Oklahoma Forage and Pasture Fertility Guide

E-1021

Oklahoma Cooperative Extension Service
Division of Agricultural Sciences and Natural Resources
Oklahoma State University

Editors

Brian Arnall
OSU Department of Plant and Soil Sciences, Nutrient Management Extension Specialist, Stillwater, Oklahoma

Alex Rocateli
OSU Professor, Department of Plant and Soil Sciences, Stillwater, Oklahoma

Contributing Authors by Alphabetical order

Brian Arnall
OSU Department of Plant and Soil Sciences, Nutrient Management Extension Specialist, Stillwater, Oklahoma

JJ Jones
OSU SE Area Agriculture Economics Specialist, Ada, Oklahoma

Brian Pugh
Extension Area Agronomist, Northeast District, Muskogee, Oklahoma

Alex Rocateli
OSU Professor, Department of Plant and Soil Sciences, Stillwater, Oklahoma

Heath Sanders
OSU Area Extension Agronomy Specialist, Duncan, Oklahoma

Jason Warren
OSU Department of Plant and Soil Sciences, Soil and Water Conservation Extension Specialist, Stillwater, Oklahoma

Hailin Zhang
OSU Department of Plant and Soil Sciences, Soil Fertility Extension Specialist, Stillwater, Oklahoma

Production Editor and Graphic Design

Gayle Hiner
OSU Ag Communications Specialist, Stillwater, Oklahoma

Thanks to Oklahoma Fertilizer Checkoff program for providing some funding for printing.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Director of Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. This publication is printed and issued by Oklahoma State University as authorized by the Vice President for Agricultural Programs and has been prepared and distributed at a cost of $4,980 for 1,000 copies. Revised 0218 GH.

Table of Contents

Foreword

Damona Doye
Assistant Director, Oklahoma Cooperative Extension Service

The forage and hay produced on Oklahoma farm and pastureland plays a huge role in the maintenance and production of the 5 million head of cattle and calves, which makes Oklahoma the fifth largest cattle producing state in the nation (Oklahoma ranks third in cow-calf production). In addition, hay sold off the farm accounts for approximately $500 million of income to hay producers in the state every year. Appropriate fertilization is almost always the key to proper livestock nutrition, economic stocking rates, yields, weed control, stand viability, length of grazing/production season and sustainability of the plant-animal system. Unfortunately, varying soils, climate, plant materials, grazing/haying objectives, pests and prices can complicate the fertilization decisions. One decision sometimes made is to “let mother nature provide” - after all, grass of some sort has been growing out there for years. Economically savvy producers in Oklahoma will not choose this as a base plan.

The authors of the Oklahoma Forage and Pasture Fertilization Guide realize that for each producer to make the right decision for his or her operation, a guide providing research-based information is a necessity. This circular is just such a guide. It is designed to help producers with the complex fertilization questions they face. The Oklahoma Forage and Pasture Fertilization Guide is unique in that it covers simple management practices in addition to a range of complex interactions related to forage and pasture fertility. It offers practical situations that can be used by producers. No other publications match the breadth of the Oklahoma Forage and Pasture Fertilization Guide. This publication is designed to support forage and livestock producers, Extension educators and Certified Crop Advisers in effective, profitable and environmentally sound management decisions regarding forage and pasture fertility practices. It is not a replacement for good management; rather, it is the road map to help good managers get even better.

Chapter 1: Nitrogen chemical and physical reactions in pasture soils

Brian Arnall

Nitrogen, or N, is an essential nutrient and the most commonly observed yield-limiting factor, with the exception of water. N is needed as it is an important part of amino acids, which are the building blocks of proteins. N is also a component of chlorophyll and necessary for vegetative growth. There is a great deal of N present in Oklahoma soils. For every 1 percent of organic matter, or OM, in the soil there is approximately 1,000 pounds of N in an acre furrow slice. Unfortunately, only a very small amount of that N may become available during the growing season. This is because much of that OM is in a form that is resistant to decay. Approximately 2 percent of the N in OM is made plant available per year. This means that the soil contributes about 20 pounds of N per acre a year to the crop per one percent of OM.

Plant available N is generally found in the soil in two forms; ammonium, or NH_4, and nitrate, or NO_3. Both of these forms may be taken up by plants, but one is mobile in the soil and one is not. NH_4 is immobile as it attaches to the soil particles because it has a positive charge and the soil has a negative charge. On the other hand, NO_3 has a negative charge and is repelled by the soil, so it is mobile. Because of the like charge, NO_3 remains in the soil solution and moves with the soil solution throughout the soil profile. This is critical in deep sandy soils where NO_3 will follow the water as it moves down and generally out of the soil profile.

Understanding N's reactions in pasture soils requires an understanding of The Nitrogen Cycle (Figure 1.1). N is integrally tied to the current environmental conditions and soil organic matter. Two of the most important processes of the N cycle are mineralization and immobilization. Mineralization, transformation of N from organic compounds to inorganic compounds, is essentially the release of N from organic matter that has decayed. This decay is dependent on microorganisms, which actually requires mineral N. Mineralization of N depends upon the ratio of carbon, or C, and N in the organic matter. Soils with a high C:N ratio are resistant to decay and those with low C:N ratios are conducive to decay and therefore the release of N. When the C:N ratio is greater than 40:1 a net nitrogen tie-up is expected (Figure 1.2). This is referred to as immobilization, the absorption of mineral N by microorganisms. When the C:N ratio of soil organic matter drops below 20:1, a net mineralization will occur. For example, wheat straw typically has a C:N ratio of 80:1, manures' C:N ratio is approximately 23:1 and alfalfa hay's ratio is 12:1. This means when straw is first incorporated into the soil, N will be immobilized. However, if manure, or high protein hay or green manure is incorporated, N will be released through mineralization. The environment also affects these two processes, since microbiological activity is driven by soil temperature and moisture levels.

N fixation is an important process that occurs when legumes are a part of the plant community. N fixation occurs when atmospheric N is converted to soil N by biological mechanisms. Legumes perform symbiotic biological fixation because the bacteria (*rhizombium sp.*) has infected the plant roots and formed nodules. The rhizobium are able to gain energy from the plant and convert atmospheric N into NH_4. Alfalfa is capable of fixing as much as 500 pounds of N per acre per year, but only a small fraction of this N is available for use by other plants unless it is plowed under as the alfalfa itself uses the majority of the N that was fixed. Most

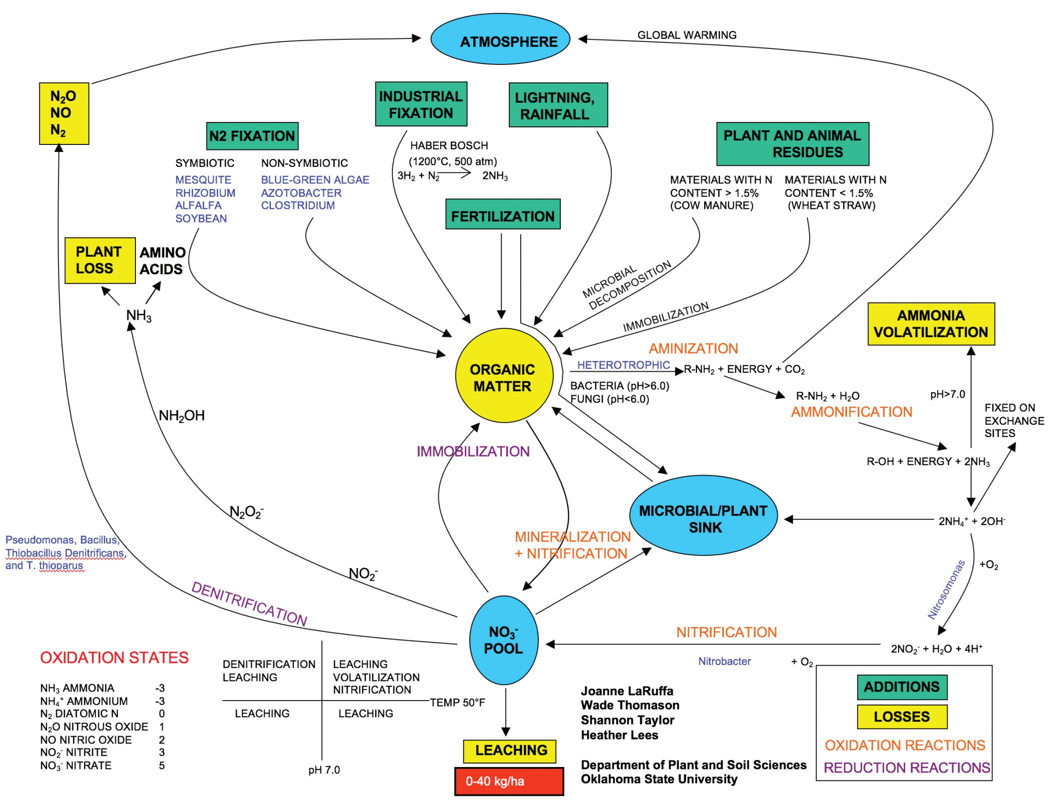


Figure 1.1. The Nitrogen Cycle. Organic matter is situated in the center as the cycle revolves around OM. The blue circles represent N sinks, the green boxes represent the sources of N additions and the yellow boxes represents the four pathways of N loss.

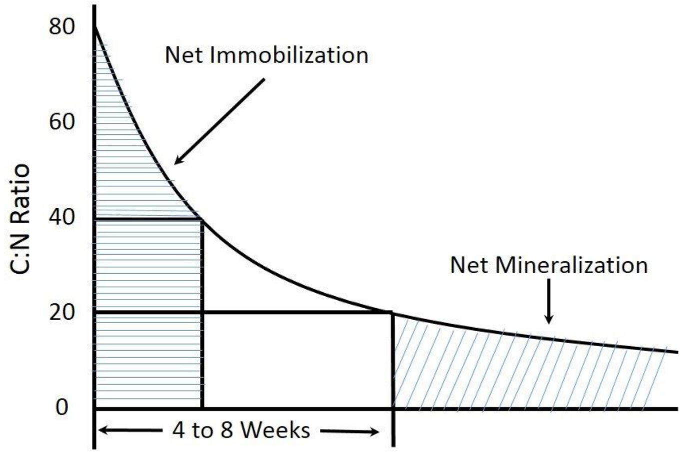


Figure 1.2. The ratio of C:N ratio drives the process of immobilization and mineralization.

clovers are credited with providing an additional 20 to 40 pounds of N per acre per year.

Nitrogen levels are drawn down through the harvest of the forage and through the four pathways within the N cycle. These pathways include:

1. nitrate leaching,
2. ammonia volatilization,
3. nitrous oxide and nitric oxide volatilization in poorly drained anaerobic soils and
4. plant losses of N when N was ambulated in excess within the plant.

The pathways of loss may result in only a small amount of N loss in an average growing season. However, there are years when N loss can be significant. Warm wet conditions generally result in higher rates of N loss.

It is because of removal and natural processes that N is the most limiting nutrient in nonlegume forage production systems, and N fertilization is recommended on an annual basis.

Figure 1.3. In pastures with nitrogen deficiencies "cow pox" or areas of defecation can commonly been seen. These spots are identifiers that yield and production are being lost and additional N will result in more yield.

Chapter 2:
Phosphorus reactions in pasture soils

Hailin Zhang

Phosphorus, or P, is adsorbed by plants mainly as inorganic orthophosphate ions from soil solutions. Organic forms of P in soils or amendments must first be degraded to orthophosphate before being taken up by plant roots. Similarly, P bound to minerals must be desorbed or dissolved into solution prior to plant uptake.

Soil solution P is transported to roots through diffusion (moving along concentration gradients) and mass flow (moving with water flow). Because of the relatively low mobility of P in most soils, mass flow is a less significant mode of P uptake compared to diffusion, except in soils with high P levels. The main soil factors that affect P diffusion are soil moisture, texture, soil temperature and soil P buffering capacity.

Since P is typically broadcast to the surface of pastures and not incorporated, P will accumulate in the top 2 inches of soil. This higher P concentration in the upper 2 inches helps to promote better P transport to plants by diffusion. However, this surface bound P is also more prone to runoff loss compared to incorporated P. Accumulated P in the surface of pasture soils serves as the source of P to the soil solution; the ability of a soil to supply the solution with P is a function of its P buffer capacity. A highly buffered soil will require a large amount of total P to adequately supply the solution P to meet plant needs. Heavy-textured soils tend to be more buffered compared to light-textured soils as indicated by their greater slopes in Figure 2.1. In addition, a well-buffered soil with sufficient soil P levels will maintain an adequate soil solution concentration for a greater period compared to a poorly buffered soil with similar soil P levels. The ultimate result of this effect is that heavier soils require less frequent P applications and higher application rates for increasing solution concentrations compared to sandy soils, which require more frequent P additions at lower application rates (Figure 2.1). If applying enough P to last for two years, the heavy soil would require a greater application rate compared to the sandy soil. Notice Figure 2.1 also indicates that as soils become more saturated with P, an equal application of fertilizer to low and high P soils will increase solution P more in the high P soil compared to the low P soil (i.e. slope of the line increases). This is why low P soils require much more fertilizer P to meet plant needs compared to medium P soils.

In addition to texture, two other soil properties have a significant impact on P reactions--mineralogy and pH. In general, the more weathered minerals that make up soils in eastern Oklahoma have a greater capacity to sorb P compared to the less weathered soils in the west; these more weathered soils are more buffered. In addition, acidic soils tend to sorb P differently from alkaline soils. As a result, the ideal soil pH for maximizing P solubility and, thus, plant availability is about 6.5.

Chemical P fertilizer applications can also have an effect on soil pH depending on the form of P added, current soil pH and soil buffer capacity. For example, diammonium phosphate, or DAP, can increase pH among acid soils, while triple super phosphate, or TSP, and monoammonium phosphate (MAP) can decrease pH among alkaline soils. Most chemical P fertilizers are nearly 100 percent soluble, thus P is completely plant available immediately at application. However, the dissolved P quickly sorbs onto mineral and organic surfaces, precipitates into solid minerals and is taken up by microorganisms, decreasing P plant availability with time.

Oklahoma State University pasture P application recommendations are based on the type of grass (i.e. plant needs) and current soil test P levels as determined by the Mehlich-3 test. Note that the P recommendations do not take into account different yield goals. In addition, the recommendations are based on a sufficiency concept, not a build-up approach. The difference is that a sufficiency program supplies only enough P to be adequate for maximum plant growth in the year of application, while a build-up program supplies P in excess of plant needs, thereby causing soil P levels to slightly increase every year. A build-up program may not be economical when the year potential is low, and is not a recommended practice due to the potential increased loss of P to surface waters through runoff and leaching that may occur.

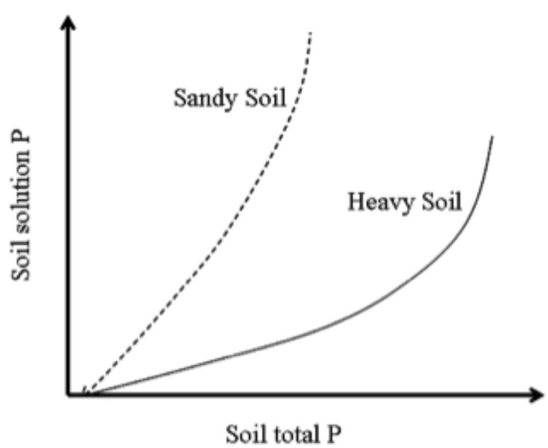


Figure 2.1 Phosphorus (P) buffer curves illustrating the greater P buffer capacity of heavy soils compared to sandier soils.

Figure 2.2. April green-up of tall fescue in Missouri. Left side: 6 pounds of P per acre. Right side: 30 pounds of P per acre.

Chapter 3:
Potassium chemical and physical reactions in pasture soils

Jason Warren

Plants remove large amounts of potassium, or K, from the soil. For example, bermudagrass will generally contain approximately 50 pounds of K_2O per ton. This is nearly equivalent to the amount of N as that can be taken up by a bermudagrass crop (45 pounds per ton). This high concentration of K in the plant indicates the importance of this nutrient for crop growth. K is essential for photosynthesis, starch formation and the movement of sugars within the plant. Although forage grasses are not generally as responsive to K as they are to N applications, it is critically important to maintain adequate levels of K in soils due to the high rate of plant removal. This is especially important in hay production systems where little K is returned back to the soils in the form of crop residues or manure.

Plants take up K from the soil solution in the form of a positively charged cation (K^+). The positively charged K^+ is attracted to negatively charged clay particles. This attraction causes K^+ to be immobile in the soil. The K^+ attracted to clay particles is called exchangeable K and can be readily released into soil solution as plant uptake removes K^+. Therefore, the K^+ in soil solution and the exchangeable K are said to be readily available soil K. However, this readily available K^+ only represents 1 to 2 percent of the total K in most soils. The remainder is referred to as non-exchangeable or relatively unavailable.

Non-exchangeable K, which is also referred to as fixed potassium, represents 1 to 10 percent of the total K found in soils. This non-exchangeable K is found in certain clay minerals that contain pore spaces large enough for the K^+ to become trapped or fixed. This reaction or fixation can occur after fertilizer applications and render fertilizer K less available for crop uptake. However, this fixation can be reversed. In fact, an equilibrium exists among non-exchangeable, exchangeable and solution K. Therefore, as the plant removes K^+ from soil solution more K^+ is released from the exchangeable component. As these two components are reduced, non-exchangeable K is released. In essence, non-exchangeable K serves as a reserve pool. During periods of rapid uptake, the release of non-exchangeable K can be insufficient to meet crop needs and plant growth can be limited. In a warm season pasture, the release of K from the non-exchangeable pool during winter months can cause the pasture to appear unresponsive to K_2O application in the spring. However, if soil test K is below sufficient levels, midseason deficiencies can appear if K_2O is not applied.

Relatively unavailable K is the K that is bound inside soil minerals, such as feldspars and micas. This K represents 90 to 98 percent of the total K in soils. These minerals were present in the parent material from which the soil formed. The release of K in these minerals occurs very slowly through the process of mineral weathering. The K in these minerals is responsible for the inherent K content of soil. In other words, soils formed from parent material containing high amounts of mica and feldspar will generally contain high levels of soil test K.

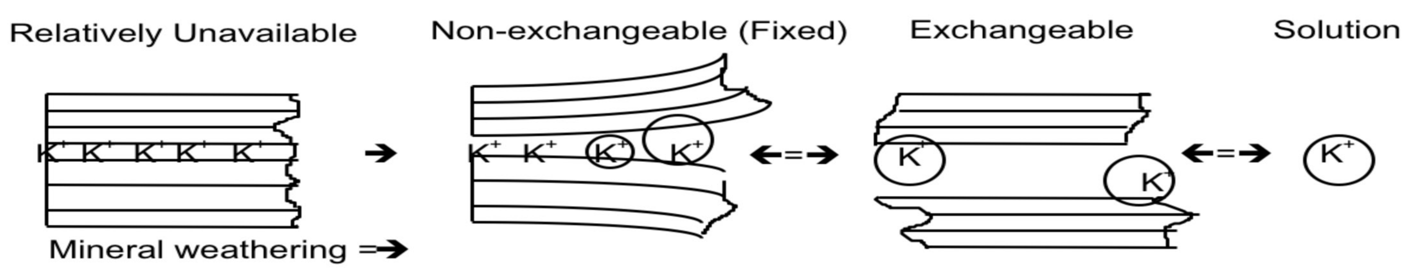


Figure 3.1. Potassium can be found in solution, adsorbed onto clays as exchangeable K, fixed in between clay particles as non-exchangeable K or inside clay minerals as relatively unavailable K.

