AGR-1

University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service

2018-2019 Lime and Nutrient Recommendations

The recommendations found in this publication are a result of a biennial review of soil fertility research and soil test data collected in Kentucky. The committee is made up of members of the Plant and Soil Science, Horticulture, and Agricultural Economics Departments. The co-chairs of the committee and editors of this publication are Drs. Edwin Ritchey and Josh McGrath, Extension Soil Specialists.

Contents

Basis of Nutrient Recommendations

Recommended nutrient additions, based on a soil test, are only made when a yield response has been measured for that crop under Kentucky soil-climatic conditions. Many field studies have been conducted by the Kentucky Agricultural Experiment Station under Kentucky farm conditions to determine the extent of any primary, secondary, or micronutrient needs. Yield and soil test data from these studies serve as guidelines for establishing recommendations contained in this publication. Recommendations in this publication strive to enable each soil/field to supply a sufficient level of available plant nutrients, regardless of seasonal weather and assuming good management practices.

Sometimes, nutrients are supplied at rates greater than those recommended by soil test, specifically when using manure and other waste products as a nutrient source. In these situations, one should never exceed the nitrogen recommendation in a given year. Some soils in Kentucky naturally have very high soil test phosphorus (P) levels. If soil test P is greater than 400 lb P/A, then environmental constraints may limit additional P applications. Special consideration should also be given to environmentally sensitive areas, such as fields near streams or springs, or karst areas (which contain caves, sinkholes, or depressions). The Kentucky Agriculture Water Quality Act requires nutrient management planning for all operations 10 acres or larger applying plant nutrients (fertilizer, biosolids, or manure) regardless of the source. Consult the USDA Natural Resources Conservation Service Practice Code 590 or University of Kentucky Extension publication ID-211 for specific nutrient utilization guidance. In all cases, applications of P (from any source) are not permitted if soil test levels exceed 800 lb P/A.

Nutrient recommendations in this publication are based on soil test values obtained using testing methods in the laboratories operated as part of the Kentucky Agricultural Experiment Station. This laboratory uses the Mehlich III solution to extract P, potassium (K), calcium (Ca), magnesium (Mg), and zinc (Zn). Soil pH is determined in a solution of 1 M KCl then converted to soil-water pH for soil test reports, and buffer pH is determined with the Sikora buffer. These methods are described in Bulletin 190 of the Southern Cooperative Series, *Procedures Used by the State Soil Testing Laboratories in the Southern Region of the United States*. The nutrient recommendations in this publication should not be used for soil test results obtained by other testing methods.

The recommendations assume average climatic and management conditions for Kentucky. Rates should be adjusted upward or downward to reflect any deviations from these assumptions.

The rates recommended are for production of a crop to be grown each year and will increase soil test values slowly for P and K. Using these recommended rates would likely take four years or longer of annual nutrient application at the recommended rates to result in appreciably higher soil test levels of P and K. Consult University of Kentucky Extension publication AGR-151, *Evaluating Fertilizer Recommendations* for additional information.

Table 1. Soil drainage classes.

Well-Drained Soils			
Allegheny	Frederick	Memphis	Uniontown
Ashton	Hagerstown	Nolin	Vicksburg
Baxter	Huntington	Pembroke	Wellston
Caneyville	Jefferson	Pope	Wheeling
Crider	Loradale	Shelbyville	Whitley
Cuba	Maury	Shelocta	
Elk	McAfee	Trimble	
Moderately Well-Drained Soils			
Beasley*	Cotaco	Lowell*	Otwell
Bedford	Eden*	Mercer	Sadler
Captina	Grenada	Morehead	Tilsit
Collins	Heitt*	Mountview	Zanesville
Commerce	Loring	Nicholson	
Somewhat Poorly and Poorly Drained Soils			
Belknap	Falaya	McGary	Stendal
Bonnie	Henry	Melvin	Tyler
Calloway	Johnsburg	Newark	Weinbach

* NRCS/USDA drainage classes for these soils may be different from above.

CEC and Percent Base Saturation

Values for cation exchange capacity (CEC) and percent base saturation (% BS) are reported for all soil samples analyzed routinely in the University of Kentucky Soil Testing Laboratories. The CEC is an estimate that is calculated according to accepted mathematical models, with a modification based on the sample's soil pH to better reflect specific Kentucky conditions.

Reported values for CEC include an estimation of acidity (expressed as hydrogen, H), as reflected in the buffer pH measurement and extractable calcium (Ca), magnesium (Mg), and potassium (K) by the Mehlich III extracting procedure. The total CEC is the sum of milliequivalents per 100 grams of soil (meq/100g) of the following cations: H, Ca, Mg, and K. The value for % BS is the sum of the meq/100g of the basic cations (Ca, Mg, and K) expressed as a percentage of the total CEC. The dominant cation in most Kentucky soils with a pH above 5.8 is calcium (Ca) and hydrogen (H) when soil pH is below 5.8. Rarely does the amount of magnesium (Mg) or potassium (K) greatly affect CEC estimation or % BS.

While CEC is not used directly in making nutrient recommendations for agronomic crops, this information does affect lime recommendations. The buffer pH is directly related to the acidity or H fraction of the CEC. The values for % BS are a good indicator of the relative presence of the basic cations in the soil. Soils with 70% or greater BS are unlikely to limit agronomic crop growth due to acidity. Agronomic crop yields on soils with a BS below 50% can be affected by excessive acidity. Other Extension publications or your county Cooperative Extension agent should be consulted for the soil pH associated with optimal growth and yield of specific horticultural or agronomic crops.

Soil Drainage Classes and Nitrogen Fertilization

Nitrogen fertilizer recommendations are related to soil drainage differences. Soils differ in the amount of water that infiltrates the soil surface and in the subsequent rate of percolation through the root zone. Important soil series are listed in Table 1. Their drainage class grouping there does not always coincide with the NRCS/USDA drainage classes (indicated by an asterisk).

Soils with Naturally High Contents of P and K

Some soils naturally contain higher levels of P and K and may not require supplemental fertilizer for crop production. Soils developed from phosphatic limestone will likely maintain high soil test P levels without fertilization as will some soils containing high native K levels.

Table 2. Converting elemental and oxide values.

To Convert		Multiply
From:	To:	By:
P_2O_5	P	0.44
P	P_2O_5	2.29
K_2O	K	0.83
K	K_2O	1.20

Elemental and Oxide Values for P and K

Soil test values for phosphorus and potassium are reported as pounds of elemental P or K/A (lb/A). Nutrient recommendations are made on the oxide basis: pounds of phosphate (P_2O_5) or potash (K_2O) per acre. Use the factors in Table 2 when converting from elemental to oxide and vice versa.

Plant Analysis

A plant analysis may be used to verify a suspected nutrient problem or to evaluate the nutrient status of a crop. Plant analysis is not a substitute for a soil test but should be used along with a soil test. Your county Extension agent has information on plant analysis services available for various crops, or see University of Kentucky Extension publication AGR-92, *Sampling Plant Tissue for Nutrient Analysis*.

Collecting a Representative Sample

In order to get reliable recommendations, it is important that the submitted soil sample accurately represent the field or area from which it was taken. Analytical results provided on the soil test report form are for the sample submitted, and the listed recommendations are based on those results. All recommendations are made on the assumption that a representative soil sample was properly taken. If soil sampling procedures are questionable, accurate nutrient and lime recommendations for the sampled field or area cannot be assured. Because results vary somewhat between fall and spring, it is better to consistently sample any given field in fall or spring. See University of Kentucky Extension publication AGR-189, *Managing Seasonal Fluctuations of Soil Tests,* for details. When sampling untilled fields in the fall, an equal number of cores should be collected from both between and close to the rows.

Sampling Depth and Frequency

For tilled areas, take soil cores to a depth of 6 to 7 inches. With pastures, lawns, no-tilled areas, and turf, take soil cores to a depth of 3 to 4 inches. Because of high fertilizer and commodity prices, each production field should be sampled every two years. Annual sampling is preferable for high-value crops that remove large amounts of soil nutrients, such as alfalfa and double-crop silage. Sampling each year after manure application is also recommended. See University of Kentucky Extension publication AGR-16, *Taking Soil Test Samples,* for details.

Nutrient Recommendations

Nitrogen

Because Kentucky soils are usually not frozen, but remain relatively wet throughout the winter months, very little residual (leftover) nitrogen (N) is available to subsequent crops. Rather, residual nitrate-N remaining after harvest is lost either by leaching or back to the atmosphere through a process called denitrification (conversion of nitrate-N to nitrous oxide (N_2O) or dinitrogen gas (N_2), the most common atmospheric gas). Kentucky crops, therefore, rely on organic matter mineralization and annual fertilizer applications. For this reason, routine soil testing for N is not recommended in Kentucky and fertilizer N recommendations in this publication are based on measured crop response to N fertilization.

Each year, UK agronomists conduct N response studies on various crops. The range in N recommendations in this publication is based on the range in agronomically optimal N rates determined from these trials. That range is due to spatial variation in the N response within field soils and also to temporal variation in the N response due to seasonal weather.

Samples Testing Low in P and K

If soil tests for phosphorus and potassium are low, one-third to one-half of the recommended amounts of P_2O_5 and/or K_2O for corn can be used if it is banded 2 to 4 inches from the row.

Samples Testing High in P and K

When soil test levels for P and K are so high that no nutrient recommendation is made for the current year, there is no assurance that these high levels will be maintained for optimal production in the following years. When soil test levels are in the lower portion of the high range, the area should be sampled again the following year.

Recommendations without Soil Tests

If nutrient recommendations must be made without soil test results, assume low levels of residual N, P, and K.

Recommendations for Multiple Years

If one nutrient recommendation is made for two years of sequential cropping, the recommended rates of phosphate and potash for each crop are added together and applied to the first crop grown. However, this method is not recommended for crops with a high nutrient demand, e.g., alfalfa, corn for silage, tobacco, etc. Double-cropping recommendations for small grains and soybean can be found in the "Small Grains" and "Soybean" sections.

Nutrient Value of Manures and Tobacco Stalks

Animal manure and tobacco stalks add nutrients when applied to soils. These should be considered when deciding on materials to use in fulfilling crop nutrient recommendations. The best method to determine the nutrient content of these materials is through sampling and analysis of the manure/stalks. In cases where it is not possible to take samples in a timely manner, Table 3 can serve as a guide in estimating nutrients contained in the materials listed until samples can be obtained and tested.

When applying organic materials to soil, it is important to remember that some of the nutrients they contain are not as available to the next crop as those nutrients contained in commercial fertilizers. While almost 100% of the potash is available, only about 80% of the phosphate is expected to be available to the next crop. Organic nitrogen availability is variable, with nitrogen from manure especially dependent on livestock species/diet, storage and handling methods, and the timing and method of application.

Animal manures also contain significant amounts of calcium, magnesium, sulfur, zinc, copper, and molybdenum that may be of value to crops. The added organic matter can also be of significant benefit to soils low in organic matter.

Table 3. Typical total nitrogen, phosphate, and potash content (pounds of nutrient per ton) of some manures and tobacco stalks.

Animal Manures[1]	Water (%)	lb/Ton		
		N[2]	P_2O_5	K_2O
Dairy cattle	80	11	9	12
Swine	80	9	9	8
Beef	80	11	7	10
Broiler litter	20	55	55	45
Broiler layers	40	35	55	30
Broiler pullets	30	40	45	40
Goat	70	22	5	15
Horse	80	12	6	12
Tobacco stalks	20	30	10	70

[1] Animal manures contain chloride, which can reduce the quality of tobacco. Limit rates to 10 tons per acre of cattle or swine manure. Poultry manure should not be applied to land in the year in which tobacco will be grown.

[2] Plant-available N can range from 20 to 80% of the total N in the year of application. See University of Kentucky Extension publication AGR-146, *Using Animal Manures as Nutrient Sources*, for more details.

Table 4. Recommendations for magnesium.

Soil Test Level	lb Mg/A[1]	Oz Mg/100 Sq Ft[2]
0 - 6	50	2
7 - 18	45	2
19 - 30	40	2
31 - 42	35	1
43 - 54	30	1
55 - 60	25	1
Above 60	0	0

[1] These rates may be applied when no lime is needed or where dolomitic lime is not available. When lime is needed, the addition of dolomitic lime is preferred.

[2] Epsom salts ($MgSO_4{\cdot}7H_2O$, 10% Mg) is readily available and may be more convenient for applying Mg to small areas.

University of Kentucky Extension publication AGR-146, *Using Animal Manures as Nutrient Sources,* and a computer spreadsheet (http://soils.rs.uky.edu/manureprogram.htm) are available to help determine application rates and fertilizer credits. Additional assistance can be obtained at your county Cooperative Extension Service office.

Tobacco stalks that are stored under cover to prevent leaching of nutrients by rainfall are a significant source of nutrients. See University of Kentucky Extension publication AGR-23, *Tobacco Stalks and Stems Fertility Value and Use,* for more information on the storage and use of tobacco stalks.

