AGR-1

Cooperative Extension Service

2025-2026 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 John Grove, Extension Soil Specialist and Research/Extension Soil Specialist, respectively.

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 and weather conditions. Many field studies have been conducted by the Kentucky Agricultural Experiment Station under Kentucky farm conditions to determine the primary, secondary, or micronutrient needs. Yield and soil test data from these studies serve as guidelines for establishing the 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 (N) recommendation in any given year. Some soils in Kentucky naturally have 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 nutrient source. Consult USDA Natural Resources Conservation Service Practice Code 590 or University of Kentucky Extension publication *Kentucky Nutrient Management Planning Guidelines* (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 2 buffer. These methods are described in Bulletin 419 of the Southern Cooperative Series, Soil Test Methods From the Southeastern United States. The lime and nutrient rate recommendations in this publication should not be used for soil test results obtained by other testing methods.

The recommendations assume above average weather and management conditions for Kentucky. Rate recommendations should be adjusted upward or downward to reflect deviations from these assumptions.

The P and K rate recommendations are for production of a crop to be grown each year and are intended to slowly increase low soil test P and K values. It will likely take four years or more of annual nutrient application at the recommended rates to result in appreciably increase in low soil test P and K levels. Consult University of Kentucky Extension publication *Evaluating Fertilizer Recommendations* (AGR-151) for additional information.

Cation Exchange Capacity (CEC)

Values for CEC 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 Kentucky soil properties.

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

While CEC is not used in making nutrient rate recommendations for agronomic crops, this information does affect lime rate recommendations. The buffer pH is directly related to the amount of the H portion of the CEC and the ability of the soil to resist pH change. The CEC also provides information regarding the soil texture and/or the amount of soil organic matter. The CEC increases as soil clay and/or soil organic matter levels increase.

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.

Soils with Naturally High Contents of P and K

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

Table 1. Soil drainage classes.

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

Elemental and Oxide Values for P and K

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

Table 2. Converting elemental and oxide values.

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

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 *Sampling Plant Tissue for Nutrient Analysis* (AGR-92).

Collecting a Representative Sample

To get reliable recommendations, it is important that the submitted soil sample accurately represents 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 taken. If soil sampling procedures are questionable, accurate nutrient and lime rate recommendations for the sampled field or area cannot be assured. Because results can vary between fall and spring sampling, it is better to consistently sample a given field at the same time of the year. See University of Kentucky Extension publication Managing Seasonal Fluctuations of Soil Tests (AGR-189), 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 the depth of primary tillage (plow, chisel plow, big disc, etc.), usually 6 to 8 inches. With pastures, lawns, no-tilled areas, and turf, take soil cores to a depth of 4 inches. With changing fertilizer and commodity prices, each production field should be sampled every two years. Annual sampling is preferable for high-value crops or rotations that remove large amounts of soil nutrients, such as alfalfa, tobacco, and double-crop silage. Sampling each year after manure application is also recommended. See University of Kentucky Extension publication, *Taking Soil Test Samples* (AGR-16) for details.

Nutrient Recommendations

Nitrogen

Because Kentucky soils are usually not frozen and remain relatively wet throughout the winter months, very little residual (leftover) N is available for subsequent crops. The 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) gas or dinitrogen (N_2) gas – the most common atmospheric gas). Kentucky crops, therefore, rely on organic matter N mineralization and annual fertilizer N application. Soil N levels fluctuate greatly, both in space and time and routine soil testing for N is not recommended, except for the pre-sidedress nitrate-N test used to guide delayed N applications to corn. Fertilizer N rate recommendations in this publication are based on measured crop response to N fertilizer.

Over time, UK agronomists conduct N response field t rials on various crops. The range in N rate recommendations in this publication was derived from the range in optimal N rates de-ter-mined from these trials. That range is due to spatial variation in the N response within field soils and to temporal variation in the N response due to seasonal weather. 'Optimal' does consider the fact that the last pound of fertilizer N should generate enough crop to pay for itself.

Samples Testing Low in P and K

If soil tests for P and K are low, one-third to one-half of the recommended amounts of P2O5 and/or K2O for corn can be used if the fertilizer is banded 2 to 4 inches from the row. Seed damage can occur when high rates of N and K2O fertilizers are placed too close to the seed.

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 following years. When soil test levels are in the lower portion of the high range, the area should probably 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 nutrients. This approach can result in greater than needed fertilizer application and expense and should only be used when necessary.

Recommendations for Multiple Years

The recommendation provided will be for the crop specified on the soil sample submission form. If the soil test results are going to be used for a second, sequential, year of cropping, use this document to get the fertilizer rate recommendation for the second crop(s) to be grown. Recommended rates of P_2O_5 and K_2O can either be applied to each crop (preferred) or summed together and all added at the beginning of the rotation (not as efficient). As an example, let's assume the sample soil test results are to be used for the two years of a corn-soybean rotation, and the soil test P and K values are 40 and 230 lb/A, respectively. For the first-year corn crop, Table 14 calls for 50 lb P_2O_5/Aand 50 lb K_2O/A. For the second year of the rotation the soybean recommendations are 40 lb P_2O_5/A and 60 lb K_2O/A (Table 16). The recommended fertilizer can either be applied prior to planting each individual crop, first corn, and then soybean, or combined and all applied prior to planting corn. Any lime recommendation is designed to cover a period of three to five years, depending on the amount of acid forming fertilizer being used, and should be applied prior to the next crop.

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 to estimating nutrients contained in the materials listed.

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 same nutrients contained in commercial fertilizers. While almost 100% of the K_2O is available, only from 70% to 85% of the P_2O_5 is expected to be available to the next crop. Organic N availability is more variable, with N from manure especially dependent on livestock species/diet, storage and handling methods, and the timing and method of application.

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.

Animal manures also contain significant amounts of Ca, Mg, sulfur (S), Zn, copper (Cu), and molybdenum (Mo) that may be of value to crops. The added organic materials can also be of significant benefit to soils low in organic matter.

University of Kentucky Extension publication *Using Animal Manures as Nutrient Sources* (AGR-146), and an Excel-based, downloadable computer spreadsheet, Animal Waste Calculator (ManureUse1-2.xlsm) are available to help determine application rates and fertilizer credits. Additional assistance can be obtained at your county Cooperative Extension Service office.

Tobacco stalks are a significant source of nutrients when properly stored prior to spreading or immediately spread after stripping. Tobacco stalks can contain a substantial amount of N, K, and, to a lesser extent, P.

Surface Mine Reclamation

See the following University of Kentucky Extension publications:

Lime and Fertilizer Recommendations for Reclamation of Surface-mined Coal Spoils (AGR-40)

Sampling Surface Mine Lands Before and After Mining (AGR-41)

Secondary Nutrients and Micronutrients

Magnesium

Magnesium levels in soils range from very high (in loess-derived soils) to low (some sandstone-derived soils). Despite low Mg testing soils, crop yield responses to Mg fertilization have been very limited in Kentucky. Soil test Mg is routinely determined because soil Mg levels are high enough in some soils to impact the CEC calculation. The Mg needs of animals can best be met by direct feeding rather than Mg fertilization of forage crops. Table 4 gives soil test Mg levels and the associated fertilizer Mg rate recommendations.

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.

Sulfur

Historically, Kentucky soil S levels have been adequate for optimal crop yield and many field trials conducted since 2000 have supported these results. This sufficiency was 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, low levels of S in other fertilizers and some continued atmospheric deposition of S derived from fossil fuel fired power plants.