Chapter 4:
How to take a soil sample and interpret results

Hailin Zhang

Soil Sampling

Soil tests provide a scientific basis for evaluating available plant nutrients in pastures. Analyses of soil samples can help producers adjust soil pH and fine-tune nutrient management plans. Properly managing the amount of nutrients added to the soil can save money and protect the environment. Soil nutrient levels vary by location, slope, soil depth, soil texture, organic matter content and past management practices. Therefore, getting a good soil sample stands out as a major factor affecting the accuracy and usefulness of soil testing.

Before collecting soil samples, the proper equipment must first be obtained. Sample collection equipment commonly consists of a soil probe, clean bucket and soil sample bag. Most of these items are available at your local county Extension office. However, good samples can be collected using a spade if the proper procedures are followed (see PSS-2207 http://factsheets.okstate.edu/documents/pss-2207-how-to-get-a-good-soil-sample/ for more details). Next, sample locations need to be considered; due to the high variability within soils, it is important to sample fields separately. It may be necessary to split a single pasture into multiple zones due to terrain and known difference in soil types.

One composite soil sample from each sampling area/field consists of 15 to 20 subsamples or cores taken to a depth of 6 inches. It is important to take at least 15 cores to ensure that a good average is reached. If too few cores are collected, the laboratory results are likely to be off as shown by Figure 4.1. Take 15 to 20 cores randomly, following a zigzag or W pattern (Figure 4.2) throughout the pasture, avoiding unusual areas such as feeding area, wet areas, urine or manure spots, close to trees and buildings. Put collected core samples into a clean bucket. The cores need to be thoroughly mixed, visible rocks and plant materials removed, and then a soil sample bag should be filled from this mixture. Soil samples may be submitted to your local Extension office.

It is important that these steps are followed to the best of one's ability since the sample represents an average of the soil in that field. The greatest errors associated with soil samples typically come from the collection of the sample. The roughly 1-pound composite sample collected represents an entire field weighing tens of millions pounds. But only 10 grams or less of this soil sample is used in the lab for analysis.

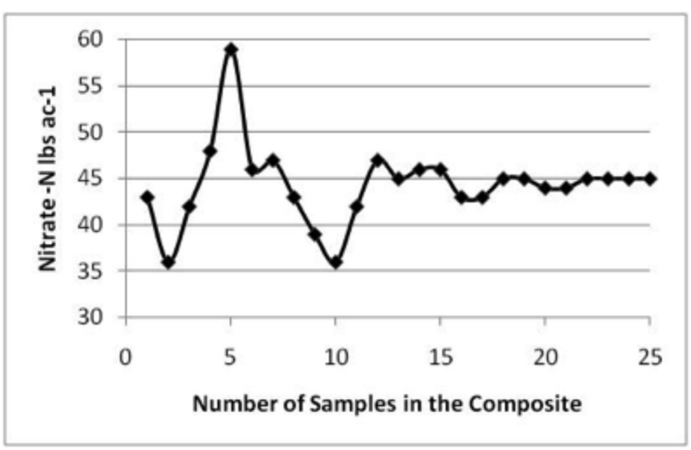


Figure 4.1 The minimum number of core samples needed to make a representative composite sample is about 20.

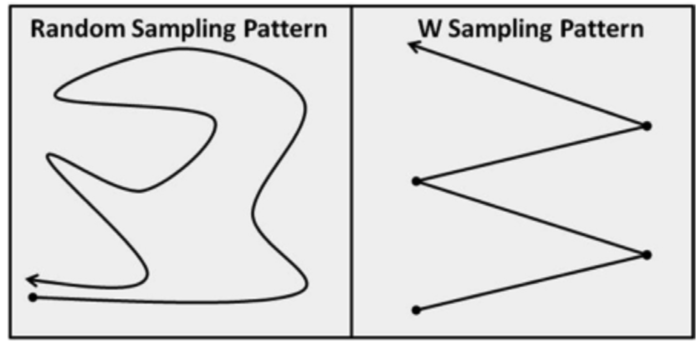


Figure 4.2 Two typical sampling patterns used; random and W. Collecting soil cores from all regions of the field is more important than the pattern used to get the samples.

Interpreting Results

Soil test values must be interpreted so well-informed management decisions can be made. A routine soil test consists of pH, buffer index, nitrate-nitrogen (NO_3-N), plant available P and K. Also available through the OSU Soil, Water, and Forage Analytical Laboratory is analysis for secondary nutrients (Magnesium, Calcium and Sulfer) and micronutrients (Iron, Zink, Copper and Boron). In most forages systems, both secondary nutrients and micronutrients are of little concern.

Soil pH and Buffer Index

Soil pH is the measurement of active acidity or alkalinity in the soil. With normal growing conditions, most plants grow well when soil pH is in the range of 6.0 to 7.5. When the soil pH drops below certain thresholds, yields of different pasture grasses and legumes will be reduced. Therefore, an application of lime should be made.

Buffer index estimates the amount of lime required to correct soil acidity and to bring the pH to the optimum range. The actual amount of lime needed varies greatly depending on soil texture and organic matter content. In general, the lower the buffer index value, the more lime will be required to raise the pH to an optimum plant growing range. Once soil pH is in range, it should be good for several years, but will need to be checked periodically to maintain proper soil pH. For more information on soil pH see Chapter 6.

Nitrogen

Nitrogen is the most important nutrient for forage production. Nitrate soil test measures the actual amount of NO_3-nitrogen in the soil, which is available to plants. Nitrate is mobile in the soil and can be leached if not credited. The amount of nitrate-N can change from year to year if fertilizer is being annually applied. The N fertilizer rate is calculated by subtracting the soil test N value from the N requirement for a grass species at a realistic yield goal. A logical yield goal is calculated by averaging the previous five years yield data and adding 20 percent. For more information on N, see Chapter 1.

Soil Test Phosphorus and Potassium

Phosphorus soil test is the measurement of plant available P in the soil and reported as Soil Test P Index, or STP (equivalent to pounds per acre P) by OSU and parts per million, or ppm, by other labs. If the soil test results come from a 6-inch soil sample, ppm can be converted to STP by multiplying the value by two (OSU STP index = 2 X ppm). The STP value is associated with a percent sufficiency of P in the soil. A soil with 80 percent sufficiency means 80 percent of plant P needs will be supplied by the soil. The remainder must be provided by adding fertilizer. If no P is added, then the yield will only be 80 percent of its potential. To achieve 100 percent potential yield, certain amounts of P needs to be applied through fertilizer. Soil test P values of 65 or greater are considered 100 percent sufficient for all forages, therefore no additional P is needed.

If the soil test results come from a 6-inch soil sample, ppm can be converted to STK by multiplying the value by two. Soil test K values of 250 or greater are considered 100 percent sufficient for most forages and no additional K is needed.

The 100 percent sufficiency STK for alfalfa is 350 since alfalfa requires more K than other forages. Fertilizer K is needed when soil tests indicate less than 100 sufficiency.

An annual application of P and K will be needed until the sufficiency levels of P and K reach 100 percent. If using manure such as poultry litter, P can be over applied and built up in the soil if the application rates are based on N needs. This is because the N:P ratio in the manure is different from the N:P ratio of plant uptake. Fertilizer P is quickly tied up by elements in the soil, so it is important that if soil test P is very low, fertilizer will need to be applied every year or every other year to maintain maximum productivity. It is important to note when P and K are both deficient and no additional nutrients are added, the sufficiency values are multiplied together, resulting in a combined sufficiency value that is the total yield potential for that site.

Example - Soil Test P of 80 percent sufficiency and Soil Test K of 80 percent sufficiency = 64 percent yield potential. So a yield goal of 3 tons per acre of bermudagrass is now approximately 2 tons per acre. This is why soil test is a powerful tool to optimize yields and protect the environment by applying only the nutrients needed. Research has shown that it is economical to apply P and K if soil tests call for them.

Chapter 5:
Common pasture fertilizers and how they react in pastures

Brian Arnall

It is important to understand the difference between fertilizer sources to choose the source that is the best fit for the situation. Purchasing a basic blend of fertilizers is seldom an economically or environmentally sound decision. Introduced species respond quite well to the addition of fertilizers, but it is important to have a soil test performed and a yield goal established before nutrient decisions are made. Chapter 4 discusses the importance of proper soil sampling and soil testing. Make sure a soil test is taken prior to applying P, K or other nutrients besides N. There is no incentive to applying an unneeded nutrient. For example, if ammonium sulfate was used for N when soil sulfur, or S, levels are adequate, the buyer is paying for S that will not increase yield or forage quality. This chapter will aid in the process of choosing the right fertilizer for your optimum blend of N, P and K.

Bulk blending of fertilizers has been a popular method since the early 1960s; allowing the proper ratio of fertilizer elements to be mixed to fit soil test requirements. In Oklahoma, most dry blends are made from combinations of the following: ammonium nitrate, urea, diammonium or monoammonium phosphate and/or concentrated superphosphate and muriate of potash. A blender with four to five bins of bulk straight materials can be blended into any ratio of materials needed. A computer program is available to assist in the calculation of the needed ingredients for a particular blend at: http://www.soiltesting.okstate.edu/Interpretation.htm.

When discussing fertilizer types, there are a few key points to keep in mind. Fertilizers are described by using three numbers, for example 10-20-15. The first number (10 in this case) refers to the percent of N, the second (20) is the percent of P_2O_5 or phosphorus, and the third (15) is the percent of K_2O or potassium. In 100 pounds of 10-20-15, there is 10 pounds of N, 20 pounds of P_2O_5 and 15 pounds of K_2O. Fertilizer labels will list secondary or micronutrient percentages as a fourth value. Soil test recommendations are given in terms of pounds of N, P_2O_5 and K_2O. As is discussed in Chapter 13, it is important to look at the price paid per pound of nutrient, not the price per ton of fertilizer.

What follows is a description, adapted from E-1039, Soil Fertility Handbook, of the most common fertilizers sold in Oklahoma. Table 5.1 also lists the primary fertilizer sources and the nutrient composition of each.

Granular

Urea, $(NH_2)_2CO$. Urea is formed by reacting ammonia and carbon dioxide. All of the nitrogen in urea is in the ammoniacal form. Urea is produced in both prilled and granular forms. It is classified as an organic compound since it contains carbon. As one of the cheapest and safest forms of N to handle, urea is a very popular N source. It does present an issue because of its tendency

Table 5.1. Fertilizer sources of nitrogen, phosphorus, potassium and secondary nutrients.

	Gas, Liquid or Dry	*Nutrient Concentrations*						
		N	*P_2O_5*	*K_2O*	*CaO*	*MgO*	*S*	*Cl*
Nitrogen								
Anhydrous Ammonia	Gas	82						
Ammonium Nitrate	Dry	34						
Ammonium Sulfate	Dry	21					24	
Urea	Dry	46						
Urea Ammonium Nitrate (UAN)	Liquid	28-32						
Calcium Nitrate	Dry	15						
Phosphorus								
Monoammonium Phosphate (MAP)	Dry	11	52		2	0.5	1-3	
Diammonium Phosphate (DAP)	Dry	18	46					
Ammonium Poly-Phosphate (APP)	Liquid	10	34					
Urea-Phosphate	Dry	17	43					
Triple Super Phosphate	Dry		46		12-14		0-1	
Potassium								
Potassium Chloride	Dry			60-62				47
Potassium Sulfate	Dry			50-52			17	
Sul-Po-Mag; K-Mag	Dry			22		11	22	
Secondary								
Calcium Sulfate (Gyspum)	Dry				22		17	
Magnesium Sulfate	Dry				2	10	14	

to lose N through ammonia volatilization when surface applied. This is especially the case in summer grass pastures. If average daily temperatures are above 60 F and there is no rain or irrigation for more than seven days, a great deal of the N may be lost. If urea is used in the summer, delay application until dew has evaporated, unless a rain event is forecast for the near future. Urea inhibitors may be used with urea if risk of volatilization is high and cost of the inhibitor is low, otherwise consider using another N source.

Ammonium Nitrate, NH_4NO_3. Ammonium nitrate is made by reacting anhydrous ammonia and nitric acid. Half of the total nitrogen in the material is in the nitrate form and half is in the ammoniacal form. Most ammonium nitrate is prilled and coated. Ammonia nitrate is an excellent source for summer applied N, the risk of loss significantly reduced when compared to urea.

Ammonium Sulfate, $(NH_4)_2SO_4$. Ammonium sulfate is formed by reacting ammonia with sulfuric acid. All of the nitrogen is in the ammoniacal form. Ammonium sulfate is an effective source of sulfur since it contains 24 percent S. All N sources can cause acidity, but ammonium sulfate lowers the pH even more so. In the soil the sulfate ion is released and forms bisulfate, lowering the pH of the soil. For this reason, the use of ammonia sulfate on acidic soils should be avoided. It is a good choice for alkaline soils with a high pH.

Diammonium Phosphate, DAP, $(NH_4)_2HPO_4$. This popular N-P material is produced by reacting ammonia and phosphoric acid. All of the N is in the ammoniacal form, and the P is highly water-soluble. It is produced in the granular form and is often blended with urea. DAP has a high initial pH (8.0), so it is preferred on acidic soils and neutral soils. However, the use of DAP in alkaline soils could increase the risk of ammonia volatilization.

Monoammonium Phosphate, MAP, $NH_4H_2PO_4$. This material is produced by reacting ammonia and phosphoric acid. All of the N is in the ammoniacal form and the P is highly water-soluble. Most MAP is produced in the granular form. MAP has a low initial pH (3.5-4.0), so the use of this fertilizer in acid soils is not recommended because it could lead to an increased tie up of P.

Potassium Chloride (Muriate of Potash), KCl. This is the K salt of hydrochloric (muriatic) acid. Most potash deposits are in this form. It is the most popular potash material used in fertilizers. Muriate of potash is a crystalline material. It is available in various particle sizes, which are chosen to coincide with other materials for bulk blending. Some muriate of potash contains iron coatings, giving it a reddish color. Most muriate of potash is white or translucent. Color or particle size does not affect potassium availability for plant growth, since it is a water-soluble compound. In addition, potassium chloride is the major source of potash for liquid fertilizers. The fine soluble 0-0-62 grade is used for both liquids and suspensions. About 10 percent K_2O is the maximum that can be dissolved in a liquid, but up to 30 percent K_2O can be carried in a suspension.

Triple Super Phosphate (TSP). This source is produced by treating ground rock phosphate with phosphoric acid. The product will vary from 42 to 46 percent P_2O_5 with the most common analysis being 46 percent P_2O_5.

Liquids

Ammonium Polyphosphate Solutions, APP. The ability to produce 10-34-0 ammonium polyphosphate solution played an important role in the rapid growth of liquid N-P-K fertilizers during the 1960s. Improved storage and application equipment and other technical advances have enabled this growth to continue.

Ammonium polyphosphate solutions can contain up to 70 percent of the total P_2O_5 as a poly-P form. The remaining P_2O_5 is as an orthophosphate. All phosphate fertilizers contain some orthophosphate with many being 100 percent in the ortho form. In fluids, it is generally accepted that high poly content, above 55 percent, improves storage quality and the opportunity to carry low cost sources of micronutrient metals in liquid grades.

Urea ammonium-nitrate, UAN. A common liquid N fertilizer is made from soluble urea and ammonium nitrate mixed in equal parts with water to form a nonpressure N solution containing 28 to 32 percent N. Ammonium nitrate or urea solution, alone, can only be handled satisfactorily in the field, in approximately 20 percent N concentrations. Like any salt solution, N solutions will salt out. Salting out is simply the precipitation of the dissolved salts when the temperature drops to a certain degree. The salting out is determined by the amount and kind of salts in solution. As a general guide, a 28 percent nonpressure solution salts out at about 0 F, and a 32 percent solution will salt out at about 32 F, although this can vary among the materials produced by different manufacturers.

Corrosion inhibitors and a pH near 7.0 in N solutions reduce the corrosion of carbon (mild) steel. The following materials are satisfactory for storing and handling N solutions: aluminum, stainless steel, rubber, neoprene, polyethylene, vinyl resins, glass and carbon steel. Materials that will be destroyed rapidly include copper, brass, bronze, zinc, galvanized metal and concrete.

Nitrogen solutions that do not contain free ammonia can be applied to the soil surface without loss of N. Incorporation is recommended where ammonia volatilization loss from urea may be a problem. Ammonia free N solutions also can be applied in sprinkler irrigation systems with good success. Nonpressure N solutions are probably the most versatile of all N materials for application to a broad range of crops with a wide variety of application equipment.

Caution should be taken when applying UAN with flat fan nozzles, as under warm conditions (65 F or greater), the salt from UAN will burn foliage. This condition is worsened if the tank is mixed with a fungicide or herbicide that requires a crop oil or surfactant.

Chapter 6:

How pH affects pasture soil fertility and forage

Hailin Zhang

Soil acidity is one area of increasing concern in crop production problems. Although acid soil conditions are more widespread in eastern Oklahoma, this problem is increasing with time in central and western Oklahoma. Forage yields and quality may be reduced if the soil acidity problem is not corrected (an example of the benefits of liming is shown on Figure 6.1).

Why Are Soils Becoming Acidic?

Excessive rainfall is an effective agent for the removal of basic ions and causes soil to become acidic. Sandy soils are often the first to become acidic because water percolates rapidly, and sandy soils have a small buffer capacity against pH changes due to the low clay and organic matter content. Since the effect of rainfall on acid soil development is very slow, it may take hundreds of years for new parent material to become acidic even with high rainfall.

Decaying organic matter produces the H^+, which is responsible for acidity. The carbon dioxide (CO_2) produced by decaying organic matter reacts with water in the soil to form a weak acid called carbonic acid. Like rainfall, the contribution to acid soil development by decaying organic matter is generally very small. Harvesting of crops has its effect on soil acidity development because crops absorb lime-like elements, such as cations, for their nutrition. When these crops are harvested and the yield is removed from the field, some of the basic material responsible for counteracting the acidity developed by other processes is lost, and the net effect is increased soil acidity. Increasing crop yields will cause greater amounts of basic material to be removed. Grain contains less basic materials than leaves or stems. For this reason, high yielding forages, such as bermudagrass or alfalfa, can cause soil acidity to develop faster than with other crops.

The use of N fertilizers has been shown to contribute to soil acidity. Acidity is produced when ammonium containing materials are transformed to nitrates in the soil. Nitrogen fertilizer increases yield and thus increases the removal of basic elements and further lowers soil pH.

