P AND K MANAGEMENT STRATEGIES FOR OPTIMAL ALFALFA PRODUCTION

J.J. Volenec, S. Lissbrant, W.K. Berg, S.M. Cunningham,
B.C. Joern, S.M. Brouder, and K.D. Johnson
Department of Agronomy, Purdue University, West Lafayette, IN 47907-2054
jvolenec@purdue.edu

Abstract
Fertilization with phosphorus (P) and potassium (K) is essential to maintain alfalfa productivity. Our objective was to examine how P and K fertilizer influenced alfalfa yield and yield components, plant persistence, and root physiology. Replicate plots of P (0, 50, 100, 150 lbs P_2O_5/A) and K (0, 100, 200, 300, 400 lbs K_2O/A) treatments were arranged in a factorial design. Forage harvests occurred four times annually between 1998 and 2005 and yield, mass per shoot, and shoots per area were determined. Roots were dug in May and December of each year to estimate plant populations and determine whether plants were dying during "summer" (May to December) or during "winter" (December to May). Roots were analyzed for starch, sugar, amino acid, and protein concentrations. 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, whereas stems/area were not related to forage yield. Plants died during summer and not during winter. Although P fertilizer increased forage yield significantly, it decreased plant populations by producing fewer but larger individual alfalfa plants. Fertilization with P alone resulted in faster stand thinning than observed in plots provided both P and K, and those left unfertilized. This rapid stand loss was associated with low concentrations of root reserves including starch, amino acids, and protein in taproots. Balanced P and K nutrition is essential to maintain stands and have high forage yield.

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 poor winter hardiness can undermine yield, persistence, and ultimately profit. Improved fertilizer management represents one approach for increasing alfalfa yield and persistence, but our understanding of how alfalfa responds to P and K application is rudimentary. Our objective was to determine how alfalfa yield, the components of yield, and forage quality are altered by P and K fertilizer applications. Our results may lead to new fertilizer management strategies that increase the profitability of growing alfalfa.