Surface Mine Reclamation

See the following University of Kentucky Extension publications:

- AGR-40, *Lime and Fertilizer Recommendations for Reclamation of Surface-Mined Coal Spoils*
- AGR-41, *Sampling Surface Mine Lands before and after Mining*

Secondary Nutrients and Micronutrients

Magnesium

Magnesium (Mg) levels in soils range from very high (in loess-derived soils) to low (some sandstone-derived soils). Despite low-testing soils, crop yield responses to magnesium fertilization have been very limited. Soil Mg levels are sufficiently high in some soils so as to influence the CEC calculation, causing soil test Mg to be determined. The Mg needs of animals can best be met by direct feeding, rather than with Mg fertilization. Table 4 gives soil test Mg levels and the associated fertilizer Mg rate recommendation.

Table 5. Crop nutrient removal values at standard harvest moisture.

Crop	Yield Unit	Nutrients Removed		
		N	P_2O_5	K_2O
		lb/Yield Unit		
From IP-56:				
Alfalfa hay	ton	50	14	55
Grass/legume hay	ton	35	12	53
Fescue hay	ton	35	18	50
Pasture forage	ton	10	4	16
Corn for grain	bu	0.7	0.4	0.35
Silage corn	ton	7.5	3.5	8
Corn stalks	ton	14	7	29
Wheat grain	bu	1.2	0.5	0.3
Wheat straw	ton	12	4	20
Wheat forage/silage	ton	44	4	20
Sorghum grain	bu	1	0.4	0.3
Sorghum fodder	ton	12	5	17
Soybean grain	bu	3	0.7	1.1
Soybean hay (R3)	ton	100	7	12
Soybean hay (R5)	ton	150	12	27
Burley tobacco	100 lb	7	1.1	7.5
Dark-air tobacco	100 lb	7	0.6	6.0
Dark-fired tobacco	100 lb	7	0.6	6.0
Barley grain	bu	0.9	0.4	0.3
From NRCS Code 590:				
Rye grain	bu	1.16	0.33	0.32
Oats grain	bu	0.6	0.25	0.2
Bermudagrass hay	ton	37.6	8.7	34
Reed canary hay	ton	27	8.2	25
Eastern gamma hay	ton	35	16	31.2
Other warm-season hay	ton	20	6.8	25

Sulfur

Sulfur (S) levels in Kentucky soil have been found to be adequate for optimal crop yields. Many field trials, conducted since 2000 and including tissue surveys and S fertilization studies, have shown S to be sufficient in soil and plant tissue. This sufficiency is due to the available S found deeper in the soil profile than is evaluated with typical topsoil sampling protocols, S release from mineralization of soil organic matter, and continued atmospheric deposition of S derived from coal-fired power plants. When S deficiencies occur, they will likely first be observed on coarse-textured (sandy) soils, soils low in organic matter, in winter annual (wheat) or perennial (alfalfa) crops, or in a crop with high S removal (silage corn). Agronomists at the University of Kentucky continue to monitor the S status of the state's crops and soils. For more information regarding S fertility, consult University of Kentucky Extension publication AGR-198, *Sulfur Fertilization in Kentucky*.

Iron, Copper, Boron, and Molybdenum

Responses to added iron or copper are rare in Kentucky. Symptomatic indicators of these deficiencies are rarely observed in Kentucky. Yield responses to boron and molybdenum have been observed for certain crops under certain conditions. Boron is recommended for topdressing on alfalfa. Consult the sections on tobacco, soybean, alfalfa, and pasture renovation with legumes for molybdenum recommendations.

Zinc and Manganese

Yield responses to zinc applications on corn and to foliar applications of manganese on soybean have been observed in Kentucky. The responses to manganese on soybean have been on a few soils in Daviess, McLean, and Webster counties. After diagnosis of manganese deficiency, responses to foliar applications have been superior to soil applications of manganese at planting. To date, soil testing has not been advantageous in solving any isolated cases of manganese deficiency in Kentucky soils.

Zinc deficiency in corn is significant in Central and south-central Kentucky and in other areas with high soil test P levels. A soil test for zinc is performed routinely on all samples submitted to the University of Kentucky Soil Testing Lab. The zinc test results along with the soil test results for P and soil pH are used to identify soils/fields needing zinc.

Nutrients Removed by Agronomic Crops

Good nutrient management involves effective use of applied nutrients at rates utilized by crops. As a basis of assessing long-term soil fertility trends, crop nutrient removal should be used. Crop nutrient removal is the quantity of nutrients removed from a field in the harvested portion of the crop. This should not be confused with crop nutrient uptakes, which is the total amount of nutrients taken up by the entire crop (roots, stems, leaves, and seed) in a field. For quick reference, Table 5 includes crop nutrient removal values, published in University of Kentucky Extension publication IP-56, *Assessment of the Potential for Livestock and Poultry Manure to Provide the Nutrients Removed by Crops and Forages in Kentucky*, and in NRCS Nutrient Management Standard Code 590.

Soil pH and Lime Recommendations

Soil Acidity

Soil-water pH provides a measure of active acidity in soil, and soil-buffer pH provides a measure of reserve acidity in soil. Soil-water pH can be lower than expected in the fall after a dry growing season due to salts from fertilizer not being leached out. To avoid the lower than expected soil-water pH, active acidity is measured in a solution with a high salt concentration (1 M KCl), which removes variable soil-salt levels occurring at much lower concentrations in the soil. The soil pH measured in 1 M KCl is about 1 pH unit lower than soil-water pH. Since soil-water pH is a much more familiar value in relationship to optimum plant growth, the measurement of 1 M KCl soil pH

Table 6. Rate of 100% effective limestone (tons/A) needed to raise soil pH to 6.4.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	4.50	4.25	4.00	3.50	3.00	2.50	2.00	1.50	2.75
4.7	4.50	4.25	4.00	3.50	3.00	2.50	2.00	1.50	2.75
4.9	4.50	4.25	3.75	3.25	2.75	2.25	1.75	1.25	2.75
5.1	4.50	4.25	3.75	3.25	2.75	2.25	1.75	1.25	2.75
5.3	4.50	4.25	3.75	3.25	2.50	2.00	1.50	1.00	2.25
5.5	4.50	4.25	3.50	3.00	2.50	2.00	1.50	1.00	2.00
5.7	4.50	4.00	3.50	2.75	2.25	1.75	1.25	1.00	1.75
5.9		4.00	3.25	2.50	2.00	1.50	1.00	0.75	1.25
6.1			2.75	2.00	1.50	1.00	0.75	0.50	1.00

Table 7. Rate of 100% effective limestone (tons/A) needed to raise soil pH to 6.6.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	4.50	4.50	4.00	3.75	3.25	2.75	2.25	1.50	4.00
4.7	4.50	4.50	4.00	3.75	3.25	2.50	2.00	1.50	3.75
4.9	4.50	4.50	4.00	3.75	3.00	2.50	2.00	1.50	3.25
5.1	4.50	4.50	4.00	3.50	3.00	2.50	2.00	1.50	3.00
5.3	4.50	4.50	4.00	3.50	3.00	2.50	1.75	1.25	2.75
5.5	4.50	4.50	4.00	3.50	2.75	2.25	1.75	1.25	2.25
5.7	4.50	4.50	4.00	3.25	2.75	2.25	1.50	1.25	2.00
5.9		4.50	4.00	3.25	2.50	2.00	1.50	1.00	1.75
6.1			3.75	3.00	2.25	1.75	1.25	0.75	1.25
6.3				2.50	1.75	1.25	0.75	0.50	1.00

Table 8. Rate of 100% effective limestone (tons/A) needed to raise soil pH to 6.8.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	4.25	4.50	4.25	4.00	3.50	2.75	2.25	1.75	4.00
4.7	4.25	4.50	4.25	4.00	3.50	2.75	2.25	1.75	4.00
4.9	4.25	4.50	4.25	3.75	3.25	2.75	2.25	1.75	4.00
5.1	4.25	4.50	4.25	3.75	3.25	2.75	2.25	1.50	4.00
5.3	4.25	4.50	4.25	3.75	3.25	2.75	2.00	1.50	3.75
5.5	4.25	4.50	4.25	3.75	3.25	2.50	2.00	1.50	3.25
5.7	4.25	4.50	4.25	3.75	3.25	2.50	2.00	1.50	3.00
5.9		4.25	4.25	3.75	3.00	2.50	1.75	1.25	2.25
6.1			4.25	3.75	3.00	2.25	1.75	1.25	2.00
6.3				3.50	2.75	2.00	1.50	1.00	1.75
6.5					2.25	1.50	1.00	0.75	1.25

is converted to soil-water pH for soil test reports using the following equation developed from the analysis of 240 samples.

$$\text{Soil-water pH} = 0.91 \times 1\ \text{M KCl soil pH} + 1.34$$

Reserve acidity in soil is determined with a Sikora-2 buffer and presented on soil test reports as buffer pH. Buffer with an initial pH of 7.5 is added to soil. The pH will decline after the buffer reacts with reserve acidity in soil. The decline in buffer pH from an initial pH of 7.5 is directly related to the amount of reserve soil acidity reacting with the buffer.

Lime Recommendation Tables

To determine how much lime is required to raise soil-water pH, see tables 6, 7, or 8 with the target pH of 6.4, 6.6, or 6.8 in the heading. The soil-water pH is shown as the first column, and the buffer pH is shown as the top row of pH values. To determine the appropriate lime rate, read down the first column to the samples soil-water pH then read across to the samples buffer pH. The lime rates were determined from a lime response curve using 1 M KCl soil pH and buffer pH with a correction factor for field application. The resultant lime rates are rounded to the nearest 0.25 tons/A.

The lime rates in tables 6, 7, and 8 are based on 100% effective lime. Because agricultural limestone is rarely 100% effective, the bulk lime rate required needs to be determined for each available lime source based on the RNV. The RNV for agricultural limestone averages about 67% whereas hydrated lime is 135%. The bulk lime recommendation can be determined from Table 9 using the 100% effective lime recommendation and the RNV for the lime to be purchased. It can also be determined using the following formula.

$$\text{Bulk lime rate} = 100\%\ \text{effective lime rate} / \text{RNV} \times 100$$

The bulk lime values in Table 9 are rounded to the nearest 0.5 ton; therefore, the amount calculated by the formula above may not be exactly the same as the amount in Table 9.

Lime Recommendation Equations

Lime requirements shown in tables 6, 7, and 8 were developed from equations which can be useful for precision agriculture programs or determining lime requirements for other target soil-water pH values. The two equations below determine lime requirement from laboratory incubations of lime added to soil. The first equation can be used with measurement of 1 M KCl soil pH (pH_{KCl}) followed by Sikora-2 buffer addition to determine soil-buffer pH which is used at the University of Kentucky. The second equation can be used with measurement of soil-water pH (pH_w) followed by Sikora buffer addition to determine soil-buffer pH.

Lab incubation lime requirement (tons acre^{-1}) to reach target pH_w =

$$\frac{(1.10 \times (\text{target } pH_w) - 1.47 - pH_{KCl}) \times (\text{soil-buffer pH} - 7.55) \times 5 \div (\text{g soil})}{[\,(\text{soil-buffer pH} - pH_{KCl}) \times (-0.364)\,]}$$

Table 9. Conversion table to bulk lime (rounded to the nearest 0.5 tons).

RNV% Unknown[1]	Recommended 100% Effective Lime Rate							
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
	Bulk Lime (Tons/A)							
	1.5	2.0	3.0	3.5	4.5	5.0	6.0	6.5
40	2.5	4.0	5.0	6.5	7.5	9.0	10.0	11.0
42	2.5	3.5	5.0	6.0	7.0	8.5	9.5	10.5
44	2.5	3.5	4.5	5.5	7.0	8.0	9.0	10.0
46	2.0	3.5	4.5	5.5	6.5	7.5	8.5	10.0
48	2.0	3.0	4.0	5.0	6.5	7.5	8.0	9.5
50	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
52	2.0	3.0	4.0	5.0	6.0	6.5	7.5	8.5
54	2.0	3.0	3.5	4.5	5.5	6.5	7.5	8.5
56	2.0	2.5	3.5	4.5	5.5	6.5	7.0	8.0
58	1.5	2.5	3.5	4.5	5.0	6.0	7.0	8.0
60	1.5	2.5	3.5	4.0	5.0	6.0	6.5	7.5
62	1.5	2.5	3.0	4.0	5.0	5.5	6.5	7.5
64	1.5	2.5	3.0	4.0	4.5	5.5	6.5	7.0
66	1.5	2.5	3.0	4.0	4.5	5.5	6.0	7.0
68	1.5	2.0	3.0	3.5	4.5	5.0	6.0	6.5
70	1.5	2.0	3.0	3.5	4.5	5.0	5.5	6.5
72	1.5	2.0	3.0	3.5	4.0	5.0	5.5	6.5
74	1.5	2.0	2.5	3.5	4.0	4.5	5.5	6.0
76	1.5	2.0	2.5	3.5	4.0	4.5	5.5	6.0
78	1.5	2.0	2.5	3.0	4.0	4.5	5.0	6.0
80	1.5	2.0	2.5	3.0	4.0	4.5	5.0	5.5
82	1.0	2.0	2.5	3.0	3.5	4.5	5.0	5.5
84	1.0	2.0	2.5	3.0	3.5	4.0	5.0	5.5
86	1.0	1.5	2.5	3.0	3.5	4.0	5.0	5.0
88	1.0	1.5	2.5	3.0	3.5	4.0	4.5	5.0
90	1.0	1.5	2.0	3.0	3.5	4.0	4.5	5.0
92	1.0	1.5	2.0	2.5	3.5	4.0	4.5	5.0
94	1.0	1.5	2.0	2.5	3.0	3.5	4.5	5.0
96	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
98	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
100	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5

[1] Unknown RNV is assumed to be 67%.

