ALFALFA RESPONSES TO PHOSPHORUS AND POTASSIUM FERTILIZATION

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Introduction

Proper phosphorus (P) and potassium (K) fertilization is a key management component for maximizing alfalfa productivity. We have summarized the results of a six-year study where we determined the impacts of fertilizer P and K additions on alfalfa yield, stand persistence and nutrient use on a field in West-central Indiana with initially low soil test P and K levels (Bray P1 < 10 ppm and exchangeable K < 100 ppm). A factorial combination of four P rates (0, 50, 100, 150 lbs P_2O_5/acre) and five K rates (0, 100, 200, 300, 400 lbs K_2O/acre) (twenty treatments) were arranged in a complete randomized block design with four replications of each treatment. Forage harvests occurred four times annually and yield, mass per shoot, shoots per area, and herbage nutrient concentrations were determined. Roots were dug in May and December each year to determine plant populations and find out whether plants were dying during the summer (May to December) or the winter (December to May). Total annual yield increased with P and K fertilization, but K fertilization did not increase first harvest yield. Yield increases were due to greater mass per shoot, not more shoots per plant. While K fertilization did not influence plant populations, P fertilization actually decreased plant populations. Plant K removal rates exceeded K fertilizer application each year even at the highest (400 lbs K_2O/acre/yr) rate as long as some P was applied.

Yield

Phosphorus and K fertilizer additions substantially increased yield in each year of this study (Figures 1 and 2). Over six years, total forage yield increased about 5 tons/acre with P fertilization and 6 tons/acre with K fertilization.

Yield increases have been due to increased mass per shoot. Phosphorus and K fertilizer additions increase mass per shoot via two mechanisms: rapid initiation of shoot regrowth

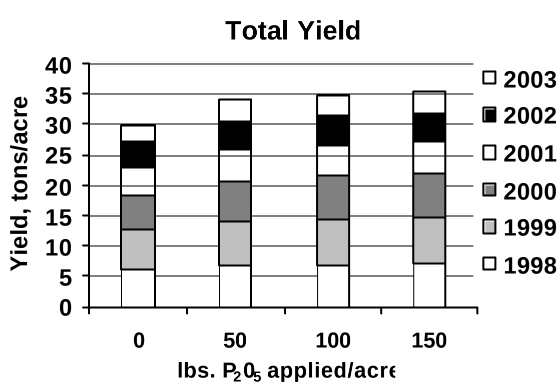

Figure 1. Total dry matter yield as influenced by phosphorus (P) fertilization. Addition of P increased dry matter yield in each year.

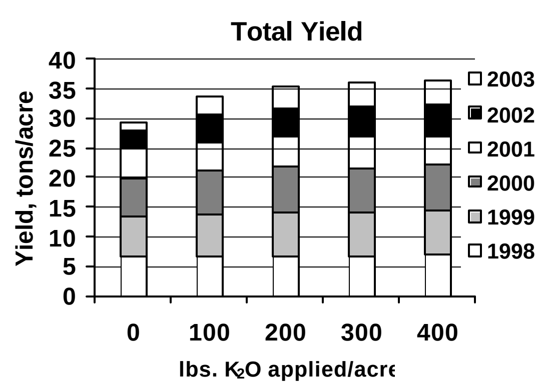

Figure 2. Total dry matter yield as influenced by potassium (K) fertilization. Addition of K increased dry matter yield in each year.

after defoliation and increased shoot growth rate between harvests. Plants receiving P and K recover more rapidly after harvest, producing greater shoot mass within 5 days following defoliation. Shoots per plant has not been affected by fertilization.

Stand Persistence

Plant populations have actually decreased with P fertilization (Figure 3) but were not affected by K fertilization. Phosphorus fertilization promoted larger more robust alfalfa plants. These plants possess greater root mass that likely enhanced water and nutrient uptake. Although these P-sufficient roots often contain increased stored reserves (soluble proteins, amino-N pools, and total nonstructural carbohydrates) at harvest, available P in the plant also allows alfalfa to metabolize these reserves and utilize their functional components throughout the plant, especially during early regrowth. Alfalfa plants supplied P were more competitive with one another, thus eliminating weaker, less competitive plants. Even though there are fewer plants in the P-sufficient plots, they produced greater biomass and sustain economically viable stands for 5 years or more.