Now, S deficiency symptoms are becoming more common. Observed S deficiencies are typically found on coarse-textured (sandy) soils, soils low in organic matter, and in winter annual (wheat) or perennial (alfalfa) crops. Crops with high biomass removal (e.g. silage corn) may also be subject to an S deficiency. University of Kentucky agronomists 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, *Sulfur Fertilization in Kentucky* (AGR-198).

Iron, Copper, Boron, and Molybdenum

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

Zinc and Manganese

Yield responses to soil Zn applications for corn and to foliar manganese (Mn) applications to soybean have been observed in Kentucky. The Mn responses on soybean have been on a few high pH soils in Daviess, McLean, and Webster counties. After diagnosis of Mn deficiency, either visually or with tissue testing, responses to foliar Mn applications are superior to soil Mn applications. To date, soil testing has not been advantageous in solving any of these isolated cases of Mn deficiency.

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

Nutrients Removed by Agronomic Crops

Good nutrient management involves effective use of applied nutrients at rates utilized by crops. Crop nutrient removal is the quantity of nutrients removed from a field in the harvested portion of the crop. Crop nutrient removal should not be confused with crop nutrient uptake, which is the total amount of nutrients taken up by the entire crop (roots, stems, leaves, and seed) in a field. Crop nutrient removal rates should not be used as the sole basis of an overall soil fertility program. Crop nutrient removal rates, over time, can be used to help understand why soil test results may deviate from expected outcomes. Nutrient removal rates might also be used when soil sampling is not possible in a certain year. However, caution must be used as crop nutrient removal rates do not provide an estimate of luxury consumption, the amount of nutrients either provided by the soil or chemically tied up (fixed) and can substantially over or underestimate soil nutrients available to the subsequent crop. Table 5 includes crop nutrient removal values from multiple published sources.

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

Crop	Yield Unit	Standard Moisture %	Nutrients Removed		
			N	P_2O_5	K_2O
			lb/Yield Unit		
Corn for grain[1]	bu	15.5	0.64	0.37	0.24
Silage corn[2]	ton	65	9.2	3.7	9.0
Corn stalks[2]	ton	0	19	5.0	30
Wheat grain[1]	bu	13	0.97	0.46	0.28
Wheat straw[2]	ton	0	16	5.0	32
Small grain silage[2,3]	ton	65	18	5.5	23
Sorghum grain[2]	bu	13	0.81	0.34	0.20
Soybean grain[1]	bu	13	3.4	0.75	1.18
Canola grain[2]	bu	8.5	1.75	0.73	0.47
Barley grain[2]	bu	14.5	0.82	0.33	0.28
Rye grain[2]	bu	14	0.87	0.40	0.31
Oats grain[2]	bu	13.5	0.56	0.24	0.17
Alfalfa/clover hay[2]	ton	18	52	10	50
Cool-season grass/fescue hay[2]	ton	18	24	8.0	34
Bermudagrass hay[2]	ton	18	29	8.0	33
Sorghum-Sudan grass hay[2]	ton	18	22	8.0	41
Native warm-season grass hay[2,4]	ton	18	12	4.0	21
Johnsongrass hay[2]	ton	18	15	5.0	19
Burley tobacco	100 lb	20	7	1.1	7.5
Dark-air tobacco	100 lb	20	7	0.6	6.0
Dark-fired tobacco	100 lb	20	7	0.6	6.0

[1] Adapted from Villamil et al., 2019
[2] Adapted from Nutrient Requirements of Beef Cattle. Eighth Revised Edition, 2016
[3] Small grain silage is an average of wheat, oat, and annual rye grown as silage
[4] Native warm-season hay is an average of Bluestem and Switchgrass
National Academics of Sciences, Engineering, and Medicine. 2016. Nutrient Requirements of Beef Cattle. Eighth Revised Edition. Washington, DC: The National Academies Press. Doi: 10.17226/19014

Soil pH and Lime Rate 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 falsely lower in the fall after a dry growing season due to fertilizer salts that have not yet leached out. To avoid these lower soil-water pH values, active acidity is measured in a solution with a high salt concentration (1 M KCl), which 'swamps' variable soil-salt levels occurring at lower concentrations. 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 when interpreting the soil pH versus optimum plant growth relationship, the measurement of 1 M KCl soil pH is converted to soil-water pH for soil test reports using the following equation developed from an analysis of 240 soil samples.

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

Reserve acidity in soil is determined with the Sikora-2 buffer and the buffer pH value is presented in the soil test report comment section. The Sikora-2 buffer, with an initial pH of 7.53, is mixed with soil and the suspension pH will fall as the buffer reacts with the soil's reserve acidity. The amount of decline in buffer pH, from the initial pH of 7.53, is directly related to the amount of reserve soil acidity reacting with the buffer and to the rate of lime needed to reach the target pH.

Lime Rate Recommendation Tables

To determine how much lime is required to raise soil pH to a given target pH, see Tables 6, 7, or 8 with target pH values of 6.4, 6.6, or 6.8, respectively. The sample's soil-water pH is shown in the first column, and the sample's buffer pH is found in the top row of pH values. To determine the appropriate lime rate, read down the first column to the sample's soil-water pH then read across to the sample's buffer pH. The soil-water pH can be determined directly or estimated from 1 M KCl soil pH as done by the University of Kentucky. The buffer pH can be determined with SMP, Sikora, or Sikora-2 buffer.

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 relative neutralizing capacity (RNV). The RNV for agricultural limestone averages about 67%. In comparison, pure hydrated lime (calcium hydroxide, $Ca(OH)_2$) has an RNV of 135%. The bulk lime rate 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.

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

The bulk lime rate values in Table 9 are rounded to the nearest 0.5 ton/A; therefore, the amount calculated by the formula above may not be the same as the amount in Table 9. Lime moisture is generally low and does not influence the application rate. However, if lime moisture content is 7% or greater, then increase the application rate by 0.5 ton/A.

Lime Rate Recommendation Equations

Lime requirement rates shown in Tables 6, 7, and 8 for 100% effective lime can be calculated from equations. This can be useful for precision agriculture programs or when determining lime requirement rates for other target soil-water pH values. The two equations below determine lime requirement rates from two pH measurements. The first equation can be used with measurement of 1 M KCl soil pH (pHKCl) and Sikora-2 soil buffer pH values, as done by the University of Kentucky. The second equation can be used with measurement of soil-water pH (pHw) and Sikora soil buffer pH values.

$$\text{Lab incubation lime requirement rate (ton/A) to reach target } pH_w = (1.10 \times (\text{target } pH_w) - 1.47 - pH_{KCl}) \times (\text{soil-buffer pH} - 7.55) \div [(\text{soil-buffer pH} - pH_{KCl}) \times (-0.364)] \times 5 \div (\text{g soil})$$

$$\text{Lab incubation lime requirement rate (ton/A) to reach target } pH_w = -1.10 \times (\text{target } pH_w - pH_w) \times (\text{soil-buffer pH} - 7.55) \div [\text{soil-buffer pH} - (1.10 \times pH_w) + 1.47] \times 13.75 \div (\text{g soil})$$

Table 6. Rate of 100% effective limestone (ton/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 (ton/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 (ton/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

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

RNV% If unknown assume 68%.	Recommended 100% Effective Lime Rate							
	1.0	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
	Bulk Lime (Ton/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

To adjust lime requirement from the method-estimated lime requirement rate to a field application rate of 100% effective lime, a correction factor is needed. If the method-estimated rate is greater than 3 ton/A, multiply the method-estimated rate by 1.42. If the method-estimated rate is less than 3 ton/A, multiply the method-estimated rate by the correction factor determined in the second equation below.