Lab incubation lime requirement (tons acre^{-1}) ÷ to reach target pH_w =

$$\frac{-1.10 \times (\text{target } pH_w - pH_w) \times (\text{soil-buffer pH} - 7.55) \times 13.75 \div (\text{g soil})}{[\,\text{soil-buffer pH} - (1.10 \times pH_w) + 1.47\,]}$$

A correction factor is used to adjust lime requirements from lab incubations to field application. If the lab incubation lime requirement is greater than 3 tons acre^{-1}, multiply the lab incubation lime requirement by 1.42 to obtain the lime requirement for field application. If the lab incubation lime requirement is less than 3 tons acre^{-1}, multiply the lab incubation lime requirement by the correction factor determined in the second equation below to obtain the lime requirement for field application.

Lab incubation lime requirement is greater than 3 tons acre^{-1}:
Correction factor = 1.42

Lab incubation lime requirement is less than 3 tons acre^{-1}:
Correction factor =
3.62 – (0.734 × (Lab incubation lime requirement))

Considerations with Field Application

The adjustment of soil pH by limestone is affected by the following factors.

- Thoroughness of mixing into the soil
- Depth of mixing into soil (top 6 inches is assumed)
- Time of reaction (two to three years are needed for complete reaction of limestone; however, the reaction time for hydrated lime is much shorter)
- Quality of limestone
- Use of acid-forming nitrogen fertilizer that can lower the soil pH

When applying lime rates greater than 4 tons per acre (T/A), the lime should be thoroughly mixed in the plow layer by applying one-half the recommended rate before plowing and the other half after plowing followed by discing.

Resources

Explanation of Aglime quality:

- Reports of lime quality in Kentucky based on testing by the Kentucky Department of Agriculture: http://soils.rs.uky.edu/technical_Info/
- University of Kentucky Extension publication ID-163, *Determining the Quality of Aglime: Relative Neutralizing Value (RNV)*

Calculators for comparing economic value of lime:

- University of Kentucky Cooperative Extension Service: http://soils.rs.uky.edu/calculators/

Analytical methodology for determining 1 M KCl soil pH and Sikora-2 buffer pH:

- Southern Extension and Research Activity Information Exchange Group 6: http://www.clemson.edu/sera6/publications1.htm

Tobacco

Lime

Limestone should be applied in the fall and thoroughly mixed with the soil one to two years ahead of the crop. If applied in the spring before transplanting, or if more than 4 T/A are applied, plow one-half down and disc in the other half for soils with a water pH below 6.0.

Rates—If water pH is below 6.4, see Page 5 and use the rate appropriate for a target pH of 6.6.

Nitrogen

Rates—Nitrogen fertilization rates (see Table 10) depend primarily on the field cropping history and soil drainage class. See Page 2 for soil drainage classes. Rotation to other crops is strongly recommended after two or more years of burley tobacco production in the same field. More frequent rotation may be necessary when growing dark tobacco or burley tobacco varieties with low levels of disease resistance.

Sources—All commonly available N sources can be used satisfactorily on tobacco, particularly on well-drained soils where a good liming program is followed and soil pH is maintained in the range of 6.0 to 6.6. If soil pH is moderately to strongly acid (pH 6.0 or less) and no lime is applied, using a nonacid-forming source of N (sodium nitrate, calcium nitrate, or sodium-potassium nitrate) will lower the risk of manganese toxicity. Use these sources (or ammonium nitrate or potassium nitrate) for sidedressing because nitrate-nitrogen is more mobile in soil than ammonium nitrogen. If tobacco is grown on sandy soils or soils that tend to waterlog regardless of pH, using ammonium sources (urea, ammonium nitrate, ammoniated phosphates, ammonium sulfate, nitrogen solutions) will lower the risk of leaching and denitrification losses.

Table 10. Nitrogen recommendations (lb/A), burley and dark tobacco.

	Soil Drainage Class	
N Levels	Well-Drained	Moderately Well-Drained
Low[1]	225 - 250	250 - 275
Medium[2]	200 - 225	225 - 250
High[3]	150 - 175	175 - 200

[1] Following tobacco or row crops.
[2] First-year tobacco following a grass or grass-legume sod.
[3] First-year tobacco following legume sod or legume cover crop.

Time and Method—The entire nitrogen requirement can be broadcast pre-plant on well-drained soils. However, Kentucky often has large amounts of rainfall during April and May, so applying the broadcast nitrogen as near to transplanting as possible will significantly lessen the chances of loss. Apply the nitrogen after plowing and disc into the surface soil.

Because losses of fertilizer nitrogen can occur on sandy soils or soils with poor drainage, it is helpful to split nitrogen applications on these soils, applying one-third of the nitrogen before transplanting and the remaining amount two or three weeks after transplanting. The use of poorly drained or somewhat poorly drained soils for tobacco production is not recommended.

Further efficiencies in nitrogen use, decreased manganese toxicity, and increased early growth can be obtained by banding (sidedressing) most of the nitrogen after transplanting. These bands should be applied 10 to 12 inches to the side of the row in either one or two bands and at depths of 4 to 5 inches. The nitrogen should be banded at one time 0 to 10 days after transplanting or split into two applications with two-thirds at 0 to 10 days and one-third at four to five weeks after transplanting. If one-third or more of the total nitrogen is applied after transplanting, the rate from Table 10 should be reduced by 15 to 25 lb N/A.

Animal Manures

Some animal manures are known to contain chloride in concentrations high enough to reduce the quality of cured tobacco. Cured tobacco leaf containing more than 1% chloride is considered unacceptable by the tobacco industry. Cattle and swine manure applications should be limited to no more than 10 tons/A. Poultry manures should not be applied in the year tobacco is grown. Fall applications of poultry litter should not exceed 4 tons/A on ground where tobacco will be planted the following spring. Fall manure applications should be made only when a living cover crop will be present to take up and recycle some of the available N.

Phosphate and Potash

Rates—Phosphorus and potassium fertilizer additions should be guided by soil testing. Based on soil test results, apply the recommended amounts indicated in Table 11. Research indicates that when soil test potassium is below 225 lb/A, a broadcast application of potassium fertilizer is more effective than banding.

Sources—Research at the University of Kentucky has shown that applications after January 1 of chloride-containing nutrient sources such as muriate of potash at rates greater than 50 lb of chloride per acre lead to excessive levels of chloride in the cured burley tobacco leaf, increased curing and storage problems, decreased combustibility of the leaf, and, ultimately, greatly reduced quality and usability of the cured leaf. Consequently, sulfate of potash should be the primary source of potassium fertilizer used after January 1. Excessive rates of manure or manure used in conjunction with chlorine-containing fertilizers may result in unacceptable chlorine levels in the cured leaf.

Table 11. Phosphate and potash recommendations (lb/A), tobacco.

	Burley and Dark		Burley		Dark	
Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed	Test Result: K	K_2O Needed
Very high	>80	0	>450	0	>450	0
High	73 - 79	30	424 - 449	30	398 - 450	30
	71 - 72	40	417 - 423	40	383 - 397	40
	68 - 70	50	409 - 416	50	368 - 382	50
	66 - 67	60	402 - 408	60	353 - 367	60
	64 - 65	70	394 - 401	70	338 - 352	70
	62 - 63	80	387 - 393	80	323 - 337	80
	58 - 61	90	379 - 386	90	308 - 322	90
			372 - 378	100	296 - 307	100
			364 - 371	110		
			357 - 363	120		
			349 - 356	130		
			342 - 348	140		
			334 - 341	150		
			327 - 333	160		
			319 - 326	170		
			312 - 318	180		
			304 - 311	190		
Medium	54 - 57	100	296 - 303	200	286 - 295	110
	50 - 53	110	286 - 295	210	276 - 285	120
	46 - 49	120	276 - 285	220	266 - 275	130
	41 - 45	130	266 - 275	230	256 - 265	140
	37 - 40	140	256 - 265	240	246 - 255	150
	33 - 36	150	246 - 255	250	236 - 245	160
	29 - 32	160	236 - 245	260	226 - 235	170
			226 - 235	270	216 - 225	180
			216 - 225	280	206 - 215	190
			206 - 215	290		
Low	25 - 28	170	195 - 205	300	195 - 205	200
	22 - 24	180	184 - 194	310	184 - 194	210
	18 - 21	190	173 - 183	320	173 - 183	220
	14 - 17	200	162 - 172	330	162 - 172	230
	11 - 13	210	151 - 161	340	151 - 161	240
	7 - 10	220	140 - 150	350	140 - 150	250
			129 - 139	360	129 - 139	260
			118 - 128	370	118 - 128	270
			107 - 117	380	107 - 117	280
			96 - 106	390	96 - 106	290
Very low	<7	230	<96	400	<96	300

Molybdenum

Molybdenum (Mo) is recommended for use on burley tobacco either as a broadcast soil application or dissolved in transplant setter water when the soil pH is below 6.6. Field trials have shown that setter water applications are equally as effective as broadcast applications in supplying molybdenum to the crop. Molybdenum can be purchased in dry solid or liquid forms. Either source is satisfactory when molybdenum is needed.

Soil Broadcast—Apply at the rate of 1 lb of sodium molybdate (6.4 oz of molybdenum) per acre. Dissolve this amount of dry sodium molybdate (or 2 gallons of 2.5% Mo liquid product) in 20 to 40 gallons of water and spray uniformly over each acre. Apply before transplanting and disc into the soil. Because sodium molybdate is compatible with many herbicides used on tobacco, it can be applied with herbicides normally applied as water-based sprays. Combining the two chemicals can result in application cost savings because only one trip over the field is necessary. It is recommended that not more than 2 lb of sodium molybdate (12.8 oz of molybdenum) per acre be applied during a five-year period.

Setter Water—Use 0.25 to 0.50 lb sodium molybdate (1.6 to 3.2 oz of molybdenum) per acre. If dry sodium molybdate is used, divide the total recommended amount (0.25 to 0.50 lb/A) equally among the number of gallons of water used per acre. To calculate the amount needed per tank multiply the rate per acre by the ratio of tank capacity in gallons/targeted gallons per acre. For example, if applying 250 gallons of water per acre with a 4 row setter having a 600 gallon tank: 0.25 lb/A X (600/250) = 0.6 lb sodium molybdate per tank full. Adding the dry material before filling the barrel will aid in dissolving and mixing. A 2.5% liquid source of molybdenum can also be used at a rate of 1 to 2 gallons/A. The amount per tank can be calculated as above: 1 gallon X (600/250) = 2.4 gallons per tank full.

Float Plant Beds

Source—Choose a water-soluble fertilizer that has less P_2O_5 than N or K_2O (i.e., 20-10-20, 15-5-15, etc.). Nitrate should be the major source of nitrogen with little or no urea to avoid problems with plant toxicity. See University of Kentucky Extension publication AGR-163, Selecting the Right Fertilizer for Tobacco Transplant Production in Float Systems for additional information.

Rates and Timing—The initial application should be made to bring the N concentration in the water to approximately 100 parts per million (ppm). For a fertilizer that has 20% N (20-10-20), this would be 4.2 lb of fertilizer for 1,000 gallons of float water. For a fertilizer that has 15% N, this would be 5.6 lb of fertilizer per 1,000 gallons of float water. For good growth and reduced disease susceptibility, N should be maintained in the range of 75 to 100 ppm. Inexpensive conductivity meters can be used to monitor fertility levels in the float bed. For additional information see University of Kentucky Extension publication AGR-174, *Using Conductivity Meters for Nitrogen Management in Float Systems*. The initial application can be made at seeding time. However, waiting 4 to 7 days after seeding may reduce the chance of salt injury to young seedlings. When fertilizer is added after seeding, care should be exercised to ensure adequate mixing and even distribution of the fertilizer in the float water.

Corn

Lime

If water pH is below 6.2, see Page 5 and use the rate appropriate for a target pH of 6.4.

Nitrogen

See Page 3 for the basis of N recommendations. Also see the "Fertility Management" chapter in University of Kentucky Extension publication ID-139, *A Comprehensive Guide to Corn Management*.

Winter Legume Cover Crops—A winter legume cover crop can provide a substantial amount of nitrogen for corn with either no-tillage or conventional tillage. Research conducted by the University of Kentucky on no-tillage corn indicates that some legume cover crops can provide yield advantages beyond that provided by fertilizer nitrogen. Hairy vetch performed better than crimson clover or big flower vetch. The dense mulch resulting from a killed legume cover crop conserves soil water, aids in weed control, and helps to control soil erosion.