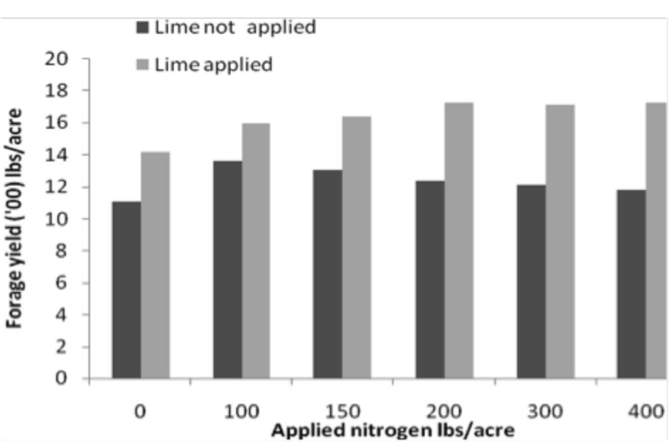


Figure 6.1. Effect of liming and nitrogen fertilization on rye-ryegrass yields in an acidic soil.

What Happens in Acid Soils?

Soil pH determines the solubility of compounds in soils, especially the availability of toxic or nutrient elements. When soil pH is above about 5.5, aluminum, or Al, in soils remains in a solid combination with other elements and is not harmful to plants. As pH drops below 5.5, Al containing materials begin to dissolve, resulting in reactive Al approaching toxic levels. In some soils, manganese, or Mn, reaches the toxic level under acidic environment as well. The availability of some nutrients, such as molybdenum and P, is low due to their solubility or reaction with other elements. Those are just a few of the reasons why crop yields are reduced in acidic soils.

Desired pH for Forages

The acid tolerance or suitable pH is different for different crop species. For example, fescue has better tolerance to low pH than bermudagrass. For most grasses, a soil pH approaching 5.5 will generally restore normal yields. Legumes, on the other hand, do best in a calcium-rich environment and often need a soil pH between 6.0 and 7.0 for maximum yields. Soil pH in the range of 6.0 to 7.0 also is desirable from the standpoint of optimum nutrient availability. Table 6.1 shows desired pH for common forage crops in Oklahoma.

Correcting Soil Acidity

Soil acidity can only be corrected by neutralizing the acids present. This is achieved by adding a basic material. While there are many basic materials that can neutralize acids, most are too costly or difficult to manage. The most commonly used material is agricultural limestone (aglime). It is used because it is relatively inexpensive and easy to manage. Liming raises soil pH and causes Al and Mn to go from the soil solution back into solid (nontoxic) chemical forms. The first step to determine if liming is needed is to conduct a soil test by collecting a representative soil sample. Lime will be recommended if the pH is below the preferred pH of the targeted crop (Table 6.1). The amount of lime required is based on the soil's Buffer Index value (Table 6.2). Different amounts of lime may be needed if two soils have the same pH due to the differences in buffering capacity. The OSU Soil, Water and Forage Analytical Laboratory recommends lime to bring soil pH to 6.5 (Table 6.2).

Table 6.1. Common pH preference of forage crops.

Forages	*pH Range*
Legumes	
Cowpeas, Crimson Clover, Soybeans and Vetch	5.5-7.0
Alsike, Red and White (Ladino) Clovers and Arrowleaf Clover	6.0-7.0
Alfalfa and Sweet Clover	6.3-7.5
Non-Legumes	
Fescue and Weeping Lovegrass	4.5-7.0
Orchardgrass, Ryegrass, Sudangrass	5.5-7.0
Bermudagrass	5.7-7.0

Table 6.2. Tons of ECCE* lime required to raise soil pH of a 6-inch furrow slice to pH 6.5.

Buffer Index	*Lime Needed (tons per acre)*
> 7.1	none
7.1	0.5
7.0	0.7
6.9	1.0
6.8	1.2
6.7	1.4
6.6	1.9
6.5	2.5
6.4	3.1
6.3	3.7
6.2	4.2

*Effective calcium carbonate equivalent guaranteed by lime vendor.

Lime requirements are expressed in terms of effective calcium carbonate equivalent, or ECCE. The ECCE is provided as a guarantee from lime vendors who are registered to sell aglime in Oklahoma. The guarantee is obtained by an analysis of the lime by the Oklahoma State Department of Agriculture, Food and Forestry. There are two components to determine the ECCE by their lab. First, the purity of the lime is determined chemically (purity factor). In this test, the fraction of $CaCO_3$ or its equivalent in the lime material is analyzed. The second measure is a determination of how finely the lime particles are ground (fineness factor). The fineness factor is determined by weighing sieved portions of a lime sample. The factor is then calculated by taking one-half times the fraction (e.g. 0.90) of sample passing an eight mesh sieve plus one-half times the fraction (e.g. 0.70) of sample passing a 60 mesh sieve. The fineness factor for these example values would be:

½ x 0.90 + ½ x 0.70 = 0.80

The purity factor (a fraction) and the fineness factor (a fraction) are multiplied. The result is then multiplied by 100 to obtain the ECCE value. If the purity factor was 0.90 (90 percent pure or equivalent calcium carbonate) then the ECCE would be (0.90 x 0.80) x 100, or 72. The more $CaCO_3$ in the material and the finer the particle size, the greater the ECCE. Good quality lime will have an ECCE value above 50 percent. **Because aglime does not always have an ECCE of 100 percent, the amount required to provide a given amount of 100 percent ECCE must be calculated.** The calculations to use are shown below:

ECCE lime required ÷ % ECCE x 100 = aglime required

For example, assume the available aglime is 65 percent ECCE and the soil test indicated a need for 1.5 tons ECCE to raise the soil pH to the desired level. The calculations would be:

1.5 ÷ 65 x 100 = 2.3 tons of aglime.

So, 2.3 tons per acre of the 65 percent ECCE lime should be applied in order to get the 1.5 tons of 100 percent ECCE lime required to do the job.

Lime Application

Because lime does not dissolve easily in water, it must be treated similarly to immobile nutrients like phosphorus. Thus, for lime to be most effective in neutralizing soil acidity, it must be thoroughly mixed with the soil. Since neutralization involves a reaction between soil particles and lime particles, the better the lime is mixed with the soil, the more efficiently the acidity is neutralized. Once the proper rate has been determined and the lime has been spread to give a uniform application over the field, it is best to incorporate it with a light tillage operation such as disking. Disking can be followed by plowing, but care should be taken not to plow too deeply or the lime will be diluted by subsoil and be less effective.

A similar approach should be used for the planting of grasses. When continuous production of perennial grasses is planned, the full rate identified by the soil test should be applied pre-plant. This practice allows incorporation of the lime to maximize its reaction with the soil and will maintain a desirable pH for several years after establishment. Careful monitoring of high-producing forage grasses, such as bermudagrass, by periodic soil testing will identify lime needs early enough to maintain desirable soil pH by unincorporated broadcast application.

Different Forms of Liming Materials

The most common and most effective liming material continues to be ground aglime. It is marketed by the ton, should generally be powdery with only a small percentage of coarse (sand size) particles and have an ECCE of 50 percent or greater. Variations and different formulations of ground aglime have been developed and marketed. These materials are often promoted on the basis of being more effective or less expensive. The merits of these products should be considered carefully.

Liquid lime is a formulation of high quality aglime (usually ECCE is above 90 percent) with water and enough clay to keep the lime in suspension. The amount of water added may range from 35 to 50 percent. Make sure the water is not included in the charges, and if so, charged as water, not lime. When 90 percent ECCE lime is mixed 50 percent (weight to weight) with water, the resulting product is only 45 percent ECCE lime (90 percent x .50 = 45 percent). The fact that it is suspended in water does not increase its effectiveness. On the contrary, wet lime will not mix as easily with soil; therefore, its neutralizing effectiveness may be less than an equal amount of dry ECCE aglime.

Similarly, water treatment lime may not be as effective as an equal rate of aglime. This material is a waste product from water treatment plants. Although it has a high ECCE, it is often wet when applied and a good mixture with soil is difficult to obtain. Too often, large chunks or globs remain mixed with the soil and only the acidic soil next to the chunk of lime is neutralized, leaving large areas of soil acidic.

Pelleted lime is finely ground lime that is pressed into pellets. Until the pellets physically break up and the fragments of powder size lime become thoroughly mixed with soil, these too are limited in neutralizing soil acidity. Pellets, liquid lime and water treatment lime can be spread or applied without the dust common to good aglime. Although easily visible, airborn dust associated with aglime application represents only a small fraction of the total applied, and loss from the field should not be significant.

Finally, sometimes coarse road grade lime is in abundance and can be purchased at a very low cost. This cheap lime is too coarse to have a reasonable ECCE and will not be sold as aglime. Because of the existing aglime law in Oklahoma, whenever a material is marketed and sold in Oklahoma as aglime, it must be accompanied by a guaranteed ECCE. The guaranteed ECCE must be of the formulated product and not its ingredients.

Chapter 7: Poultry litter use and management in pastures

Hailin Zhang

What is Poultry Litter?

Poultry litter consists of manure, bedding material and other components such as feathers and soil. Wood shavings, sawdust, soybean hulls, peanut hulls or rice hulls are all common bedding materials added to the poultry house floor and utilized for raising multiple flocks on a single placement prior to complete cleanout. After removal from the poultry house, litter is generally land-applied to pastures and cropland as a fertilizer source.

Benefits to Soil

Poultry litter is recognized as an excellent source of the primary plant nutrients N, P and K. In addition, litter returns organic matter, secondary nutrients--such as calcium, or Ca; magnesium, or Mg; and sulfur, or S and micronutrients to the soil, improves soil fertility and quality. Continuous applications of litter have been shown to gradually increase soil pH and neutralize soil acidity.

Nutrient Availability

Nutrients in commercial fertilizer are mostly water soluble and readily available for plant uptake. The N in litter is not 100 percent available to crops during the year of application because much of the N is in the organic form (slow release) and some N can be lost during storage and application (mainly due to ammonia volatilization). Due to this fact, supplementation with commercial N may be necessary to meet the expected yield goal. Table 7.1 lists the estimated N availability in poultry litter, based on application method. Incorporation of litter into the soil reduces ammonia volatilization losses. The availability of P and K in litter is similar to commercial fertilizer since much is found in the inorganic form (fast release) and nearly all is available for plant use during the year of application.

Table 7.1. Estimated poultry litter nitrogen availability based on application method.

Year after Application	*Surface Application*	*Soil Incorporation*
1st Year	50%	60%
2nd Year	15%	15%
3rd Year	6%	6%

Valuing Litter

Poultry litter is commonly valued based on current commercial fertilizer prices (reported as price per pound of a specific nutrient) and the litter nutrient analysis (reported as pounds per ton). For example, if calculating the N, P and K value of broiler litter, we know from Table 7.2 that broiler litter contains an average of 63, 61 and 50 pounds per ton of N, P_2O_5 and K_2O, respectively.

Table 7.2. Average nutrient analyses (as is) of major types of manure in Oklahoma.

Manure Type	*Dry Matter*	*Total N*	*P_2O_5*	*K_2O*
	%	--------------lbs/ton------------		
Feedlot manure	62	24	21	25
Broiler litter	77	63	61	50
		----------lbs/1,000 gal----------		
Lagoon effluent	0.5	4.2	1.0	5.0
Lagoon sludge	7	15	16	11
Dairy slurry	3	13	11	11

Using summer 2017 commercial N, P_2O_5 and K_2O prices of $0.38, $0.32 and $0.27 per pound, respectively, and assuming long-term N availability is 70 percent, the maximum value of litter can be determined.

Litter N: $0.38/lb x 63 lbs/ton x 70% availability =	**$16.8/ton**
Litter P: $0.32/lb x 61 lb/ton =	**$19.5/ton**
Litter K: $0.27 x 50 lb/ton =	**$13.5/ton**
Total Maximum Value:	*** $50/ton**

*** This total maximum value to the end-buyer assumes a soil nutrient deficiency exists for N, P and K.**

There may be additional value derived from organic matter and other nutrients found in the litter. Due to the nutrient variability in poultry litter, obtaining a recent litter nutrient analysis is critical when determining litter value. There are two online tools available to assist producers when comparing the value of litter to commercial fertilizer: the poultry litter value calculator found at http://littermarket.okstate.edu/, and the fertilizer blending and cost calculator found at www.soiltesting.okstate.edu/Interpretation.htm. Finally, loading, transportation and application costs affect the end buyer's total cost and should be considered when comparing the total cost per ton to the total maximum value per ton.

To encourage appropriate use of the nutrients in litter, government programs may be available to subsidize litter management costs. These programs can help reduce transportation costs, increasing litter value as it is more fully utilized as a fertilizer source where it is most needed. Information about current litter transportation incentives can be found at http://poultrywaste.okstate.edu or at the local Oklahoma State University county Extension office.

Application Timing and Litter Availability

Ideally, poultry litter should be applied during active forage growth to reduce environmental contamination risks and maximize nutrient use efficiency. For warm-season grasses such as bermudagrass, late spring application is optimal. However, early fall applications work best for cool season grasses such as ryegrass and tall fescue.

Consideration should be given to poultry litter availability as the supply and demand fluctuates based on transportation costs, commercial fertilizer prices, replacement bedding material availability, timing of house cleanout and other factors. With this in mind, producers wishing to apply litter should have a flexible range of application dates. Some producers may wish to purchase litter during the fall when demand is low and store it under cover for a later application. This practice would help reduce the uncontrolled variables associated with litter availability, allowing for application when needed at the producer's convenience.

Environmental Considerations

Because the nutrient content in litter is not balanced based on annual plant growth requirements, careful consideration must be taken when land applying to avoid over-application of certain nutrients, primarily P. For example, application rates based on N needs could apply too much P. If poultry litter land application is not properly managed, excess nutrient application could degrade water quality. Soil testing, litter analysis and proper estimation of forage yield goal are essential to determine proper agronomic application rates. Litter application rates should follow soil test recommendations based on soil and litter P levels.

Regulations

Oklahoma regulations require that poultry litter must be applied by a certified applicator. To become certified, an individual must apply for an applicators certificate through the Oklahoma Department of Agriculture, Food and Forestry (ODAFF). Additionally, applicators must attend OSU poultry waste management training classes. If a producer is not interested in becoming certified to land apply poultry litter, but wants to have litter applied to their property, they can contract the service to certified commercial applicators. These middlemen often offer loading, transportation and spreading services to the end-buyer of poultry litter.

Anyone applying poultry litter in the state of Oklahoma must obtain a current soil sample on all fields that will be receiving litter. For information on properly taking a soil sample, refer to Chapter 4. Along with a soil sample, a recent litter analysis must be provided. These two documents are used by the certified applicator to determine land application rates. The certified applicator is responsible for submitting these documents along with an applicator report to ODAFF annually. Both soil and litter analyses can be obtained through the local OSU county Extension office.

Land application rates must follow the current Natural Resources Conservation Services (NRCS) Code 590 Standard, which is covered in the OSU poultry waste management training classes. According to state law, all litter being stored must be covered overhead or surrounded by a compacted soil berm to prevent litter movement. Additional information on poultry waste management regulations and training classes can be found at www.poultrywaste.okstate.edu

Summary

When properly managed, poultry litter provides an excellent fertilizer source to pastureland while returning organic matter and raising soil pH. Since the N in litter is slowly released, supplementation with commercial N may be required for optimum forage growth. Many variables affect the overall value and cost of litter to the end-buyer and should be carefully considered prior to purchasing. Increasing environmental concerns and regulations require that litter, along with other manure types, be applied based on agronomic rates to reduce negative impact on water quality.

Chapter 8:
How soil type, depth and structure affect pasture fertility

Brian C. Pugh

There have been many strategies and new technologies discovered over the last century that allow the producer to tailor his or her forage system to their respective property. These strategies can result in large forage yields and increased forage quality through timely management and inputs. Regardless of increased understanding of soil properties, one aspect that is still uncontrollable is the inherent characteristics of the native soil. Ironically, it is this characteristic that ultimately determines the base fertility of the chosen property and the possible shortcomings of the planned forage system.

What does a forage plant need to maintain healthy and high-yielding growth? Much like humans, plants require water, nutrients and air to survive and grow. Soil qualities that promote moisture retention and good aeration are desirable. Plants also need adequate nutrients, which must be supplied either by the soil or through additional fertilizer applications. Additionally, soil conditions that allow for proper root exploration and growth will promote forage quality and health as well as stand longevity. Producers should not be discouraged if their soil is less than ideal because forages are adaptable to various soil properties. Since soil characteristics are very difficult or impossible to change during a lifetime, it is important that we understand the acceptable operating range of these soils for typical forage species and understand ways to improve what we have. The characteristics discussed include soil type, soil depth and soil structure.

Soil Type

Soil type or texture is the classification of soil into the recognizable groups of sands, silts and clays. Figure 8.1 shows the relationship of these three fractions and how to determine where a soil will type. One other term that is used in soil classification, but is not a base soil fraction, is loam. This word literally means an ideal soil. A true loam is 40 percent sand, 40 percent silt and 20 percent clay. Loams hold many benefits to the forage producer and will be discussed further. By modifying the word loam with one of the fraction identifiers, we might end up with a silt loam.

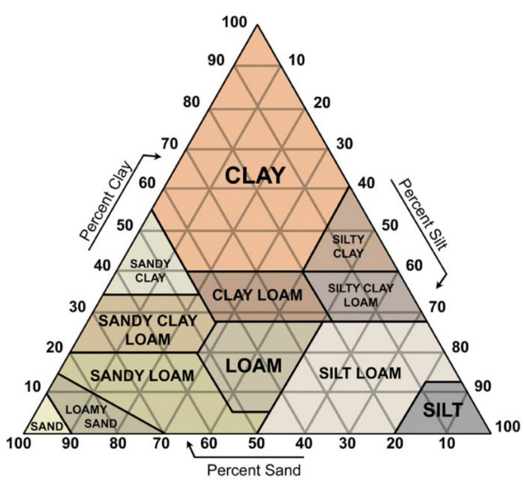


Figure 8.1. Soil textural triangle used for classification of soil type.

This would indicate a soil with a loamy composition that is dominated by silt. This happens to be a very common pasture soil in Oklahoma. Soil type is a characteristic that we cannot change without adding new soil to our pasture. Obviously this is not feasible, so we must try to understand what type of soil is desirable for optimum forage production and how to manage the soil type we have. Soil texture can be determined easily by feel. Figure 8.2 is a flow chart describing the process.

Sand

The sand fraction of soil is typically particles that fall in a size range of 0.05 to 2.0 mm. Due to their large size, sands offer excellent aeration, root exploration potential and water infiltration into the root zone. However, they tend to lose water very rapidly and become droughty. They typically require frequent fertilization and liming. Sand particles have a poor attraction to each other and usually do not form a definite structure within the soil. Because of this, sands are prone to all erosion forces.

Silt

The silt fraction of soils has a smaller particle size ranging from 0.002 to 0.05 mm, the thickness of a human hair. When compared to sand, this smaller size results in an increased surface area, which offers a low to moderate attraction to water and nutrients necessary for plant growth. Silt particles also exhibit moderate attraction to each other, which allows silts to form weak structures within the soil. When this structure is present, silts provide moderate aeration, root exploration and water infiltration. However, if soil structure is absent or destroyed, these soils can become compacted, causing poorer aeration and reduced water infiltration. Dry silt is recognizable as a powder and is very prone to erosion (especially wind).