Method-estimated lime requirement rate is greater than 3 ton/A : Correction factor = 1.42

Method-estimated lime requirement rate is less than 3 ton/A : Correction factor = 3.62 – (0.367 × (method-estimated lime requirement rate)))

Considerations with Field Application of Limestone

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
- Continued use of acid-forming nitrogen fertilizer that lowers soil pH

When applying lime rates greater than 4 ton/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. Soil pH management is more critical in no-tillage systems due to the lack of mixing with surface applied lime. It is always best to monitor soil pH so large amounts of lime are not needed. However, if high rates of lime are needed in a no-till field, it is best to make smaller and more frequent lime applications to reduce the chance of creating an alkaline (pH>7) soil surface that can negatively influence micronutrient availability and/or the activity of some herbicides. Avoid making limestone applications greater than 3 ton/A in no-till fields.

Resources

Explanation of Ag lime quality:

- Reports of lime quality in Kentucky based on testing by the Kentucky Department of Agriculture (Rock Quarry Lime Reports)
- University of Kentucky Extension publication ID-163:, *Agricultural Lime Recommendations Based on Lime Quality*

Calculators for comparing economic value of lime:

- University of Kentucky Cooperative Extension Service (https://www.rs.uky.edu/soil/cal.php)

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

- Bulletin 419 of the Southern Cooperative Series, *Soil Test Methods From the Southeastern United States*

Tobacco

Soils

The use of poorly drained or somewhat poorly drained soils for tobacco production is not recommended. These soils require additional management to achieve good tobacco yields.

Lime

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

Rates—If water pH is below 6.4, consult Table 7 and use the limestone rate appropriate for a target pH of 6.6.

Nitrogen

Rates—Nitrogen fertilization rates (see Table 10) depend primarily on field cropping history and soil drainage class. See Table 1 for soil drainage classes. Rotation to other crops is strongly recommended after two 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 in tobacco production, particularly on well-drained soils where a good liming program is followed, and soil pH is maintained between 6.0 and 6.6. If soil pH is moderately to strongly acid (less than 6.0) 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 Mn toxicity. Use these sources (or ammonium nitrate or potassium nitrate) for sidedressing because nitrate-N is more mobile in soil than ammonium-N. Regardless of soil pH, if tobacco is grown on sandy soils or soils that tend to waterlog, using ammonium-N sources (urea, ammonium nitrate, ammoniated phosphates, ammonium sulfate, nitrogen solutions) will lower the risk of leaching and denitrification losses.

Time and Method—The entire N 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 N as near to transplanting as possible will significantly lessen the chances of loss. Apply the N after primary tillage and use secondary tillage to incorporate the fertilizer into the surface soil.

Because losses of fertilizer N can occur on sandy soils or soils with poor drainage, it is helpful to split N applications on these soils, applying one-third of the N before transplanting and the remaining amount two or three weeks after transplanting.

Further efficiencies in N use, decreased Mn toxicity, and increased early growth can be obtained by banding (sidedressing) most of the N after transplanting, even on well-drained soils. These bands should be placed on either one or both sides of the row, 10 to 12 inches away from the row, at a depth of 4 to 5 inches. The N 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 N is applied after transplanting, the rate from Table 10 should be reduced by 15 to 25 lb N/A.

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

N Levels	Soil Drainage Class	
	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.

Animal Manures

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

Phosphate and Potash

Rates—Phosphate (P_2O_5) and potash (K_2O) fertilizer additions should be guided by soil testing. Summaries of Kentucky soil test results have revealed relatively high levels of P and K in many fields with a history of tobacco production. Some fields may only require N for the current crop due to high levels of residual P and K. Growers are encouraged to take full advantage of soil nutrients to help reduce their fertilizer expenses and reduce potential environmental concerns associated with nutrient runoff. Based on soil test results, apply the recommended P_2O_5 and K_2O rates indicated in Table 11.

Sources—Spring applications of K_2O for tobacco should ideally be made using a combination of muriate of potash (0-0-60) and sulfate of potash (0-0-50). One hundred pounds per acre of 0-0-60 supplying 60 lb K_2O/A can be applied without negative impacts on leaf quality. Recent research has suggested that including muriate of potash in spring K_2O applications can help reduce TSNAs in cured leaf for both burley and dark tobacco. The balance of the K_2O requirement should be supplied by sulfate of potash because spring applications of Cl-containing fertilizers at rates greater than 50 lb Cl/A (100 lb muriate of potash) can lead to excessive levels of Cl in cured leaf. Excessive Cl levels in leaf lead to increased moisture retention, curing and storage problems, decreased combustibility, and ultimately, reduced quality and usability. Recent shortages of sulfate of potash mean growers must consider other alternatives such as sulfate of potash-magnesia (sul-po-mag, K-mag, 0-0-22) or potassium nitrate (13-0-44) to meet their K_2O needs. Another option for growers to consider is fall applications of muriate of potash on medium or fine textured soils. Fall application allows time for a portion of the Cl to leach below the root zone, limits the uptake of Cl in the tobacco crop and reduces K_2O fertilizer expenses. Leaf Cl levels are higher with fall muriate of potash application than they are when sulfate of potash is used but generally remain below the industry accepted standard of 1% Cl in cured leaf.

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

Category	Burley and Dark		Burley		Dark	
	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-water pH is below 6.6. Field trials have shown that setter water applications are equally effective as broadcast applications in supplying Mo. Molybdenum can be purchased in dry solid or liquid forms. Either source is satisfactory when Mo is needed.

Soil Broadcast—Apply at a rate of 1 lb of sodium molybdate (6.4 oz of Mo) per acre. Dissolve this amount of dry sodium molybdate (or add 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 full tank. Adding the dry material before filling the tank will aid in dissolving and mixing. A 2.5% liquid source of Mo 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 full tank.

Boron

Boron deficiency has been reported on tobacco in Kentucky. A common symptom noticed by burley and dark tobacco growers is leaf breakage. The midrib of the leaf is typically broken or cracked about 1-2 inches from the point of attachment to the stalk. Often there are a series of what appear to be small slits in the underside of the mid-rib near the area of the break. Another symptom observed on young tobacco is bud yellowing and distortion, eventually resulting in bud death in severe cases. Occasionally, a hollowed area has been observed in the pith of the stalk, just below the bud. Boron deficiency has been observed more often in dark tobacco than in burley tobacco and is often associated with soils that have a soil-water pH above 7.0. In fields with a high soil pH or a history of B deficiency, a broadcast application of 0.25 to 0.5 lb B/A is recommended. The B application may be made as a pre-transplant broadcast spray or as a foliar spray after transplanting. As with all micronutrients, care must be taken to avoid over-application that could lead to toxicity. Recent research with transplant water applications of B showed that as little as 0.5 lb B/A, delivered in 300 gallons of transplant water per acre, was enough to cause B toxicity symptoms in young transplants.

No other micronutrient deficiencies have been reported for field grown tobacco in the areas where burley and dark tobacco are typically grown. Improper rates of certain micronutrients could result in toxicity to the plant, so they are not recommended on tobacco unless a deficiency has been identified. In lieu of a reliable soil test for most micronutrients, the best method to identify potential micronutrient deficiencies is tissue testing. Tissue sample results can be compared between normal and suspect plants within the same field to help guide corrective actions.