Three important factors should be considered when using a legume cover crop:

1. The amount of nitrogen provided will depend on the amount of growth the legume makes before it is chemically killed or plowed under. However, corn planting should not be delayed later than mid-May, particularly on well-drained soils.
2. A cover crop, legume or non-legume, can deplete soil water during a dry spring, resulting in decreased germination and seedling growth of corn.
3. Some vetch seeds are hard and can remain in the soil for one or more years before germinating. The result can be volunteer vetch in small grains grown in rotation with corn unless the vetch is killed with herbicides in the early spring.

Table 12. Recommended application of nitrogen (lb N/A), corn.[1]

Cover Crop	Tillage[3]	Soil Drainage Class[2]: Well-Drained	Moderately Well-Drained[4]	Poorly Drained
Corn, sorghum, soybean, small grain, fallow	Intensive	100 - 140	140 - 175	175 - 200
	Conservation	125 - 165	165 - 200	
Grass, grass-legume sod (4 years or less), winter annual legume cover	Intensive	75 - 115	115 - 150	150 - 175
	Conservation	100 - 140	140 - 175	
Grass, grass-legume sod (5 years or more)	Intensive	50 - 90	90 - 125	125 - 150
	Conservation	75 - 115	115 - 150	

1 Nitrogen rate for irrigated corn should be increased to 175 to 200 lb N/A.
2 Soil drainage class examples are given on Page 2.
3 Intensive tillage has less than 30% residue cover, and conservation tillage has more than 30% residue cover on the soil at planting.
4 Poorly drained soils that have been tile drained should be considered moderately well-drained.

Table 13. Phosphate and potash recommendations (lb/A), corn.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
Very high			>420	0
High	>60	0	355 - 420	0
			336 - 354	0
			318 - 335	0
			301 - 317	0
Medium	46 - 60	30	282 - 300	30
	41 - 45	40	264 - 281	30
	37 - 40	50	242 - 263	30
	33 - 36	60	226 - 241	40
	28 - 32	70	209 - 225	50
			191 - 208	60
Low	23 - 27	80	173 - 190	70
	19 - 22	90	155 - 172	80
	14 - 18	100	136 - 154	90
	9 - 13	110	118 - 135	100
	6 - 8	120	100 - 117	110
Very low	1 - 5	200	<100	120

Placement—Small amounts of N plus K_2O can be applied in the row, but if more than 15 lb/A of N plus K_2O is banded, it should be banded at least 2 inches below the soil surface and 2 inches to the side of the seed-row center. No more than 100 lb/A of N plus K_2O should be banded near the row. Fertilizer for banding near or in the row should not contain urea.

Adjustments to Nitrogen Recommendations

Irrigation—The nitrogen rate on irrigated corn should be increased to 175 to 200 lb N/A due to increased risk of depletion of available N from crop uptake, leaching, and denitrification.

Sidedressed N—On moderately well-drained to poorly drained soil, rates of nitrogen can be decreased by 35 lb/A if as much as two-thirds of the N is applied 4 to 6 weeks after planting.

Conservation Tillage—On moderately well-drained to poorly drained soils, the risk of denitrification loss is great from N applied at or near planting on conservation-till corn. Alternative practices may include:

- Sidedressed N application as noted above
- Use of maximum rate in appropriate recommended range at planting
- Use of a nitrification inhibitor at planting with N sources that include urea, N-solutions, or anhydrous ammonia with minimum rate of N within the appropriate recommended range (see AGR-185 for additional information).

Surface-Applied Urea—Volatilization losses of N from urea-based products can be significant when they are surface-applied after May 1. See University of Kentucky Extension publication AGR-185, *Nitrogen Transformation Inhibitors and Controlled Release Urea,* for specific information on products designed to reduce N loss. Alternative urea management practices include:

- Irrigation or incorporation within two days after application
- Use of a urease inhibitor
- Use of maximum N fertilization rate in appropriate recommended range

Zinc

Where zinc deficiency of corn has previously occurred or is suspected, a zinc soil test is helpful in determining if zinc should be applied. The following table gives the soil test zinc levels at various soil pH and soil test P levels below which a response to zinc fertilization is likely to occur. However, many other factors including weather conditions and cool soil temperatures affect soil zinc availability to corn, making it difficult to predict a response to added zinc for a specific growing season. Zinc can be a broadcast or banded treatment. Broadcast zinc fertilizer should raise the Zn soil test to acceptable levels for several years.

Table 14. Zinc recommendations[1] (lb/A), corn.

Test Result: P	Soil Water pH																	Elemental Zn Needed	
	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	Broadcast	Banded
25	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.1	3.3	10 - 15	2 - 3
50	1.1	1.2	1.4	1.6	1.8	1.9	2.1	2.3	2.5	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.9		
75	1.4	1.5	1.7	1.9	2.1	2.2	2.4	2.6	2.8	3.0	3.1	3.3	3.5	3.6	3.8	4.0	4.2		
100	1.6	1.8	1.9	2.1	2.3	2.5	2.6	2.8	3.0	3.2	3.4	3.5	3.7	3.9	4.1	4.2	4.4		
150	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.1	3.3	3.5	3.7	3.8	4.0	4.2	4.4	4.5	4.7		
200	2.1	2.3	2.5	2.7	2.8	3.0	3.2	3.4	3.5	3.7	3.9	4.1	4.2	4.4	4.6	4.8	4.9	20 - 30	4 - 6
250	2.3	2.5	2.7	2.8	3.0	3.2	3.4	3.5	3.7	3.9	4.1	4.2	4.4	4.6	4.8	4.9	5.1		
300	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.9	4.0	4.2	4.4	4.6	4.7	4.9	5.1	5.3		
350	2.6	2.7	2.9	3.1	3.3	3.4	3.6	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.0	5.2	5.4		
400	2.7	2.9	3.0	3.2	3.4	3.6	3.7	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.1	5.3	5.5		
450	2.8	2.9	3.1	3.3	3.5	3.6	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.1	5.2	5.4	5.6		
500	2.8	3.0	3.2	3.4	3.6	3.7	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.1	5.3	5.5	5.7		

[1] Zinc and phosphorus levels shown are from soil extraction by the Mehlich III procedure. To determine if zinc is needed, find the appropriate soil test P level in the left column and read across the table to the appropriate soil pH level. If soil test zinc is less than that shown for the appropriate soil test P level and pH, apply fertilizer zinc as recommended in the table.

Soybean

Lime

If water pH is below 6.2, consult Table 6 and use the appropriate limestone rate to attain a target pH of 6.4.

Nitrogen

No nitrogen is recommended for well-nodulated soybean roots.

Double Cropping of Small Grains and Soybean—The phosphate recommendation should be taken from small grains, and the potash recommendation should be taken from soybean. The recommended amount of fertilizer should be applied in the fall before seeding the small grain.

Inoculation

Soybean should be inoculated when planted in fields where soybean has not been grown in the past three to five years or where previously grown soybean had few nodules. If inoculation is necessary, the inoculant should be applied to the seed or in the row at planting. Delays in planting inoculated seed often result in poor nodulation. Numbers of live rhizobia in inoculum decrease rapidly under dry conditions, with exposure to sunlight and high temperatures, or when dry-packaged with sodium molybdate and fungicides.

Table 15. Phosphate and potash recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	40 - 60	30	242 - 300	30
	34 - 39	40	226 - 241	40
	28 - 33	50	209 - 225	50
			191 - 208	60
Low	22 - 27	60	173 - 190	70
	16 - 21	70	155 - 172	80
	11 - 15	80	136 - 154	90
	9 - 10	90	118 - 135	100
	7 - 8	100	100 - 117	110
	6	110		
Very low	1 - 5	120	82 - 99	120
			64 - 81	130
			46 - 63	140
			<46	150

Molybdenum

If soils are limed to maintain pH values at 6.2 or above, aluminum and manganese toxicities and molybdenum deficiency usually do not occur in soybean. However, in soils with pH values below 6.2 at seeding time, molybdenum application to soybean is recommended. Apply 1 to 2 oz of sodium molybdate

(0.4 to 0.8 oz of elemental molybdenum) per acre as a seed treatment. This is a satisfactory method of applying a small amount of molybdenum where no seed inoculant is needed. Where soybean seed is to be inoculated, including sodium molybdate with the inoculum may seriously lower the numbers of live rhizobia if seed is not planted immediately. If both inoculum and molybdenum are needed, apply inoculum to the seed, and broadcast the molybdenum on the soil. For each acre, dissolve 1 lb sodium molybdate (6.4 oz molybdenum) in 20 to 40 gallons of water and spray uniformly ahead of final seedbed preparation. Not more than 2 lb sodium molybdate (13 oz molybdenum) per acre should be used during any five-year period. Use of molybdenum should not be substituted for a good liming program.

Manganese

Foliar applications of manganese to manganese-deficient soybean have been superior to soil applications made at planting. Foliar manganese spray is recommended in two forms: (1) as chelated manganese at rates recommended by the manufacturer on the label and (2) as manganese sulfate at a rate of 1.0 to 1.5 lb of actual manganese per acre in 20 to 25 gallons of water when the soybean is 10 inches high or higher. The symptom of Mn deficiency is interveinal chlorosis of the emerging (youngest) leaves. Tissue analysis can also be used to evaluate the Mn status of the plant. The sufficiency range is 15 to 200 parts per million (ppm) Mn in the uppermost mature trifoliate leaves (petiole discarded).

Small Grains

(Barley, Oats, Rye, Wheat, and Triticale)

Lime

If water pH is below 6.2, see Page 5 and use the rate appropriate for a target pH of 6.4.

Nitrogen

Fall Application—Only enough N to provide for good ground cover and to stimulate tillering is necessary. Seedings following tobacco, soybean, or well-fertilized corn will likely have enough carryover N for fall growth. For optimal fertilizer N efficiency, the total fall application should not exceed 40 lb N/A for seedings in fields with insufficient N carryover. Fall-applied N will be of little benefit where little fall growth is expected.

Spring Application—Application from late February to early April is the most effective. Where excessive rainfall occurs in late winter or early spring, causing excessive wetness on less than well-drained soils, split applications of spring-applied N may be justified.

Sources—Experimental results have shown little difference among nitrogen materials commonly used to supply supplemental N to small grains.

Small Grains for Grazing—Total forage production from small grains can be increased by splitting nitrogen applications between fall and spring. For fall grazing, apply 50 to 60 lb N/A at seeding. A late winter or early spring topdressing of 30 to 50 lb N/A will stimulate early growth for additional grazing.

Intensively Managed Wheat—When managed for high yields (70 to 100 bu/A), wheat should receive higher rates of N in the spring. If spring N is split into two applications (early to mid-February and mid- to late March), yields will be 3 to 5 bu/A higher than if all N is applied in a single application in mid- to late March. The February application should be made at green-up, and the March application should be made at Feekes growth stage 5 or 6 (just prior to or at jointing). Green-up may not occur until March in Central and Northern Kentucky.

Double Cropping of Small Grains and Soybean—The phosphate recommendation should be taken from small grains, and the potash recommendation should be taken from soybean. This recommendation can be applied in the fall before seeding the small grain.

Table 16. Spring nitrogen rates (lb N/A), small grains.

Seedbed	lb N/A
Tilled	60 - 90
No-till	90 - 120

Table 17. Spring nitrogen rates (lb N/A), intensive wheat.

Applications	Feb.	Mar.	Total
Single	0	95	95
Split	30 - 60	75 - 45	105

Table 18. Phosphate and potash recommendations (lb/A), small grains.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	48 - 60	30	213 - 300	30
	45 - 47	40	187 - 212	40
	41 - 44	50		
	38 - 40	60		
	34 - 37	70		
	31 - 33	80		
Low	24 - 30	90	159 - 186	50
	17 - 23	100	132 - 158	60
	10 - 16	110	104 - 131	70
Very low	<10	120	<104	80

Sensor Based Application

Two algorithms have been developed specifically for Kentucky soils for the use of variable rate nitrogen applications on wheat using the Greenseeker sensors. Field trials using the moderate to well-drained soil algorithm has resulted in yield increases in intensively managed wheat averaging about 4 bu/A and increased economical returns. Nitrogen should be applied at greenup as is customary, using tiller counts and greenness of the crop. At that time, a rate of 150 lb/A N should be applied to either strips or small areas in the field. This will be used as a reference at Feekes 6 for the Greenseeker in making the variable rate N application. The difference between the NDVI readings in this N rich strip and any other reading in the field is termed the Differential NDVI in the algorithms below. It is recommended that a minimum rate of 20 to 30 lb/A be applied even in areas where the Differential NDVI would approach or be at zero. For additional information see University of Kentucky Extension publication SR-107, *Sensor Technology for Variable-Rate Nitrogen Applications on Wheat in Kentucky*.

Table 19. Final algorithms for use with Greenseeker for variable rate nitrogen applications at Feekes 6 wheat on moderately to well-drained soils in Kentucky.

Differential NDVI[1]	N Needed (lb/A)
0.015	25
0.02	40
0.03	55
0.04	70
0.075	85
0.11	97.5
0.175	110
0.24	125

[1] Difference between the NDVI reading in the 150 lb/A N-rich strip and NDVI reading in other parts of the field.

Table 20. Final algorithms for use with Greenseeker for variable rate nitrogen applications at Feekes 6 wheat on moderately to somewhat poorly drained soils in Kentucky.