Why is it important to know mass per shoot is driving yield increases with increased fertilization? Many extension bulletins suggest that stands of 40 shoots per square foot or below are not viable, and that this is the critical value of ending a stand. In our study shoots per square foot in plots receiving 150 lbs P_2O_5 per acre per year have not been above 40 shoots per square foot since May of 1999, yet these plots have produced the highest dry matter yield each year. When assessing an alfalfa stand, be aware that greater mass per shoot can support high yields even in lower population stands.

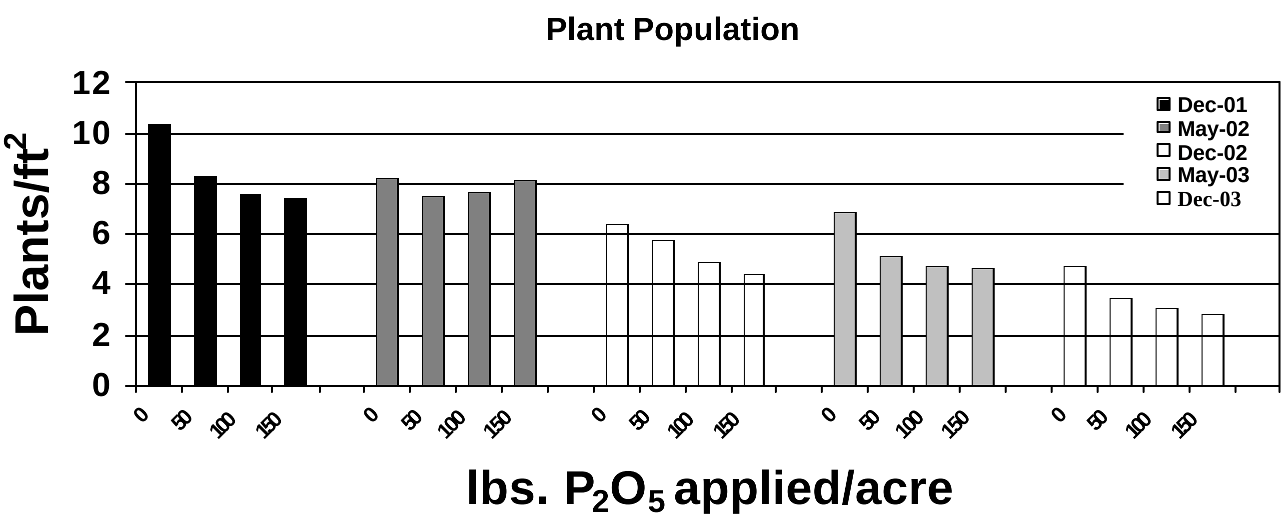

Figure 3. Influence of P fertilizer application on plants/ft^2. Data are averaged over the K fertilizer treatments. Additions of P_20_5 decreased plant populations in each sample date.

Nutrient Balance

Extensive stand losses associated with specific fertility treatments occurred during the last two years. These losses have prompted us to examine in detail the physiological basis for plant death in these plots. Our experimental design placed Replicate 4 on the poorest fertility soils located at this site. During Summer 2002, we noticed severe stand decline in Replicate 4 where P had been applied without K. To our surprise, these stand losses were even greater than what we observed in plots where no P and K fertilizer had been applied for six years. To understand this stand decline in detail, we grouped the plots in Replicate 4 where P is provided without K (0K+50 lbs P_2O_5/acre/yr; 0K+100 lbs P_2O_5/acre/yr; 0K+150 lbs P_2O_5/acre/yr) so we could consider them as a single treatment (0K Plus P). The responses of these 0K Plus P plots were compared to those of plots in Replicate 4 that had been provided 200 lbs K_2O/acre/yr with these same P rates (200 lbs K_2O/acre/yr+50 lbs P_2O_5/acre/yr; 200 lbs K_2O/acre/yr+100 lbs P_2O_5/acre/yr; 200 lbs K_2O/acre/yr+150 lbs P_2O_5/acre/yr) designated hereafter as 200K Plus P. The 200 lbs/acre/yr K rate was selected for comparison because it provided good agronomic performance at moderate K application rates, and because several of the 200K Plus P plots were immediately adjacent to the 0K Plus P plots that had suffered extensive stand loss. We also included the control plot (0K 0P) from Replicate 4 for comparison, recognizing that there is no repetition of this plot in Replicate 4.

Trends in plant populations for these three "treatments" within Replicate 4 were similar to those observed for the entire study, with plants per square foot declining from 15 to approximately 10 between May 2000 and May 2002 (Figure 4). Extensive stand loss occurred in all plots between May and Dec. of 2002, but losses were especially acute in 0K Plus P plots. Stand counts in December confirmed that these plots contained less than 2 plants per square foot; below the 4 plants per square foot minimum generally used to define an "acceptable" alfalfa stand.