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 N, 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* (agr163.pdf) 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 per 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, the float water N concentration should be maintained between 75 and 100 ppm. Inexpensive conductivity meters can be used to monitor fertility levels in float bed water. For additional information see University of Kentucky Extension publication *AGR-174:, Using Conductivity Meters for Nitrogen Management in Float Systems*. The initial fertilizer application to float water can be made at seeding. 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, consult Table 6 and use the limestone rate appropriate for a target pH of 6.4.

Nitrogen

See Page 3 for the basis of N rate recommendations. Nitrogen rate recommendations are largely influenced by the previous crop, tillage, soil drainage class, presence of a cover crop and N loss inhibitor use. Table 12 provides N-rate guidance for previous crop, tillage practice and soil drainage class. Refer to Table 13 when heavy cereal cover crop residues are present and N loss inhibitors are being considered. Other adjustments to N rate recommendations, considering differences in N application timing, N placement, and use of irrigation are discussed below. See also ID-139: *A Comprehensive Guide to Corn Management in Kentucky*, Chapter 7: "Fertility Program Components Resulting in Excellent Corn Nutrition."

Winter Legume Cover Crops—A winter legume cover crop can provide a substantial amount of N for corn with either no-tillage or tillage. Research conducted by the University of Kentucky on no-tillage corn indicates that legume cover crops can provide yield advantages beyond that provided by fertilizer nitrogen (a rotation effect). Hairy vetch and crimson clover have performed better than big flower vetch in central Kentucky, but big flower vetch performed well in western Kentucky. Other benefits of a dense killed legume cover crop mulch, including soil moisture conservation, general weed suppression, and soil erosion control, are the same as those expected from a dense winter cereal cover crop.

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 cover crop seeds, like vetch, are 'hard' and can remain in the soil for one or more years before germinating. This can result in 'volunteer' vetch in small grains grown in rotation with corn that must be considered in small grain weed control programs.

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.

Adjustments to Nitrogen Recommendations

Irrigation—The nitrogen rate on irrigated corn should be increased by 10 to 25 lb N/A over the rate recommended for dryland corn grown under otherwise similar conditions due to increased risk of depletion of available N from crop uptake, leaching, and denitrification.

Delayed N—See Table 13 for recommendations for well/moderately well-drained soils. For somewhat poorly/poorly drained soils, the total rate of N can be decreased by 25 lb N/A if as much as two-thirds of the N is applied 4 to 6 weeks after planting.

Table 12. Recommended nitrogen application rate (lb N/A) for dryland corn.[1]

Previous Crop	Tillage[3]	Soil Drainage Class[2]	
		Well and Moderately Well Drained[4]	Somewhat Poorly and Poorly Drained[4]
Corn, Sorghum	No-Till	160-190	175-205
	Tilled	150-180	165-195
Soybean, Small Grain, Fallow	No-Till	140-170	155-185
	Tilled	130-160	145-175
Grass, Grass-Legume (≤ 4 years), Winter Annual Legume Cover Crop	No-Till	110-140	125-155
	Tilled	85-115	100-130
Grass, Grass-Legume (≥ 5 years)	No-Till	85-115	100-130
	Tilled	60-90	75-105

1 Assumes no cereal rye cover crop ahead of corn planting. Assumes no N loss inhibitor used.
2 Soil drainage class examples are given on Page 2.
3 No till: no primary or secondary tillage, fall or spring, prior to planting the crop. Tilled: any primary or secondary tillage, fall or spring, prior to planting the crop.
4 Somewhat poorly or poorly drained soils that have been tile drained should be considered moderately well-drained soils.

No Tillage and Soil Drainage—On somewhat poorly to poorly drained soils, the risk of denitrification loss is significantly greater from N applied to corn pre/at planting. Alternative practices may include:

- Delayed N application as noted above
- At planting, use the maximum N rate found in the appropriate range in Table 12
- At planting, use the minimum N rate found in the appropriate range in Table 12, but also use a nitrification inhibitor compatible with N sources that include urea, N-solutions, or anhydrous ammonia (see University of Kentucky Extension publication AGR-185 below, for additional information).

Surface Applied Urea—Volatilization losses of N from urea containing products can be significant when these are surface applied after May 1. See University of Kentucky Extension publication AGR-185, Nitrogen Transformation Inhibitors and Controlled Release Urea (AGR185.pdf), for specific information on products designed to reduce N loss. See Table 13 for associated adjustments to the recommended total N rate, especially when at least two-thirds of the total N is applied 4 to 6 weeks after planting (V3-V4 growth stage). Alternative urea management practices include:

- Injection/placement below soil surface at application
- Incorporation or irrigation/rainfall within two days after application.

Phosphate and Potash

The P_2O_5 and K_2O rate recommendations are intended to build and maintain available soil P and K at levels sufficient to ensure P and K nutrition for optimal crop yield with good management and weather while minimizing applications that have a low probability of a benefit. Refer to Table 14 for P_2O_5 and K_2O rate recommendations for corn grain production. For corn silage production, see Table 21.

Zinc

Where Zn deficiency of corn has previously occurred or is suspected, a Zn soil test is helpful in determining if Zn should be applied. Table 15 gives the soil test Zn levels at various soil pH and soil test P levels below which a response to Zn fertilization is likely to occur. However, many other factors, including weather conditions and cool soil temperatures, affect soil Zn availability to corn. This makes it difficult to predict a response to added Zn for a specific growing season. Zinc additions can be broadcast or banded. Broadcast Zn fertilizer rates are substantially higher than banded rates and should raise the Zn soil test to acceptable levels for several years.

Table 13. Cereal cover crop and/or urease inhibitor use:[1] Recommended total nitrogen application rate (lb N/acre) for no-till dryland corn where two-thirds or more of the total N rate is top/side-dressed[2].

Previous Crop	Cereal Cover Crops[3]	Recommended Total N Rate (lb N/A)	
		No Inhibitor[2]	With Inhibitor[2]
Corn, Sorghum	No	160-190	150-180
	Yes	185-215	165-195
Soybean, Small Grain, Fallow	No	140-170	135-165
	Yes	165-195	150-180

[1] Considers only well/moderately well drained soils and only corn, sorghum, soybean, small grain or fallow previous crops.
[2] N loss inhibitor is a urease/ammonia volatilization inhibitor to be used with delayed, surface applied, urea containing N materials.
[3] Cereal (rye, triticale, wheat, barley) cover crops with heavy biomass (greater than 1,000 lb dry matter/A) due to early planting date and/or higher seeding rate and/or later termination date.

Table 14. Phosphate and potash rate recommendations (lb/A), corn for grain.[1]

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	> 60	0	≥ 300	0
Medium	37 - 60	50	209 - 300	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	1 - 5	200	<100	120

[1] For phosphate and potash rate recommendations for silage corn, see Table 21.

Table 15. 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		
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	10 - 15	2 - 3
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		
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	20 - 30	4 - 6
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 right two table columns.

Soybean

Lime

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

Nitrogen

No N fertilizer is recommended for well-nodulated soybean.

Phosphorus and Potassium

Refer to Table 16 for P_2O_5 and K_2O rate recommendations.

Double Cropping of Small Grains and Soybean—The P_2O_5 rate recommendation should be taken from the small grains table (Table 20), and the K_2O rate recommendation should be taken from the soybean table (Table 16). The recommended amounts of P and K fertilizers 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. Inoculum live rhizobia numbers decrease rapidly under dry conditions, with exposure to sunlight and high temperatures, or when dry-packaged with sodium molybdate and fungicides.