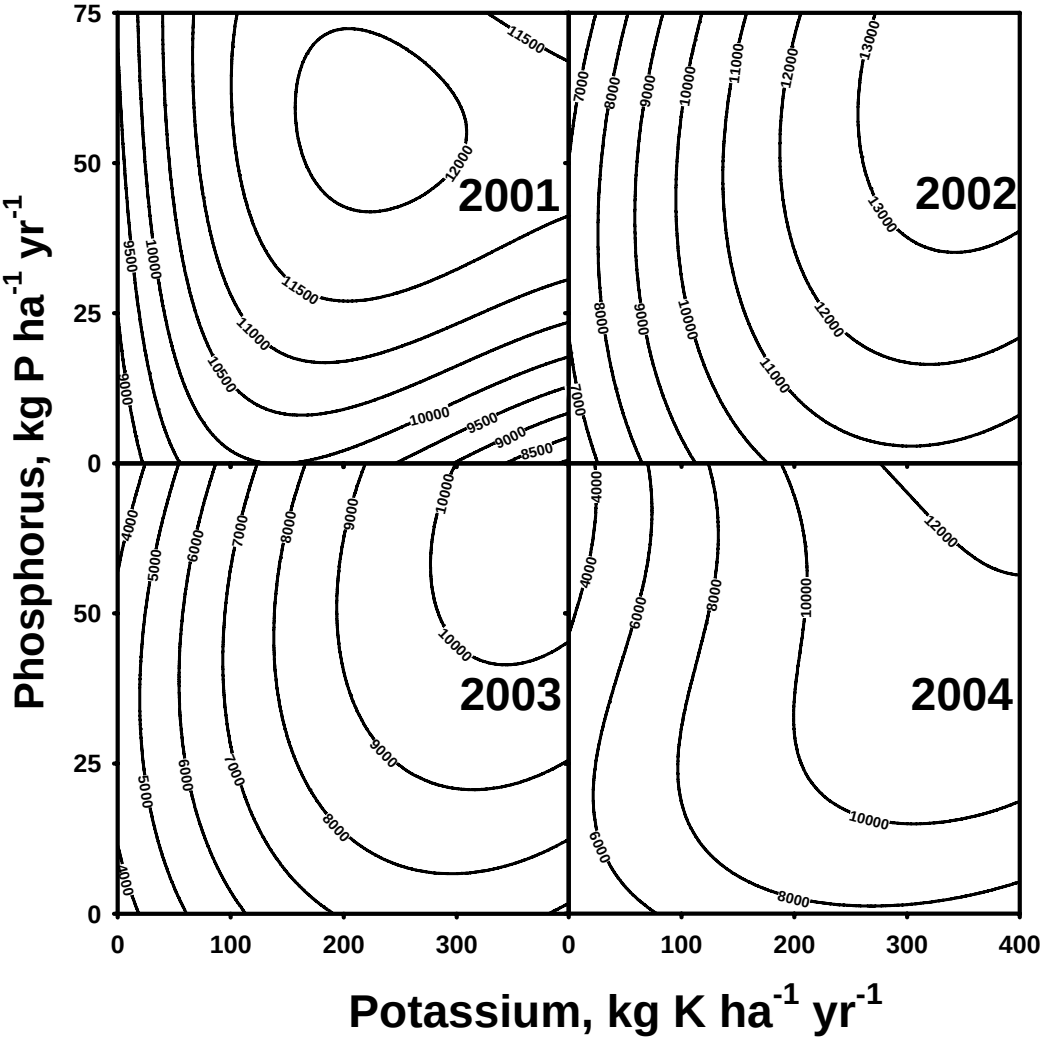
Methods
In May 1997, a three-acre field of Pioneer Brand 5454 alfalfa was established. Initial soil tests levels were approximately 90 ppm K and 5 ppm P. In September 1997, plots were fertilized with every possible combination of four P treatments (0, 25, 50, and 75 kg P/ha equivalent to 0, 50, 100, 150 lbs P_2O_5/A) and five K treatments (0, 100, 200, 300, 400 lbs K_2O/A) (20 treatment combinations). Beginning in May 1998 and continuing until September 2004, forage was harvested four times annually and yield, mass/shoot, and shoots/area determined. Roots were dug in May and December of each year to determine plants/m^2 and to determine when plants died; during "summer" (May to December) or during "winter" (December to May). Forage quality was determined on forage samples using near infrared spectroscopy.

Results and Discussion

Yield
Fertilizer application increased forage yield in 1998 through 2000 (data not shown). Large consistent yield differences were apparent from 2001 to 2004 as forage removal depleted soil P and K levels of unfertilized plots (Figure 1). Highest yields were obtained when at least 200 kg K/ha and 50 kg P/ha were

provided annually. Application of the highest rate of K fertilizer without P had no effect on yield in 2001. Similarly, high rates of P fertilization, without K application, did not result in increased yield over the unfertilized control plots (0K/0P) most years, and in 2004 reduced yields significantly because of poor plant persistence observed in these plots.