Clay

The clay fraction of soils has very small particles (less than 0.002 mm) that group tightly together. This can lead to problems with water and air infiltration into the root zone. However, because clays have more surface area than any other fraction, they are excellent at holding moisture and nutrients for later use by plants. The clay fraction is the largest reserve of nutrients for future plant growth. In many cases, a soil high in clay can hold excess nutrients for decades of future plant growth. Clays also resist the change of pH within a forage system much better than sands and silts. Although a lime application may be large on a clayey soil, one application can often last more than 10 years, as compared to small—but frequent—lime applications on sands lasting one to three years. For more information on liming, see Chapter 6. Clay particles have a high attraction to each other, which promotes a solid soil structure (this is why clay is useful for pottery). Wet clay has a “sticky” appearance and becomes hard as moisture is lost.

By understanding these key concepts of the three fractions, it is easy to see why a loamy soil is so desirable for forage production. Loams tend to exhibit some of the benefits from each fraction, while minimizing the negative traits. For instance, silt loams hold enough sand to allow good aeration and root exploration, with silt and clay for adequate water retention, nutrient adsorption and structure.

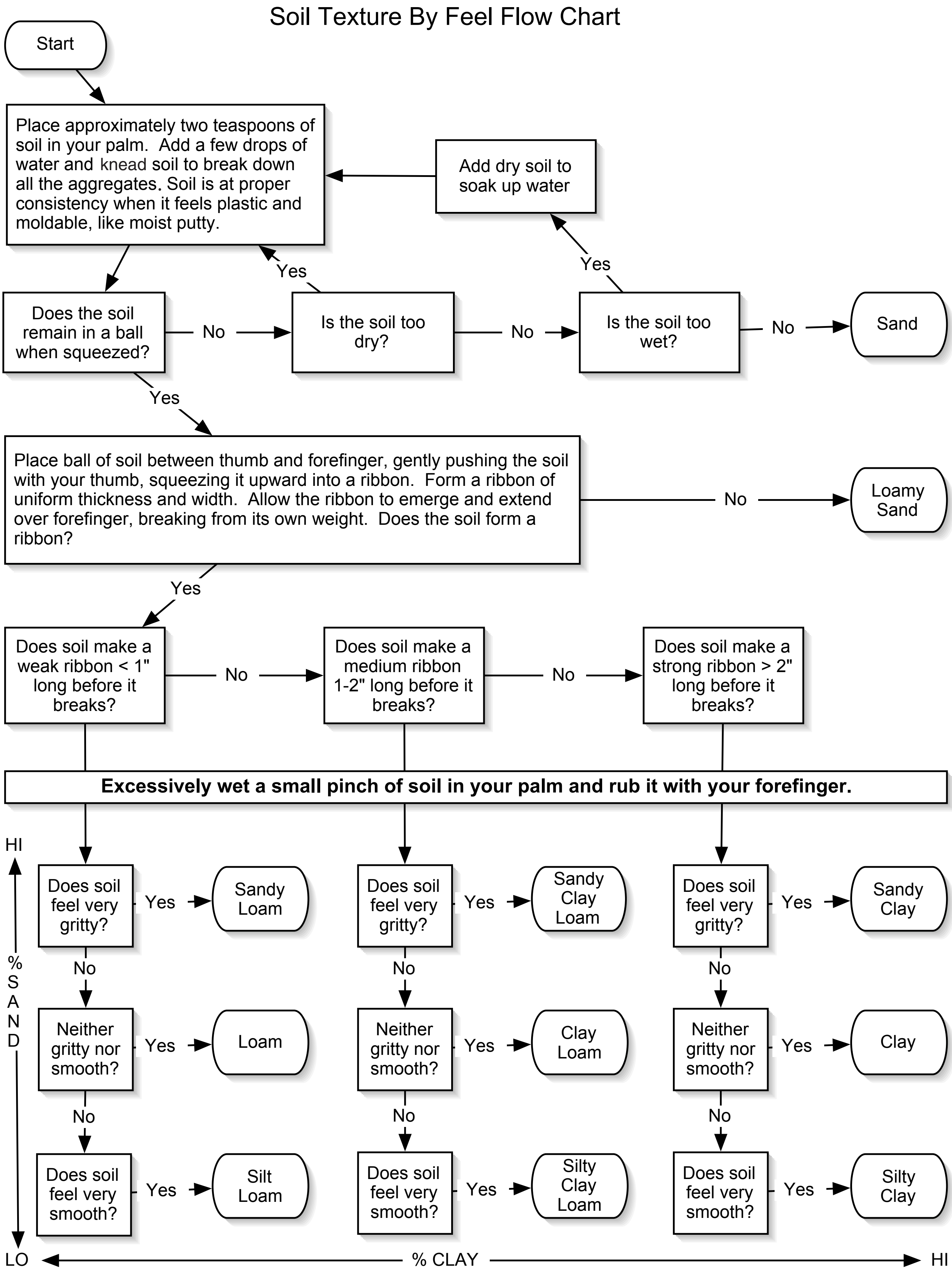


Figure 8.2. Modified from S.J. Thien. 1979. A flow diagram for teaching texture by feel analysis. *Journal of Agronomic Education*. 8:54-55.

Soil Depth

Soil depth is a critical component of high-yielding forage systems because it plays a major role in soil: plant water relations and nutrient availability. In fact, soil depth can play a larger role in forage production than what type of soil a producer has. Typically, deep soils give more room for vertical root exploration, which supplies more nutrients and increased water potential for the growing plant. Many rocky soils are shallow in depth with exposed parent material. These tend to restrict root growth while reducing nutrient and water uptake. These soils also become droughty much quicker due to excessive evaporation of soil moisture. Many producers believe the only factor in soil depth is how far you have to dig to find rock. Yet, to a plant root, this is not the case.

As seen in Figure 8.3, a soil profile is made up of various horizons, or layers. The thickness of the layers is different for each soil type and even within the same field. The uppermost horizon usually seen in healthy pasture soils is the O horizon, or the organic layer. This dark colored layer is comprised of very fertile organic materials in the process of becoming soil (essentially compost). This material is generally comprised of dead plant materials, insects, manure, etc. that have begun the decomposition process. Due to the high organic matter content and structure, this layer is very fertile and excellent at holding moisture. This layer varies in thickness from a few millimeters to 2 inches in prairie soils, and sometimes many feet thick in peat bogs. This layer is rapidly degraded in warm humid climates and lends a great deal of stored nutrients to growing plants.

The next layer down, the A horizon, is generally considered the topsoil. This moderate to dark horizon usually holds the bulk of the available nutrients, can contain moderate amounts of organic matter—which promotes water retention—and contains beneficial microorganisms. For most improved forage varieties, the majority of roots will lie within the A horizon where there is better aeration, more nutrients and improved structure. A good rule of thumb for a healthy forage stand is to have at least a 4-inch A horizon. Typically, as the depth of the A horizon increases, fertility and water-holding capacity also increases. Some A horizons in prairie soils can reach 18 inches in depth.

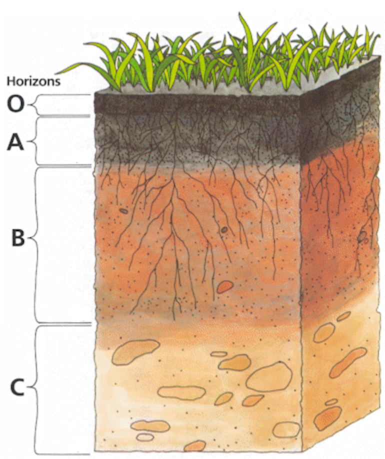


Figure 8.3. Example of a soil profile with common pasture soil horizons.

The B horizon is typically referred to as the subsoil. This light colored layer has valuable nutrients but not in the quantities found in the A horizon. Subsoil is inferior for forage production because generally it has poor soil structure and reduced organic matter, can be "tight" due to high clay content and is therefore low in oxygen. Some Oklahoma soils have B horizons very close to the soil surface. These soils are typically less productive, prone to erosion or droughty. Producers wanting to grow forage with a large portion of the root system in this soil horizon should consider applications of organic fertilizer materials such as poultry litter or cattle and swine manure.

Soil Structure

Soil structure is the natural process of soil assuming formations, and refers to how sands, silts and clays are arranged into aggregates (clumps). These aggregates are typically bound together by clay and organic matter and have a significant impact on forage establishment, growth, productivity and stand life. Structure is beneficial as it allows increased root exploration, water infiltration and aeration, which can promote beneficial microorganism activity. Soil structure can deteriorate over time due to tillage, continued harvesting, continuous irrigation and even excessive compaction. Therefore, this is a soil characteristic that can be improved with a sound management plan.

Summary

It is unreasonable to believe we can significantly change the soil on land we inherited or bought. However, by gaining a working knowledge of the soil type present, producers can better manage their forage crop for maximum production. Utilizing manure applications, alternating hay meadows, maintaining ground cover, along with reducing tillage and compaction will all result in long term structure formation and soil improvement, while preventing the erosion of quality topsoil. This will ultimately increase plant health and desirable soil qualities such as aeration, water infiltration and nutrient retention due to organic matter.

References

Brady, N.C., and R.R. Weil. 1999. *The Nature and Properties of Soils*. Prentice-Hall Inc.

Scott, H., D. 2000. Soil Physics, Agricultural and Environmental Applications. Iowa State University Press.

Zhang, H. and W.R. Raun. 2016. Oklahoma Soil Fertility Handbook. Oklahoma State University Cooperative Extension Publication. Stillwater, OK.

Chapter 9:
Stocking rate and fertility relationships

Alex Rocateli and Heath Sanders

This chapter will discuss the important interaction between fertility and stocking rate and provide tools to determine the fertilizer needs or stocking rate. There are two ways to approach fertility and stocking rate. If the amount of fertilizer to be applied is already known, the stocking rate can be determined from the expected forage yield potential. Alternatively, fertility needs can be determined for a specific stocking density. At the end of this chapter is an example of calculations needed to figure stocking rates and fertilizer needs. The average annual forage production for determining stocking rate is easily determined from previous production records or obtained from the web soil survey data. For more information on how to determine forage production using the web soil survey, access the current report: CR 2597 Assessing Potential Forage Production using the NRCS Web Soil Survey by following the link: http://factsheets.okstate.edu/documents/cr-2597-assessing-potential-forage-production-using-the-nrcs-web-soil-survey/.

The amount of forage produced is multiplied by the harvest efficiency. The result is the amount of grazeable forage, which is the actual fraction of the total forage that is consumed by the livestock. The harvest efficiency changes according to the adopted grazing method (Table 9.1). The grazeable forage is divided by the amount of forage needed per head to determine stocking rate. As an example, a 1,200-pound cow will consume about 30 pounds of forage per day (2.5 percent of body weight). When a slow rotational stocking system is used (two or more pastures), animals graze 60 percent of the forage grown. Of the non-grazed forage, some will be consumed by insects, some will be non-grazeable because of deposited urine and manure, and some will be laid on or trampled. That means only 30 out of 50 pounds of forage will be consumed every day. Thus, it will take approximately 9 tons (50 x 365 = 18,250 lbs.) of forage to meet the animal's annual needs.

The calculated stocking rate should be based on the productivity of the soil and the forage species growing on that soil type. Without additional fertility inputs, forage production is limited. The production potential of a soil can be improved by adding fertility amendments and thereby allowing an increase in stocking rates. All fertilizer decisions should be based on a soil test and the yield potential of the forage being grown. Keep in mind both stocking rate and fertility are not set in stone. If forage management changes result in more forage production or better utilization, then stocking rate and fertility should be adjusted. Based on the animal weight and the potential forage production, land requirement per animal for large and small ruminants can signifi-

Table 9.1: Grazing efficiency based on pasture utilization.

Grazing Method	*Harvest Efficiency (%)*
Continuous Stocking	25 – 50
Slow rotation (2-4 paddocks)	50 – 60
Moderate Rotation (4-6 paddocks)	60 – 70
Strip grazing, MOB, Daily, etc.	70 – 75

Table 9.2: Stocking rate estimates for large ruminant animals. The values given are for the number of acres of pasture required to keep one animal of listed weight for either 365 days or 245 days at 60 percent harvest efficiency. Values assume animal consumption at 2.5 percent of body weight per day. The 365-day values assume the forage requirements will be met from grazing for the entire year. The 245-day values do not include the hay needed for winter feeding programs.

	Grazing for 365 days				*Grazing for 245 days (April-Nov)*			
Cow Wt (lbs)	*Forage Production (tons per acre)*				*Forage Production (tons per acre)*			
	1	2	3	4	1	2	3	4
750	5.7	2.8	1.9	1.4	3.8	1.9	1.2	1.0
850	6.5	3.2	2.2	1.6	4.3	2.1	1.4	1.1
950	7.3	3.6	2.4	1.8	4.8	2.4	1.6	1.2
1000	7.6	3.8	2.5	1.9	5.1	2.5	1.7	1.3
1100	8.4	4.2	2.8	2.1	5.6	2.8	1.8	1.4
1200	9.2	4.6	3.0	2.3	6.1	3.0	2.0	1.5
1400	10.7	5.3	3.6	2.7	7.1	3.5	2.3	1.8

Table 9.3: Stocking rate estimates for small ruminant animals. The values given are for the number of acres of pasture required to keep one animal of listed weight for either 365 days or 245 days at 75 percent harvest efficiency. Values assume animal consumption at 4.0 percent of body weight per day. The 365-day values assume the forage requirements will be met from grazing for the entire year. The 245-day values do not include the hay needed for winter-feeding programs.

	Grazing for 365 days				*Grazing for 245 days (April-Nov)*			
Doe Wt (lbs)	*Forage Production (tons per acre)*				*Forage Production (tons per acre)*			
	1	2	3	4	1	2	3	4
60	0.68	0.29	0.19	0.14	0.39	0.19	0.13	0.1
80	0.77	0.39	0.26	0.19	0.52	0.26	0.17	0.13
100	0.97	0.48	0.32	0.24	0.65	0.32	0.22	0.16
120	1.17	0.58	0.39	0.29	0.78	0.39	0.26	0.19
140	1.36	0.68	0.45	0.34	0.91	0.46	0.30	0.23
150	1.46	0.73	0.48	0.36	0.98	0.49	0.33	0.24
160	1.56	0.78	0.52	0.39	1.04	0.52	0.35	0.26

cantly differ (Tables 9.2 and 9.3). These estimates may be used to help determine stocking rate and nitrogen fertilizer requirements. See chapters 14 and 15 to determine the yield potential and N response of specific forage species. Keep in mind that for native stands, utilization rate which includes not only the forage grazed by livestock but also decomposition, waste and consumption by insects and other herbivores should not be above 50 percent, otherwise stand health will be risked. Furthermore, Table 9.2 uses a harvest efficiency of 75 percent; this is just an estimate, as the rate for small ruminants is not well researched. Setting a sustainable stocking rate on a farm or ranch is important to achieve long-term profitability. Proper stock densities result in better animal performance and lower the cost of animal supplementation.

Overstocking will lead to poor animal performance, low reproductive rates, pasture degradation and increased supplementation. These will reduce the profitability of the forage/animal enterprise. Thus, understanding proper stocking rate is critical for an operation to be profitable. Attention should be paid to the cost of the fertilizer and purchased feeds. In some particular cases, it may be cheaper to buy supplemental feed than fertilizer. Forage production economics are discussed in more detail in Chapter 13.

There are many ways to improve the management of a ranch so that forage production and/or utilization of the forage grown are increased. Visit with the local county Extension educator to find the program that best suits your farming/ranching operation.

The following example provides three common management scenarios that can be used to calculate cattle stocking rates based on forage production.

The Location: 200 acres of bermudagrass pasture; phosphorus, potassium and soil pH are adequate.

Scenario 1: No fertility, no rotational grazing, 1,200-pound cows.

Question: Stocking rate

Typically, 1 ton of production is expected from non-fertilized bermudagrass, so the expected production potential for the 200-acre pasture is 2,000 pounds per acre per year. Thus, this pasture will produce a total forage production potential of 400,000 pounds of forage per year. Without some form of rotational grazing, the expected forage utilization will be 50 percent.

Steps:

1. Calculate available forage by multiplying forage production by percent utilization. So, 400,000 pounds x 0.5 = 200,000 pounds.
2. Determine forage requirement per animal (1,200-pound cows, 30 pounds of forage required per day for 365 days). Then, 30 pounds per cow per day x 365 days = 10,950 pounds per cow
3. Calculate stocking rate using available forage divided by forage requirement per animal. So, 200,000 pounds ÷ 10,950 pounds per cow = 18.3 cows.

The 200-acre bermudagrass pasture could support approximately 18 cows per year.

Scenario 2: 100 pounds of applied N, no rotational grazing, 1,200-pound cows .

Question: Stocking rate

The rule of thumb for bermudagrass fertilization is that 50 pounds of N per acre are required for each additional ton of production. Thus, the production potential would be 3 tons per acre or a total forage production potential of 1,200,000 pounds for the 200 acres.

Steps:

1. Calculate available forage by multiplying forage production by percent utilization. So, 1,200,000 pounds x 0.5 = 600,000 pounds.
2. Determine forage requirement per animal (1200-pound cows, 30 pounds of forage required per day for 365 days). Then, 30 pounds per cow per day x 365 days = 10,950 pounds per cow.
3. Calculate stocking rate using available forage divided by forage requirement per animal. So, 600,000 pounds ÷ 10,950 pounds per cow = 54.8 cows.

The 200-acre bermudagrass pasture could support approximately 55 cows per year.

Scenario 3: No Rotational Grazing, 75 1,200-pound cows.

Question: Nitrogen fertilizer rate

The amount of forage needed to feed 75 cows on 200 acres needs to be then how much fertilizer N has to be added to reach that goal.

Steps:

1. Calculate forage needed per animal. Assuming 1,200-pound cows, 30 pounds of forage required per day for 365 days. So, 30 pounds per day x 365 days = 10,950 pounds required for 365 days.
2. Determine forage requirement for the 75 cows in the herd. So, 75 cows x 10,950 pounds per cow = 821,250 pounds required for the herd.
3. Determine total forage production needs by dividing herd requirement by utilization. So, 821,250 pounds ÷ 0.5 = 1,642,050 pounds forage needed.
4. Calculate total forage needed per acre. So, 1,642,050 pounds ÷ 200 acres = 8,213 pounds per acre (about 4 tons).
5. Using the rule of thumb that 50 pounds of N produces 1 ton of forage, then 3 tons per acre x 50 pounds N per ton = 150 pounds of N per acre.

For a 4-ton bermudagrass yield goal, additional N fertilizer is required for the additional 3 tons of production needed. According to the bermudagrass fertility requirements, 150 pounds of N fertilizer will be needed per acre to produce the additional forage.

Chapter 10:
Hay production and grazing

Alex Rocateli and Josh Bushong

Fertility recommendations for many forage species are well documented and available to producers. However, a statement often heard is "I cannot afford to fertilize my pastures." This statement is usually in response to fertilizer prices, which can be high depending on consumer demand and fertilizer source. Fertilizer costs are the likely reason why many pastures are not properly fertilized. To maximize fertilizer efficiency and to minimize costs is important to fertilize forages according to their yield potential and soil analysis, regardless of the type of harvest management.

