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Fertilizer Management in Alfalfa

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Introduction

Alfalfa is a high quality, valuable forage crop that can be successfully produced on most well-drained soils in Kentucky for hay, silage, and grazing. Fertilizing alfalfa can be uniquely challenging because it is a high-yielding crop that removes a tremendous amount of soil nutrients when compared to other crops grown in Kentucky. A thorough understanding of alfalfa's growth habits, nutrient requirements, and soil nutrient supply mechanisms is necessary to effectively manage fertilizer inputs and maximize profitability while minimizing environmental impact.

Fertilizing Perennial Crops

The goal of any fertilizer management program should be to maximize the profitability of the crop. Growers should be aware that maximizing yield seldom results in maximum profit. Often, additional yield can be obtained with additional inputs, but the cost of these inputs may exceed the value of the additional yield. Consider the example of an alfalfa producer who could increase their alfalfa yield by five bales per acre by adding 50 lb of potassium fertilizer. The additional fertilizer would only be beneficial if the value of the five extra bales exceeds the cost of the additional 50 lb of fertilizer.

Fertilizing perennial crops such as alfalfa presents an added challenge because a single year's productivity is not the only objective; the overall longevity of the crop must also be considered. Often, early management decisions will determine the number of years the alfalfa stand will remain productive. Fertilizer decisions prior to planting are of particular importance, since this is the only opportunity the producer will have to incorporate immobile soil nutrients such as phosphorus (P), potassium (K), and large quantities of lime. After planting, annual fertilizer and lime applications, based on soil tests results, can only be broadcast onto the soil surface.

Alfalfa Establishment

One of the most common mistakes producers make is not properly preparing for alfalfa establishment. Alfalfa can be established using tillage or no-tillage practices. Soil samples should be collected from prospective alfalfa fields well in advance of planting, preferably six to twelve months prior. If spring seeding is the goal and a low (acidic) soil pH is suspected, fall soil testing prior to spring seeding would be ideal so fall applied lime would have time to dissolve and increase soil pH. However, if low levels of P and/or K is suspected, then soil testing prior to seeding will allow for a more accurate rate of P and K to be applied. It is always best to soil sample the same time every year due to seasonal differences that may affect soil test results. Early sampling gives the producer time to correct nutrient deficiencies and make adjustments in soil pH.

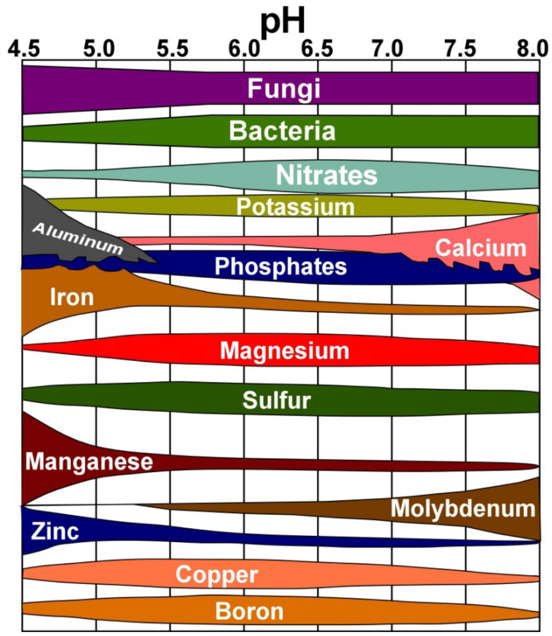

Figure 1. The availability of plant nutrients, toxic elements and microbial activity as influenced by soil pH. Wider bars indicate increased availability (activity).

Soil pH is probably the most important soil chemical characteristic that can be tested when preparing to establish alfalfa because the availability of many essential plant nutrients is a function of soil pH (Figure 1). In addition to nutrient availability, the survival of nitrogen fixing bacteria in the soil (rhizobium) is also highly dependent upon soil pH. If the soil pH is below 6.4, lime should be applied according to the soil test recommendation to achieve a soil pH near 6.8. Lime application rates should also be adjusted based on the quality of limestone you plan to purchase. You can contact your local county Extension agent for help making necessary adjustments in liming rates. Where the risk of soil erosion is low, lime can be incorporated with tillage if the recommended application rate is more than 4 tons per acre. Research has shown that soil incorporation speeds up the reaction time deeper within the soil profile if half of the recommended rate of lime is mixed into the soil during plowing and the other half after plowing followed by disking. The reaction time of limestone in the soil is not immediate. Surface applied lime is effective in adjusting soil pH; however changes in soil pH below the surface will be much slower compared to incorporation.

If the soil pH is extremely acidic (pH 5.3 or lower) and lime is applied less than six months prior to establishing, or when the starting pH at seeding is less than 6.2, then an application of molybdenum is advisable to aid alfalfa establishment and allow time for the lime to react. Molybdenum deficiencies in legumes occur on acid soils due to reduced molybdenum availability. Molybdenum is important in legumes and is involved with enzyme systems relating to symbiotic N_2 fixation.

