ENHANCING ALFALFA PRODUCTION THROUGH IMPROVED PHOSPHORUS AND POTASSIUM MANAGEMENT

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Abstract

Addition of phosphorus (P) and potassium (K) fertilizer is vital to maintain alfalfa productivity. The objective of this study was to examine how P and K fertilizer application increases alfalfa yield, nutrient use, and plant persistence. Replicate plots of P (0, 50, 100, 150 lbs P_2O_5/acre) and K (0, 100, 200, 300, 400 lbs K_2O/acre) treatments were arranged in a factorial design. Forage harvests occurred four times annually for 5 years and yield, mass per shoot, shoots per area, and herbage nutrient concentrations were determined. Roots were dug in May and December of each year to ascertain plant populations and determine whether plants were dying during the summer (May to December) or during the winter (December to May). Total annual yield increased with application of P and K, but K application did not increase first harvest yield. Yield increases were due to greater mass per shoot. Addition of P decreased plant populations, whereas K did not alter stand populations. Removal rates of K exceeded K application each year even at the highest (400 lbs K_2O/acre/yr) rate.

Introduction

High yield and excellent forage quality make alfalfa (*Medicago sativa* L.) the forage of choice in many producers' livestock systems, but intensive harvest management and average winter hardiness can undermine maximum yield, persistence, and ultimately profit. Plant breeders can improve alfalfa productivity, but gain from selection is often disappointing. Improved fertilizer management represents another approach for increasing alfalfa yield and persistence, but our understanding of how alfalfa responds to P and K application remain unclear. Our objective was to determine how yield and especially yield components of alfalfa, as well as nutrient removal are altered with enhanced P and K fertility. Our results may lead to new fertilizer management strategies that increase the profitability of growing alfalfa.

Approach

In May 1997, a three-acre field of alfalfa was established. Beginning soil test estimates for the experimental site were approximately 90 ppm K and 5 ppm P. In September 1997, plots were created using a randomized complete block design containing four P treatments (0, 50, 100, 150 lbs P_2O_5/acre) and five K treatments (0, 100, 200, 300, 400 lbs K_2O/acre) arranged in a factorial design. Beginning in May 1998, forage was harvested four times annually and yield, mass/shoot, and shoots/area determined. Roots were dug in May and December to document plant populations and to determine when populations declined; during the summer (May to December) or during the winter (December to May). Both herbage and root tissue were digested for P and K concentrations, and nutrient removal in herbage harvested was calculated.

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Summary

Yield

Increased yield has often been associated with applications of phosphorus and potassium. Our findings have produced the expected results (Fig. 1 and 2), but examination of what is driving the increase in yield must be carefully considered. Alfalfa yield is comprised of three yield components: plants/area, shoots/plant, and mass/shoot, that when multiplied together determine forage yield. An increase in forage yield should result from an increase in one or more of these yield components.

Yield Components

Plants/area (plant population) declines as an established alfalfa stand ages. Stresses such as cold temperature and freeze/thaw cycles in the winter and competition for light, water, and nutrients as well as defoliation every 30 days in summer can increase plant death and thin stands prematurely.

Since establishment of our stand in 1997, plant population has declined with time and in May 2002, plants/area were approximately 8 plants/ft^2 averaged over all treatments (Fig. 3). Contrary to popular belief, extensive plant losses have not occurred during winter, but have been extensive during summer. From December 1998 to May 1999, December 1999 to May 2000, and December 2001 to May 2002 plant losses over those winters were 2, 0, and 2 plants/ft^2, respectively. Injury during winter, however, may create a weaker, less competitive plant that dies during summer. Work is continuing in an adjacent set of plots that are much larger and will permit us to determine when alfalfa plants die in summer, and the physiological basis for their demise.