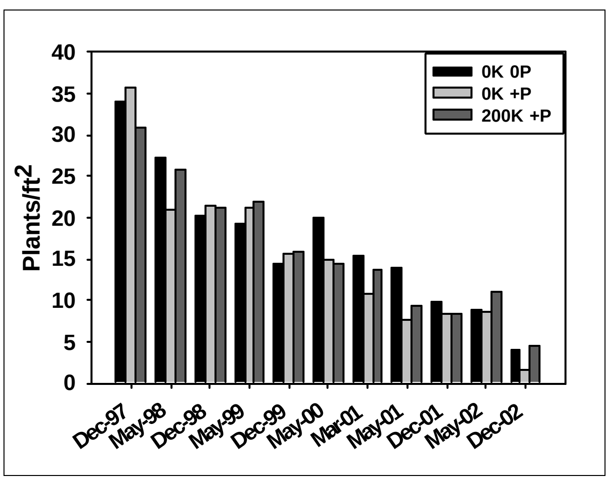

Figure 4. Changes in alfalfa stand between December 1997 and December 2002 as influenced by P and K fertilization. Data are from Replicate 4. Plant populations are presented for the control plot (0K 0P), plots provided 50, 100, and 150 lbs P_2O_5/acre/yr without additional K fertilizer (0K Plus P; mean of these three P plots in Replicate 4 ± standard error), and plots provided 200 lbs K_2O/acre/yr receiving 50, 100, and 150 lbs P_2O_5/acre/yr (200K Plus P; mean of these three plots in Replicate 4 ± standard error). Plant loss occurred in all plots from May 2002 to December 2002, but losses were very extensive in the 0K Plus P plots. In these 0K Plus P plots, plant populations declined below the critical density of 4 plants/ft^2 in December of 2002.

The rapid decline in plant population found in the 0K +P plots also had a substantial effect on total forage yield in 2002. In the first four years of the study, these 0K Plus P plots had yields comparable with the 200K Plus P plots; both of these treatment groups consistently out yielded the 0K 0P plots receiving no fertilizer (Figure 5). Due to the loss of plants in the 0K Plus P plots, yields were low at the first and second forage harvests of 2002, but these plots were abandoned at the third and fourth harvests because of low plant populations and weed invasion. Yield of the 0K Plus P plots in 2002 were actually lower than yield in plots receiving no fertilizer for five years. The plant populations in he 0K 0P plots are still economical and yield determinations continued throughout 2003.

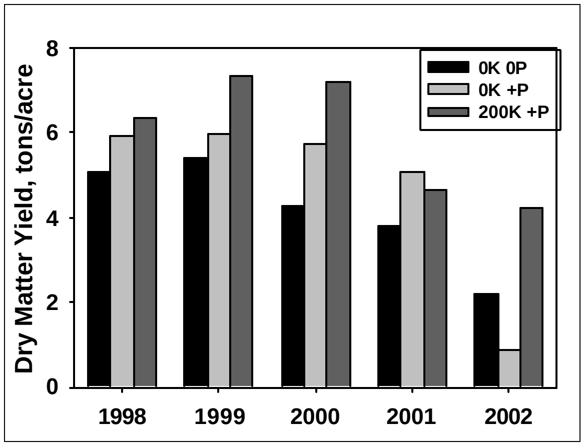

Figure 5. **Yield as influenced by P and K fertilization of selected treatments in Replicate 4. See Fig. 6 heading for definition of the treatments. As expected, alfalfa yield from 0K Plus P and 200K Plus P plots were greater than alfalfa yield from 0K 0P plots from 1998 to 2001. In 2002, yield of the 0K Plus P plots was lower than that of the 200K Plus P and the 0K 0P control plots because of extensive plant death that occurred between May and Dec. 2002 (see Fig. 4).**

Clearly, nutrient imbalance (adding P without K) has much graver consequences for alfalfa survival than we had anticipated. Regarding alfalfa persistence and total yield over the life of a stand, producers should soil test and apply P and K at rates recommended to meet the yield goals set for their alfalfa stand.

Seasonality of K Response

Over the past six years, yield response due to K fertilization has been seasonal. In Harvest 1 of each year, yield differences due to K additions have not been detected, but by Harvest 4 in September, K deficiency is acute. The seasonality of K response may be due to K release from clay minerals between fall and spring. This K release may sustain growth in Harvest 1 of each year, but as subsequent harvests occur, K availability becomes limited once again.