Molybdenum

If soils are limed to maintain pH values at 6.2 or above, aluminum (Al) and Mn toxicities, and Mo deficiency, usually do not occur in soybean. However, in soils with pH values below 6.2 at seeding time, Mo application to soybean is recommended to ensure N fixation is not limited by Mo deficiency. Apply 1 to 2 oz of sodium molybdate (0.4 to 0.8 oz of elemental Mo) per acre as a seed treatment. This is a satisfactory method of applying a small amount of Mo when no seed inoculant is needed. Where soybean seed is to be inoculated, including sodium molybdate with the inoculum may seriously lower live rhizobia numbers if the seed is not planted immediately. If both inoculum and Mo are needed, apply inoculum to the seed, and broadcast the Mo on the soil. For each acre, dissolve 1 lb sodium molybdate (6.4 oz Mo) in 20 to 40 gallons of water and spray uniformly ahead of final seedbed preparation. Not more than 2 lb sodium molybdate (13 oz Mo) per acre should be used during any five-year period. Use of Mo should not be used instead of a good liming program.

Manganese

Foliar Mn applications to Mn deficient soybean are superior to soil Mn applications. Recommended foliar Mn sources are: (1) chelated Mn at rates recommended by the manufacturer on the label and; (2) Mn sulfate at a rate of 1.0 to 1.5 lb Mn per acre in 20 to 25 gallons of water. Both should be applied when soybean height is 10 inches or taller. The symptom of Mn deficiency is interveinal chlorosis of the emerging (youngest) leaves. Tissue analysis can also be used to evaluate plant Mn status. The tissue Mn sufficiency range for flowering soybean is 17 to 100 parts per million (ppm) Mn in the uppermost mature trifoliate leaves (petiole discarded). See University of Kentucky Extension publication AGR-92, Sampling Plant Tissue for Nutrient Analysis (AGR92.pdf).

Table 16. Phosphate and potash rate recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	34 - 60	40	191 - 300	60
	28 - 33	50		
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

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

Lime

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

Nitrogen

Fall Application—Only enough N to provide for good ground cover and stimulate tillering, without excessive fall growth that can encourage spring freeze damage, 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— Barley, rye and triticale require less N to optimize yield compared to wheat and oats (Table 17). Nitrogen application between late February and early April is most effective. Where excessive rainfall occurs in late winter or early spring, causing excessive wetness on less well-drained soils, split spring N applications may be justified.

Sources—Experimental results have shown little difference among N fertilizers commonly used to supply N nutrition to small grains. The use of stream bars to apply liquid urea-ammonium nitrate (UAN) reduces leaf burn potential relative to broadcast application.

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 early March. Split application reduces lodging potential. The February application should be made at green-up (typically Feekes 2-3), and the March application should be made at Feekes growth stage 4-5 (just prior to jointing). Green-up may not occur until March in central and northern Kentucky.

Small grains grown as a cover crop are intended to scavenge residual soil nutrients from the previous crop, reduce soil erosion potential, and provide a mulch in the spring for the following crop. Nitrogen should not be added to small grains grown as a cover crop.

Sensor Based Nitrogen Application

Two algorithms, using Greenseeker sensors, have been developed specifically for use with variable rate N applications to wheat in Kentucky. Table 18 is the algorithm for moderately well-drained and well-drained soils and Table 19 is the algorithm for somewhat poorly and poorly drained soils. Field trials using the moderately well-drained and well-drained soil algorithm have resulted in yield increases in intensively managed wheat averaging about 4 bu/A and increased economic 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 each field. These are used as a reference for the Greenseeker sensor at Feekes 6 when 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 shown below. It is recommended that a minimum rate of 20 to 30 lb N/A be applied even in areas where the Differential NDVI is approaching or at a zero value. For additional information see University of Kentucky Extension publication SR-107, *Sensor Technology for Variable-Rate Nitrogen Applications on Wheat in Kentucky (SR107.pdf)*.

Phosphorus and Potassium

Refer to Table 20 for P_2O_5 and K_2O rate recommendations.

Double Cropping of Small Grains and Soybean—The P_2O_5 recommendation should be taken from small grains (Table 20), and the K_2O recommendation should be taken from soybean (Table 16). This recommendation should be applied in the fall before seeding the small grain.

Table 17. Spring nitrogen rates (lb N/A), small grains.

Small Grain Crop	Application Timing	February[1] (Feekes 2-3)	March [1] (Feekes 4-5)	Single[2] (Feekes 4-5)	Total
Wheat and Oats	Single[2]	0	0	60-100[3]	60-100[3]
	Split[4]	30-60	75-45	0	105-120[5]
Barley, Rye and Triticale	Single[6]	0	0	35-75	35-75

1 Nitrogen application times (growth stages) for split applications.
2 Single N applications should be made at Feekes 4-5, typically around mid-March.
3 Use lower N rates on fields with a yield potential less than 70 bu/A and higher N rates on fields with a yield potential greater than 70 bu/A.
4 Use lower N rates for February N on fields with less than 70 tillers/ft^2 and higher N rates with thinner stands, less than 70 tillers/ft^2.
5 For fields established after soil tillage, reduce the total N rate by 20 lb N/A.
6 Current research shows no yield advantage to split N applications or total N rates higher than 75 lb N/A for barley, rye or triticale.

Table 18. 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 19. Final algorithms for use with Greenseeker for variable rate nitrogen applications at Feekes 6 wheat on somewhat poorly to 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.

Table 20. Phosphate and potash rate 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	45 - 60	40	187- 300	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

Corn Silage and Small Grain Hay/Silage

Because the entire plant is removed, silage/hay production results in higher 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 nutrient amount can be supplied via appropriate use of animal manure from either on or off-farm confined animal enterprises. For additional information see University of Kentucky Extension publications AGR-17, Double Crop Silage Production (agr17.pdf), and AGR-165, The Agronomics of Manure Use for Crop Production (agr165.pdf).

Lime

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

Nitrogen and Zinc

Fall-applied N for small grain is usually not needed, but most producers apply some if they use 18-46-0 or 11-52-0 for fall phosphate 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 barley, rye and triticale should not exceed 75 lb N/A or 120 lb N/A for wheat and oats (Table 17). There is no Zn recommendation for Kentucky small grains.

Nitrogen and Zn applications for corn silage are no different from those for corn grown for grain. See Tables 12, 13 and 15 for specific recommendations.

Phosphorus and Potassium

Refer to Table 21 for P_2O_5 and K_2O rate recommendations. For double-crop silage, all the P_2O_5 can be applied in the fall before small grain planting if total fall N does **NOT** exceed 30 lb N/A. Potash should be applied before **EACH** crop is planted, according to **EACH** crop's K_2O rate recommendation, to minimize luxury consumption of K (see Page 19 for additional information).

Table 21. Phosphate and potash rate recommendations (lb/A) for corn, small grain and double crop silage production.