Potassium fertilization has not influenced trends in plant population, but addition of P fertilizer has decreased plant populations since December 1999 (Fig. 4). Addition of P fertilizer has produced much larger plants as compared to plants receiving no P. The enhanced growth of the P-sufficient alfalfa has increased competition between adjacent plants leading to the death of inferior plants early in the life of the stand. However in May 2002, plant populations receiving 100 and 150 lbs. P_2O_5/acre/year did not decline when compared to populations in December 2001. Alfalfa plant losses are now greatest in the control plots not receiving P. Despite declines in population of plots receiving P fertilizer, these plots have maintained high forage yields into this the 5th year of the study, and probably will remain economically viable for years to come. Characteristics of these P-sufficient plants that make them competitive include the fact that they have greater root mass, which allows for superior water and nutrient accessibility, and fast regrowth due to greater amount and mobilization of stored root reserves.

Increased shoots/plant is often thought as a primary mechanism used to sustain maximum alfalfa yields as populations thin. Through the first four years of this study, increased shoots/plant has not been positively associated with greater yield. Traditionally, the value of 40 shoots/ft^2 has been the break point in determining whether an alfalfa stand is economically viable. Stands possessing less than 40 shoots/ft^2 have been foreseen as not viable. In the final three harvests this past growing season, addition of K increased shoots/ft^2, but only in Harvest 4 were shoots/ft^2 over 40 (Fig. 5). This harvest produces the lowest yields of the year. In plots receiving the highest increment of P, shoots/ft^2 has not been above 40 since May of 1999, but these plots have produced the maximum yield in each of the production years. These data indicate that perhaps shoots/ft^2 is not the proper concept for assessing the productivity potential of an alfalfa stand.

Greater alfalfa yield obtained with P and K additions has primarily been generated from an increased mass/shoot (Fig. 6). Throughout the first five years mass/shoot has increased as applications of P and K increased, while the other yield components have either decreased or have not been influenced by P and K addition. Increased mass/shoot is produced through two different mechanisms. Initiation of shoot regrowth after defoliation ("bud break") is substantially faster when alfalfa is supplied P and K. Elongation rate of the shoots after bud break also increases dramatically with addition of P and K. With the increased root growth found in P- and K-sufficient alfalfa, a greater amount of stored reserves is available for regrowth, and this may be a factor contributing to the rapid shoot initiation and growth after cutting.

Seasonality of K Response

Despite the occurrence of acute K deficiency symptoms and greatly reduced yields the previous fall (Fig. 7), yield differences due to K fertility were not evident in May (Harvest 1), even in plots receiving 400 lbs. K_2O/acre (Fig. 8). The increased availability of K is thought to occur due to the freeze/thaw cycles that the soil experiences during winter and early spring. The cycles release K that was bound between soil clay particles and previously unavailable to the plants. The release of K, if it occurs, may be adequate to sustain maximum yields in Harvest 1, but not subsequent harvests. Work is being initiated to determine factors contributing to the seasonality of alfalfa K responses.

The lack of yield response due to K fertilization in Harvest 1 indicates that application of K in spring before Harvest 1 would be unwise and could contribute to the luxury consumption of K. Luxury consumption is a condition where plants accumulate as much K as is available in the soil, far exceeding the minimum requirement. Increased concentrations of K will occur in forage without a positive yield response, thus decreasing the fertilizer efficiency of K and possibly depriving subsequent harvests of adequate K nutrition. Applying half the specified amount of fertilizer to meet the specific yield goals after the first harvest, and the remainder after the last harvest in the fall will increase K fertilizer use efficiency. Phosphorus fertilization also may be split in this manner and occur at these times.

Increased K availability also has implications for timing of soil sampling and in the interpretation of soil test concentrations. Soil samples taken in spring may indicate falsely inflated K soil concentrations. The enlarged values may alter K management decisions and reduce K applications, subsequently placing the crop at risk of K-deficiency. Also when comparing soil tests from previous years to a current soil test, time of sampling must be considered. A comparison between a soil test taken in the fall three years previously and a soil test taken this spring may not provide a clear indication of how individual management practices have influenced soil test concentrations over time.

Nutrient Removal

Total P removal from the soil has not differed from previously published values. Approximately 60 lbs. P_2O_5/ acre is removed in the hay harvested regardless of K application (Fig. 9).

Removal of K has greatly exceeded expectations (Fig. 9). Application of 300 and 400 lbs. K_2O/acre only surpassed removal where no P is applied. Addition of any amount of P increased removal rates over every application of K even 400 lbs. K_2O/acre.