If molybdenum is needed, apply 1 lb sodium molybdate (6.4 oz of molybdenum) per acre in 20 to 40 gallons of water per acre, or as a seed treatment at 1 to 2 oz of sodium molybdate per acre. Treating seed with molybdenum will reduce live numbers of rhizobia so a separate application of molybdenum might be warranted. It is important not to add more than 2 lb of sodium molybdate per acre during a given five-year period.

A productive stand of alfalfa can remove significant quantities of P and K per acre per year. The goal of your P and K fertilizer program should be to maintain soil test (Mehlich III) levels of P at or above 60 lb per acre and K at or above 300 lb per acre. It is important to have soil test values at or above these levels at planting. Phosphorus and K are relatively immobile in the soil, so incorporation of these elements can be beneficial but are not critical. Once alfalfa is established, rhizobium bacteria living on the roots help the crop get most of its required nitrogen (N) from the atmosphere. However, research has shown that 30 lb N per acre applied at planting can be beneficial before a well-established root system has developed.

Fertilizing Established Stands

Adequately fertilized alfalfa removes approximately 55 lb K_2O per harvested ton. This nutrient removal rate is much higher than grain crops or pastures. Because of the high K demand and removal for alfalfa, a neglected stand will quickly show visual signs of K deficiency (Figure 2). Visual symptoms of P deficiency are less obvious. Nutrient removal estimates from hay harvest or grazing alone should not be used as the basis for fertilizer application rates. In general, soils in Kentucky contain a large amount of nutrients in primary and secondary minerals. For example, a Crider silt loam soil has approximately 32,000 lb per acre total mineral K just in the surface 7 inches, while only a fraction of the nutrients present in the minerals is immediately available to the plant or measured in a soil test. Through the weathering process, nutrients that are present but not detected in a soil test become slowly available to the plant over time. Additional nutrients may be present in the subsoil and not measured in a routine 6-inch soil sample. For these reasons, soil test results are not absolute quantitative measurements of plant available nutrients, but they help predict the probability of getting a yield response to a fertilizer application. University of Kentucky soil tests results have been calibrated with alfalfa yield response research trials. The results of these calibration studies are the foundation of our fertilizer recommendations for alfalfa. (*Kentucky Lime and Nutrient Recommendations* [AGR-1] can found at **http://www.ca.uky.edu/agc/pubs/agr/agr1/agr1.pdf**.)

University research has shown that yield is not nutrient-limited when soil test levels are above 50 lb P per acre and 300 lb K per acre. Once these soil test levels have been reached, K fertilization can be based on annual crop removal or annual soil test values reported in AGR-1. In addition, AGR-1 recommends fertilization until soil test values (for the composite field sample) are 60 lb P per acre and 450 lb K per acre (Table 1). When a producer follows K recommendations in AGR-1, soil test K values will eventually stabilize at values near 300 lb K per acre. If a producer chooses to apply K based on crop removal, a good rule of thumb is that one ton of alfalfa can remove approximately 14 lb per acre P_2O_5 and 55 lb per acre K_2O at standard harvest moisture. A producer can apply rates of fertilizer based on the above values and tonnage of hay removed per acre. For example, if the soil test K level is between 300 and 450 lb per acre and 4 tons of hay are harvested, then 220 lb of K_2O would be added to replace the amount removed in the harvested hay. This method of determining a K fertilization rate may result in soil test K levels increasing over time because it does not account for additional K that might be

Figure 2. Potassium deficiency symptoms in alfalfa (photo courtesy of Steve Phillips, International Plant Nutrition Institute).

Table 1. Phosphate and potash recommendation (lb/A) for alfalfa and alfalfa-grass hay and pastures, annual topdressing.*

Category	Test result: P	P_2O_5 needed	Test result: K	K_2O needed
High	>60	0	>450	0
			394–450	60
			363–393	90
			338–362	100
			313–337	110
			297–312	120
Medium	46–60	30	291–296	130
	41–45	40	285–290	140
	37–40	50	279–284	150
	33–36	60	272–278	160
	28–32	70	266–271	170
			260–265	180
			254–259	190
			247–253	200
			241–246	210
			235–240	220
			229–234	230
			222–228	240
			216–221	250
			210–215	260
			204–209	270
Low	23–27	80	194–203	280
	19–22	90	180–193	290
	14–18	100	166–179	300
	9–13	110	152–165	310
			139–151	320
			125–138	330
			111–124	340
			97–110	350
Very Low	< 9	120	< 97	360

* From *Kentucky Lime and Nutrient Recommendations* (AGR-1)

released naturally from soil minerals. Unfortunately, not all soils in the state have the same ability to supply nutrients, especially K, to the crop. Soils such as the Crider silt loam mentioned above have a tremendous amount of mineral potassium and do not require as much fertilizer to maintain adequate soil test levels. Soils in the Bluegrass, however, particularly the outer Bluegrass, can trap (fix) K making it unavailable for plant uptake (K fixation). These types of soils often require more potassium input to maintain soil test K. In order to accurately monitor soil test levels for optimum production of crops that remove high rates of nutrients, it is very important to soil test on an annual basis, regardless of the fertility method followed. With good sampling procedures, producers will be able to fine-tune the fertilizer recommendations for their specific cropping system/soils. These adjustments should be made when a clear downward or upward trend in soil test values are observed regardless of the fertilization method utilized.

