Assessing the Nutrient Status of Alfalfa Stands in Kentucky

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Abstract. Alfalfa (*Medicago sativa* L.) is a perennial forage legume and is sometimes referred to as the "Queen of Forages" due to its high nutritional value. Alfalfa is commonly produced as hay for use in the dairy and equine industries. Alfalfa yield increased exponentially from the 1950s to the1980s due to new breeding and management innovations. However, during the 1980s yields plateaued at around 7.5 Mg/ha and remain there today. The overarching goal of this study was to determine the role of soil fertility in the observed yield plateau. Fifty alfalfa stands in Kentucky were sampled to gather information about their macro and micronutrient status. Samples were taken, when the stand reached the late bud to early flower stage of maturity, from a 6 x 6 m^2 area that was representative of the entire stand. Soil samples were collected to 10 and 15 cm depths and were sent to the University of Kentucky soil testing lab for analysis. The top 15 cm of 30 stems were dried, ground, and sent to Kansas State University for tissue analysis. In 2022, soil and tissue data from the alfalfa stands sampled indicated that potassium, sulfur, and magnesium were the nutrients most commonly reported to be below established sufficiency ranges. In addition, pH was low in just under half of the sampled stands. Tissue analysis indicated that soil testing overestimated potassium deficiencies in alfalfa stands in Kentucky. Even so, potassium levels were below the sufficiency range in nearly one-fourth of the alfalfa stands sampled.

Introduction

Alfalfa (*Medicago sativa* L.), also known as the "Queen of Forages" due to its high forage quality, is a perennial forage legume and the fourth most widely grown crop in the United States. The most common use for alfalfa is as hay and haylage for dairy cattle but it is also used as feed for equine and other livestock (USDA-ARS, 2020). Alfalfa yields in the United States grew exponentially from the 1950s to the 1980s, but in the 1980s alfalfa yields plateaued at approximately 7.5 Mg/ha where they remain today (USDA-NASS). Increases in yields during that time are accredited to the development of new cultivars with resistance to multiple pests, higher yield potential, and improved management practices (Barns et al., 1988). The overarching objective of this study was to determine the role of soil fertility in the observed yield plateau in three different regions of the United States. This paper will only present data from Kentucky for the 2022 growing season.

Methods and Study Site

Study Site

Starting in mid-June and ending in late-August, samples were collected from 53 alfalfa stands across Kentucky. Alfalfa stands sampled in this study were chosen based on the ability to obtain the management history and the producer's willingness to participate in the study. Stands were from 1-5 years of age and sampling was conducted when plants were between the late bud to the early flower stage of maturity. Samples were collected from a 6 x 6 m^2 area that was representative of the entire stand.

Soil and tissue nutrient status

Composite soil samples were collected from within the 6 x 6 m^2 area at depths of 10 and 15 cm and dried at 55°C before being sent to the University of Kentucky soil testing laboratory. Analysis for plant available P, K, S, Ca, Mg, Mn, Cu, Zn, and Fe was performed using the Mehlich 3 extraction method. Boron analysis was performed using hot water extraction (2020-2021 Lime and Fertilizer Recommendations). Soil water pH and Sikora buffer pH were also determined. Soil test results were compared to recommended nutrient levels for alfalfa in the University of Kentucky's 2020-2021 Lime and Fertilizer Recommendations, AGR-1. Tissue nutrient status was quantified by collecting the top 15 cm of 30 random stems from each 6 x 6 m area and drying them for 3 days at 55°C. Dried samples were ground to pass 2 mm and 1 mm screens using Wiley (Thomas Scientific, Swedesboro, NJ) and Cyclone (Udy Corp., Fort Collins, Co) sample mills, respectively. Ground samples were sent to Kansas State University for N, P, K S, Ca, Mg, Mn, Cu, Zn, and Fe analysis. Results from tissue analysis of each nutrient were compared to recommended nutrient levels for alfalfa in the University of Kentucky's Sampling Plant Tissue for Nutrient Analysis, AGR-92.

Results and Discussion

Soil Nutrient Status

Approximately 40% of stands had a pH level below the ideal range (Table 1). Low pH has been shown to cause declines in nitrogen fixation and inhibition of nodulation in legumes. Low pH also impacts the availability of other nutrients in the soil (Lanyon and Griffith, 1988). Rice and coauthors (1977) found that alfalfa yield declines were reported at pH levels below 6.0. Further, Walworth and Sumner (1990) reported that liming increased both dry matter production and persistence of alfalfa.

Table 1. Proportion of sampled stands in each pH range.