Category	Test Result: P	P_2O_5 Needed			Test Result: K	K_2O Needed	
		Corn	Small Grain	Dbl-Crop Silage		Corn	Small Grain
Very high					>420	0	0
High	>60	0	0	0	355 - 420	50	50
					336 - 354	60	50
					318 - 335	70	50
					301 - 317	80	50
Medium	41 - 60	50	40	90	282 - 300	90	80
	37 - 40	50	50	100	264 - 281	90	80
	33 - 36	60	60	120	242 - 263	90	80
	28 - 32	70	70	140	226 - 241	100	80
					209 - 225	110	80
					191 - 208	120	80
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

Grain Sorghum

Lime

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

Nitrogen, Phosphorus, and Potassium

Nitrogen needs are less than those for corn, but P_2O_5 and K_2O requirements are similar. Refer to Table 22 for recommended N rates and to Table 23 for P_2O_5 and K_2O rate recommendations. All N fertilizer sources are acceptable for grain sorghum production. Different sources have different N loss potentials that should be considered when choosing an N source and the application timing and method. Refer to the corn N management section (pages 11-12) for methods to improve fertilizer N use efficiency.

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 N+K_2O/A. 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 rate 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, consult Table 6 and use the limestone rate appropriate for a target pH of 6.4.

Nitrogen, Phosphorus, and Potassium

Fall N Application—Only enough N to provide for good root growth and ground cover 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 N Application—Applications between late February and late March are the most effective. This coincides with spring green-up. All N should be applied before stem elongation to prevent damage to the main stem from ground spreading equipment. Apply 120 lb N/A to canola if the previous crop was corn, small grains, soybean, or fallow/set-aside. Apply 90 lb N/A when the previous crop was grass-legume or legume sod.

Phosphorus and Potassium

Consult Table 24 for P_2O_5 and K_2O rate recommendations.

Double Cropping of Canola and Soybean—The P_2O_5 recommendations should be taken from canola (Table 24), and the K_2O recommendation should be taken from soybean (Table 16). This recommendation can be applied in the fall before seeding the canola.

Table 24. Phosphate and potash rate 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

Hay and Pasture

New Seedings

Lime

If water pH is below 6.6, consult Table 8 and use the limestone rate appropriate for a target pH of 6.8 for alfalfa or alfalfa-grass production. For long-term production of alfalfa or alfalfa grass forage, it is important to maintain pH between 6.5 and 7.0. For all other forage legumes, cool-season grasses, or legume-grass mixtures consult Table 6 and use the limestone rate appropriate for a target pH of 6.4.

Nitrogen

Apply 0 to 30 lb N/A at seeding of 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.

Phosphorus and Potassium

Hay production removes a large amount of K, relative to P, and more than is removed in grain crop production. For this reason, producers must start with good fertility, maintain a good soil testing program, and make sure to provide adequate K fertility for stand longevity. The P_2O_5 and K_2O rate recommendations for new seedings of alfalfa, alfalfa-grass, clover and clover-grass for hay and pasture are found in Table 25.

Surface Mine Reclamation

See Page 4 for more details.

Molybdenum

If soils are limed to maintain pH values at 6.2 or above, Al and Mn toxicities, and Mo deficiency, usually do not occur in forage legumes. However, for soils having pH values below 6.2 at seeding time, Mo application to forage legumes is recommended. Apply at the rate of 1 lb of sodium molybdate (6.4 oz 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 using no-till establishment. It is recommended that not more than 2 lb of sodium molybdate (12.8 oz Mo) 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. Live rhizobia numbers 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 pastures, new seedings.

Category	Alfalfa, Alfalfa-Grass, Clover, Clover-Grass		Alfalfa, Alfalfa-Grass		Clover, Clover-Grass		Cool-Season Grasses			
	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 lb P/A and 270 to 300 lb K/A 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

If water pH is below 6.2, consult Table 6 and use the limestone rate appropriate for a target pH of 6.4. For alfalfa or alfalfa-grass, use Table 8 to find the limestone rate appropriate for a target pH level of 6.8 when the water pH is below 6.6.

Nitrogen, Phosphorus, and Potassium

Topdress N applications 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 (Table 28).

Consult Table 26 for P_2O_5 and K_2O rate recommendations for established stands of legumes and grass-legume mixtures.

Boron

For alfalfa production, apply 1.5 to 2.0 lb B/A 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 B. If soil test B exceeds 2.0 lb B/A, additional B should not be applied.

Higher Yields

For an alfalfa yield above 5 ton/A and a red clover yield above 3 ton/A, fields should be soil sampled every year to monitor available soil P and K levels.

Luxury Consumption of Potassium

Luxury consumption of K is a phenomenon that all alfalfa producers should be aware of and should try to avoid. Luxury consumption occurs when the 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. A good practice to limit luxury consumption of K is to make two applications - after the first and third harvests. This will limit luxury consumption, provide K nutrition and improve alfalfa stand health prior to winter dormancy. 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 (*AGR210.pdf*).

Table 26. Phosphate and potash recommendations (lb/A), hay and pastures, established stands of legumes and grass-legume mixtures, annual topdressing.

Category	Alfalfa or Alfalfa-Grass				Clover or Clover-Grass			
	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 Table 6 for the limestone rate appropriate for 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 Aug. 1 to Aug. 15. Be sure any increased grass growth is grazed off before legume renovation.

Annual Topdressing of Nitrogen, Phosphorus and Potassium

Topdress N applications 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 (Table 28).

Consult Table 27 for P_2O_5 and K_2O rate recommendations for clover or annual lespedeza renovation of established grass.

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. Live rhizobia numbers decrease rapidly under dry conditions, with exposure to sunlight and high temperatures, or when dry-packaged with sodium molybdate and fungicides.

Molybdenum

Molybdenum deficiency does not usually occur in forage legumes when soil pH is 6.2 or higher. However, with soil pH values below 6.2 at seeding, Mo application to forage legumes is recommended. Apply at a rate of 1 lb of sodium molybdate (6.4 oz 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 Mo) per acre should be used during a five-year period.

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

Hay and Pastures

Established Stands of Cool-Season Grasses

Lime

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

Phosphorus and Potassium

Hay production removes a large amount of K, relative to P, and more than is removed in grain crop production. For this reason, producers must start with good fertility, maintain a good soil testing program, and make sure to provide adequate K fertility for stand longevity. Potash deficiency in hay fields is common due to high K removal coupled with infrequent soil sampling. Table 29 contains the recommended amounts of phosphate (P_2O_5) and potash (K_2O) for established stands of cool season grasses.

Topdressing With Nitrogen

Cool-season grasses such as tall fescue, bluegrass, timothy, orchardgrass, and bromegrass grow best from early spring into early summer and then again, as temperatures cool, in the fall. If moisture, soil pH (6.0 to 6.4), and soil test levels of P and K are adequate, the use of N can greatly stimulate their growth during these peak production periods. Topdress N rates should depend on what is expected from the grass. In stands with less than 25% clover N 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 utilized, N fertilization is not an economical choice.

Pasture Nitrogen Management

In general, N applications are not recommended in the spring and early summer for pastures with low grazing pressure or stocking rates (Table 28). In this situation most grass pastures will have a forage surplus from late April through mid-June, even without additional N. 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 N. 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, potentially crowding out the legume stand component.

Topdressing with N in late spring, following a graze down, will increase growth that will carry over into the normally low summer production period. But given the typically lower response of N at this time of year, the cost-benefit needs to be evaluated 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 high quality new 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. Stockpiled 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.

Grass Tetany—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 Mg. For prevention of grass tetany, a general recommendation is to provide a high Mg mineral supplement (15% Mg) at least 30 days prior to calving. Applying fertilizer containing Mg to offset potential grass tetany problems is NOT effective. There is little guarantee that the plant will take up the additional applied Mg when soil test Mg 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" (ID226.pdf).