A comparison of the removal rates of P and K during forage production revealed that 30 lbs. triple superphosphate (0-46-0) and 100 lbs. potash (0-0-60) are removed per ton of hay per acre. Application of P and K at these rates will replenish the amount of P and K acquired from the soil. To increase soil test concentrations of these nutrients, greater application rates of P and K would be required.

Figures

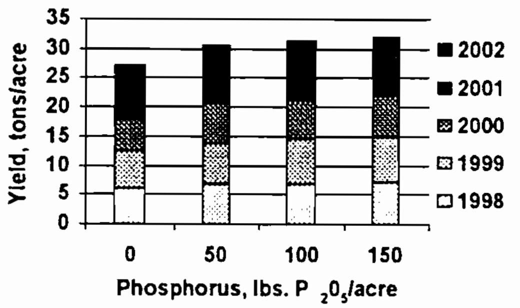

Figure 1. Impact of P addition on yield in each of the five experimental years. Yield was increased with each increment of P.

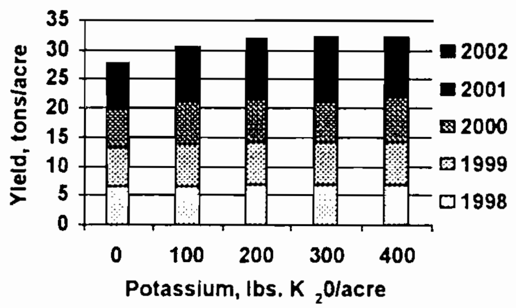

Figure 2. Impact of K addition on yield in each of the five experimental years. Yield was increased with each increment of K.

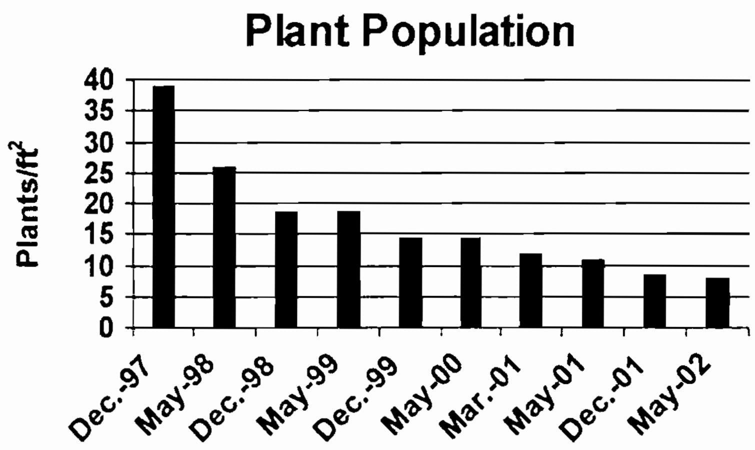

Figure 3. Trends in plants/ft² from December 1997 to May 2002. Data are averaged over P and K fertilization treatments. After the initial decline, plant populations have declined during summer (May to December) not over winter (December to May).

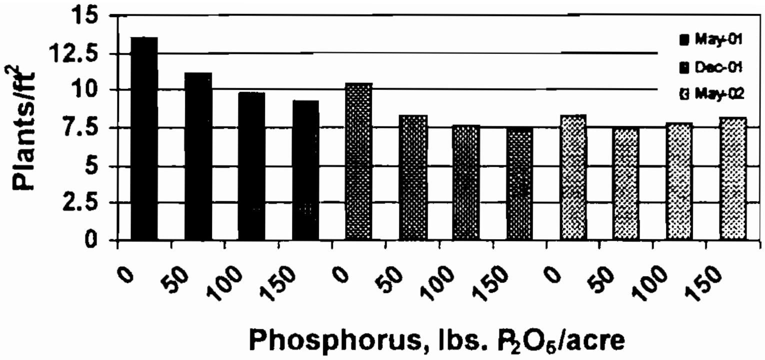

Figure 4. Influence of P fertilizer application on plants/ft^2. Data are averaged over the K fertilizer treatments. Additions of P_2O_5 decreased plant populations at each sample date