Soil-Water pH	Proportion of Stands
	%
High (>7.0)	23
Ideal (6.5 to 7.0)	36
Low (6.0 to 6.4)	30
Very low (<6.0)	11

Soil test values, averaged over the 10 cm and 15 cm sampling depths, indicate that phosphorus was low in 5% of sampled stands while potassium was low in 33% (Figure 1). However, the plant tissue analysis indicated that phosphorus was sufficient in all samples and potassium was below the sufficiency range in only 26% of sampled stands (Table 2). This discrepancy was likely due to some soil samples falling into upper portion of the low range where yield may not have been limited.

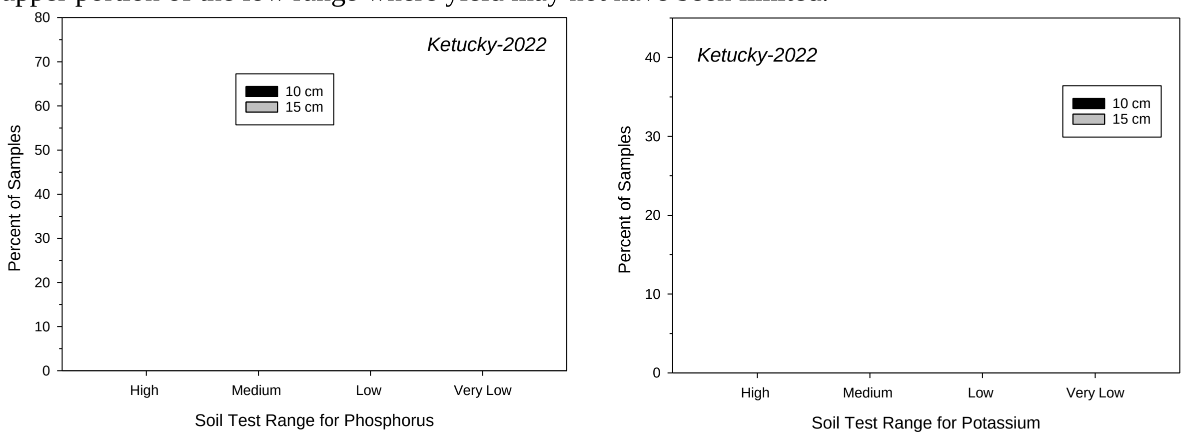

Figure 1. Percent of soil samples falling into the high, medium, low, and very low ranges for soil test phosphorus and potassium for the 10 and 15 cm soil sampling depths (Lime and Nutrient Recommendations, 2020).

Low phosphorus or potassium can inhibit alfalfa yields. Jungers et al. (2019) found that potassium application increased yields in a four to five cuttings per year management system, but they found it lowered forage quality. It has been reported that applications of phosphorus and potassium or phosphorus alone after the final cutting increased the yields in the first cutting in the spring. But potassium application did not cause a yield increase, indicating that phosphorus levels may impact winter hardiness (Berg et al., 2021). Walworth and Sumner (1990) found that potassium applied in the spring increased yields. However, in two out of the three years this was only observed when magnesium was applied with it. They also found that magnesium levels in the soil and tissue were suppressed when potassium was applied. Magnesium applied on its own decreased dry matter production (Walworth and Sumner, 1990). They concluded that these two nutrients are in competition with each other. This offers a potential explanation for the low magnesium levels reported in Table 2.

Table 2. Percent of sampled alfalfa fields falling into the high, sufficient, and low ranges for P, K, S, and Mg as indicated by plant tissue testing (Schwab et al., 2007).

Nutrient Status	P	K	S	Mg
	-----------------% of fields sampled---------------			
Sufficient	100	74	87	77
Low	0	26	13	23

Tissue analysis indicated sulfur was below the sufficiency range in 13 percent of the stands that were sampled (Table 2). Currently, the University of Kentucky does not have a soil test based recommendation for sulfur in alfalfa production. Low sulfur could hinder symbiotic nitrogen fixation. Pumphrey and Moore (1965) reported yield increases and increased shoot nitrogen content when they applied sulfur to alfalfa growing under low sulfur conditions. Reductions in fossil fuel use have caused sulfur deposition to decrease across the United States, resulting in lower sulfur concentrations in soils. The United States Environmental Protection Agency reported that sulfur deposition across Kentucky declined from 10 to 18 kg S/ha to 0 to 6 kg S/ha over the last 20 years.

Conclusions

Soil and tissue analyses indicate that alfalfa yields may be limited in some cases by soil fertility. Soil pH was below the optimal range in more than 40% of the fields sampled. This may result in decreased nitrogen fixation and nutrient availability. Potassium was reportedly low in approximately one-quarter of the sampled stands according to tissue analysis. This was not unexpected since hay production removes large quantities of potassium. Sulfur and magnesium were found to be low in 13 and 23 percent of stands, respectively. More work is needed to better understand if these two nutrients are truly limiting alfalfa yield in Kentucky.

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