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 lb N/A 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 N/A 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

Long-term research indicates that pure grass stand dry matter can be increased from about one ton per year with no N up to about 4 ton 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 to additional N will be. The cost-benefit to this practice needs to be evaluated on a case-by-case basis. The higher the value of the product (e.g. pure orchardgrass in small square bales), the more likely the cost-effectiveness. 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 are generally uneconomical since the legume component produces "free" N via biological N fixation.

Late summer N applications 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 N applications for hay production less advantageous than those 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 topdressed urea will not be as effective as other N sources due to N volatilization losses. Average efficiency values for topdressed 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 protects the urea-N. However, urease inhibitors are only effective for up to 14 to 21 days after application. Research also indicates that the efficiency of liquid nitrogen (UAN, urea-ammonium nitrate solution) applied after early May is greater than that of urea, but lower than that of 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 (AGR185.pdf), for specific information on products designed to reduce N losses.

Hay and Pastures

Warm-Season Forages

Annual Sudangrass, Millets, Sorghum-Sudangrass Hybrids

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 limestone at a rate appropriate for a target pH of 6.4 (Table 6). If the stand is already established, apply limestone at a rate needed for a target pH of 6.4 when the water pH is less than 6.2. Apply 60 to 100 lb N/A at seeding plus 40 to 60 lb N/A topdressed after first and second graze downs or hay clippings. Apply phosphate and potash according to soil test results (Table 30).

Bermudagrass

Bermudagrass is a perennial warm-season grass with a high yield potential that responds well to greater nutrition.

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 limestone at a rate appropriate for a target pH of 6.4 (Table 6). If the stand is already established, apply limestone at a rate needed for a target pH of 6.4 when the 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 N/A 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 at green-up. A N 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 graze down. The last N application should be made by mid-August. Apply P_2O_5 and K_2O according to soil test results. Table 31 summarizes N, P_2O_5 and K_2O rate recommendations. Consult University of Kentucky Extension publication AGR-48. Bermudagrass: A Summer Forage in Kentucky (AGR48.pdf), for management details.

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.

Do not apply N 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. For increased yield, an additional 40 to 60 lb N/A can be applied after harvest in June or July. Apply P_2O_5 and K_2O according to Table 32. See University of Kentucky Extension publication AGR-145, Native Warm-Season Perennial Grasses for Forage in Kentucky (AGR145.pdf), for detailed information on management.

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.

Hay and Pastures

Horse Pastures

Lime

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

General Fertility Requirements

As with all pastures, soil samples should be taken from horse pastures every two years. Then pastures should be amended with lime (see above) and P_2O_5 and K_2O containing fertilizers (Table 35) according to soil test recommendations to maintain vigorous growth of desired grasses and legumes and provide competition against undesirable weeds. Pasture fertilization is not a sound approach to alleviate macro- and micronutrient deficiencies of grazing animals. These problems are better addressed by more direct action, such as feeding mineral supplements.

Topdressing Nitrogen on Cool-Season Grass Pastures

The need to topdress nitrogen (N) on horse pastures in Kentucky is often less than that for cow-calf pastures because the goal with mature horses is weight/condition maintenance, whereas the goal on most beef cattle pastures is to maximize calf weight gain while maintaining cow condition. 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 grow most vigorously from early spring to early summer and then again in the fall into early winter. When soil moisture, pH (>6.0), and soil test P and K levels are adequate (P >30 lb/A, K >200 lb/A), fertilizer N will stimulate cool-season grass growth during these peak production periods. 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. Stimulating grass growth in the spring can be helpful to maintain a high stocking rate, but frequent clipping will be required to maintain pasture quality in a lightly stocked horse pasture. Late spring N applications may have the unintended result of promoting the growth of summer weeds. In tall fescue 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) in broodmares.

Nitrogen fertilizer rate recommendations for cool-season grass horse pastures are given in Tables 33 and 34. At low stocking rates, on productive soils (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 dense grass stand, then one late fall application between late October and early November is sufficient. If fall pasture growth is important, then apply N between mid-August and mid-September. For suggested dates and N application rates for horse pastures managed at a low stocking rate, see Table 33.

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 in 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

At higher stocking rates, on productive soils (1 acre 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. A n Napplication 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 if moisture is available. The major limitation to summer N fertilization is the stimulation of summer weed growth. Excessive N application 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 steep 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 (https://websoilsurvey.nrcs.usda.gov/app/). 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 from October 15 to May 1 there is little difference among the N sources commonly used for topdressing cool-season grasses. Between May 1 and October 15 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 (AGR185.pdf), 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. Consider using stream bars when applying N solutions. 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. See AGR-200, *Soil Sampling and Nutrient Management in Horse Pastures* (AGR200.pdf).

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 limestone at a rate appropriate for a target pH of 6.4 (Table 6). 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 P_2O_5 and K_2O 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. Examples of the various plant species are given 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 (https://trace.tennessee.edu/utk_agexfish/5/)

The soil pH should be maintained between 5.8 and 6.4. If the water pH is below 5.8, apply limestone at a rate appropriate for a target pH of 6.4 (Table 6). Most of the seeding mixtures recommended for wildlife food plots contain one or more legume species that will add N 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 the appropriate 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 P_2O_5 and K_2O according to Table 38.

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.

Native Grassland Restoration

Native warm-season grasses can be planted on 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 use warm-season grasses for 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 native warm-season grasses, see University of Kentucky Extension publication AGR-145 *Native Warm-Season Perennial Grasses for Forage in Kentucky* (AGR145.pdf).

Fertilizer should not be applied at seeding (usually May to early June). Fertilizer, particularly N, 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 ton/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 into the top 4 to 6 inches of soil before seeding using the rates recommended in Table 39.

For seeded turfgrass, nutrient applications may commence following the first mowing event. The time from sowing to mowing allows the turfgrass to establish a root system, which is essential for the uptake of applied nutrients. Following the first mowing, nitrogen may be applied at 1.5 lb N/1,000 sq ft and should not exceed the annual N recommendation detailed in University of Kentucky Extension publication AGR-212, *Fertilizing Your Lawn* (AGR212.pdf). Applications of P_2O_5, K_2O and Mg should be made based upon soil test results and follow the rate recommendations in Table 40.

For sodded turfgrass, nutrient applications may commence 30 days after planting for two reasons. First, the sod normally contains nutrients from the last fertilizer application at the sod farm. These nutrients are often sufficient to maintain acceptable turfgrass growth during the first 30 days following planting. Second, until new roots have grown into the soil, applied nutrients have little chance of being absorbed and used by the turf. After the sod has been planted for 30 days, N may be applied at 1.5 lb N/1,000 sq ft and should not exceed the annual N recommendation detailed in Table 41. Consult University of Kentucky Extension publication AGR-212, *Fertilizing Your Lawn* (AGR212.pdf) for additional information . Applications of P_2O_5, K_2O and Mg should be made based upon soil test results and follow the rate recommendations in Table 40.

For sprigged turfgrass, N may be applied weekly during the first 10 weeks following sprigging or until the turfgrass is fully established. It is recommended that the amount of N applied each week be relative to the percentage of turfgrass establishment (1 lb N/1,000 sq ft equals 100% establishment). For example, if the turfgrass is 25% established during week 2, then only 0.25 lb of N/1,000 sq ft may be applied during week 2, 50% establishment = 0.5 lb of N/1,000 sq ft, and so on. Applications of P_2O_5, K_2O and Mg should be made based upon soil test results and follow the rate recommendations in Table 40.