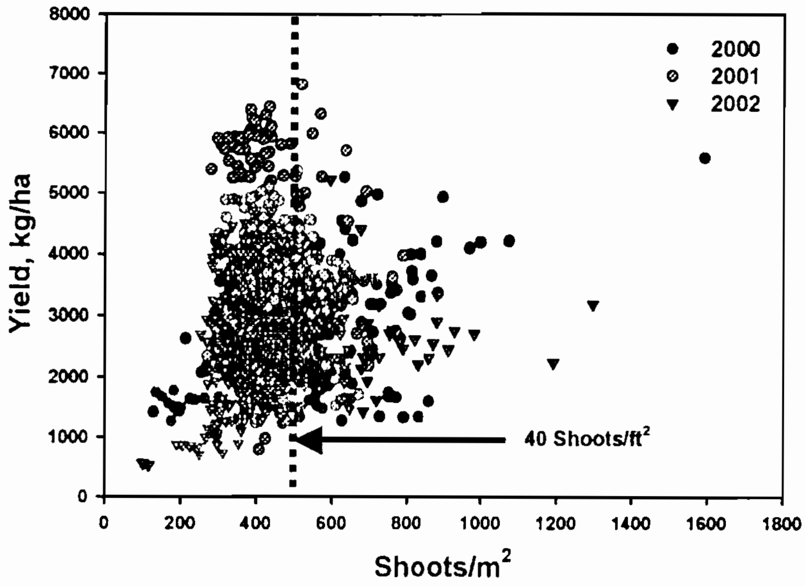

Figure 5. Yield as influenced by shoots/m^2 in 2000, 2001, and 2002. The dashed line indicates forty shoots/ft^2. Increased stems did not necessarily produce increased yield. High yields can still be achieved with stem numbers lower than 40 stems/ft^2.

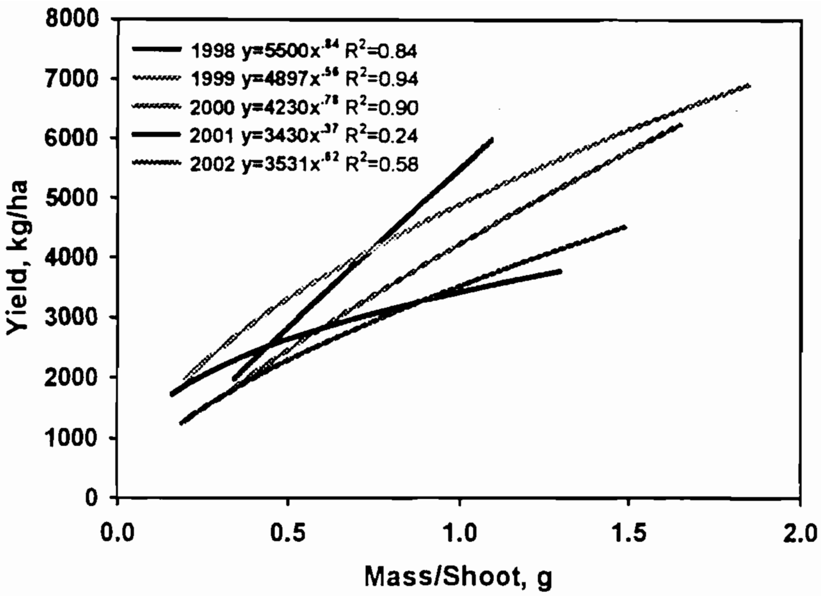

Figure 6. Yield as influenced by mass/shoot in 1998 through 2002. Increases in forage yield have been produced primarily through enhanced mass/shoot. Each line represents 320 data points taken from harvests during each year.