Luxury consumption of potassium by forage crops is a phenomenon that should be understood by all forage producers. Simply put, luxury consumption refers to the plant uptake of K in excess of the plant needs. This can occur when a plant is supplied with more than adequate amounts of K. When an alfalfa plant is adequately fertilized, the K concentration in the tissue is usually between 2.0 and 3.5 percent. If the soil supply of K exceeds the needs of the crop, tissue K concentrations can be as high as 4.5 percent. For grain crops such as corn or wheat, luxury consumption is not a problem, because excessive K uptake remains in the plant tissue (leaves and stalk) and is returned to the soil with the fodder. For alfalfa and other crops where the entire plant is harvested, excessive K uptake is removed as hay or silage and is not recycled in the soil. Luxury consumption can increase K removal rates to 90 lb K_2O per ton (55 lb K_2O per ton is normal removal). The main drawback to luxury consumption of K is that fertilizer applied to increase soil test K can be immediately removed with the first harvest, resulting in lower than optimum soil test K levels for subsequent harvest.

Figure 3. Boron deficiency symptoms in alfalfa (photo courtesy of Steve Phillips, International Plant Nutrition Institute).

There are several ways to limit the risk of luxury consumption. First, try to maintain soil test K between 300 and 450 lb per acre. This soil test K range prevents the over-supply of available K to the plant. When soil test K values drop below 300 lb per acre, a fertilizer recommendation and application should be made with the goal of maintaining at least a 300 lb per acre soil test level. Applying fertilizer up to a soil test level of 450 lb per acre will provide adequate K for optimum yield that crop year and limit the opportunity for luxury consumption to occur. Soil test levels between 300 and 450 lb per acre only require relatively modest application rates of K fertilizer (Table 1). Second, avoid applying any K fertilizer between the last fall harvest and the first cutting the following spring if soil test levels are between the 300 and 450 lb per acre range. The freezing and thawing of the soil through winter months usually releases enough K (from soil fixation sites) to supply crop needs for the first cutting. The first cutting is typically the highest yielding harvest, so more hay harvested with a higher than necessary tissue K concentration equals more lb of K removed from the soil. If soil test K levels are allowed to drop below 200 lb per acre (medium range), then split applications of K fertilizer during the summer months will be necessary for increasing soil test K levels to the desired range while reducing the opportunity for luxury consumption to occur. Many alfalfa producers have found that split applications of K after the first and third harvest is a practical way to reduce luxury consumption in the spring, enhance crop yield in later cuttings, and improve stand survival over winter.

Boron Fertilization

Of the micronutrients, boron (B) is the only one that is commonly deficient for alfalfa production in Kentucky (Figure 3). Therefore, it is important to request a boron analysis when a soil sample is submitted for testing. If soil test results show more than 2 lb per acre of available B, then no fertilizer B is needed. Fields testing less than 2 lb per acre should receive 1.5–2.0 lb B per acre every other year. Care must be taken when applying B because there is a fine line between plant sufficiency and toxicity, especially in grass species such as orchardgrass or timothy that may also be in the stand. In order to avoid plant toxicity problems, do not apply more B than recommended.

Conclusions

Annual soil testing is highly recommended for profitable alfalfa production. Properly managed alfalfa stands can provide profitable yields for six or more years, while poorly managed fields may only last three year or fewer. Understanding and managing fertilizer inputs is one of the keys to alfalfa stand longevity. An analysis of UK soil tests relative to the age of alfalfa stand indicates that many stands fail (i.e. low plant populations and weed encroachment) because soil test K levels are not maintained at an adequate level. It is important to have the appropriate soil pH, P and K levels prior to planting to obtain maximum plant density. Because of the high cash and feed value of alfalfa and the high rate of crop nutrient removal, soil samples should be collected annually after establishment. Lime and phosphorus fertilizer can be added anytime, but K fertilizer should not be applied in the period between the last fall cutting and the first spring cutting if soil test K levels are in the 300 to 450 lb per acre range to limit luxury consumption and to utilize nutrients released throughout the winter months. Taking these steps will maximize nutrient use efficiency and help to minimize the effects of rising fertilizer prices.

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