The major difference between hay production and grazing is the cycling and distribution of nutrients. Hay production tends to be more straightforward than grazing management. For hay production, forage yield response versus applied N tends to be a straight line between zero and 400 pounds per acre of applied N if other factors are not limiting. This statement is also true for grazed pasture, but the response is seldom seen at high levels of N fertilization. From an economic standpoint, this means that forage yield is limited by the amount of N that a producer can afford. In theory, producers will get the same return for each additional pound of N, up to a total of 400 pounds per acre for most warm-season perennial grasses. Unfortunately, the inconsistency of Oklahoma's rainfall ultimately results in conditions where moisture is more limited than N. Therefore, a response to 400 pounds of N is not always achieved.

In hay production systems, making fertility recommendations is somewhat predictable. N fertilization is performed according to a yield goal, and P and K fertilization is based on removal. In hay meadows, it is assumed that bermudagrass removes N-P-K in an approximate ratio of 4-1-3. Using a 4-ton Bermudagrass hay yield goal as an example, we know that this will require 200 pounds N per acre. Thus, we are removing 50 pounds of P_2O_5 and 150 pounds of K_2O of which some must be replaced annually in marginal soils. Following hay harvest, P and K removal can be determined from forage mineral analysis rather than soil analysis.

Fertility management for grazed pastures is not quite as easy as for hay production. In grazed pastures, forages are growing and being removed concurrently making it impossible to estimate forage production. Thus, the actual yield goal is not estimated which complicates N recommendations. Furthermore, forage mineral analysis will not accurately determine P and K removal in grazed pastures. In this case, soil analysis is essential for accurate P and K fertilization. Unlike hay production, a portion of the nutrients removed by grazing returns to the soil as urine and feces; consequently, the nutrients are not rapidly depleted from the system. Therefore, less fertilization is expected in grazed pastures. The general guideline is that grazing to produce 500 pounds of beef per acre will remove a total of 18 pounds of N, 9 pounds of P_2O_5 and only 1 pound of K_2O. This 500 pounds of beef production requires approximately a production of 4 tons of forage per acre. Furthermore, for short-term grazing, the first 50 pounds of N per acre appears to be the most beneficial since there is a two-fold reduction in the number of acres required to maintain one cow during the summer grazing period (Table 10.1). The differences in fertilization demands between hayed and grazed pastures can be shocking. A hay meadow with a 4-ton yield goal needs to receive 200 pounds of N, while a grazed pasture that supports one cow for four months will only need 50 pounds of N. From this example, it is apparent that a productive bermudagrass hay system requires substantially more nutrients than a grazed bermudagrass pasture.

Table 10.1. Nitrogen requirements for summer grazing based on bermudagrass forage yield goal.

Production goal tons/acre	*Nitrogen[1] lbs/acre*	*Summer grazing (90 days) acres/cow*
1	0	3.3
2	50	1.6
3	100	1.1
4	150	0.8

[1]Non-fertilized grass pastures will generally yield about 1 ton of forage per acre over the growing season. However, this will not be sustainable and should not be considered a long-term solution.

Planning for hay production is usually more straightforward when it is managed separately from grazing. However, in many cases, managing hay separately from grazing may require additional pastures, which increases costs. When nutrients and moisture are adequate, forage production often exceeds livestock needs early in the season. Consequently, hay production can be planned so that some pastures are hayed early, then grazed later to reduce acreage and production costs. Moreover, the decision in which areas to fertilize first relies on the differences in soil type and topography. Fertilization should be applied first in deep, well drained, flat and high responsive soils. In this case, it may be possible to meet all annual pasture and hay production from fewer acres reducing equipment and fertilizer costs.

Unfortunately, pasture fertilization is usually neglected because managers are not aware of its profitability when correctly employed. The positive results of fertilizer application to pastures have been scientifically confirmed. For tame pastures such as bermudagrass, fertility is critical for grass growth. The statement "I cannot afford to fertilize grass pastures" is inaccurate. The fact is that fertility of grass pastures cannot be ignored for reasons related to both economical and optimum forage production.

Chapter 11:
The effects of environment on pasture soil fertility

Brian Arnall

The influence of the environment on pasture soil fertility is just another way of saying that climate, landscape position and soil type have an impact on soil fertility. Obviously, this effect from the environment is out of our control. Relevant climatic factors can be narrowed down into two categories: temperature and moisture.

The biggest influence of temperature on soil fertility is a result from the fact that most chemical and biological reactions slow down with decreases in temperature (in the range of 40 F to 95 F) and at excessive temperature (> 95 F). This means that many processes that help to supply nutrients to the soil solution for plants will not provide as much at lower temperatures. Mineralization of nutrients from organic matter and nitrification of ammonium (NH_4) are good examples of this; at low temperature, the release of N, P, K and S from organic matter to solution is significantly lowered. During a period of dormancy, low temperature and slowed mineralization of nutrients when plants are not actively taking them up can reduce nutrient leaching. Decreased temperature also will reduce the amount of N that is fixed from the atmosphere with legumes. Low soil temperature also is known to greatly reduce P uptake. This occurs because low temperature slows diffusion, which is the mechanism that moves P to plant roots. For this reason, its best to apply P fertilizers (usually diammonium phosphate, or DAP) prior to spring green up. In regard to cold soils, the rule of thumb is that wet soils are cold soils.

With the exception of prescribed burns, fire is another uncontrollable environmental factor that could be placed in the category of temperature. When burning events consume most of the above-ground biomass, it is usually assumed that fire depletes the system of nitrogen. Although soil ammonium and nitrate levels tend to decrease after a burn event, nitrogen uptake by plants will often increase, suggesting that burning increases nitrogen mineralization.

The other significant environmental factor is moisture. Proper moisture levels (not too wet or dry) have an impact on nutrient cycling and availability. Floods resulting in saturated soils can promote P dissolution (process of non-plant available P becoming plant available), thereby increasing availability. Another impact of saturated soils is the loss of N to the atmosphere through de-nitrification. Both de-nitrification and phosphorus dissolution occur in saturated soils because of the depletion in oxygen. Also, if excess water is moving through the soil profile, it can deplete the soil of mobile nutrients such as N, P, sulfur and chloride.

On the opposite end, drought has a negative impact on soil microorganisms, which will reduce both nitrogen fixation by legumes, along with nitrification of ammonium and mineralization of organic N. Also, since plants are mostly unable to take up nutrients in extremely dry soils, the nutrients and ions tend to become more concentrated in the soil. This usually causes the pH to decrease (i.e. become more acidic).

Sometimes a condition occurs in the spring during times with adequate precipitation and plenty of available soil N (perhaps after a fertilizer application) along with low sunlight due to heavy cloud cover. Under these conditions, the plant is not rapidly growing due to the lack of photosynthesis (i.e. low sunlight), and the N can become highly concentrated in the plant. Although not harmful to the plant, this can potentially lead to nitrate toxicity in livestock when consumed.

Chapter 12:
Economics of pasture fertility

JJ Jones

The economics of pasture fertility is a challenging management issue for any operation. From year to year, producers may be confronted by challenges such as increases in fertilizer prices, nutrient deficiencies, drought, stocking rate problems and other issues that could cause them to reevaluate and modify their forage production plan. Generally, it is the cost of fertilizing that affect the producer's forage production plans the most. This chapter will evaluate the costs of fertilizing at different price levels in an effort to determine at what price level using commercial fertilizer becomes too costly.

Before Beginnning

Before any producer starts to analyze their costs of production they must first estimate their forage needs. Type(s) of animal being grazed, number of animals, total days of grazing, pounds of forage consumed per day, forage type, number of acres, projected forage production per acre and fertilizer requirement for projected forage production will need to be either known or estimated before any forage plan can be determined. OSU fact sheet PSS-2584, "Forage-Budgeting Guidelines" has step-by-step instructions that can help producers determine their forage needs. This fact sheet also could be used to determine the amount of hay needed for winter feeding.

Another important step before analyzing fertilizer costs or applying fertilizer is to have a current soil test. Having a current soil test allows a producer to know the correct amounts of N, P and K needed to produce the desired amount of forage. Without a soil test, a producer could fertilize too much or too little and not get the desired results, therefore costing more in either fertilizer expense or extra feed expense. Either way, the cost of the soil test is far less expensive. Soil testing is discussed in greater detail in Chapter 1.

Once a producer determines their forage needs and fertility requirements, they can then start to explore the different options available. It is important to consider all costs involved with each option. For example, if a producer does not choose to fertilize because they have determined prices are too high, but they are not going to reduce livestock numbers, that producer will need to purchase feed or hay for those animals. This cost of purchased hay or feed may be higher than the cost of the fertilizer. In some cases, the cost of the purchased feed may be the least expensive option. In other cases, the least cost option may still add too much cost to the bottom line for the operation to remain profitable. In both cases, other options, such as reduction in livestock numbers or complete herd liquidation, may be the better option. The producer will have to decide which is the best option for their operation.

Nitrogen Fertility Costs

Nitrogen fertilizer comes from several different sources: there is ammonium nitrate (34-0-0), urea (46-0-0), anhydrous ammonia (82-0-0) and urea ammonium nitrate (UAN) (32-0-0). Even DAP has 18 percent N. When pricing N fertilizer it is important to remember not to just price the product on a price per ton, but consider the cost on a price per pound of actual N.

For example, consider having to choose between using ammonium nitrate and urea. The price of ammonium nitrate is $400 per ton and urea is $450 per ton. Which fertilizer is the cheaper N source? Ammonium nitrate has 680 pounds of N per ton (2,000 pounds x 34 percent). At a cost of $400 per ton the price per pound of N would be $0.588 ($400 ÷ 680). Urea has 920 pounds of N per ton (2,000 pounds x 46 percent). At a cost of $450 per ton the price per pound of N would be $0.489. Therefore in this example, urea would be the least cost choice even though it cost more per ton; it cost less per pound of N.

When fertilizer prices start to rise, producers begin to question the feasibility of fertilizing pasture for forage production. The price at which fertilizer gets to high depends on each individual producer's situation. Stocking rates, weather, availability of fertilizer, markets, operational goals, resources and financial situation can influence this decision, but when all variables are considered, it is easy to figure out just how much a producer can afford to pay for fertilizer.

Figure 12.1 compares the costs of feeding an 1,100-pound cow per day with forage grown with commercial fertilizer versus purchased hay. This fertilizer cost assumes that only N was needed to grow one ton of forage. Therefore, 109 pounds of urea was used to get the desired 50 pounds of N needed. The cost of urea started at $300 per ton and went up to $1,000 per ton. This cost is shown by the green columns on the graph. The horizontal lines represent the cost of feeding 1,100-pound cow purchased hay at four different prices. If the green columns are below the colored lines the fertilized forage is cheaper to feed than the purchased hay. When the green columns cross the colored lines, the purchased hay at that price level becomes cheaper to feed than forage grown with urea at that price.

Figure 12.1 shows that the cost the forage grown with urea is less than the cost of feeding hay purchased for $25 per bale until the price of urea reaches $700 per ton. Urea at cost of $700 per ton equals a cost of $0.76 per pound for N. If a producer expected to

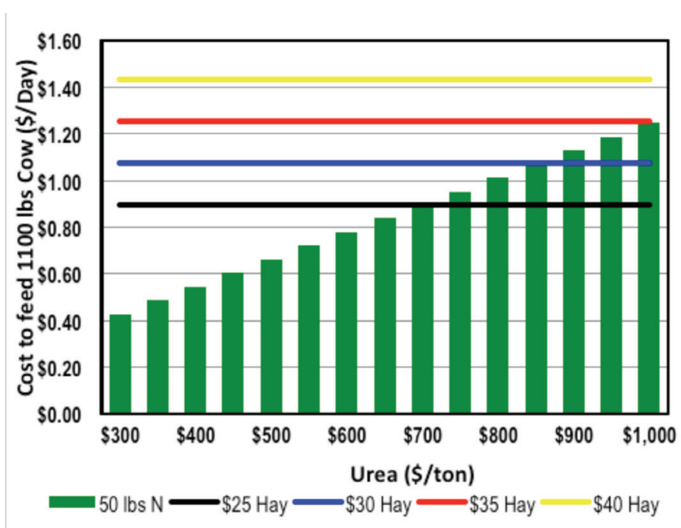


Figure 12.1. Cost of feeding forage grown with N versus purchased hay.

pay $30 per bale for hay then they could afford to pay up to $850 per ton for urea. Therefore, the answer to the question of when N fertilizer becomes too expensive depends on how much a producer expects to pay for replacement forage or hay.

Phosphorus and Potassium Fertility Costs

Unfortunately, N is not the only nutrient typically needed. Most soils will need either P and/or K in order to reach the desired production goals. Adding either of these nutrients adds cost and lowers the tipping point where fertilizer is more expensive than purchased hay.

Figure 12.2 shows the cost of adding 50 pounds of nitrogen and three different levels of phosphorus using urea and DAP. This figure assumes that the price of urea and DAP are the same.

By adding P, the price at which fertilizer becomes more expensive than purchased hay is lower than N alone. Of course how much lower depends on how much P is needed and the price of purchased hay. When comparing applying 50 pounds of N and 30 pounds of P (green plus orange bar) to purchasing bales of hay at $25 per bale the breakeven point is when urea and DAP go over $450 per ton. If a producer were to expect to have to pay $35 per bale, the breakeven point for urea and DAP would be between $650 and $700 per ton.

By applying 50 pounds of N and 50 pounds of P (green plus orange plus purple plus light green bars), a producer lowers the breakeven point even further. At $35 per bale hay would be the less expensive option after the price of urea and DAP went over $550 per ton.

One production method a producer can use to reduce costs when P costs are high is to only apply P on half of their acreage (preferably the most productive acreage) and double the amount of N to 100 pounds. This will produce the same amount of forage as adding 50 pounds of N and P to all of the pasture, but it will spread the P costs out over more production. Figure 12.3 shows how the breakeven price can be increased when adding an additional 50 pounds of N and spreading the P costs out over the

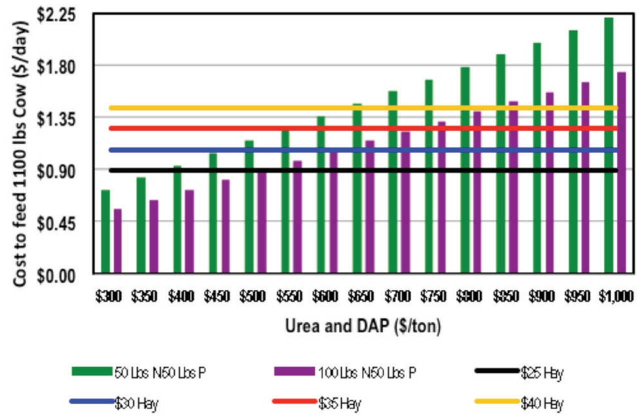


Figure 12.3. Cost of feeding forage nitrogen and phosphorus versus purchased hay.

additional production. In this example, the breakeven price for fertilizer when hay is assumed to be $35 per bale increases from $550 per ton to over $700 per ton.

Adding K increases the costs and decreases the breakeven point. Figure 12.4 shows the cost of feeding forage grown with 50 pounds of N, 40 pounds of P and 40 pounds of K using urea, DAP and potassium chloride (0-0-60).

When applying all three nutrients the breakeven point for hay costing $40 per bale is when all three fertilizers reach $500 per ton. Producers facing the situation of needing all three nutrients and high fertilizer prices face a tough situation. Producers can choose to just fertilize their most productive forage pastures or those pastures that require the least amount of nutrients. This will lessen their fertilizer costs, but may not meet their forage needs.

Other Fertilizer Sources

Different areas of the state have access to other sources of fertilizer such as poultry litter, swine or dairy affluent. These types

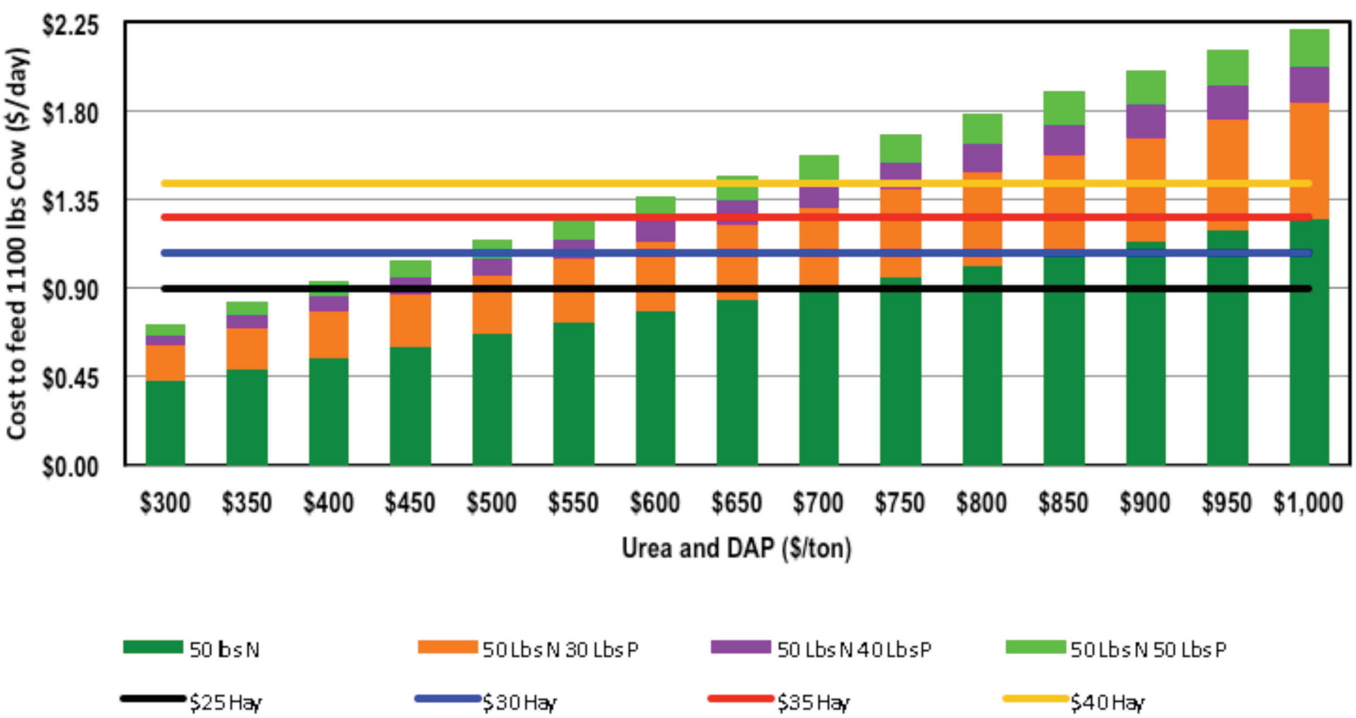


Figure 12.2. Cost of feeding forage grown with N, P and K versus purchased hay.

