Attacking the Yield Plateau: Assessing the Nutrient Status of Kentucky Alfalfa Stands

W.R. Fleming, C.D.Teutsch, E.L. Ritchey, J.H. Grove

Alfalfa (*Medicago sativa* L.), 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; however, in the 1980s alfalfa yields plateaued where they remain at approximately 3.3 tons/A today (USDA-NASS, 2022). 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.

In this study, samples were collected from 53 alfalfa stands across Kentucky. Stands 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 to 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 20 x 20 ft^2area that was representative of the entire stand.

Composite soil samples were collected from within the 20 x 20 ft^2 area at depths of 4 and 6 in and dried at 131°F before being sent to the University of Kentucky soil testing laboratory. Analysis of 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. Tissue nutrient status was quantified by collecting the top 6 in of 30 random stems from each 20 x 20 ft^2 area and drying them for 3 days at 131°F. Dried samples were ground to pass 0.08 and 0.04 in 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, B, Mn, Cu, Zn, and Fe analysis.

Results indicated that 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 yield declines in alfalfa occurred 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 pH	Proportion of Stands
	----------------------%-------------------------
High (>7.0)	23.00
Ideal (6.5 to 7.0)	36.00
Low (6.0 to 6.4)	30.00
Very Low (<6.0)	11.00

Soil tests averaged over the 4 and 6 in sampling depths indicated 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 26% of sampled stands (Table 2). This discrepancy was likely due to some soil samples falling into the upper portion of the low range where yield may not have been limited.

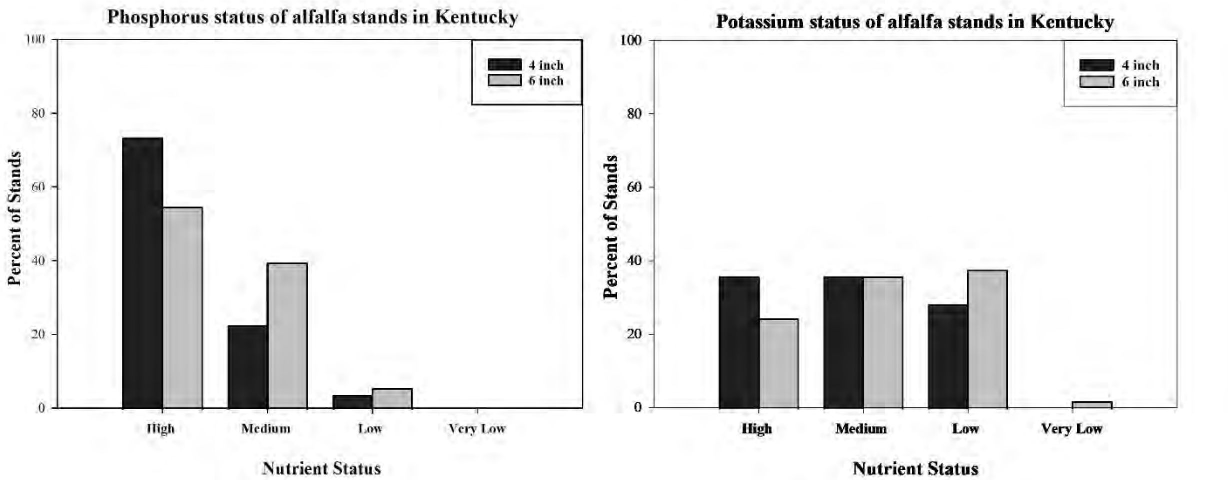

Figure 1. Percent of soil samples falling into the high, medium, low, and very low range for soil test phosphorus and potassium at 4 and 6-inch soil sampling depths.

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

Nutrient Status	P	K	S	Mg	B
	------------------------------%------------------------------				
High	0	0	0	0	0
Sufficient	100	74	87	77	94
Low	0	26	13	23	6

Low phosphorus or potassium can restrict alfalfa yields. Jungers et al. (2019) found that potassium application increased yields in four to five cuttings per year management system; however, they found it lowered forage quality. Applications of phosphorus and potassium or phosphorus alone after the final cutting have been shown to increase yields of the first cutting the following spring. However, potassium addition did not result in 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 increase 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.

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 recommendation for sulfur in alfalfa production. Low sulfur could hinder symbiotic nitrogen fixation. Pumphrey and Moore (1965) reported increases in both yield and 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 decreased from 9 to 16 lb S/A to 0 to 5 lb S/A over the last 20 years. This trend is expected to continue with an increased reduction in the use of fossil fuels.

Boron was reported low in only 6% of the sampled stands according to tissue analysis. The University of Kentucky recommends applying 1.5 to 2.0 lb/A of elemental B every other year unless soil tests indicate current B levels exceed 2.0 lb B/A. Symptoms of a boron deficiency include yellowing of the upper leaves and shortening of the upper internodes and are often confused with potato leafhopper (*Empoasca fabae*) damage. Overall, low boron levels can result in slight yield losses and a decline in forage quality (Lanyon & Griffith, 1988).

In conclusion, soil and tissue analyses indicated 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 reported low in approximately one-quarter of the sampled stands according to tissue analysis. This was not unexpected since hay production removes large quantities of potash. Sulfur and magnesium were reported 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 Boron was low in about 6% of stands. According to tissue analysis, all other micronutrients were sufficient in all the sampled stands This survey will be repeated in the 2023 growing season.

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