Differential NDVI[1]	N Needed (lb/A)
0.025	20
0.04	33
0.055	45
0.08	60
0.105	75
0.135	90
0.18	105
0.21	120

[1] Difference between the NDVI reading in the 150 lb/A N-rich strip and NDVI reading in other parts of the field.

Corn Silage and Small Grain Hay/Silage

Because the entire plant is removed, silage/hay production results in much different nutrient removal than when growing the same crops for grain. Additionally, because of land area limitations, silage is usually produced for several consecutive years without rotation. The high nutrient removal and high recommended N application rates mandate that soils under continuous silage production be sampled every year to assure appropriate pH and nutrient levels. Much of the required nutrients can be supplied via appropriate use of animal manures from either on or off-farm confined animal enterprises. For additional information see University of Kentucky Extension publications AGR-17, *Double Crop Silage Production,* and AGR-165, *The Agronomics of Manure Use for Crop Production*.

If water pH is below 6.2, consult Table 6 and use the appropriate limestone rate to attain a target pH of 6.4.

Nitrogen and Zinc

Fall-applied nitrogen (N) for the small grain is usually not needed, but most producers apply some if they use 18-46-0 or 11-52-0 for fall phosphorus applications. An additional topdressing of N should be made to the small grain in late winter or early spring just before growth begins. Total N application to the small grain should not exceed 110 lb N/A. There is no zinc (Zn) recommendation for small grains grown in Kentucky.

Nitrogen and Zn application for corn silage is no different from that for corn grown for grain. See Table 12 and Table 14 for specific recommendations.

Table 21. Phosphate and potash recommendations (lb/A) for corn and small grain silage (hay) production.

		P_2O_5 Needed				K_2O Needed[2]	
Category	Test Result: P	Corn	Small Grain	Dbl-Crop Silage[1]	Test Result: K	Corn	Small Grain
Very high					>420	0	0
High	>60	0	0	0	355 - 420	30	40
					336 - 354	40	40
					318 - 335	50	40
					301 - 317	60	40
Medium	46 - 60	30	30	60	282 - 300	70	70
	41 - 45	40	40	80	264 - 281	80	70
	37 - 40	50	50	100	242 - 263	90	70
	33 - 36	60	60	120	226 - 241	100	70
	28 - 32	70	70	140	209 - 225	110	70
					191 - 208	120	70
Low	23 - 27	80	80	160	173 - 190	130	80
	19 - 22	90	90	180	155 - 172	140	80
	14 - 18	100	100	200	136 - 154	150	90
	9 - 13	110	110	220	118 - 135	160	110
	6 - 8	120	120	240	100 - 117	170	120
Very low	1 - 5	200	120	320	<100	180	120

[1] For double-crop silage, all of the P can be applied in the fall before the small grain (as long as total fall N does NOT exceed 30 lb N/A).
[2] Potassium should be applied according to the recommendation before each of the crops are planted to minimize luxury consumption of K (see Page 15 for additional information).

Grain Sorghum

Lime

If water pH is below 6.2, see Page 5, and use the rate appropriate to attain a target pH of 6.4.

Placement—Banded fertilizer should be placed 2 inches below the soil surface and 2 inches to the side of the row with a maximum of 40 lb/A N plus K_2O. Additional fertilizer should be broadcast.

Table 22. Recommended application of nitrogen (lb N/A), grain sorghum.

Previous Crop	lb N/A Needed[1]
Corn, sorghum, soybean, small grain, fallow, set-aside	100 - 125[2]
Grass, grass-legume sod (4 years or less)	75 - 100
Grass, grass-legume sod (5 years or more)	50 - 75

1 Recommended rates are for moderately well-drained soils which comprise the basis of current field data. See Page 2 for soil drainage class.
2 **Note:** Rates of nitrogen fertilization can be decreased 25 lb/A if two-thirds or more of the nitrogen is applied 4 to 6 weeks after planting.

Table 23. Phosphate and potash recommendations (lb/A), grain sorghum.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	46 - 60	30	242 - 300	30
	41 - 45	40	226 - 241	40
	37 - 40	50	209 - 225	50
	33 - 36	60	191 - 208	60
	28 - 32	70		
Low	23 - 27	80	173 - 190	70
	19 - 22	90	155 - 172	80
	14 - 18	100	136 - 154	90
	9 - 13	110	118 - 135	100
	6 - 8	120	100 - 117	110
Very low	<6	200	<100	120

Canola

Lime

If water pH is below 6.2, see Page 5, and use the rate appropriate to attain a target pH of 6.4.

Nitrogen

Fall Application—Only enough N to provide for good ground cover and good root growth is necessary to aid in winter survival. Seedings following tobacco, soybean, or well-fertilized corn will likely have enough carryover N for fall growth. For optimum fertilizer N efficiency, the total fall application should not exceed 30 lb N/A for seeding in fields with insufficient N carryover.

Spring Applications—Applications between late February and late March are the most effective time. This coincides with spring green-up. All N should be applied before stem elongation. Apply 120 lb N/A to canola if the previous crop was corn, small grains, soybean, fallow, or set-aside. Apply 90 lb N/A when the previous crop was grass-legume or legume sod.

Table 24. Phosphate and potash recommendations (lb/A), canola.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	48 - 60	30	213 - 300	30
	45 - 47	40	187 - 212	40
	41 - 44	50		
	38 - 40	60		
	34 - 37	70		
	31 - 33	80		
Low	24 - 30	90	159 - 186	50
	17 - 23	100	132 - 158	60
	10 - 16	110	104 - 131	70
Very low	<10	120	<104	80

Double Cropping of Canola and Soybean—The phosphate recommendations should be taken from canola, and the potash recommendation should be taken from soybean. This recommendation can be applied in the fall before seeding the canola.

Hay and Pastures

New Seedings

Lime

See Page 5, and use the rate appropriate to attain a target pH of 6.8. For long-term production of alfalfa and alfalfa grass, it is important to raise pH and maintain it in a range between 6.5 and 7.0. (See Page 5 for the rate of lime needed to attain a target pH of 6.8 when the water pH is below 6.6.)

Nitrogen

Apply 0 to 30 lb N/A at seeding for legumes or grass-legume mixtures and 0 to 50 lb N/A for grass-only seedings. If the field has a history of high N application, omit N at seeding.

Surface Mine Reclamation

See Page 4 for more details.

Molybdenum

If soils are limed to maintain pH values at 6.2 or above, aluminum and manganese toxicities and molybdenum deficiency usually do not occur in forage legumes. However, for soils having pH values below 6.2 at seeding time, molybdenum application to forage legumes is recommended. Apply at the rate of 1 lb of sodium molybdate (6.4 oz of molybdenum) per acre. Dissolve this amount of molybdate in 20 to 40 gallons of water, and spray uniformly over each acre. Apply before planting and disc into the soil unless using no-till establishment. It is recommended that not more than 2 lb of sodium molybdate (12.8 oz of molybdenum) per acre be used during a five-year period.

Inoculation

Appropriate good-quality inoculant should be applied to legume seed or in the row at planting. Delays in planting inoculated seed may result in poor root nodulation. Numbers of live rhizobia decrease rapidly under dry conditions, with exposure to sunlight and high temperatures, or when dry-packaged with sodium molybdate and fungicides.

Table 25. Phosphate and potash recommendations (lb/A), hay and pasture, new seedings.

	Alfalfa, Alfalfa-Grass, Clover, Clover-Grass		Alfalfa, Alfalfa-Grass		Clover, Clover-Grass		Cool-Season Grasses			
Category	**Test Result: P**	**P_2O_5 Needed**	**Test Result: K**	**K_2O Needed**	**Test Result: K**	**K_2O Needed**	**Test Result: P**	**P_2O_5 Needed**	**Test Result: K**	**K_2O Needed**
High	>60	0	>450	0	>300	0	>60	0	>300	0
			394 - 450	60						
			363 - 393	90						
			338 - 362	100						
			313 - 337	110						
			297 - 312	120						
Medium	51 - 60	30	291 - 296	130	266 - 300	30	48 - 60	30	213 - 300	30
	48 - 50	40	285 - 290	140	256 - 265	40	45 - 47	40	187 - 212	40
	46 - 47	50	279 - 284	150	246 - 255	50	41 - 44	50		
	43 - 45	60	272 - 278	160	236 - 245	60	38 - 40	60		
	40 - 42	70	266 - 271	170	226 - 235	70	34 - 37	70		
	37 - 39	80	260 - 265	180	216 - 225	80	31 - 33	80		
	35 - 36	90	254 - 259	190	206 - 215	90				
	32 - 34	100	247 - 253	200	191 - 205	100				
	28 - 31	110	241 - 246	210						
			235 - 240	220						
			229 - 234	230						
			222 - 228	240						
			216 - 221	250						
			210 - 215	260						
			204 - 209	270						
Low	23 - 27	120	194 - 203	280	173 - 190	110	24 - 30	90	159 - 186	50
	19 - 22	130	180 - 193	290	155 - 172	120	17 - 23	100	132 - 158	60
	14 - 18	140	166 - 179	300	136 - 154	130	10 - 16	110	104 - 131	70
	9 - 13	150	152 - 165	310	118 - 135	140				
			139 - 151	320	100 - 117	150				
			125 - 138	330						
			111 - 124	340						
			97 - 110	350						
Very low	<9	160	<97	360	<100	160	<10	120	<104	80

Hay and Pastures

Established Stands of Legumes and Grass-Legume Mixtures

Topdressing Legumes and Grass-Legume Mixtures

Top production from hay and pasture fields can best be obtained if soil test levels are in the range of 50 to 60 P and 270 to 300 K and are maintained at those levels. If initial soil test levels are below these ranges, they can be raised more quickly by heavy nutrient applications at seeding and then maintained by annual topdressings as outlined in the following tables. Another alternative is to raise soil test levels gradually over a longer period of years by foregoing a heavy nutrient application at seeding but increasing topdressing rates each year over the rates shown. An initial soil test, followed by periodic soil tests, will indicate changes in field fertility levels that are taking place.

Lime

See Page 5, and use the table to determine the rate appropriate to attain a target pH of 6.4. For alfalfa or alfalfa-grass, use the table on Page 5 to find the rate needed for a target pH level of 6.8 when the water pH is below 6.6.

Nitrogen

Topdress applications of N are not recommended for legumes or legume-grass mixtures containing more than 25% legumes. If there is less than 25% legume in a legume-grass stand, topdress with N at rates shown for established grass stands.

Boron

For alfalfa production, apply 1.5 to 2.0 lb/A of elemental boron (B) per acre every two years either as a borated fertilizer or as fertilizer borate. If boron-containing materials or wastes from a coal-fired power plant have been applied in successive years to established stands of alfalfa, the field should be tested for boron. If soil test B exceeds 2.0 lb/A, additional B should not be applied.

Surface Mine Reclamation

See Page 4 for more details.

Higher Yields

For alfalfa yields above 5 tons/A and red clover yields above 3 tons/A, fields should be soil sampled every year to monitor P and K levels.

Luxury Consumption of Potassium

Luxury consumption is a phenomenon that all alfalfa producers should be aware of and should try to avoid. Luxury consumption occurs when the alfalfa plant takes up more K than is needed for maximum yield. The additional K is removed with hay harvest and is not available for future cuttings. To minimize luxury consumption, K fertilizer should not be applied in the spring prior to the first cutting for existing stands. For new stands of alfalfa, K fertilizer should be thoroughly incorporated prior to planting. For additional information see University of Kentucky Extension publication AGR-210, *Fertilizer Management in Alfalfa*.

Table 26. Phosphate and potash recommendations (lb/A), hay and pasture, annual topdressing.

	Alfalfa or Alfalfa-Grass				Clover or Clover-Grass			
Category	**Test Result: P**	**P_2O_5 Needed**	**Test Result: K**	**K_2O Needed**	**Test Result: P**	**P_2O_5 Needed**	**Test Result: K**	**K_2O Needed**
High	>60	0	>450	0	>60	0	>300	0
			394 - 450	60				
			363 - 393	90				
			338 - 362	100				
			313 - 337	110				
			297 - 312	120				
Medium	46 - 60	30	291 - 296	130	41 - 60	30	271 - 300	30
	41 - 45	40	285 - 290	140	36 - 40	40	263 - 270	40
	37 - 40	50	279 - 284	150	31 - 35	50	255 - 262	50
	33 - 36	60	272 - 278	160			246 - 254	60
	28 - 32	70	266 - 271	170			238 - 245	70
			260 - 265	180			230 - 237	80
			254 - 259	190			221 - 229	90
			247 - 253	200			213 - 220	100
			241 - 246	210			205 - 212	110
			235 - 240	220				
			229 - 234	230				
			222 - 228	240				
			216 - 221	250				
			210 - 215	260				
			204 - 209	270				
Low	23 - 27	80	194 - 203	280	27 - 30	60	191 - 204	120
	19 - 22	90	180 - 193	290	23 - 26	70	173 - 190	130
	14 - 18	100	166 - 179	300	19 - 22	80	155 - 172	140
	9 - 13	110	152 - 165	310	16 - 18	90	136 - 154	150
			139 - 151	320	12 - 15	100	118 - 135	160
			125 - 138	330	8 - 11	110	100 - 117	170
			111 - 124	340				
			97 - 110	350				
Very low	<9	120	<97	360	<8	120	<100	180

Hay and Pastures

Renovation of Grass with Clovers or Annual Lespedeza

Lime

If water pH is below 6.2, see the table on Page 5 for the rate appropriate to attain a target pH of 6.4.