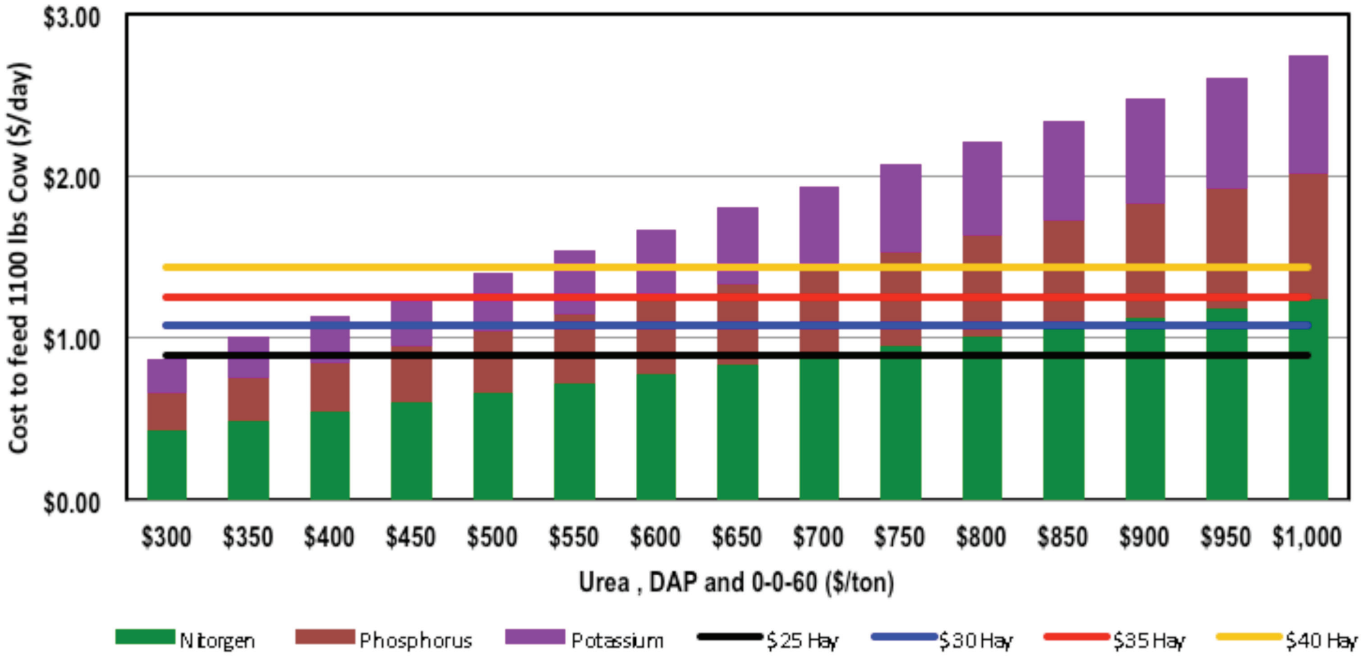


Figure 12.4. Cost to feed forage grown with nitrogen, phosphorus and potassium versus purchased hay.

of fertilizers can be less costly than commercial fertilizer, but a producer wanting to use these types of fertilizers will need to analyze the value of this animal waste carefully.

These types of fertilizers contain all three nutrients, N, P and K, but these nutrients do not have any value for the producer if the producer's soil does not require them. See Chapter 3 for more on makeup and value of animal manures.

When considering alternative fertilizer sources, make sure to take into account all costs associated with the purchasing, transporting and applying of that fertilizer. Often, these fertilizers are relatively inexpensive at the source, but transportation over long distances can add significant costs that make the fertilizer more expensive than commercial alternatives.

Other considerations when using alternative source fertilizer are regulations on application; government programs and subsidies; and state tax incentives. These items can affect the cost of the application process or cause the producer to be eligible for reimbursement. Government programs and tax incentives change without notice. Producers should investigate thoroughly before assuming they exist.

Cost of Production and Profit

All of the analysis so far evaluates the cost of fertilizer versus the cost of purchased hay. At no time was the increase in the price of fertilizer equated back to the total costs of production per cow per year. This goes to the assumption that the producer has determined what his/her stocking rate will be and is trying to figure out the least expensive method of feeding or producing forage. The price at which fertilizer becomes too costly or unprofitable depends on a producer's total costs of production, which will include the cost of forage production. To determine what price fertilizer becomes unprofitable, producers should complete an enterprise budget. OSU offers enterprise budget software and support for producers. Also, OSU has a farm business analysis program called IFMAPS that helps producers analyze their farm business. Producers interested in budget software or the IFMAPS program can contact their county Extension office or call 1-800-522-3755.

Summary

The economics of pasture fertility can be a challenging management subject. The answer to the question will depend on a producer's management capability, resources, goals and assumptions. If a producer decides to maintain certain stocking rates, then a certain amount of forage will be needed. That forage will either have to be grown or purchased. The fertility requirements of the soil will dictate how much fertilizer will be needed and therefore the cost. If a producer just requires N then the price of fertilizer has to reach $0.76 per pound (equates to $700 per ton for urea) before it becomes more expensive than $25 per bale hay. Now if P and K are required, the breakeven price drops significantly. One way to counter the high cost of P and/or K is to apply required amounts on selected fields and increase the N, therefore doubling the forage production for that field and spreading the cost of P and/or K out over more production.

Poultry litter and other animal wastes are a good fertilizer product. Producers need to know the nutrient composition of the product and their fertility needs. The nutrient in the product is only a value to the producer if the producer needs that nutrient. Also, producers need to evaluate the value of the animal waste and compare that value to the cost of purchasing, transporting and applying to their land. If the value is higher than the cost, then the animal waste product is a good value.

Chapter 13:
Fertilizing cool-season forages

Alex Rocateli

Cool-season, perennial forage grasses provide the least costly means for wintering livestock. Tall fescue is used in eastern Oklahoma, with some wheatgrasses used in the western portions of Oklahoma. In areas where perennial, cool-season forage grasses are not adapted, cool-season annual forage grasses are used. Both of these groups of forages are best managed using high fertility levels. By default, producers have decided to provide the necessary fertility inputs required. The first step in the soil fertility program is to obtain a soil sample for analysis.

A soil analysis is used to determine the levels of N, P and K in the soil, as well as soil pH. Under certain circumstances, analyses for other nutrients may be required. Based on the yield goal for specific forage crops, written recommendations for the level of each fertilizer nutrient required are usually furnished by the laboratory conducting the analysis.

Inadequate fertility can be any one or a combination of low soil pH, inadequate N fertilization, inadequate soil P or inadequate soil K. Both annual and perennial introduced cool-season forage grasses respond to a good fertility program, which supplies adequate amounts of N, P and K.

Acidic soils generally do not have direct negative effects on the growth of most forage plants; however, indirect effects can hamper plant production. Soil nutrients, particularly P, are most available at near-neutral pH levels (7.0). Even though a few of the cool-season forages used for pasture can tolerate slightly lower soil pH better than some warm-season forages, it is still important to apply crushed limestone (lime) to increase soil pH to enhance nutrient availability for optimum forage production.

After correcting the soil pH to greater than 5.7 and meeting the P and K needs, there are only two basic fertilization principles required for introduced cool-season grasses. The first principle is that N fertility is required for grass growth. The second principle is that N fertilization should be based on a reasonable yield goal.

Nitrogen is second only to moisture in relative importance for maximum plant growth and is positively correlated with forage yield. The general rule of thumb for fertilizing cool-season grass pastures is simple. Cool-season grasses—such as tall fescue and the winter annual forages—typically require 60 pounds of actual N per acre to produce one ton of forage. Thus, proper application of N fertilizer is generally a good investment in forage production systems. Other nutrients such as P, K and S are applied as required based upon the soil test recommendations. Only a soil analysis will provide this information.

Nitrogen fertilization rates vary by region of the state. In the eastern portion of Oklahoma, from 150 to 200 pounds of actual N per acre can be effectively used by both cool-season annual and perennial grasses. As cool-season forage production moves farther west, less N is needed for forage growth due to the reduced precipitation. In western Oklahoma, only 75 to 150 pounds of actual N per acre may be required to reach maximum production potential.

Most cool-season forages have a bimodal growth pattern of forage production. The primary peak in production occurs during the spring (March and April) with a secondary peak of production occurring during the fall and early winter (October and November). Depending on soil type, non-fertilized, cool-season grasses usually produce less than one ton of forage per acre during both growing periods. Approximately 75 percent of the yearly total, usually no more than 1,500 pounds of forage per acre, will occur during the spring if not fertilized with N. Less than one-half ton of forage per acre can be expected during the fall production period. Forage yields will increase accordingly with the application of N fertilizer.

Nitrogen fertilizer application on cool-season grasses is a little more complicated than warm-season grasses because of the bimodal forage growth pattern. A fall N fertilizer application is usually better for N fertilizer rates of 60 pounds of N per acre or less. For rates of more than 100 pounds of N per acre, a split application (60 pounds of N per acre in September followed by 60 pounds of N per acre in February or March) may be an advantage. However, no more than 90 pounds of N per acre should be applied in the fall to reduce possible N losses from runoff and leaching.

During the spring growing season, yield potential is greater because of the increased reliability of moisture. Thus, it becomes necessary to evaluate forage needs so only the needed amount of N is applied to avoid production of forage that could be wasted.

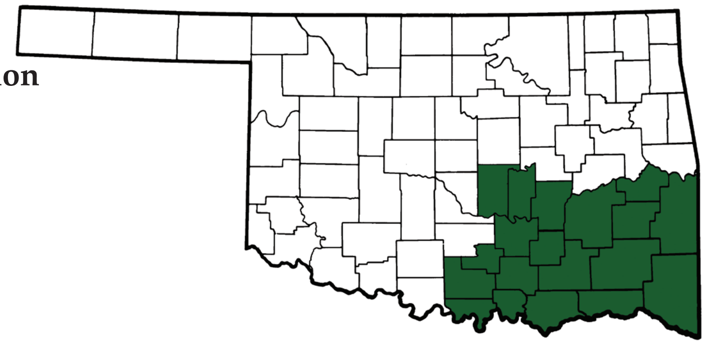
Depending on soil type, non-fertilized, cool-season grasses usually produce less than 1 ton of forage per acre during the entire growing season. When P and K levels are adequate, an additional ton of production for each 60 pounds N applied per acre is expected.

The critical order for proper cool-season grass fertilization is:

1. **soil test,**
2. **lime as recommended,**
3. **apply P and K as recommended,**
4. **identify a reasonable yield goal and**
5. **apply N fertilizer ahead of moisture according to yield goal.**

Close attention to basic soil fertility fundamentals will ensure the desired forage production and nutritive value. Poorly managed pastures, on the other hand, can result in high-cost forage that is low in nutritive value. Lack of attention to basic soil fertility will result in the increased purchase of off-farm feed and forage, decreased animal performance, and a reduced level of profitability for the forage-livestock enterprise.

Annual bromegrasses



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Southeastern	1 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120
3	180

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
60+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

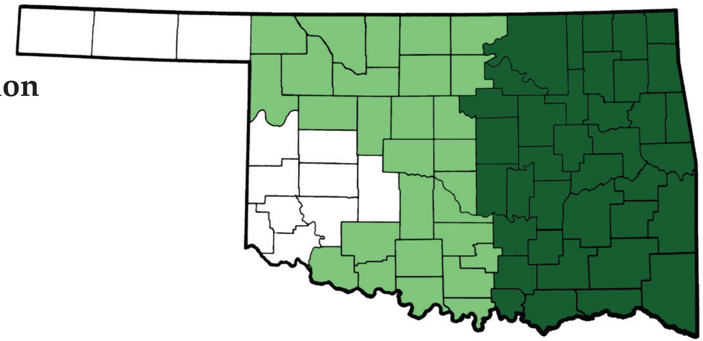
4. *Timing*

Apply no more than 60 pounds of N per acre following stand establishment. For spring fertilization, apply remaining N to meet desired yield goal before March 1.

5. *Exceptions*

Most production occurs during the early spring, so most—if not all—of the N fertilizer could be applied well in advance of the spring growth.

Annual ryegrass



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 5
Western	1 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120
3	180
4	240
5	300

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

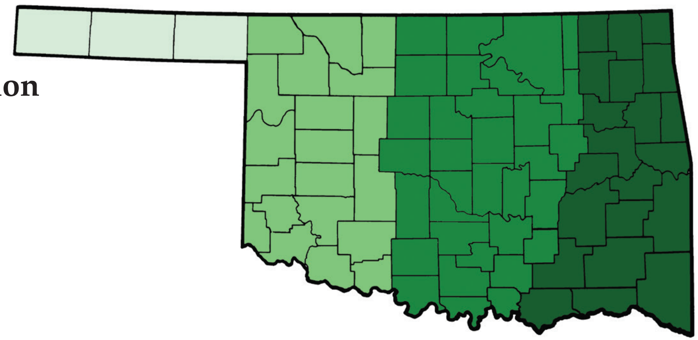
4. *Timing*

Apply no more than 60 pounds of N per acre following stand establishment. For spring fertilization, apply remaining N to meet desired yield goal before March 1.

5. *Exceptions*

In northeastern Oklahoma, it is likely that less than 1 ton per acre of production will occur during the fall. In extreme southeastern Oklahoma, yields up to 1 ton may occur during the fall.

Wheat pasture



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 4
Central	1 to 3
Western	1 to 2
Panhandle (dryland)	1 to 2
Panhandle (irrigated)	2 to 4

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
0.5	30
1.0	60
1.5	90
2.0	120
2.5	150
3.0	180

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	25	80	0	50	60
10	45	60	75	70	50
20	80	40	125	80	40
40	90	20	200	95	20
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

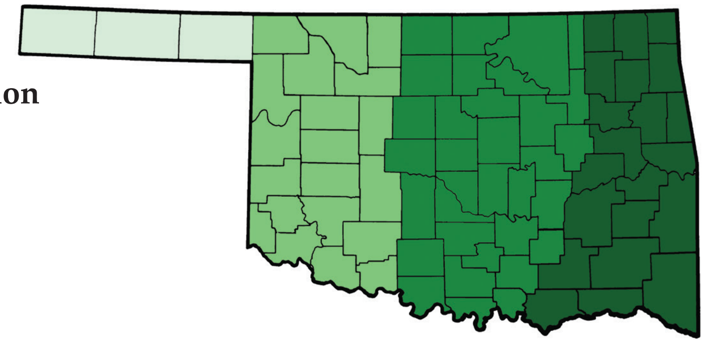
4. *Timing*

It is permissible to apply approximately 40 pounds of N per acre to aid in early establishment. Up to 90 pounds of N per acre can be applied following fall establishment. The remaining N to meet the desired forage production yield goal can be applied prior to March 1.

5. *Exceptions*

When P and K are banded at planting, recommended amounts can be reduced by 20 percent. To avoid seedling injury do not exceed 30 pounds of N plus K_2O per acre.

Cereal rye, Oat and Barley



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 5
Central	2 to 4
Western	1 to 3
Panhandle (dryland)	1 to 3
Panhandle (irrigated)	2 to 5

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120
3	180
4	240
5	300

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0 (Cereal rye and Oat); 6.3 to 7.0 (Barley)

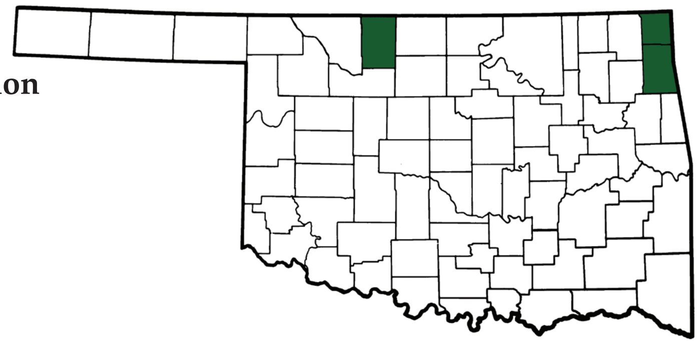
4. *Timing*

Apply no more than 90 pounds of N per acre to cereal rye and barley after fall establishment. Remaining N fertilizer to meet the desired yield goal can be applied anytime after Feb. 1. Fertilize oats with no more than 120 pounds of N per acre following stand establishment in the spring.

5. *Exceptions*

When P and K are banded at planting, recommended amounts can be reduced by 20 percent. To avoid seedling injury, do not exceed 30 pounds of N plus K_2O per acre.

Orchardgrass



Five Steps for Proper Forage and Pasture Fertilization

1 *Yield Potential*

Region	*Yield potential (tons/acre)*
Northern	1 to 2

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

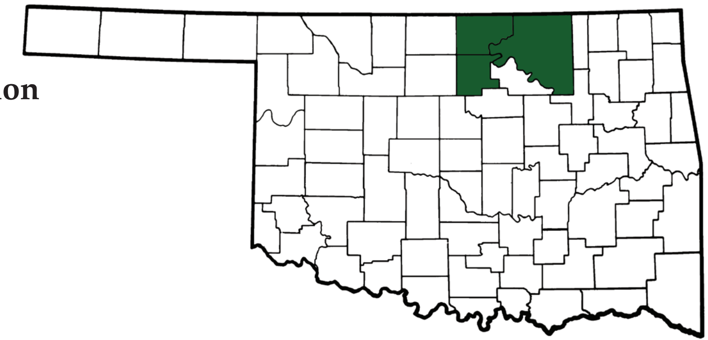
4. *Timing*

Apply up to 60 pounds of N per acre in September or October with an additional 60 pounds of N per acre applied before March 1.

5. *Exceptions*

There are no notable exceptions for orchardgrass fertility management.

Smooth bromegrass



Five Steps for Proper Forage and Pasture Fertilization

1 *Yield Potential*

Region	*Yield potential (tons/acre)*
Northern	1 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120
3	180

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

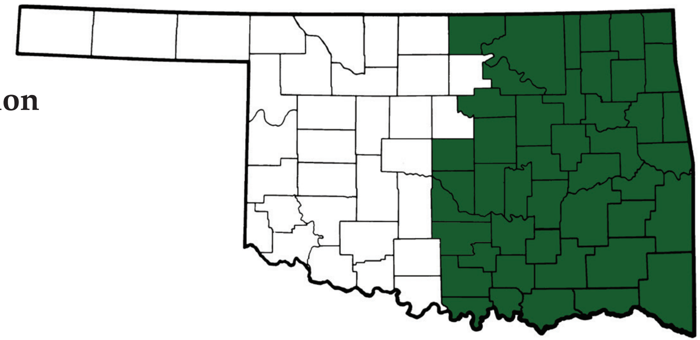
4. *Timing*

Apply no more than 90 pounds of N per acre in September. For spring fertilization, apply remaining N to meet desired yield goal before March 1.

5. *Exceptions*

If legumes are a major component in a mixed pasture, no more than 60 pounds of N per acre should be applied in September.

