**
151 Saint Andrews Court, Suite 710
Mankato, MN 56001
*Web: www.mnsoybean.org*

# Useful Soybean Websites

## Soybean Production Management

North Dakota State University Extension Service
*www.ag.ndsu.edu/extension*

North Dakota State University Extension Service soybean publications
*www.ag.ndsu.edu/pubs/legumes.html*

North Dakota State University Research Extension Centers
*www.ag.ndsu.nodak.edu/recenthp.htm*

North Dakota State University ProCrop
*www.ag.ndsu.edu/procrop/procrop.htm*

NDSU Crop and Pest Report
*www.ag.ndsu.nodak.edu/aginfo/entomology/ndsucpr/index.htm*

North Dakota State University Weed Science
*www.ndsu.edu/weeds*

NDSU Seedstock and other related seed links
*www.ag.ndsu.nodak.edu/aginfo/seedstock/fss/index.htm*

NDSU Insect Updates for North Dakota
*www.ag.ndsu.nodak.edu/aginfo/entomologyentupdates/index.htm*

University of Minnesota Extension-Agriculture
*www.extension.umn.edu/Agriculture*

University of Minnesota Extension Service
*www.extension.umn.edu*

University of Minnesota Agriculture Experiment Station
*www.maes.umn.edu*

University of Nebraska Extension
*http://cropwatch.unl.edu/web/soybeans/home*

University of Illinois Extension
*http://web.extension.illinois.edu/state/index.html*