From a fertilizer management perspective, this K release has two serious implications. First when soil sampling, be aware of when the soil sample was taken. Tests performed in the spring may produce falsely inflated values of available K in the soil. Also, caution should be taken when comparing a recent soil test with past tests. Comparisons between soil tests taken in the fall with tests taken in the spring may not be indicative of how K fertilizer management practices are influencing soil test K levels. Secondly, spring K fertilization should occur after the first cutting in May. Early spring K fertilization (before the first cutting) may not increase yield, however, the forage may contain high K levels as a result of "luxury consumption", potentially resulting in feed K imbalances to livestock and subsequent harvests experiencing K deficiency.

P and K Removal Rates

Removal of P and K from the soil has been substantial (Figure 6). Potassium removal exceeded K fertilization even where 400 lbs. K_2O per acre was applied as long as any P was provided. Only in plots receiving 300 and 400 lbs. K_2O per acre and no P did K application surpass K removal, and these were the only plots that showed an increase in soil test K. In all other plots, soil test K decreased. Alfalfa P removal did not exceed 100 lbs. P_2O_5 per acre regardless of K application. Application of 100 and 150 lbs. P_2O_5/acre would be considered rates that we could expect soil test P levels to increase, whereas applications of 50 lbs. P_2O_5/acre and below would not be sufficient to compensate for removal. Soil test results confirm this. Available P in the soil only increased in plots where 100 and 150 lbs. P_2O_5/acre was applied.

Key Points for Alfalfa Fertility Management

- Each ton of hay removes 100 lbs. of potash (0-0-60) and 30 lbs. of triple superphosphate (0-46-0)
- Soil test in summer or fall so samples better reflect plant-available K in the soil
- Apply half the recommended rate of fertilizer specified by your yield goal after the 1st cutting in May/June and the remaining half after your last cutting in September

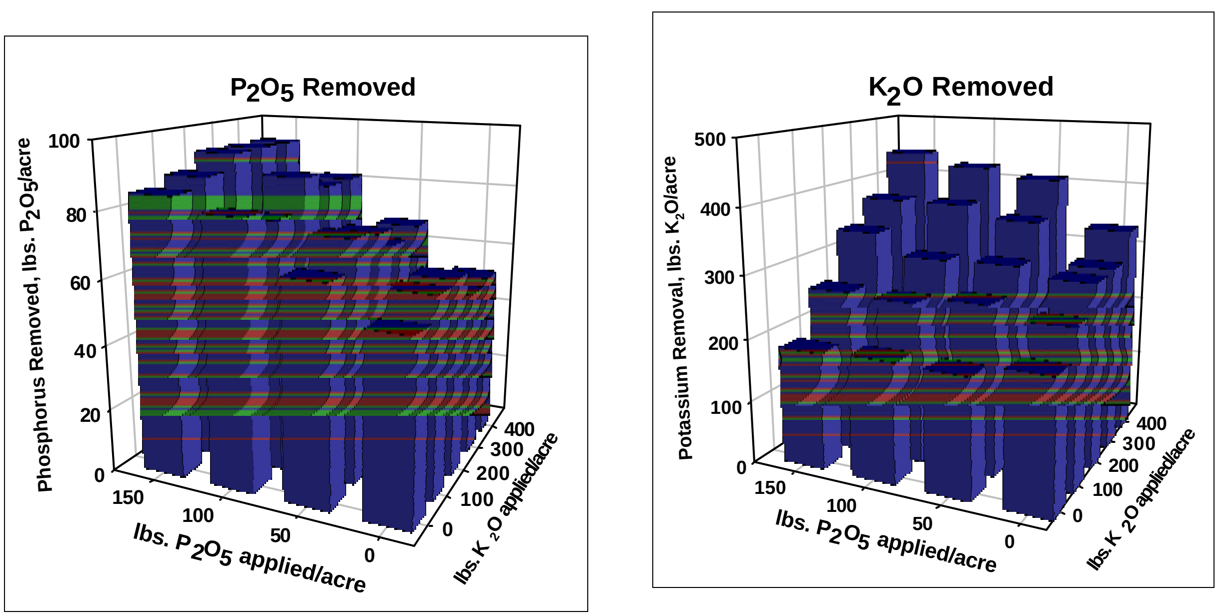

Figure 6. Removal of P and K by additions of both nutrients. Removal of P never exceeded 100 lbs. P_2O_5/acre application rate. When supplied any amount of P, removal of K exceeded each application rate even in plots receiving 400 lbs. K_2O/acre.