Tall fescue



Five Steps for Proper Forage and Pasture Fertilization

1 Yield Potential

Region	*Yield potential (tons/acre)*
Eastern	1.5 to 5

2. Nitrogen Fertilization Rate

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120
3	180
4	240
5	300

3. Critical Nutrient Values

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
65+	100	0	250+	100	0

Soil pH range – 4.5 to 7.0

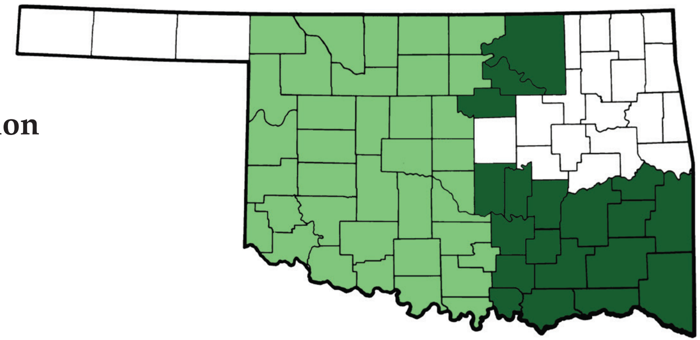
4. Timing

Apply no more than 90 pounds of N per acre in September. For spring fertilization, apply remaining N to meet desired goal before March 1.

5. Exceptions

If legumes are a major component in a mixed pasture, no more than 60 pounds of N per acre should be applied in September.

Tall and Intermediate wheatgrass



Five Steps for Proper Forage and Pasture Fertilization

1 *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 4
Western	1 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	60
2	120
3	180
4	240

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	80	0	60	70
10	50	60	75	70	60
20	70	40	125	80	50
40	95	30	200	95	30
65+	100	0	250+	100	0

Soil pH range – 4.5 to 7.0

4. *Timing*

The wheatgrasses only respond slightly to fall applied N. Only 60 pounds of N per acre should be applied in September. It is likely that split fertilizer applications will be needed for N rates above 120 pounds of N per acre.

5. *Exceptions*

Tall wheatgrass has greater tolerance to low soil pH and subirrigated soils than intermediate wheatgrass. Thus, tall wheatgrass may respond better to higher N rates than intermediate wheatgrass. Maximum yield potential of intermediate wheatgrass may approach only 2 to 3 tons per acre in some areas.

Chapter 14:
Fertilizing warm-season forages

Alex Rocateli

Producers often decide to take advantage of the high forage production potential of introduced forages. These forages are planted and best managed with high fertility inputs as opposed to native plant communities, which typically receive no fertility inputs. By default, producers have decided to provide the necessary fertility inputs that are required. The first step in the soil fertility program is to obtain a soil sample for analysis.

A soil analysis is used to determine the levels of N, P and K in the soil and the soil pH. Under certain circumstances, analyses for other nutrients may be required. Based on the yield goal for specific forage crops, written recommendations for the level of each fertilizer nutrient required are usually furnished by the laboratory conducting the analysis.

Inadequate fertility can be any one or a combination of low soil pH, inadequate N fertilization, inadequate soil P or inadequate soil K. All introduced, warm-season forages respond to a good fertility program, which supplies adequate amounts of N, P and K.

Acidic soils generally do not have direct negative effects on the growth of most forage plants; however, indirect effects can hamper plant production. Soil nutrients, particularly P, are most available at near-neutral pH levels (7.0). Many producers therefore, apply crushed limestone (lime) to increase soil pH to enhance nutrient availability for optimum forage production.

After correcting the soil pH to greater than 5.7 and meeting the P and K needs, there are only two basic fertilization principles required for introduced grasses. The first principle is N fertility is required for grass growth. The second principle is N fertilization should be based on a reasonable yield goal. The first N application should be in early May, just as the grass is beginning to grow and ahead of late-spring rainfall. Properly timed fertilization can result in a better utilization of late-spring rainfall.

Nitrogen is second only to moisture in relative importance for maximum plant growth and is positively correlated with forage yield. The general rule of thumb for fertilizing warm-season grass pastures is simple. Warm-season grasses, such as bermudagrass, typically require 50 pounds of actual N per acre to produce one ton of forage. Thus, proper application of N fertilizer is generally a good investment in forage production systems. Other nutrients such as P, K and S are applied as required based upon the soil test recommendations. Only a soil analysis will provide this information.

Depending on soil type, non-fertilized warm-season grasses usually produce about 1 ton of forage per acre during the entire growing season. If P and K levels are adequate, an additional ton of production is expected for each 50 pounds of N applied per acre.

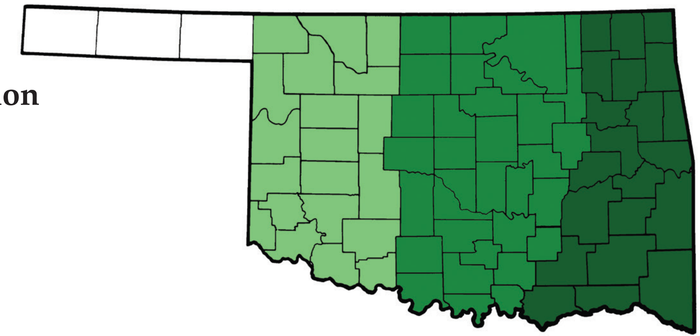
The critical order for proper warm-season grass fertilization is:

1. **soil test,**
2. **lime as recommended,**
3. **apply P and K as recommended,**
4. **identify a reasonable yield goal and**
5. **apply N fertilizer ahead of moisture according to yield goal.**

Close attention to basic soil fertility fundamentals will ensure the desired forage production and nutritive value. Poorly managed pastures, on the other hand, can result in high-cost forage that is low in nutritive value. Lack of attention to basic soil fertility will result in the increased purchase of off-farm-feed and forage, decreased animal performance and a reduced level of profitability for the forage-livestock enterprise.

Warm-season annual forages

Crabgrass and Foxtail millet



Five Steps for Proper Forage and Pasture Fertilization

1 *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	1 to 3
Central	1 to 3
Western	1 to 2

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	50
2	100
3	150

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	75	0	50	140
10	65	60	75	65	80
20	80	40	125	80	50
40	95	20	200	95	30
65+	100	0	250+	100	0

Soil pH range – 5.7 to 7.0

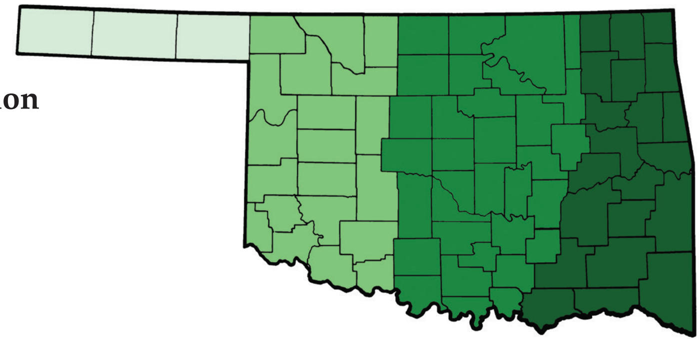
4. *Timing*

Up to 150 pounds of N per acre can be applied following emergence to meet desired production level. Lime to correct low soil pH is best applied in fall or winter. Phosphorus and K deficiencies can be corrected in spring.

5. *Exceptions*

There are no notable exceptions for crabgrass and foxtail millet fertility management.

Forage sorghums



Five Steps for Proper Forage and Pasture Fertilization

1 *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	7.5 to 15.0
Central	5.0 to 12.5
Western	3.0 to 7.5
Panhandle	2.5 to 4.0

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1.0	0
2.5	45
5.0	90
7.5	135
10.0	185
12.5	240
15.0	300

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	100	0	40	180
10	60	75	75	60	130
20	80	45	125	75	90
40	95	25	200	90	60
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

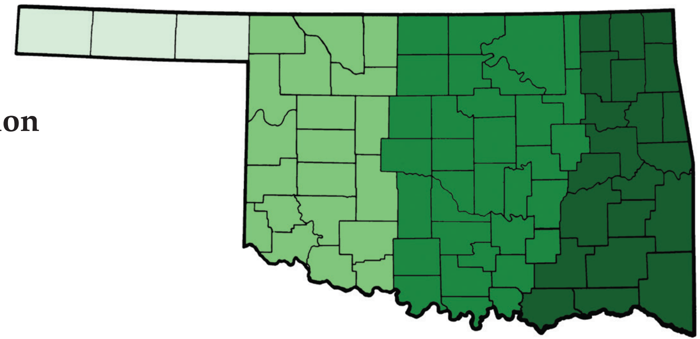
4. *Timing*

Up to 40 pounds of N per acre can be applied at planting. Additional N applications must be applied following establishment.

5. *Exceptions*

Irrigated forage sorghums in western Oklahoma, as well as the Panhandle region, can have yields similar to those in eastern and central Oklahoma. Thus, higher N fertilizer rates should be applied. When P and K are banded at planting, recommended amounts can be reduced by 20 percent. To avoid seedling injury, do not exceed 7 pounds of N plus K_2O per acre.

Sudangrass and Pearl millet



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 5
Central	2 to 4
Western	1 to 3
Panhandle (dryland)	1 to 3
Panhandle (irrigated)	2 to 5

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	50
2	100
3	150
4	200
5	250

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	100	0	40	180
10	60	75	75	60	130
20	80	45	125	75	90
40	95	25	200	90	60
65+	100	0	250+	100	0

Soil pH range – 5.5 to 7.0

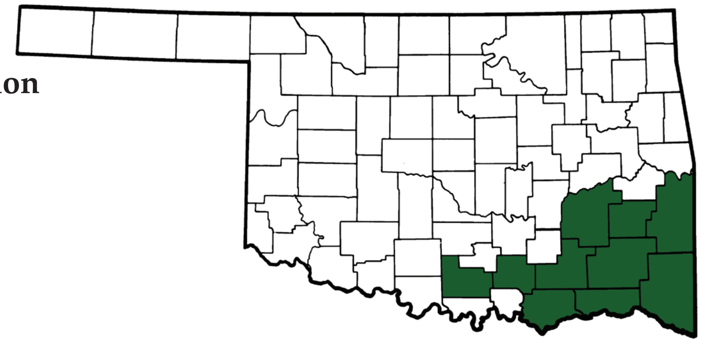
4. *Timing*

Following emergence and establishment, up to 100 pounds N per acre can be applied.

5. *Exceptions*

It is possible to apply up to 150 pounds N per acre to summer annual forages. However, due to the effect of moisture on yield potential, it may be preferable to apply enough N fertilizer to meet the growth demand of approximately 2,000 to 3,000 pounds of forage growth per month.

Bahiagrass



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Southeast	2 to 4

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
.75	0
1.5	50
2.5	100
3.5	150
4.5	200

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	75	0	50	140
10	65	60	75	65	80
20	80	40	125	80	50
40	95	20	200	95	30
65+	100	0	250+	100	0

Soil pH range – 5.7 to 7.0

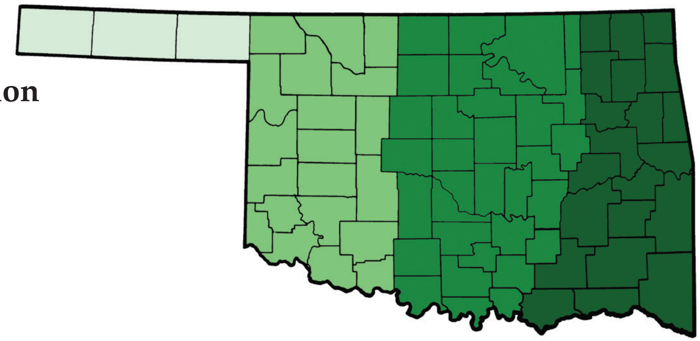
4. *Timing*

Lime applications to correct soil pH and any P or K deficiencies can be corrected in late winter to early spring. Nitrogen fertilizer should be applied to bahiagrass pastures just prior to green up, usually no later than mid May.

5. *Exceptions*

Since bahiagrass is found growing primarily on coarse, sandy coastal plains soils subject to leaching, no more than 100 pounds of N per acre should be applied during a single application.

Bermudagrass



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	5 to 10
Central	4 to 8
Western	3 to 6
Panhandle	2 to 4

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	50
2	100
3	150
4	200
5	260
6	320
7	400

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	75	0	50	140
10	65	60	75	65	80
20	80	40	125	80	50
40	95	20	200	95	30
65+	100	0	250+	100	0

Soil pH range - 5.7 to 7.0

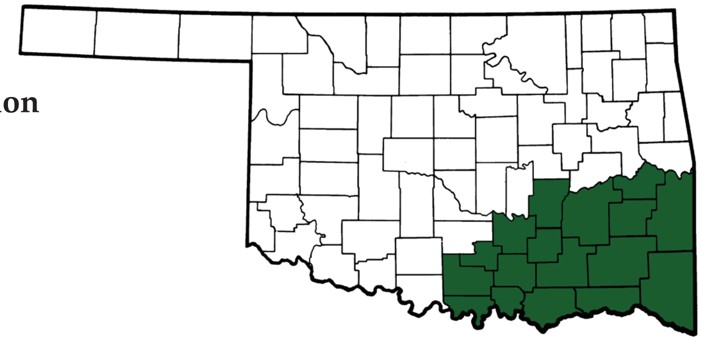
4. *Timing*

Research has shown no benefit to split N applications up to 200 pounds of N per acre. At amounts greater than 200 pounds of N per acre, it may be best to divide the total amount and apply in equivalent amounts. On coarse soils subject to leaching, no more than 100 pounds of N per acre should be applied at a time.

5. *Exceptions*

Irrigated bermudagrass-Yield potential is much greater when bermudagrass is irrigated. Yields ranging from 10 to 15 tons per acre have been reported in Oklahoma. The seasonal N requirements should be applied in split applications.

Dallisgrass



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Southeast	2 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
.75	0
1.5	50
2.5	100
3.5	150
4.5	200

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	75	0	50	140
10	65	60	75	65	80
20	80	40	125	80	50
40	95	20	200	95	30
65+	100	0	250+	100	0

Soil pH range - 5.7 to 7.0

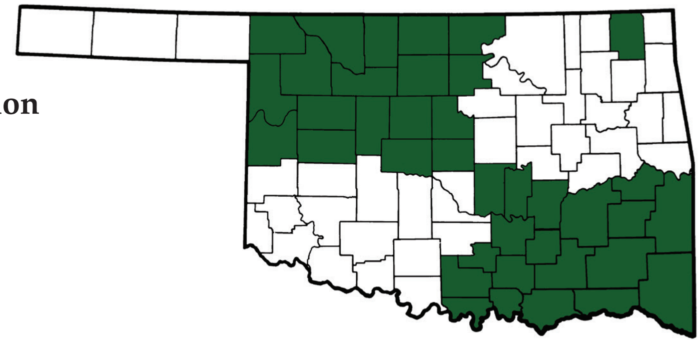
4. *Timing*

Lime applications to correct soil pH and any P or K deficiencies can be corrected in late winter to early spring. Nitrogen fertilizer should be applied to dallisgrass pastures just prior to green up, usually no later than mid May.

5. *Exceptions*

Dallisgrass is found growing primarily in mixed warm-season pastures, usually with bermudagrass. When it is the primary forage component, dallisgrass should be managed similar to bahiagrass.

Eastern gamagrass



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 6
Western	2 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1.2	0
2.5	45
5	90
7.5	135

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	30	100	0	40	180
10	60	75	75	60	130
20	80	45	125	75	90
40	95	25	200	90	60
65+	100	0	250+	100	0

Soil pH range - 5.7 to 7.0

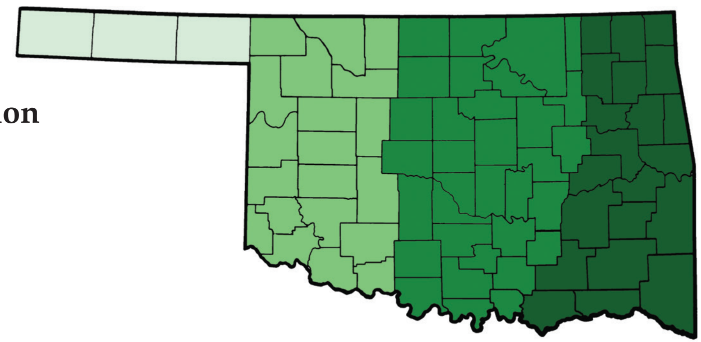
4. *Timing*

Nitrogen should be applied when eastern gamagrass is 3 to 5 inches tall in the spring.

5. *Exceptions*

Oklahoma does not currently have a specific fertilizer recommendation for eastern gamagrass. The most common recommendation is to apply 100 pounds of N per acre.

Native grasslands



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	3 to 6
Central	2.5 to 5
Western	1 to 2.5
Panhandle	0.75 to 1.5

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	0
1.5	50
1.6	100

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	40	0	40	40
10	80	20	75	70	30
20	95	0	125	85	20
40	95	0	200	95	0
65+	100	0	250+	100	0

Soil pH range – 4.5 to 7.0

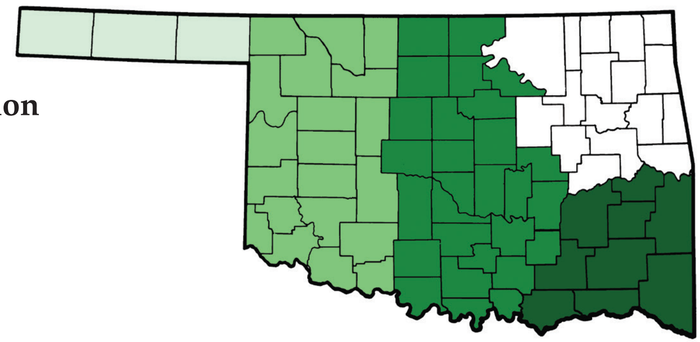
4. *Timing*

Any fertilization should occur at green-up. Yield response to fertilization is not predictable due to normal precipitation variances. It is important to note that a shift in species could occur to more undesirable species.

5. *Exceptions*

Traditional experience with fertilizing native grasslands suggests that these species do not respond to application of nutrients. This is not entirely accurate. In years of adequate to above adequate precipitation, plant response to fertilization does occur, and many times is similar to the response observed in introduced grasses.

Old World bluestems



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	3 to 5
Central	2 to 5
Western	1 to 4
Panhandle	1 to2

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	35
2	70
3	110
4	150
5	200

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	60	0	40	80
10	70	40	75	60	60
20	85	30	125	80	40
40	95	20	200	95	20
65+	100	0	250+	100	0

Soil pH range – 4.5 to 7.0

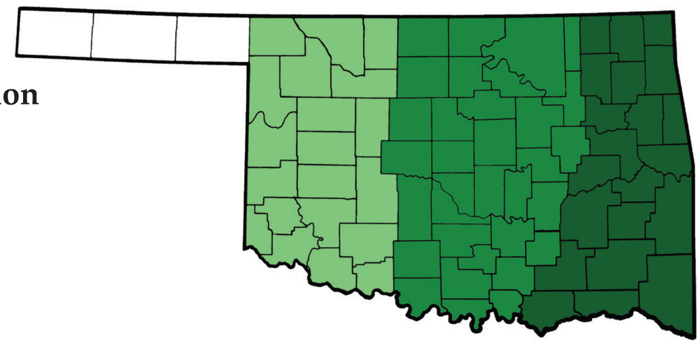
4. *Timing*

Soil P and K deficiencies should be corrected no later than late spring. Nitrogen fertilizer should be applied just as pastures are beginning to show green growth.