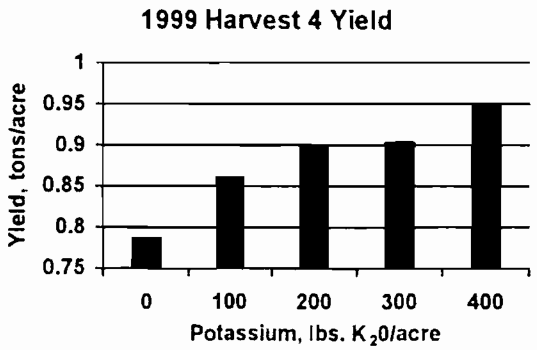

Figure 7. Effects of potassium on forage yield at Harvest 4 of 1999. As increased increments of K were provided to alfalfa, yield was dramatically enhanced. LSD=0.12

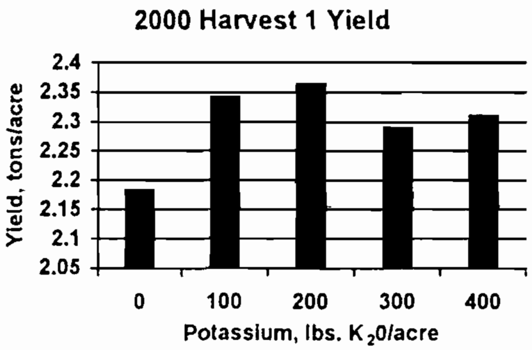

Figure 8. Effects of potassium on forage yield at Harvest 1 in 2000. Application of K did not influence forage yield. LSD=0.43

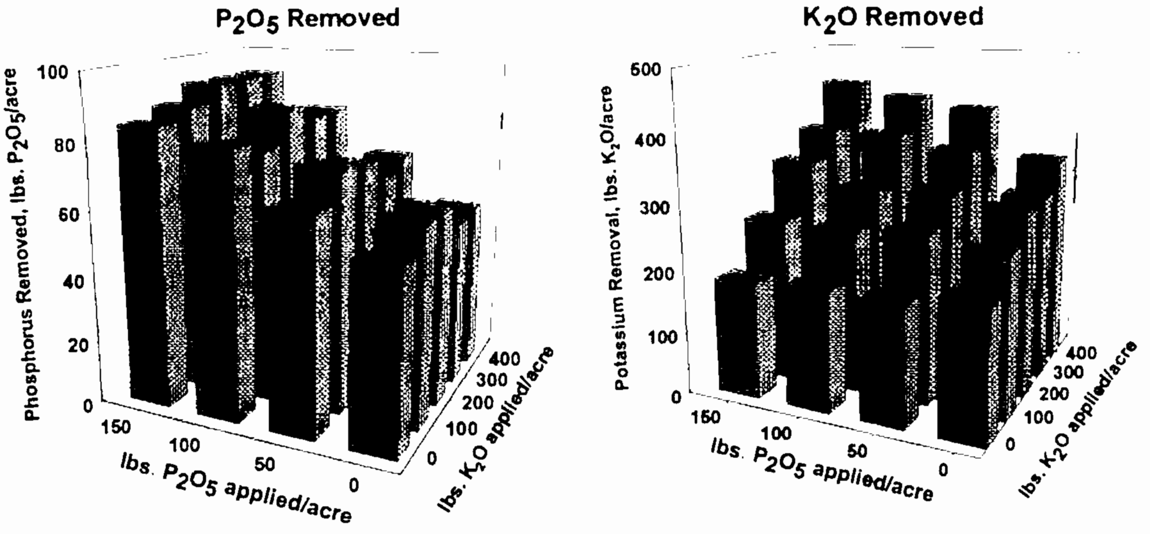

Figure 9. Removal of P and K in alfalfa forage as influenced by P and K fertilization. Removal of P in forage never exceeded 100 lbs. P_2O_5/acre. When supplied any amount of P, removal of K exceeded K application rates even in plots receiving 400 lbs. K_2O/acre.

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)
- Acquire samples for soil test in summer or autumn so soil test results 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
- Yield responses are due to high yield per shoot, so cultivars must possess this trait in order to be responsive to P and K fertilization.
- Shoot production per plant was not associated with forage yield regardless of P and K nutrition.
- High P rates reduced plant populations. Nevertheless, P-fertilization was necessary for high yield and for plants to respond to K fertilization.

For more information regarding the information presented, contact Kess Berg (email: kberg@purdue.edu) or Jeff Volenec (email: jvolenec@purdue.edu).

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