Nitrogen

One factor that is critical to legume establishment in established grass sods is grass competition with young legume seedlings. Use of N at renovation will stimulate grass growth and increase the likelihood of legume stand failure. However, if there is a need for increased grass production during the fall preceding spring legume renovation, a small amount of N (up to 50 lb N/A) can be topdressed from August 1 to August 15. Be sure any increased grass growth is grazed off before legume renovation.

Table 27. Phosphate and potash recommendations (lb/A), clover or annual lespedeza (renovation into established grass).

Category	**Test Result: P**	**P_2O_5 Needed**	**Test Result: K**	**K_2O Needed**
High	>60	0	>300	0
Medium	48 - 60	30	257 - 300	30
	45 - 47	40	244 - 256	40
	41 - 44	50	232 - 243	50
	38 - 40	60	219 - 231	60
	34 - 37	70	207 - 218	70
	31 - 33	80	187 - 206	80
Low	24 - 30	90	159 - 186	90
	17 - 23	100	132 - 158	100
	10 - 16	110	104 - 131	110
Very low	<10	120	<104	120

Annual Topdressing

See recommendations for topdressing legume-grass mixtures.

Inoculation

Appropriate good-quality inoculant should be applied to the legume seed or in the row at planting. Delays in planting inoculated seed often result in poor inoculation. Numbers of live rhizobia decrease rapidly under dry conditions, with exposure to sunlight and high temperatures, or when dry-packaged with sodium molybdate and fungicides.

Molybdenum

Molybdenum deficiency usually does not occur in forage legumes when soil pH is 6.2 or higher. However, with soil pH values below 6.2 at seeding, molybdenum application to forage legumes is recommended. Apply at a rate of 1 lb of sodium molybdate (6.4 oz actual Mo) per acre. Dissolve this amount of sodium molybdate in 20 to 40 gallons of water, and spray uniformly over each acre. Apply before planting and disc into the soil unless performing no-till renovation. Not more than 2 lb of sodium molybdate (12.8 oz of Mo) per acre should be used during a five-year period.

Hay and Pastures

Established Stands of Cool-Season Grasses

Topdressing

Cool-season grasses such as tall fescue, bluegrass, timothy, orchardgrass, and bromegrass grow best from early spring into early summer and again in the fall. If moisture, soil pH (6.0 to 6.4), and soil test levels of P and K are adequate (P >30, K >200), the use of nitrogen greatly stimulates their growth during these peak production periods. The use of nitrogen should depend on what is expected from the grass. In stands with less than 25% clover nitrogen fertilization can help increase total production and protein content and can be used to shift the seasonality of production. However, unless the increased grass and forage production is uti-lized, nitrogen fertilization is not an economical choice.

Pasture Nitrogen Management

In general, nitrogen applications are not recommended in the spring and early summer for typical Kentucky pasture situations (Table 28). This is because in most grass pastures there will be a forage surplus from late April through mid-June even with-out additional nitrogen. Topdressing low rates of N (25-40 lb N/A) in late winter, just before growth begins, will increase production so that grazing can begin about two weeks ahead of pastures receiving no nitrogen. This can potentially lower over-winter feed costs. However, as discussed in the previous section, no late winter and spring N applications are recommended in grass/legume pastures, as this will cause excessive competition from the grass component and potentially crowd-out the clover component of the stand.

Topdressing with N in late spring, following a grazedown, will increase growth that will carry over into the normally low sum-mer production period. But given the typically lower response of nitrogen at this time of year the cost-benefit needs to be evalu-ated on a case-by-case basis. Caution should also be used with late spring N applications as they may have the unintended consequence of stimulating the production of warm season annual weeds.

Late summer (mid-August) topdressing with N (up to 80 lb N/A, Table 28) and then resting pastures can stimulate fall growth. This practice of deferring grazing and allowing forage growth to accumulate in late summer and fall is commonly referred to as stockpiling. It is important to graze down or clip pastures before stockpiling to stimulate new high quality leaf growth. This is a practical method to lower winter feed cost in most years by reducing the amount of hay fed during the winter months. Stock-piled pastures will last longer and the nutritive value will be more uniform if efficiently utilized with strip grazing or other rotational grazing methods that reduce trampling and waste.

Table 28. When to topdress nitrogen.

Date	Cool season grass pastures[1]	Cool season grass hay-fields[2]
	lb N/A per Application	
Feb. 15 - Mar. 15	Generally not recommended	up to 100
May 1 - 15	Generally not recommended	up to 50 in limited situations
Aug. 15 - 30	up to 80	up to 80 in limited situations

1 In general, no N is recommended for most grass pasture situations in the spring unless additional spring growth is needed. To jump-start growth in early spring, applications of 25-40 units of N can be made in late winter.

2 Total amount of N to topdress should depend on how much additional production is needed. If a total of more than 100 lb of N per acre per year is to be used, it should be applied in split applications. Suggested dates and rates for topdressing with N are shown above.

Table 29. Phosphate and potash recommendations (lb/A), cool-season grasses, annual topdressing.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	Pasture:[1] K_2O Needed	Hay: K_2O Needed
Very high			>420	0	0
High	>60	0	321 - 420	0	30
			301 - 320	0	40
Medium	46 - 60	30	267 - 300	30	50
	41 - 45	40	240 - 266	30	60
	37 - 40	50	213 - 239	30	70
	33 - 36	60	187 - 212	40	80
	28 - 32	70			
Low	23 - 27	80	159 - 186	50	90
	19 - 22	90	132 - 158	60	100
	14 - 18	100	104 - 131	70	110
	9 - 13	110			
Very low	<9	120	<104	80	120

1 If pasture is clipped and harvested for hay in the spring, K applications should be according to the hay recommendations.

Hay Field Nitrogen Management

Research over a period of years indicates that dry matter can be increased in pure grass stands from about one ton per year with no nitrogen up to about 4 tons per year with 150 to 200 lb N/A.

Late winter/early spring applications of 50-100 lb N/A are generally recommended for grass hay fields as this is the most cost-effective application time for hay production (Table 28).

Nitrogen applications in late spring, following the first cutting are sometimes recommended. However, the later into spring and early summer this occurs, the lower the yield response of cool-season grasses will be from additional nitrogen. The cost-benefit of this practice needs to be evaluated on a case-by-case basis. The higher the value of the product (e.g. pure or-chardgrass in small square bales), the more likely it will be cost-effective. Caution should be used with these N applications as they may have the unintended consequence of stimulating the production of warm season weeds.

As previously discussed, spring N applications are not recommended in grass/legume pastures and hay fields that contain more than 25% legumes, as they will cause excessive competition from the grass component and they are generally uneconomical since the legume component produces "free" nitrogen through N fixation.

Late summer applications of nitrogen for hay production need to be evaluated on a case-by-case basis. In contrast to grazing stockpiled grass, there are significant production costs for the additional hay produced with each unit of N. This makes the cost-benefit of late summer nitrogen applications for hay production less advantageous than for pasture.

Sources—Research in Kentucky has shown that during late winter and early spring there is little difference among the N sources commonly used for topdressing cool-season grasses. After early May, there is an increased risk that top-dressed urea will not be as effective as other N sources. Average efficiency values for top-dressed urea after early May ranged from 51% to 78% of that observed with ammonium nitrate, depending largely on the length of time between urea application and the next rainfall. When a urease inhibitor is used in conjunction with urea, the efficiency of urea becomes comparable to that of ammonium nitrate or ammonium sulfate, because the inhibitor conserves the urea-N against volatilization losses. However, urease inhibitors are only effective for up to 14 days follow nitrogen application. Research indicates the efficiency of liquid nitrogen (UAN, urea-ammonium nitrate solutions) applied after early May is greater than that of urea, but lower than that for ammonium nitrate or ammonium sulfate. A urease inhibitor can also be used with UAN solutions. See University of Kentucky Extension publication AGR-185, *Nitrogen Transformation Inhibitors and Controlled Release Urea*, for specific information on products designed to reduce N loss.

Grass tetany (hypomagnesaemia tetany) problems with cattle are sometimes encountered on straight grass pastures, particularly with nursing cows where grass pasture is the only source of feed. Tetany is a disorder caused by an abnormally low blood concentration of magnesium (Mg). For prevention of grass tetany, a general recommendation is to provide a high magnesium mineral supplement (15% magnesium) at least 30 days prior to calving. Applying fertilizer containing magnesium to offset poten-tial grass tetany problems is NOT effective. There is little guarantee that the plant will take up the additional applied magnesium when soil test magnesium levels are adequate. For more information on managing grass tetany in beef cattle, see ID-226, *Forage-Related Cattle Disorders, Hypomagnesemic Tetany or "Grass Tetany".*

Lime

See Page 5, and use the rate appropriate to attain a target pH of 6.4.

Surface Mine Reclamation

See Page 4 for more details.

Hay and Pastures

Warm-Season Forages

Sudangrass, Millets, Sorghum-Sudangrass Hybrids

This category includes annual warm-season grasses. Consult University of Kentucky Extension publication AGR-88, *Producing Summer Annual Grasses for Emergency or Supplemental Forage,* for management details.

The soil pH should be maintained between 5.8 and 6.4. If establishing a stand and the water pH is less than 6.2, add lime to attain a target pH of 6.4 (see Page 5). If the stand is already established, apply lime to reach a target pH of 6.4 when the water pH is less than 5.8. Apply 60 to 100 lb N/A at seeding plus 40 to 60 lb N/A topdressed after first and second grazedowns or hay clippings. Apply phosphate and potash according to soil test results (Table 30).

Table 30. Phosphate and potash recommendations (lb/A), annual warm-season crops.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	48 - 60	30	271 - 300	30
	45 - 47	40	263 - 270	40
	41 - 44	50	255 - 262	50
	38 - 40	60	246 - 254	60
	34 - 37	70	238 - 245	70
	31 - 33	80	230 - 237	80
			221 - 229	90
			213 - 220	100
			205 - 212	110
Low	24 - 30	90	191 - 204	120
	17 - 23	100	173 - 190	130
	10 - 16	110	155 - 172	140
			136 - 154	150
			118 - 135	160
			100 - 117	170
Very low	<10	120	<100	180

Table 31. Annual nitrogen, phosphate, potash applications (lb/A), bermudagrasses.

Soil Test Level	Annual Application					
	Pasture			Hay		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
High >60 P 300 K	120 - 240	0	0	120 - 400	0	0
Medium 60 - 30P 300 - 200K	120 - 240	30 - 65	30 - 90	120 - 400	30 - 95	30 - 180
Low <30P 200K[1]	120 - 240	65 - 120	90 - 180	120 - 400	95 - 120	180 - 360

[1] The maximum P_2O_5 or K_2O rate shown should be used if P is less than 10 or K is less than 100.

Table 32. Annual phosphate and potash applications (lb/A), establishment or forage use of native warm-season grasses.

Soil Test Level	P_2O_5	K_2O
High >60 P 300 K	0	0
Medium 60 - 30 P 300 - 200 K	30 - 40	30 - 50
Low[1] <30 P 200 K	40 - 80	50 - 100

[1] The maximum rates should be used if P is less than 6 lb/A or K is less than 90 lb/A.

Bermudagrass

Bermudagrass is a perennial warm-season grass. Consult University of Kentucky Extension publication AGR-48. *Bermudgrass: A Summer Forage in Kentucky,* for management details.

The pH should be maintained between 5.8 and 6.4. If a stand is being established and the water pH is less than 6.2, then add lime to attain a target pH of 6.4 (see Page 5). If the stand is already established, apply lime to reach a target pH of 6.4 when water pH is less than 5.8. For establishing new stands, apply 30 to 60 lb N/A one month after seeding or sprigging. As ground cover is attained, an additional 30 to 50 lb applied around August 15 can be beneficial in stimulating first-year growth. The total amount of N used should be based on the amount of forage needed and whether it is grazed or cut for hay. Nitrogen should be applied in split applications for best results. Apply 60 to 100 lb N/A in the spring when green-up begins. A nitrogen application near 100 lb N/A is needed for top hay production. Apply an additional 60 to 100 lb N/A after each hay cutting or 40 to 60 lb N/A after each grazedown. The last N application should be made by mid-August. Apply phosphate and potash according to soil test results. Table 31 summarizes nitrogen, phosphate, and potash rate recommendations.

Native Warm-Season Grasses

Native warm-season perennial grasses can be used for forage. These plant species include bluestems, switchgrass, indiangrass, side oats grama, and eastern gamagrass. See University of Kentucky Extension publication AGR-145, *Native Warm-Season Perennial Grasses for Forage in Kentucky,* for detailed information on management.