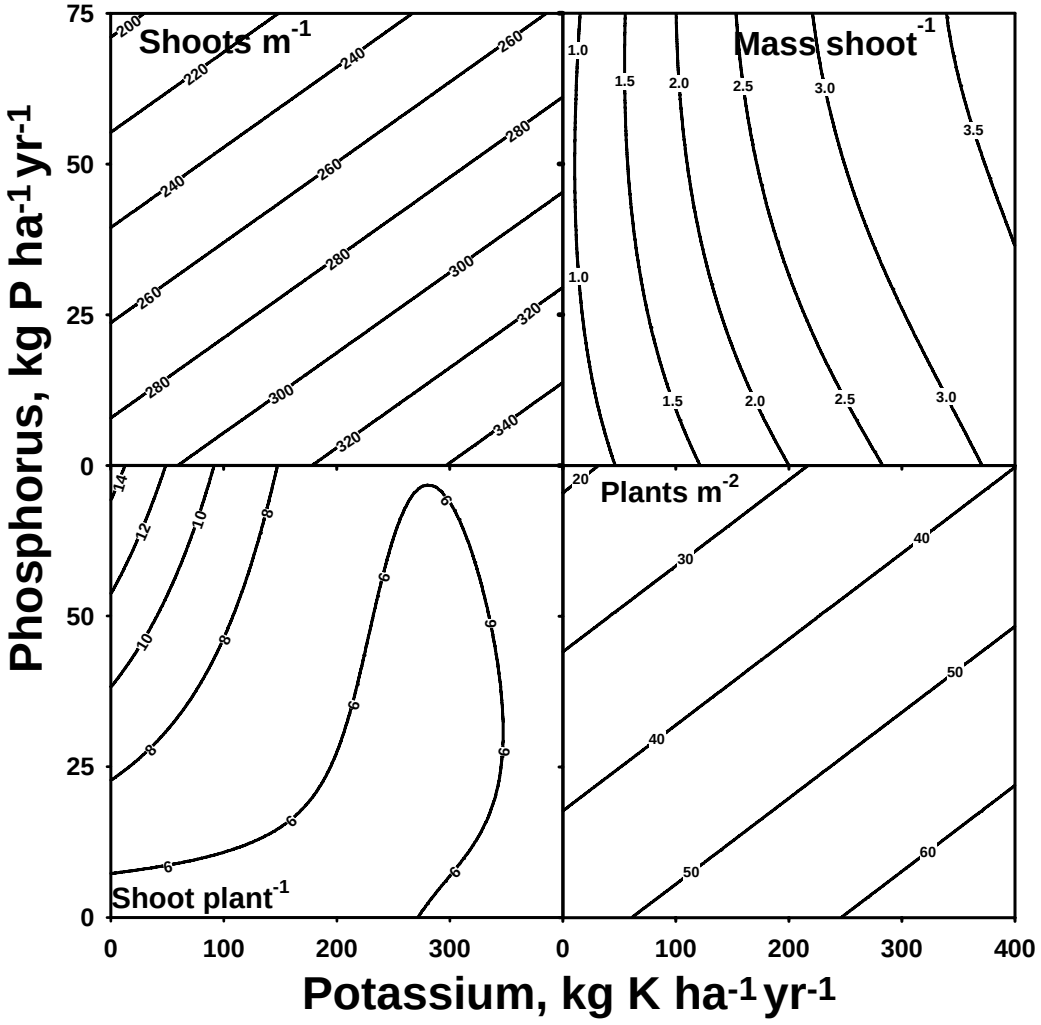
Figure 1. Influence of P and K application on total annual forage yield (dry weight) of alfalfa in 2001 through 2004. Numbers in contour lines are yields in kg/ha and can be converted to lbs/A by multiplying values by 0.0892 (for example, in 2001 the 12000 kg/ha yield is equal to 12,000 x 0.892=10,704 lbs/acre or 5.4 tons/A). From Berg et al., 2006 (in press).



Yield Components

Alfalfa yield is comprised of three yield components: plants/area, shoots/plant, and mass/shoot, that when multiplied together determine forage yield. Multiply plants/area with shoots/plant and you calculate shoots/area. An increase in forage yield (Figure 1) should be the result of increase(s) in one or more of these yield components.

Figure 2. Influence of P and K fertilizer application on shoots m^{-2}, mass $shoot^{-1}$, shoots $plant^{-1}$, and plants m^{-2} Harvest 1 in May



2004.