Maintenance of Turf

Lime—Based on soil test pH values, apply limestone at rates recommended in Table 39, but do not apply more than 70 to 100 lb limestone/1,000 sq ft at any one time. Additional needed limestone can be supplied in additional applications at three to six month intervals.

Nitrogen—Apply 0 to 1.5 lb N/1,000 sq ft per application or 0 to 60 lb N/A. The frequency of N applications depends on the level of overall maintenance. Low and medium maintenance levels are recommended for general lawns like schools, commercial lawns and many home lawns that receive little or no summer irrigation and need fewer N applications. The high and very high maintenance levels usually require some irrigation, more N applications and a high mowing frequency (see Table 41).

See University of Kentucky Extension publication AGR-212, Fertilizing Your Lawn (AGR212.pdf), for more specific details on lawn fertilization.

Phosphate, Potash, and Magnesium—According to soil test results, apply P_2O_5, K_2O and Mg at rates indicated in Table 40.

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.

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

Soil Test Level lb/A	lb/1,000 sq ft		
	P_2O_5	K_2O	Mg
Adequate > 30 P > 200 K > 40 Mg	0	0	0
Inadequate < 30 P < 200 K < 40 Mg	1-2.5	1-3	See Table 4[1]

[1] Magnesium levels are usually adequate in Kentucky and response is rare.

Table 41. Recommended numbers of, and months for, N applications for both cool- and warm-season grass turf at low, medium, high and very high maintenance levels.

Maintenance level	N Applications/Year[1]	Cool-Season[2]	Warm-Season[3]
Low	1	Oct - Nov	June
Medium	2	Sept- Oct Nov- Dec	May, July
High	3	Sept - Oct Oct - Nov Nov- Dec	April, June, Aug
Very high	4	Sept- Oct Oct - Nov Nov- Dec Late May - Early June (½ rate)	April, May, June, Aug

[1] 1 lb N/1,000 sq ft per application.
[2] Kentucky bluegrass and tall fescue. Red fescue and all cool-season grasses grown in shady lawns should be fertilized only once per year.
[3] Bermudagrass and zoysiagrass. Zoysiagrass needs only a minimal amount of N after the lawn is fully established.

Tree Fruits, Blackberries, Raspberries, and Grapes

New Plantings

Lime—Limestone should be applied according to soil test pH values three to six months before planting and plowed and disked deeply into the soil. 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 6.4 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 6, Tables 6, 7 and 8, using the table appropriate to the target pH, and apply limestone at the recommended rate.

Nitrogen—Nitrogen fertilization rates depend on the field cropping history and soil types. Broadcast 80 lb N/A (2.9 oz N/100 sq ft) or, if a legume cover crop is plowed down prior to planting, 40 lb N/A (1.5 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 when applied at planting time.

The above recommendations are only for establishment. 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* (Home_Fruit_Fertility_Guides_2016.pdf).

Phosphorus and Potassium

Refer to Table 42 for P_2O_5 and K_2O rate recommendations for tree fruits, blackberries, raspberries and blueberries. Refer to Table 43 for P_2O_5 and K_2O rate recommendations for grapes.

Magnesium

Fruit crops require more Mg 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 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, P_2O_5, K_2O and Mg adjustments for fruit crops are much more effective when performed prior to planting. It is very difficult to incorporate the required nutrients if they are not plowed or cultivated deeply into the soil prior to planting.

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 analysis should be coupled with a recent soil analysis to provide a complete nutrient status evaluation. Tissue analysis allows a grower to determine when any essential nutrient is low and then to correct the problem before crop health and growth are reduced. Tissue analysis should be done every 2 to 3 years. See University of Kentucky publication HortFact-3001, *Fruit Crop Tissue Analysis* (HortFact-3001.pdf) or contact your county Extension agent to obtain information and source plant analysis kits.

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

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 value to 4.5 to 5.2. If available soil Ca levels are below 2,500 lb Ca/A, the site can usually be effectively acidified. At soil Ca levels above 2,500 lb Ca/A, the soil has a higher cation exchange capacity (CEC)/buffer capacity. A higher CEC is an indication of higher resistance to pH change. Consequently, considerably more acidifying material is required to lower pH and becomes difficult and prohibitively expensive. Elemental S application is the most inexpensive way to lower soil pH, but this reaction only occurs when the soil is warm since the conversion of S to sulfuric acid is performed by soil bacteria. The process is slow, and application and incorporation of S should be done at least six months before planting. A full year is required for a complete reaction. Ferrous sulfate may also be used to decrease soil pH. The reaction is more rapid than when using S since ferrous sulfate disassociates directly into Fe and sulfuric acid. However, this is considerably more expensive than S and eight times more ferrous sulfate is required to give the same acidification as S. 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. See University of Kentucky Extension publication HO-60, Growing Highbush Blueberries in Kentucky (HO60.pdf), for further information on lowering soil pH.

Phosphorus, Potassium and Magnesium

Refer to Table 42 for P_2O_5 and K_2O rate recommendations for blueberries. Refer to Table 44 for Mg rate recommendations for blueberries.

Soil pH, P_2O_5, K_2O and Mg adjustments for blueberries are much more effective when performed prior to planting. It is very difficult to incorporate the required nutrients if they are not plowed or cultivated deeply into the soil prior to planting. If K_20 is needed for blueberries it is best to use sulfate of potash (K sulfate, 0-0-50) instead of muriate of potash (K chloride, 0-0-60) to avoid root burn.

Nitrogen—Nitrogen fertilization rates depend on the field cropping history and soil types. Broadcast 80 lb 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 N for blueberries where continued lowering of the soil pH is desired. Ammonium sulfate is sidedressed at the rate of 0.1 lb fertilizer/plant at bloom and 6 weeks later the first season, and increased by 0.1 lb fertilizer/plant in subsequent years until a rate of 0.3 lb fertilizer/plant is reached. Urea is used when the soil pH is below 5.0. Avoid using calcium nitrate as a N source as blueberries utilize the ammonium (NH_4) form of N and do not do well with the nitrate (NO_3) form of N.

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

Once soil pH has been brought below 5.0 and is stable, blueberries should be fertilized with urea because this N source will not continue to reduce soil pH at the same rate as ammonium sulfate. Growers should be aware that oak or hardwood mulches tend to gradually increase the pH of an acid soil since these mulches release organic anions balanced by Ca, not H, cations as these mulches break down. Pine sawdust, chips or needles are an ideal mulch for blueberries, if available, as pine materials do not contain much Ca 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 44. Magnesium rate 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

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

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

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 is between 6.0 and 6.5. See Table 6 and apply limestone at a rate appropriate for 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 N per 100 sq ft), broadcast before planting. Side-dressing 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 weed competition.

For an early fall application, apply 30 to 40 lb N/A between August 15 and 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.

Phosphorus, Potassium and Magnesium

Refer to Table 46 for P_2O_5 and K_2O rate recommendations for strawberries. Refer to Table 44 for Mg rate recommendations for strawberries.

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* (HortFact-3001.pdf), or contact your county Extension agent to obtain information and source plant analysis kits or contact one of the companies listed in HortFact-3001 to obtain 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 P_2O_5 and K_2O according to soil test as recommended in Table 46. Fertilization should be done before any cultivation during renovation.

Types of Fertilizer Application

Broadcast—Apply fertilizer over the top 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 off 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.

Table 46. Phosphate and potash recommendations for strawberries.

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 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

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