Do not apply nitrogen at the time of seeding to avoid growth of other plants that can compete with the young seedlings. An application of 40 to 60 lb N/A can be applied in July of the seeding year to aid establishment. Apply 40 to 60 lb N/A for established stands after the grass begins to green up in the spring. If N is applied too early, it will promote the growth of cool-season plant species that will compete with the warm-season grass. An additional 40 to 60 lb N/A can be applied after harvest in June or July for increased yields. Apply phosphate and potash according to Table 32.

Hay and Pastures

Horse Pastures

General Fertility Requirements

As with all pastures, soil samples should be taken from horse pastures every two years. Then pastures should be limed and fertilized with phosphorus (P) and potassium (K) to soil test recommendations to maintain vigorous growth of desired grasses and legumes and provide competition against undesirable weeds (Table 35). Pasture fertilization is not a sound approach to alleviate macro- and micronutrient deficiencies of livestock. These problems may be better addressed by more direct actions, such as feeding of mineral supplements.

Topdressing Nitrogen on Cool-Season Grass Pastures

See AGR-200, *Soil Sampling and Nutrient Management in Horse Pastures* (http://www.uky.edu/Ag/Forage/Agr200.pdf).

The need to topdress nitrogen (N) on horse pastures in Kentucky is often less than that for cattle pastures because the goal with mature horses is weight/condition maintenance, whereas the goal on most beef cattle pastures is maximum growing animal weight gain. The guidelines shown below base N topdressing rates on stocking rate (horses per acre) and the percentage of clover (pasture containing more than 25% clover will supply most N needs of the pasture grass) in the stand (tables 33 and 34).

Cool-season grasses, such as Kentucky bluegrass, orchardgrass, timothy, and tall fescue, grow most vigorously from early spring into early summer and then again in the fall into early winter. When soil moisture, pH (>6.0), and soil test levels of P and K are adequate (P >30, K >200), fertilizer N will stimulate cool-season grass growth during these peak production periods. The use of N should depend on what is expected from the pasture. Nitrogen fertilization can help increase total production and protein content, extend spring grass growth into the early summer, and extend fall pasture production into early winter. However, unless the increased pasture yield is utilized, there is no return to the added N expense, and there are several disadvantages. Stimulating grass growth in the spring can be helpful to maintaining a high stocking rate, but frequent clipping will be required to maintain pasture quality in a lightly stocked horse pasture. Late spring N application may have the unintended result of promoting the growth of summer weeds such as crabgrass, yellow foxtail, nimblewell, and ragweed. In addition, there is an extra caution when broodmares are on pastures that contain tall fescue. In these pastures, spring N has been known to increase levels of ergot alkaloids, leading to an increased likelihood of fescue toxicity symptoms (prolonged gestation, difficult birth, and lack of milk production). Fortunately, this is only an issue with broodmares since tall fescue toxicity symptoms are not known to occur in other classes of horses.

Kentucky N fertilizer recommendations for cool-season grass horse pastures are shown in tables 33 and 34. At low stocking rates, on soils with good productivity (>2 acres per mature horse), N should only be topdressed during the fall. Fall applications stimulate tillering of individual grass plants, producing a denser grass stand, which will suppress weed growth. Fall applications also lengthen the period of active photosynthesis, which promotes root growth and winter survival. If the primary goal is a more dense grass stand, then one late fall application between late October and early November is sufficient. If fall pasture growth is important, then also apply N between mid-August and mid-September. For suggested dates and N application rates for horse pastures managed at low stocking rate, see Table 33.

At higher stocking rates, on soils with good productivity (<2 acres per mature horse), fertilizer N may be topdressed on cool-season grasses throughout much of the growing season (Table 34). A late winter application will stimulate an early spring growth flush. An N application in May will help extend the pasture into the early summer, and a late summer application in August will stimulate cool-season pasture grass production in the fall and early winter. The major limitation to summer N fertilization is its stimulation of the growth of summer weeds. Excessive N applications may merely result in wasted forage. For suggested dates and N application rates for high stocking rate horse pastures, see Table 34.

The above-stated stocking rates are estimates for Kentucky soils of average productivity. The highest productivity soils in Kentucky will support one mature horse on 2 acres or less, while those with the lowest productivity (often with significant slopes) require 10 or more acres per horse. It is important to determine the recommended stocking rate for your soil type. See your county Extension agent for the average stocking rates associated with the soil types found in your area. Or go to the Web Soil Survey Web site for this information (www.websoilsurvey.nrcs.usda.gov). Often, stocking rate information in soil surveys is given in animal unit months (AUM). To convert animal unit months to recommended acres per horse, use the following formula: (12 ÷ AUM) x (wt of horse ÷ 1,000) = acres required per horse.

Sources of Nitrogen—Research in Kentucky has shown that during late fall, late winter, and early spring, there is little difference among the N sources commonly used for topdressing cool-season grasses. After May 1, there is an increased risk that topdressed urea will not be as effective as other N sources. Average efficiency values for urea N applied after early May ranged from 51 to 78% of that observed with ammonium nitrate or ammonium sulfate, depending largely on the length of time between urea application and the next rainfall. When a urease inhibitor is used in conjunction with urea, the efficiency of urea becomes comparable to that of ammonium nitrate or ammonium sulfate. Research indicates that efficiency of liquid urea-ammonium nitrate (UAN) applied after early May is greater than that of urea, but lower than that for ammonium nitrate or ammonium sulfate. A urease inhibitor can also be used with UAN solutions. See University of Kentucky Extension publication AGR-185, *Nitrogen Transformation Inhibitors and Controlled Release Urea,* for specific information on products designed to reduce N loss.

To avoid burning symptoms on grass forages, remember to apply any granular N source when the leaf surface is dry. Also, avoid leaving piles of granular N in the field, either from misapplication or improper equipment operation because ingestion of significant quantities of N fertilizer can be toxic to horses.

Table 33. Topdressing nitrogen (lb/A) on cool-season horse pastures when maintained at low stocking rates (more than 2 acres/horse).

Date	N per Application[1]
Aug. 15 - Sept. 15	30 - 40
Oct. 15 - Nov. 15	30 - 60

[1] Total amount of N to topdress depends on desired result. No N is recommended if clover makes up more than 25% of the pasture. If primary goal is increased tillering for a denser grass stand winter, then one late fall application is sufficient. If fall pasture growth is important then also apply N in late August-early September. Suggested dates and rates for topdressing with N are shown above.

Table 34. Topdressing nitrogen (lb/A) on cool-season horse pastures when maintained at high stocking rates (less than 2 acres/horse).

Date	N per Application[1]
Feb. 15 - Mar. 15	up to 40 - 80
May 1 - 15	up to 30 - 40
Aug. 15 - 30	up to 40 - 80

[1] Total amount of N to topdress should depend on how much additional production is needed. Late spring N applications may have the unintended effect of stimulating unwanted summer weeds. Little or no N is recommended if clover makes up more than 25% of the pasture. Suggested dates and rates for topdressing with N are shown above.

Table 35. Phosphate and potash recommendations (lb/A) for cool-season grass horse pastures when applying annual fertilizer applications.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
Very high			>420	0
High	>60	0	321 - 420	0
			301 - 320	0
Medium	46 - 60	30	267 - 300	30
	41 - 45	40	240 - 266	30
	37 - 40	50	213 - 239	30
	33 - 36	60	187 - 212	40
	28 - 32	70		
Low	23 - 27	80	159 - 186	50
	19 - 22	90	132 - 158	60
	14 - 18	100	104 - 131	70
	9 - 13	110		
Very low	<9	120	<104	80

Conservation and Wildlife Land

Land can be managed to improve soil and water quality, enhance growth of native plant species, or provide habitat and food for wildlife. These types of land management are commonly referred to as conservation programs. The government can offer cost-sharing money to promote the management of land using specific conservation methods.

Riparian Buffer and Filter Strips

Riparian buffers and filter strips are land uses designed to improve water quality. Riparian buffers include land kept in an undisturbed condition for some distance away from the edge of streams. Filter strips are land containing grasses that filter out sediment in runoff from agricultural fields before entering surface water. Riparian buffers can include grasses, bushes, or trees. Filter strips can include warm- and cool-season grasses useful for trapping particles suspended in runoff water.

The pH should be maintained between 5.8 and 6.4. If water pH is below 5.8, apply lime to attain a target pH of 6.4 (see Page 5). To ensure thick and vigorous growth, apply 40 to 60 lb N/A at seeding for cool-season grass or in July of the establishment year for warm-season grass. Apply phosphate and potash at seeding according to Table 36. Fertilizer or other sources of nutrients should not be applied on established stands. The management of this land can involve mowing, with no plant removal, so the nutrients in the grass are recycled back into the soil.

Wildlife Food Plots

Land can be planted with a varied mixture of plant species to provide food for wildlife. An example of the various plant species are shown in Table 37. Land management depends on the composition of the plant species. Details on managing wildlife food plots can be found in University of Tennessee Extension publication PB 1743, *Growing and Managing Successful Wildlife Food Plots in the Mid-South*.

The soil pH should be maintained between 5.8 and 6.4. If the water pH is below 5.8, apply lime to attain a target pH of 6.4 (see Page 5). Most of the seeding mixtures recommended for wildlife food plots contain one or more legume species that will add nitrogen to the soil. Therefore, only 0 to 30 lb N/A is required at seeding to establish the stand, and no N is applied to established stands. Be sure to inoculate the legume with species-specific inoculant prior to planting. If a legume is not in the seeding mixture, apply 40 to 60 lb N/A in the spring for cool-season grasses or after green-up occurs in warm-season grasses. Do not apply N at time of seeding warm-season grasses. Apply phosphate and potash according to Table 38.

Native Grassland Restoration

Native warm-season grasses can be planted in conservation land to restore native grassland conditions in Kentucky. Native warm-season grass species include bluestem, switchgrass, indiangrass, side oats grama, and eastern gamagrass. Warm-season grasses offer good habitat for wildlife with their bunch-type growth characteristic providing open spaces for travel and feeding. Deer also use warm-season grasses as bedding sites. Warm-season grasses are not as good a wildlife food source because the grass is not as palatable as other plant species. For information on establishing native warm-season grasses, see University of Tennessee Extension publication PB-1747, *A Landowner's Guide to Warm-Season Native Grasses in the Mid-South*. Information on establishing native warm-season grasses in Kentucky can be found on the Internet at http://www.uky.edu/Ag/Forestry/TBarnes/Web%20pages/how_to_NWSG.htm.

Table 36. Phosphate and potash recommendations (lb/A) for establishing riparian buffers and filter strips.

Soil Test Level	P_2O_5	K_2O
High >60 P >300 K	0	0
Medium 60 - 30 P 300 - 200 K	30 - 40	30 - 50
Low[1] <30 P <200 K	40 - 80	50 - 100

[1] The maximum rate should be used if soil test P is less than 6 lb/A or soil test K is less than 90 lb/A.

Table 37. Sample plant species for wildlife food plots.

Species	Life Cycle
Cool-Season Legumes	
Arrowleaf clover, Austrian winter pea, Ball clover, Crimson clover, Subterranean clover	annual
Red clover, Sweetclover (yellow or white)	biennial
Alfalfa, Alsike clover, Bird's-foot trefoil, Ladino white clover, White-Dutch clover	perennial
Warm-Season Legumes	
Alyceclover, American jointvetch, Catjang pea, Common (Kobe) lespedeza, Cowpea, Lablab, Partridge pea, Soybean	annual
Cool-Season Grasses	
Oats, Rye, Wheat	annual
Ryegrass	annual or perennial
Warm-Season Grasses	
Browntop millet, Corn, German (foxtail) millet, Grain sorghum (milo), Japanese millet, Pearl millet, White proso millet	annual
Other Plantings	
Buckwheat (warm-season), Chufa (warm season), Rape (typhoon; cool-season), Sunflower (warm season), Turnip (forage-type; cool-season)	annual
Chicory (puna), Rape (dwarf essex; cool-season)	perennial

Table 38. Annual phosphate and potash recommendations for wildlife food plots (lb/A).

Soil Test Level	P_2O_5	K_2O
High >60 P >300 K	0	0
Medium 60 - 30 P 300 - 200 K	30 - 40	30 - 50
Low[1] <30 P <200 K	40 - 80	50 - 100

[1] The maximum rate should be used if soil test P is less than 6 lb/A or soil test K is less than 90 lb/A.

Fertilizer should not be applied at seeding (usually May to early June). Fertilizer, particularly nitrogen, will encourage growth of undesirable plant species that will compete with the young seedlings. Apply 15 to 30 lb N/A in the summer of the seeding year when the plants are 4 to 6 inches high and there is adequate soil moisture to help the stand become established. Native warm-season grasses are adapted to nutrient-deficient soils with low pH. Therefore, lime and fertilizer are needed only if the soil is extremely low in pH or deficient in nutrients. Apply 100% effective lime at a rate of 2 tons/A if water pH is below 5. Apply 50 lb P_2O_5/A if soil test P is below 10 lb/A. Apply 60 lb K_2O/A if soil test K is below 100 lb/A.

Lawns and General Turf

Establishing New Turf

Mix lime, nitrogen, P_2O_5, and K_2O into the top 4 to 6 inches of soil before seeding. Use 1.5 lb N/1,000 sq ft and lime, P_2O_5, and K_2O rates recommended in the following tables.