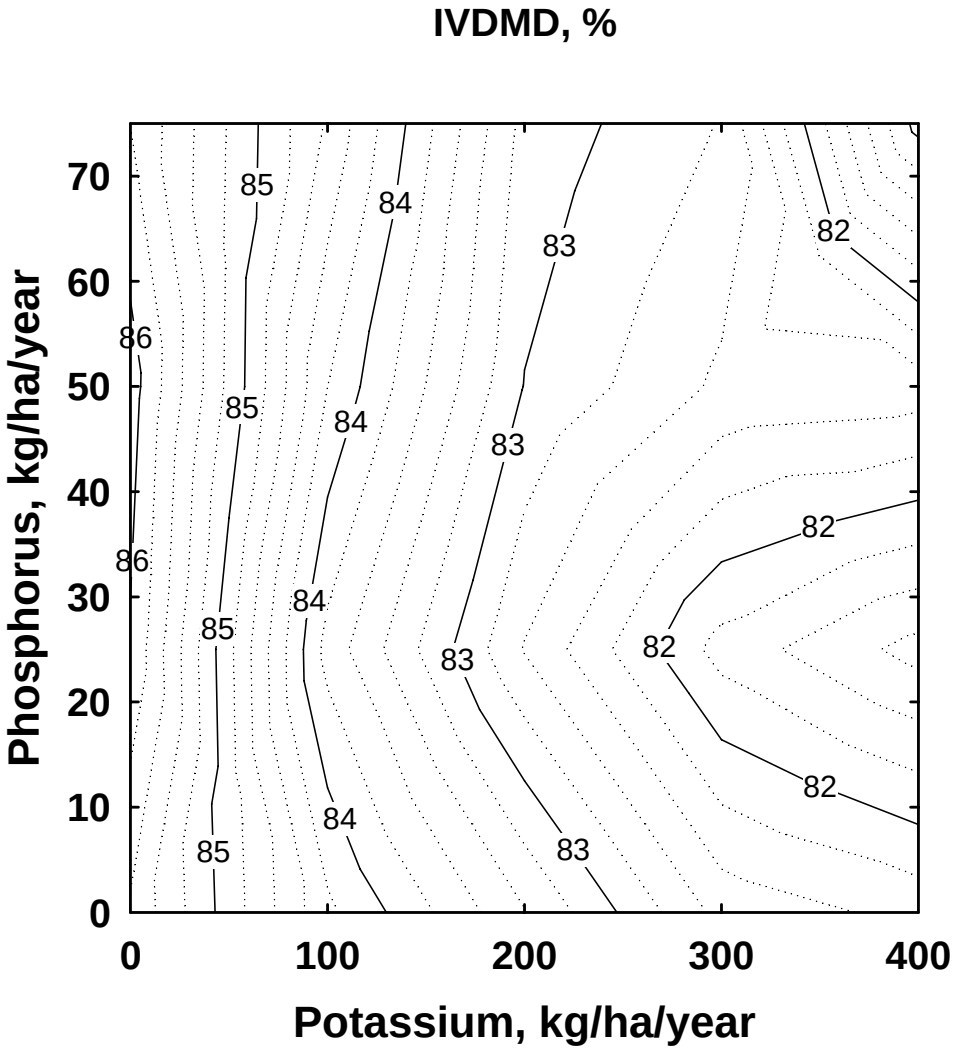
Greater alfalfa yield obtained with P and K fertilization has primarily resulted from increased mass/shoot (Figure 2). Mass/shoot has consistently been associated with P- and K-induced increases in forage yield each harvest of every year, whereas, the other yield components have either decreased or have not been influenced by P and K addition. For example, the greatest number of shoots/area (340 m^2) was observed when alfalfa was fertilized with high K rates and no P, whereas the highest forage yield was obtained when both P and K were provided at high rates (Figure 1) where plants produced fewer shoots/area (approx. 260 m^2). Similarly, forage yield was greatest at intermediate plant populations (about 40 m^2 which is equal to 4 ft^2). The higher plant populations observed at high K rates without P application actually had significantly lower forage yield. Shoots/plant were generally greatest with high rates of P

fertilizer application without K because this treatment had the poorest plant persistence, lowest populations, and this minimal interplant competition permitted each plant to produce more shoots.

Forage Quality-Yield Interactions

We used in vitro dry matter disappearance (IVDMD) as an estimate of forage quality. IVDMD was influenced by both P and K fertility. In general, as the rate of K fertilizer application increased, IVDMD declined from 86% to less than 82% of dry matter (Figure 3). The impact of P was less consistent, altering IVDMD only slightly at high K fertilizer rates.