Iowa State University Soybeans
*www.extension.iastate.edu/crops/soybean*

## Commodity Groups and Organizations

American Soybean Association
*www.soygrowers.com*

Minnesota Soybean
*www.mnsoybean.org*

North Dakota Soybean Council
*http://ndsoybean.org*

Northern Crops Institute
*www.northern-crops.com*

Northern Food Grade Soybean Association
*www.nfgsa.org/index.php*

Soybean check-off research
*www.soybeancheckoffresearch.org*

United Soybean Board
*www.unitedsoybean.org*

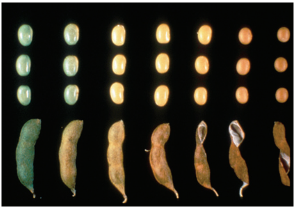
# SOYBEAN – GENERAL

**Nodules on soybean roots**
*(Courtesy D. Berglund)*

**Iron chlorosis deficiency**
*(Courtesy D. Berglund)*

**Soybean flower**
*(Courtesy D. Berglund)*


**Soybean pod 10 mm long**
*(Courtesy D. Berglund)*



**Bean development stages**
*(Courtesy D. Berglund)*


**Harvest loss: four beans per square foot is 1 bu/a**
*(Courtesy D. Berglund)*

# SOYBEAN – INSECTS

**Armyworm adult**
*(Courtesy G. Fauske, NDSU)*

**Armyworm larva**
*(Courtesy R. Smith, Auburn University, www.Bugwood.org)*

**Bean leaf beetle adult**
*(N. Wright, Florida Department of Agriculture and Consumer Services, www.Bugwood.org)*

**Bean leaf beetle defoliation**
*(Courtesy C. Strunk, South Dakota State University, www.Bugwood.org)*

**Dingy cutworm adult**
*(Courtesy G. Fauske, NDSU)*

**Dingy cutworm larvae**
*(Courtesy J. Gavloski, Manitoba Agriculture, Food and Rural Initiatives)*

# SOYBEAN – INSECTS

**Redbacked cutworm adult**
*(Courtesy G. Fauske, NDSU)*

**Redbacked cutworm larvae**
*(Courtesy J. Gavloski, Manitoba Agriculture, Food and Rural Initiatives)*

**Darksided cutworm adult**
*(Courtesy G. Fauske, NDSU)*

**Green cloverworm adult**
*(Courtesy J. Gavloski, Manitoba Agriculture, Food and Rural Initiatives)*

**Green cloverworm larva**
*(Courtesy J. Gavloski, Manitoba Agriculture, Food and Rural Initiatives)*

**Green cloverworm pupae**
*(Courtesy J. Gavloski, Manitoba Agriculture, Food and Rural Initiatives)*

**Painted lady butterfly**
*(Courtesy W. Ciesla, Forest Health Management International, www.Bugwood.org)*

**Thistle caterpillar**
*(Courtesy J. Knodel, NDSU)*

**Alfalfa webworm adult**
*(Courtesy W. Cranshaw, Colorado State University, www.Bugwood.org)*

**Alfalfa webworm larva**
*(Courtesy J. Knodel, NDSU)*

**Grasshopper adult**
*(Courtesy P. Beauzay, NDSU)*

**Grasshopper nymph**
*(Courtesy G. Fauske, NDSU)*

**Potato leafhopper adult**
*(Courtesy S. Brown, University of Georgia, www.Bugwood.org)*

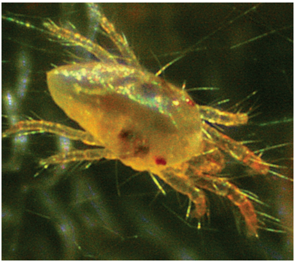
**Potato leafhopper nymph**
*(Courtesy S. Brown, University of Georgia, www.Bugwood.org)*

**Soybean aphids (adults, nymphs and white-casted skins) on underside of leaf**
*(Courtesy P. Beauzay, NDSU)*

**Close-up of soybean aphid alate**
*(Courtesy P. Beauzay, NDSU)*


**Seedcorn maggot adult**
*(Courtesy Pest and Diseases Image Library, www.Bugwood.org)*

**Seedcorn maggot larva**
*(Courtesy W. Cranshaw, Colorado State University, www.Bugwood.org)*



**Close-up of two-spotted spider mite**
*(Courtesy D. Cappaert, Michigan State University, www.Bugwood.org)*

**Stippling injury from two-spotted spider mites**
*(Courtesy W. Cranshaw, Colorado State University, www.Bugwood.org)*

**Webbing from two-spotted spider mites**
*(Courtesy D. Cappaert, Michigan State University, www.Bugwood.org)*

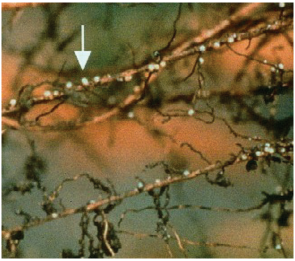
**Click beetles (adult wireworm)**
*(Courtesy S. Brown, University of Georgia, www.Bugwood.org)*

**Wireworm**
*(Courtesy M. Boetel, NDSU)*

# SOYBEAN – DISEASES

**Phytophthora root rot**
*(Courtesy H.A. Lamey)*

**White mold**
*(Courtesy B.D. Nelson)*



**Soybean cyst nematode**
*(Courtesy G. Tylka)*

**Rhizoctonia root rot**
*(Courtesy B.D. Nelson)*

**Fusarium root rot**
*(Courtesy B.D. Nelson)*

**Sudden death syndrome**
*(Courtesy B.D. Nelson)*

# SOYBEAN – DISEASES

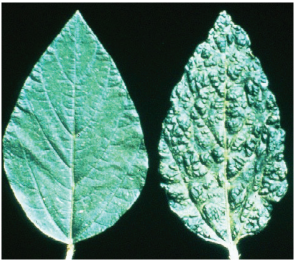
**Bacterial blight**
*(Courtesy L. Prom)*

**Septoria brown spot**
*(Courtesy H.A. Lamey)*

**Downy mildew**
*(Courtesy B. Nyvall)*

**Pod and stem blight**
*(Courtesy USDA)*

**Brown stem rot**
*(Courtesy C. Grau)*



**Leaf puckering from virus**
*(Courtesy Illinois Agricultural Experiment Station)*

**Seed mottling from virus**
*(Courtesy H. J. Johnson)*

**Leaf distortion from virus**
*(Courtesy M.C. Shurtleff)*

**Soybean rust pustules through hand lens**
*(Courtesy S. Markell)*

**Soybean rust through hand lens**
*(Courtesy S. Markell)*

**Charcoal rot**
*(Courtesy D. Jardine, Kansas State University)*

**Stem canker**
*(Courtesy D. Malvick)*

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