Lime—Use the rate of limestone needed to attain a target pH of 6.4 as indicated in Table 39.

Table 39. Rate of bagged lime (lb/1,000 sq ft)[1] needed to raise soil pH to 6.4.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	250	230	220	190	160	140	110	80	140
4.7	250	230	220	190	160	140	110	80	140
4.9	250	230	200	180	150	120	100	70	130
5.1	250	230	200	180	150	120	100	70	120
5.3	250	230	200	180	140	110	80	50	100
5.5	250	230	190	160	140	110	80	50	100
5.7	250	220	190	150	120	100	70	50	80
5.9		220	180	140	110	80	50	40	60
6.1			150	110	80	50	40	30	50
6.3				50	40	30	10	10	30

[1] Based on bagged lime with 84% RNV.

Maintenance of Turf

Lime—Based on the soil test pH, apply limestone at rates indicated under the "Establishing New Turf" section. Apply no more than 70 to 100 lb/1,000 sq ft at any one time. Additional lime can be supplied as repeated applications at three- to six-month intervals.

Phosphate and Potash—According to soil test results, apply phosphate or potash at rates indicated in Table 40.

Nitrogen—Apply 1 to 1.5 lb actual N/1,000 sq ft per application or 40 to 60 lb N/A. The frequency of nitrogen applications depends on the level of overall maintenance. The following low- and medium-maintenance levels are best for general lawns that get little or no summer irrigation. The high and very high levels usually require some irrigation and a high mowing frequency (see Table 41).

See University of Kentucky Extension publication AGR-53, *Lawn Fertilization in Kentucky,* for more specific details on lawn fertilization.

Table 40. Phosphate and potash recommendations for lawns and turf.

lb/A Soil Test Level	lb/1,000 Sq Ft	
	P_2O_5	K_2O
High >60 P 300 K	0	0
Medium 60 - 30 P 300 - 200 K	0 - 1	0 - 1
Low <30 P 200 K	1 - 3	1 - 3

Table 41. Best months to make nitrogen applications for turf maintenance.

N Applications/ Year		Cool-Season Grasses[1]	Warm-Season Grasses[2]
Low	1	October - November	June
Medium	2	September - October November - December	May, July
High	3	September - October October - November November - December	April, June, August
Very high	4	September - October October - November November - December late May - early June (½ rate)	April, May, June, August

[1] Kentucky bluegrass and tall fescue. Red fescue and all cool-season grasses grown in shady lawns should be fertilized only once a year.
[2] Bermudagrass and zoysiagrass. Zoysiagrass needs only a minimal amount of N after lawn is fully established.

Tree Fruits, Blackberries, Raspberries, and Grapes

New Plantings

Lime—Limestone should be applied three to six months before planting and plowed and disked deeply into the soil based on a soil test. The sod should be included with the soil sample. Tree fruits, blackberries, and raspberries are most productive when soil pH is between 6.4 and 6.6. For plantings of American and French-American hybrid grapes, adjust the soil pH to 6.5 at establishment, and maintain between 5.5 and 6.0 during production. European or *Vitis vinifera* grapes perform best when soil pH is between 6.0 and 7.0. See Page 5, and use the table appropriate to the target pH; apply lime at the recommended rate.

Nitrogen—Nitrogen fertilization rates depend on the field cropping history and soil types. Broadcast 80 lb of N/A (2.9 oz

N/100 sq ft) or 40 lb N/A (1.5 oz N/100 sq ft) if a legume cover crop is plowed down prior to planting. This is for establishing a new sod in the planting. Apply an additional 20 lb N/A as a broadcast application after grass has become established in drive rows. Nitrogen is most effective when it is applied at planting time.

The above recommendations are for establishment only. During subsequent seasons, fertilizer application should be based on the plant growth rate and condition. General fertility guidelines may be found in University of Kentucky Extension Publication HortFact-3004, *Fertility Guidelines for Home Fruit and Nut Plantings* (http://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/Home_Fruit_Fertility_Guides_2016.pdf). Fertility guidelines for commercial grape growers may be found in HortFact-3104, *Fertilization of Grapevines* (www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/grapefertilization.pdf).

Magnesium—Fruit crops require more magnesium than most agronomic crops. The soil should be adjusted if soil test Mg is less than 200 lb Mg/A for grapes or less than 120 lb of Mg/A for other fruit crops prior to planting. Use Tables 44 and 45 for adjusting Mg levels in the soil according to the soil test Mg value.

Soil pH, phosphorus, potassium and magnesium adjustments for fruit crops are much more effective when performed prior to planting. It is very difficult to incorporate required nutrients if they are not plowed or cultivated in deeply prior to planting

Table 42. Phosphate and potash for tree fruits, blackberries, raspberries, and blueberries.

Soil Test Level lb/A	P_2O_5		K_2O	
	lb/A	Oz/100 Sq Ft	lb/A	Oz/100 Sq Ft
High >70 P >300 K	0	0	0	0
Medium 35 - 70 P 200 - 300 K	0 - 80	0 - 3	0 - 80	0 - 3
Low <35 P <200 K	80 - 120	3 - 5	80 - 120	3 - 4

Table 43. Phosphate and potash for grapes.

Soil Test Level lb/A	P_2O_5		K_2O	
	lb/A	Oz/100 Sq Ft	lb/A	Oz/100 Sq Ft
High >100 P >200 K	0	0	0	0
Medium 40 - 100 P 150 - 200 K	50	0 - 2	0 - 120	0 - 4
Low <40 P <150 K	100	4	60 - 180	2 - 7

Established Plantings

Tissue analysis is the most accurate method for determining plant nutrient status in commercial fruit plantings once plants have been established. Soil analysis provides an incomplete understanding of fruit crop nutritional needs. However a tissue analyses should be coupled with a recent soil analysis to provide a complete nutrient status evaluation. Tissue analysis allows a grower to determine when an essential nutrient(s) is low and to correct the problem before cropping and growth are reduced. Tissue analysis should be done every several years. See University of Kentucky publication HortFact-3001, *Fruit Crop Tissue Analysis* (www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/foliar.pdf) or contact your county Extension agent to obtain information and a source for plant analysis kits.

Blueberries

New Plantings

Blueberries require a low soil pH to enable plants to take up iron from the soil. For blueberries, adjust the soil pH to a value between 4.5 and 5.2. If available soil calcium levels are below 2,500 lb/A, the site can usually be effectively acidified. At soil calcium levels above this the soil has a high cation exchange capacity (CEC) and buffer capacity. A high CEC is an indication of high resistance to pH change. Consequently, considerably more acidifying material is required to lower the pH and this becomes difficult and prohibitively expensive. Sulfur application is the most inexpensive means to lower soil pH, but this reaction only occurs when the soil is warm since the conversion of sulfur to sulfuric acid is performed by soil bacteria. The process is slow and the application and incorporation of sulfur is recommended at least six months before planting. A full year is required for a complete reaction. See University of Kentucky Extension publication HO-60, *Growing Highbush Blueberries in Kentucky* (http://www2.ca.uky.edu/agcomm/pubs/ho/ho60/ho60.pdf), for further information on lowering soil pH.

Ferrous sulfate may also be used to decrease soil pH. The reaction is more rapid than when using sulfur since ferrous sulfate disassociates directly into iron and sulfuric acid. However, this is considerably more expensive than sulfur and eight times more ferrous sulfate is required to give the same acidification as sulfur. Aluminum sulfate may be used to lower the soil pH, but can cause injury to blueberry plants due to aluminum toxicity if high rates are used. It is strongly recommended that blueberries be planted on raised beds to improve soil drainage and reduce phytophthora root rot problems.

Table 44. Magnesium recommendations (lb/A) for tree fruits, blackberries, raspberries, blueberries, and strawberries.

Soil Test Level lb/A	Mg lb/A
High 120	0
Medium 61 - 120	20 - 80
Low < 60	80

Soil pH, phosphorus, potassium and magnesium adjustments for blueberries are much more effective when performed prior to planting. It is very difficult to incorporate required nutrients if they are not plowed or cultivated in deeply prior to planting

Nitrogen—Nitrogen fertilization rates depend on the field cropping history and soil types. Broadcast 80 lb of N/A (2.9 oz N/100 sq ft. This is for establishing a new sod in the planting. Apply an additional 20 lb N/A as a broadcast application after grass has become established in drive rows. Nitrogen is most effective on blueberries when half is applied at bloom and the second half is applied 6 weeks later. Ammonium sulfate or sulfur coated urea are the preferred sources of nitrogen on blueberries where continued lowering of the soil pH is warranted. Ammonium sulfate is sidedressed at the rate of 0.1 lb/plant at bloom and 6 weeks later the first season and increased by 0.1 lb in subsequent years until a rate of 0.3 lb is reached. Urea is used when the soil pH is below 5.0. Avoid using calcium nitrate or ammonium nitrate as a nitrogen source as blueberries utilize the ammonium (NH_4) form and do not do well with the nitrate (NO_3) form of nitrogen.

Potash—If potash or K_20 is needed for blueberries it is best to use sulfate of potash instead of muriate of potash (potassium chloride) to avoid root burn.

Established Plantings

If the soil pH was not adjusted to the 4.5-5.2 range prior to planting a soil test after planting may indicate that a large amount of sulfur should be applied. Amounts of sulfur greater than 400 lb/A or 0.91 lb/100 sq ft may injure the roots as the sulfur is converted to sulfuric acid. Consequently, after planting do not apply more than this amount of sulfur on an annual basis. Continue to fertilize with an acidic nitrogen fertilizer such as ammonium sulfate to progressively reduce the soil pH. The use of an iron chelate as a foliar or soil application will allow the plant to pick up iron at a high pH to keep the plants growing, but it will not reduce the soil pH. Alternatively, the plants may be fertilized with Osmacote Plus 15-9-12 + minors 3-4 month release at 2 oz/plant monthly from March to July on plants that are 3-years old or older. Use a lower rate on younger plants. This will supply iron at a high soil pH as a stop gap until the soil pH has been reduced to the desired range, but is expensive.

Once the soil pH has been adjusted to below 5.0 and is stable, blueberries should be fertilized with Urea which will not continue to reduce the soil pH. Growers should be aware that oak or hardwood mulches will tend to gradually increase the soil pH since these mulches contain calcium that is released as the chips break down. Pine sawdust, chips or needles are an ideal much for blueberries if they are available as they do not contain much calcium and help to maintain a low soil pH.

Tissue analysis performed on leaf samples collected during the first week of harvest or between June 15 and August 15 are very helpful in determining blueberry nutritional needs.

Table 45. Magnesium recommendations (lb/A) for grapes.

Soil Test Level lb/A	Mg lb/A
High 400	0
Medium 300 - 400	0
Low < 300	100 - 200

Table 46. Phosphate and potash recommendations for strawberries.

Soil Test Level lb/A	P_2O_5 lb/A	P_2O_5 oz/100 Sq Ft	K_2O lb/A	K_2O oz/100 Sq Ft
High >70 P >300 K	0	0	0	0
Medium 70 - 35 P 300 - 200 K	0 - 80	0 - 3	0 - 40	0 - 1.5
Low <35 P <200 K	80 - 150	3 - 6	40 - 80	1.5 - 3

Strawberries

Matted Row

Establishment

Lime—Limestone should be applied three to six months before planting and worked into the top 4 inches of soil. Strawberries are most productive when the soil pH falls between 6.0 and 6.5. See Page 5 and apply the rate of lime to attain a target pH of 6.4. If established plantings need lime, an application of agricultural limestone during the dormant season is best.

Nitrogen—Nitrogen fertilizer should not exceed 60 lb N/A (2.2 oz nitrogen per 100 sq ft) broadcast before planting. Sidedressing with 30 lb N/A in two bands, one on each side of the row with each band placed 2 to 4 inches deep and 8 inches from the plants, is just as effective as broadcast N applications and reduces competition from weeds.

For an early fall application, apply 30 to 40 lb N/A from August 15 to September 10 to promote fruit bud development in the next season.

Spring nitrogen applications are generally avoided during fruiting years because these applications lead to greater vegetative growth, lower fruit yield, delayed ripening, and increased fruit rot.

Magnesium—See Table 44 for recommendations.

Renovation

Use tissue analysis on leaves collected between July 15 and August 15 and fertilize accordingly, or obtain a soil test following harvest. See University of Kentucky publication HortFact-3001, *Fruit Crop Tissue Analysis* (http://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/foliar.pdf) or contact your county Extension agent to obtain information and a source for plant analysis kits. Apply 30 lb N/A (1.1 oz N/100 sq ft), follow lime rate recommendations to attain a target pH of 6.4, and apply phosphate and potash as recommendations in the "Establishment" section. Fertilization should be done before any cultivation during renovation. Contact one of the companies listed in HortFact-3001 to obtain plant analysis kits.

Types of Application

Broadcast—Apply fertilizer over the tops of the plants when leaves are dry. Avoid possible foliage burn by brushing nitrogen granules off the plant leaves. A canvas attached to the back of the fertilizer applicator works well in brushing fertilizer from the plants.

Sidedress—Banded fertilizer should be placed 2 inches below the soil surface and 6 to 8 inches from the plants in established stands.

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