5. *Exceptions*

Even though the Old World bluestems will respond to N fertilizer rates up to 200 pounds of N per acre, lack of predictable rainfall, coupled with poor soil characteristics are usually the factors that limit forage production. Based on this, recommended N rates are typically no greater than 100 pounds of N per acre.

Switchgrass



Five Steps for Proper Forage and Pasture Fertilization

1 *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 13
Central	2 to 12
Western	1 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	0
2	40
3	80
>4	120

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	40	0	40	40
10	80	20	75	70	30
20	95	0	125	85	20
40	95	0	200	95	0
65+	100	0	250+	100	0

Soil pH range – 4.5 to 7.0

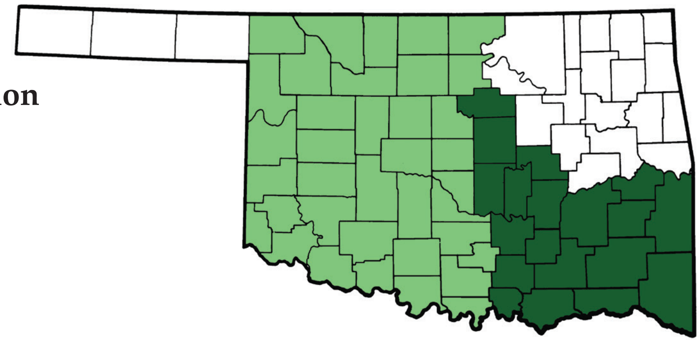
4. *Timing*

Nitrogen should be applied when switchgrass is 3 to 5 inches tall in the spring.

5. *Exceptions*

Oklahoma does not currently have a specific fertilizer recommendation for switchgrass. The most common recommendation is to apply 75 pounds of N per acre.

Weeping lovegrass



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 4
Western	1 to 3

2. *Nitrogen Fertilization Rate*

Yield (tons/acre)	*N rate (lbs/acre)*
1	35
2	70
3	110
4	160
5	220

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	60	0	40	80
10	70	40	75	60	60
20	85	30	125	80	40
40	95	20	200	95	20
65+	100	0	250+	100	0

Soil pH range – 4.5 to 7.0

4. *Timing*

Nitrogen fertilizer should be applied just as pastures are beginning to show green growth. Weeping lovegrass begins growth somewhat earlier than most other warm-season grasses. Thus, N fertilizer applications will typically occur a few weeks earlier than most other warm-season grasses.

5. *Exceptions*

One of the more successful management strategies for utilizing weeping lovegrass is to burn it early (February), fertilize it heavily (100 pounds of N per acre), and graze it hard. Since weeping lovegrass is best adapted to sandier soils, N applications should be no more than 100 pounds of N per acre in a single application.

Chapter 15: Fertilizing legumes

Alex Rocateli

Forage legumes are used in forage systems because they have no N fertilizer requirement, but instead rely on N-fixing bacteria to provide and meet the plant's N needs. Even so, legume fertility requirements are somewhat higher than both cool-season and warm-season forage grasses.

A soil analysis is used to determine the levels of N, P and K in the soil, as well as soil pH. Under certain circumstances, analyses for other nutrients may be required. Based on the yield goal for specific forage crops, written recommendations for the level of each fertilizer nutrient required are usually furnished by the laboratory conducting the analysis.

Inadequate fertility can be any one or a combination of low soil pH, inadequate soil P or inadequate soil K. All introduced, forage legumes respond to a good fertility program, which supplies adequate amounts of P and K.

Acidic soils generally do not have direct negative effects on the growth of most forage plants; however, indirect effects can hamper plant production. Soil nutrients, particularly P, are most available at near-neutral pH levels (7.0). Even though a few legumes can tolerate lower than neutral soil pH, it is still important to apply crushed limestone (lime) to increase soil pH to enhance nutrient availability for optimum forage production.

Many of the annual clovers also are intolerant of high pH soils. Most perennial clovers and the medics, including alfalfa, tolerate a fairly wide range in soil pH values, but most are more productive when the soil pH is near neutral. Thus, maintaining soil fertility at moderate levels is critical for forages to be productive. The first step in the soil fertility program is to obtain a soil sample for analysis.

Because of the symbiotic relationship that exists between the host plant and the *Rhizobium* bacteria, N fertilizer is usually not required. As a result, we often incorrectly assume N is not needed when growing forage legumes. While it is possible to establish and grow legumes without N-fixing bacteria, production and quality will be similar to the grasses. Without *Rhizobia*, N fertilizer must be applied for high yield and quality, which would eliminate the primary advantage of using legumes.

In general, legumes are typically more sensitive to soil nutrient deficiencies than forage grasses. P and K, however, are critical to maintaining a productive stand of legumes. An annual soil test should be used to determine the need for P and K and will also indicate if there is a deficiency in micronutrients. Legumes are more sensitive to low soil pH than most forage grasses and, based on soil test recommendations, lime should be applied when pH values fall below 6.0.

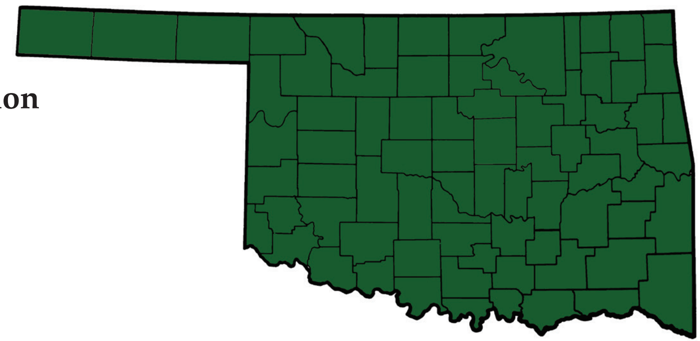
Depending on soil type, legumes usually produce 1 to 3 tons of forage per acre during the entire growing season. Successful legume production depends on maintaining adequate levels of P and K with a soil pH of at least 6.0. Even though fertilizer N is not required, fertilizers containing P and K may be needed to maintain productive and persistent stands. Soils should be sampled and tested to determine the pH as well as the level of P and K. Soil fertility and pH are critical for successful legume establishment and production.

The critical order for proper legume fertilization is:

1. **soil test,**
2. **lime as recommended and**
3. **apply P and K as recommended.**

Close attention to basic soil fertility fundamentals will ensure the desired forage production and nutritive value. Poorly managed pastures, on the other hand, can result in high-cost forage that is low in nutritive value. Lack of attention to basic soil fertility will result in the increased purchase of off-farm-feed and forage, decreased animal performance and a reduced level of profitability for the forage-livestock enterprise.

Alfalfa



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*	
Effective rainfall	*Without irrigation*	*With irrigation*
12	2.4	10.0
18	3.0	9.0
30	5.0	8.0
40	6.7	6.0

2. *Nitrogen Fertilization Rate*

Legumes will produce N for their growth. Very little N remains after legume growth stops, unless the legume growth is not harvested.

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	40	200	0	20	280
10	60	150	75	50	210
20	80	100	125	70	140
40	90	60	200	90	80
65+	100	0	275	95	40
-	-	-	350+	100	0

Soil pH range – 6.3 to 7.5

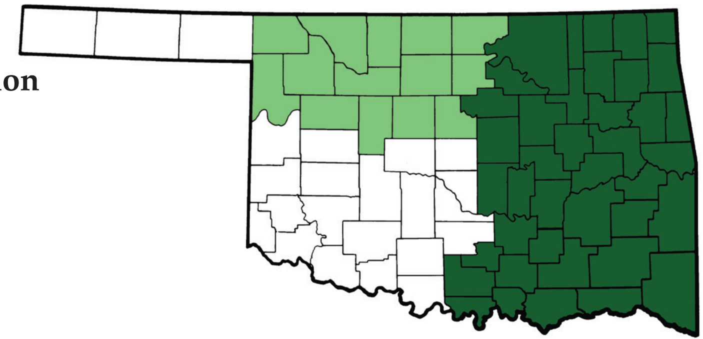
4. *Timing*

Phosphorus and K fertilizer can be applied at planting. Lime to correct soil pH is best applied and incorporated prior to planting. Make sure specie-specific inoculums are used.

5. *Exceptions*

A small amount of N (20 to 30 pounds of N per acre) is required at planting for establishing seedling alfalfa.

Austrian winterpea



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	Yield potential (tons/acre)
Eastern	1 to 3
Western	1 to 2

2. *Nitrogen Fertilization Rate*

Legumes will produce N for their growth. Very little N remains after legume growth stops, unless the legume growth is not harvested.

3. *Critical Nutrient Values*

Phosphorus			Potassium		
P index	Sufficiency	P_2O_5 (lbs/acre)	K index	Sufficiency	K_2O (lbs/acre)
0	40	70	0	40	100
10	60	50	75	60	70
20	80	30	125	75	60
40	90	20	200	90	40
65+	100	0	275+	100	0

Soil pH range – 5.8 to 7.0

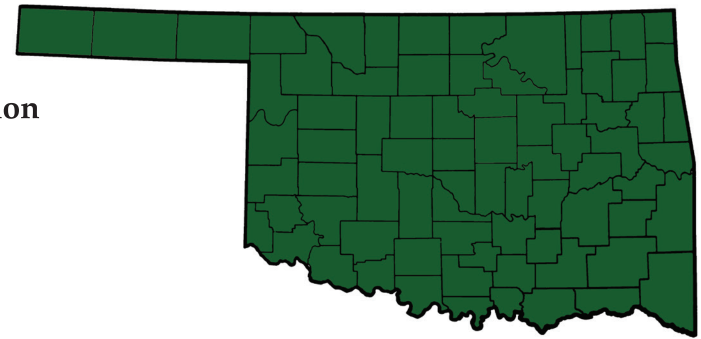
4. *Timing*

Phosphorus and potassium fertilizer can be applied at planting. When P and K are banded at planting, recommended amounts can be reduced by 20 percent. Legumes are very sensitive to fertilizer salt injury, so do not place any N or K_2O with seed. These fertilizers can be placed in a 2 x 2 or surface dribbled without injury. Lime to correct soil pH is best applied during the spring prior to planting. Make sure specie-specific inoculums are used.

5. *Exceptions*

A small amount of N (20 to 30 pounds of N per acre) can be applied at planting to aid in establishing Austrian winter pea.

Forage legumes
Cowpea and Mungbean



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern (Cowpea)	2 to 4
Western (Mungbean)	1 to 2

2. *Nitrogen Fertilization Rate*

Legumes will produce N for their growth. Very little N remains after legume growth stops, unless the legume growth is not harvested.

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	40	70	0	50	80
10	60	50	75	60	60
20	80	30	125	80	45
40	90	20	200	90	30
65+	100	0	275+	100	0

Soil pH range – 5.5 to 7.0

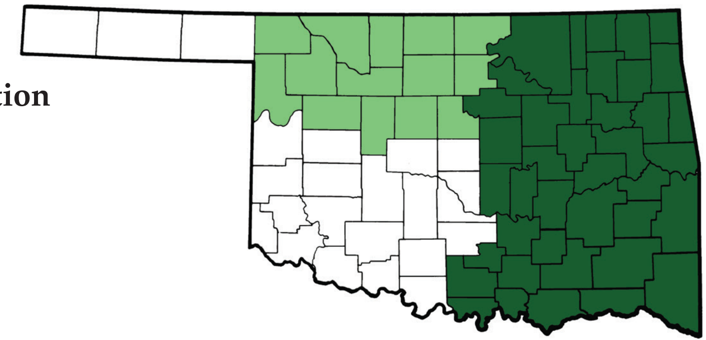
4. *Timing*

Phosphorus and potassium fertilizer can be applied at planting. When P and K are banded at planting, recommended amounts can be reduced by 20 percent. Legumes are very sensitive to fertilizer salt injury, so do not place any N or K_2O with seed. These fertilizers can be placed in a 2 x 2 or surface dribbled without injury. Lime to correct soil pH is best applied during the spring prior to planting. Make sure specie-specific inoculums are used.

5. *Exceptions*

A small amount of N (20 to 30 pounds of N per acre) can be applied at planting to aid in establishment. These two species are very similar with mungbean having a greater degree of drought tolerance.

Soybean forage



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	2 to 4
Western	1 to 2

2. *Nitrogen Fertilization Rate*

Legumes will produce N for their growth. Very little N remains after legume growth stops, unless the legume growth is not harvested.

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	40	70	0	50	80
10	60	50	75	60	60
20	80	30	125	80	45
40	90	20	200	90	30
65+	100	0	275+	100	0

Soil pH range – 5.5 to 7.0

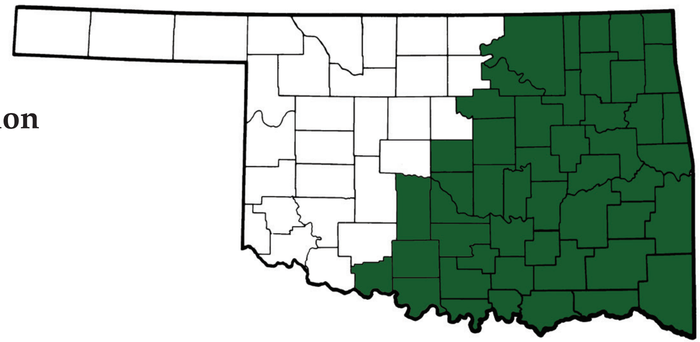
4. *Timing*

Phosphorus and potassium fertilizer can be applied at planting. When P and K are banded at planting, recommended amounts can be reduced by 20 percent. Legumes are very sensitive to fertilizer salt injury, so do not place any N or K_2O with seed. These fertilizers can be placed in a 2 x 2 or surface dribbled without injury. Lime to correct soil pH is best applied during the spring prior to planting. Make sure specie-specific inoculums are used.

5. *Exceptions*

A small amount of N (20 to 30 pounds of N per acre) is required at planting for establishing soybean. Soybeans were originally introduced into the U.S. as a forage crop, so there are soybean cultivars that have been developed specifically for forage. Even so, most of the soybean harvested as forage is a result of grain crop failure.

Pasture legumes



Five Steps for Proper Forage and Pasture Fertilization

1. *Yield Potential*

Region	*Yield potential (tons/acre)*
Eastern	1 to 3
Central	1 to 2
Western	1

2. *Nitrogen Fertilization Rate*

Legumes will produce N for their growth. Very little nitrogen remains for the grasses after legume growth stops unless the legume growth is not harvested.

3. *Critical Nutrient Values*

Phosphorus			*Potassium*		
P index	*Sufficiency*	*P_2O_5 (lbs/acre)*	*K index*	*Sufficiency*	*K_2O (lbs/acre)*
0	50	75	0	50	80
10	65	60	75	65	60
20	80	40	125	80	40
40	95	20	200	95	20
65+	100	0	250+	100	0

Soil pH range – 6.0 to 7.0

4. *Timing*

Phosphorus and potassium fertilizer can be applied from early fall through early spring when needed. Lime to correct soil pH is best applied during early summer seed production. Make sure specie-specific inoculums are used.

5. *Exceptions*

Since legumes are often grown as a component of a grass-legume mixed pasture, it is important that N fertilization be limited especially during early legume growth. Although it is extremely difficult to determine, there should be at least 20 percent legumes in the pasture. Otherwise, the pasture should be managed as a grass-only pasture until legumes become established.

Related Documents and Websites

Chapter 1 Nitrogen chemical and physical reactions in pasture soils
E-1039 Oklahoma Soil Fertility Handbook
PSS-2590 Forage Legumes and Nitrogen Production
www.NPK.okstate.edu
www. Soiltesting.okstate.edu

Chapter 2 Phosphorus reactions in pasture soils
E-1039 Oklahoma Soil Fertility Handbook
www.NPK.okstate.edu
www. Soiltesting.okstate.edu

Chapter 3 Potassium chemical and physical reactions in pasture soils
E-1039 Oklahoma Soil Fertility Handbook
www.NPK.okstate.edu
www. Soiltesting.okstate.edu

Chapter 4 How to take a soil sample and interpret results
E-1039 Oklahoma Soil Fertility Handbook
www. Soiltesting.okstate.edu
PSS-2207 How to get a Good Soil Sample
L-Soil Testing. The Right First Step

Chapter 5 Common pasture fertilizers and how they react in pastures
E-1039 Oklahoma Soil Fertility Handbook
www.NPK.okstate.edu
www.nue.okstate.edu
www. Soiltesting.okstate.edu

Chapter 6 How pH affects pasture soil fertility and forage
E-1039 Oklahoma Soil Fertility Handbook
F-2239 Causes and Effects of Soil Acidity
PT 2003-8 Lime Acid Soils: What You Should and Should not Expect
PT 2002-15 The Risk of Not Liming
PSS-2240 Managing Acid Soils for Wheat Production
www.NPK.okstate.edu
www. Soiltesting.okstate.edu

Chapter 7 Poultry litter use and management in pastures
E-1039 Oklahoma Soil Fertility Handbook
AGEC-254 Value of Poultry Liter in Meeting Soil Fertility Requirements
CR-2201 Using Bio-solids as a Plant Nutrient Source
PSS-2245 Using Lagoon Effluent as a Fertilizer
PSS-2246 Using Poultry Litter as a Fertilizer
PSS-2247 Using Animal Manure as a Fertilizer
PSS-2228 Fertilizer Nutrients in Animal Manure
PSS-2249 Managing Phosphorus from Animal Manure
PSS-2250 Using Stock Piles Feedlot Manure as a Fertilizer
PSS-2251 Selecting Forages for Nutrient Removal from Animal Manure

Chapter 8 How soil type, depth and structure affect pasture fertility
E-1039 Oklahoma Soil Fertility Handbook
B819 DEQ/OSU Soil Classification Manual
PSS-2244 Soil Compaction and Crust
PSS-2902 What Soil, Forage, and Water Test do for You
www.soiltesting.okstate.edu

Chapter 9 Stocking rate and fertility relationships
PSS- 2570 Reducing Winter Feeding Costs
PSS-2584 Forage-Budgeting Guidelines

Chapter 10 Hay production and grazing
PSS- 2570 Reducing Winter Feeding Costs

Chapter 11 The effects of environment on pasture soil fertility
E-1039 Oklahoma Soil Fertility Handbook

Chapter 12 Economics of pasture fertility
PSS- 2570 Reducing Winter Feeding Costs
AGEC-568 Economics of Producing Alfalfa
AGEC-254 Value of Poultry Liter in Meeting Soil Fertility Requirements

Chapter 13 Cool-season annual forages
E-1039 Oklahoma Soil Fertility Handbook
L-Soil Testing. The Right First Step

Chapter 14 Warm-season annual forages
E-1039 Oklahoma Soil Fertility Handbook
L-Soil Testing. The Right First Step
ANSI-3020 Production and Management of Old World Bluestem
PSS-2263 Fertilizing Bermudagrass Hay and Pasture
E-1012 Switchgrass Production Guide for Oklahoma

Chapter 15 Forage legumes
E-1039 Oklahoma Soil Fertility Handbook
L-Soil Testing. The Right First Step
AGEC-568 Economics of Producing Alfalfa
PSS-2590 Forage Legumes and Nitrogen Production
PSS-2089 Alfalfa Stand Establishment

OKLAHOMA STATE UNIVERSITY

EXTENSION