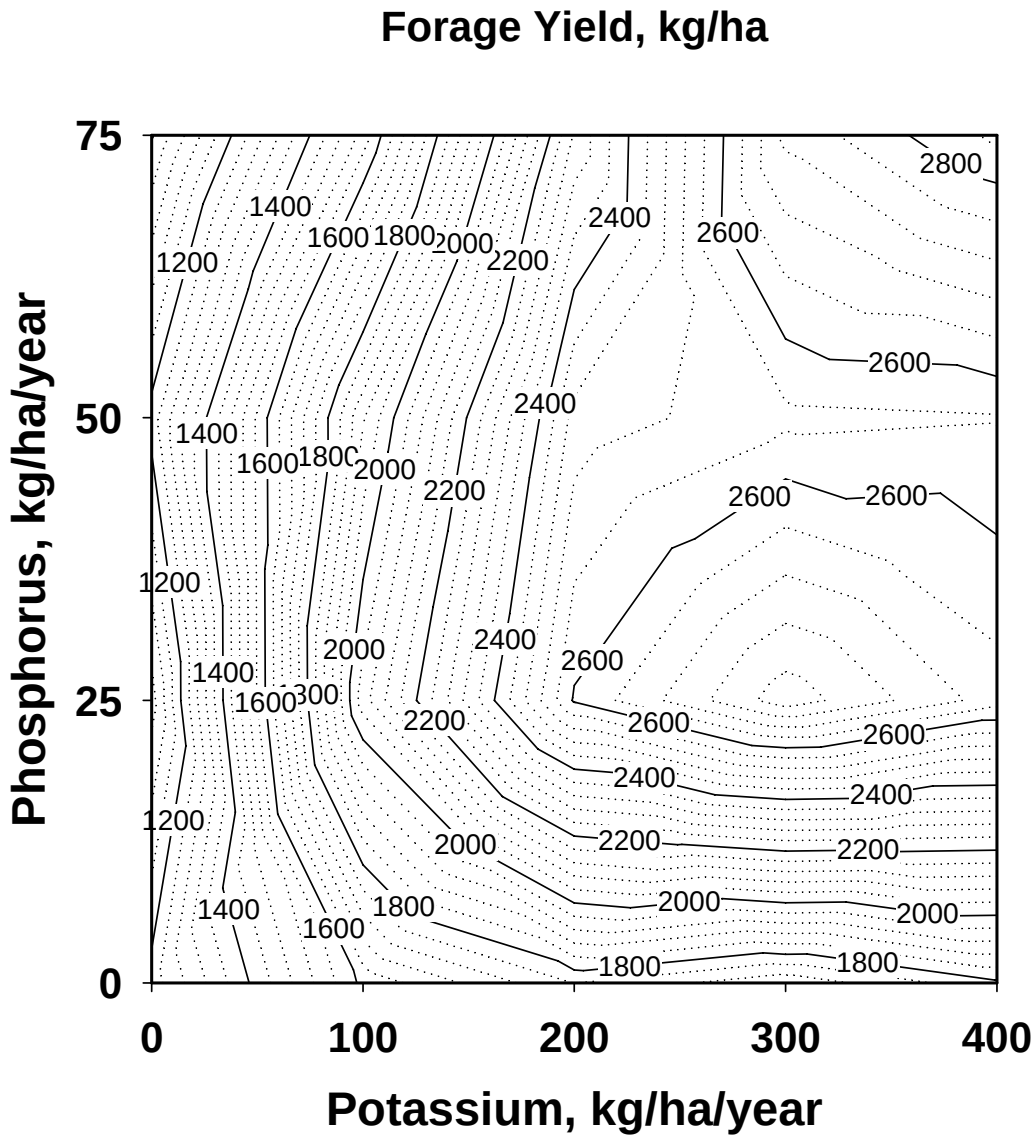
Figure 3.Influence of P and K fertilizer application on in vitro dry matter disappearance (IVDMD) of alfalfa forage. Values in the figure are percent of forage dry matter, and have been adjusted for differences in ash content.



There was a negative relationship observed between forage quality and forage yield. In other words, the highest forage quality coincided with the lowest forage yield, whereas the highest yielding plots had the lowest IVDMD (Figure 4). For example, forage from plots fertilized with 25 to 50 kg P/ha but no K had IVDMD values of 86% (Figure 3) and also had the lowest forage yields observed at this harvest (approximately 1200 kg/ha) (Figure 4). By comparison, plots fertilized with at least 200 kg K/ha and at

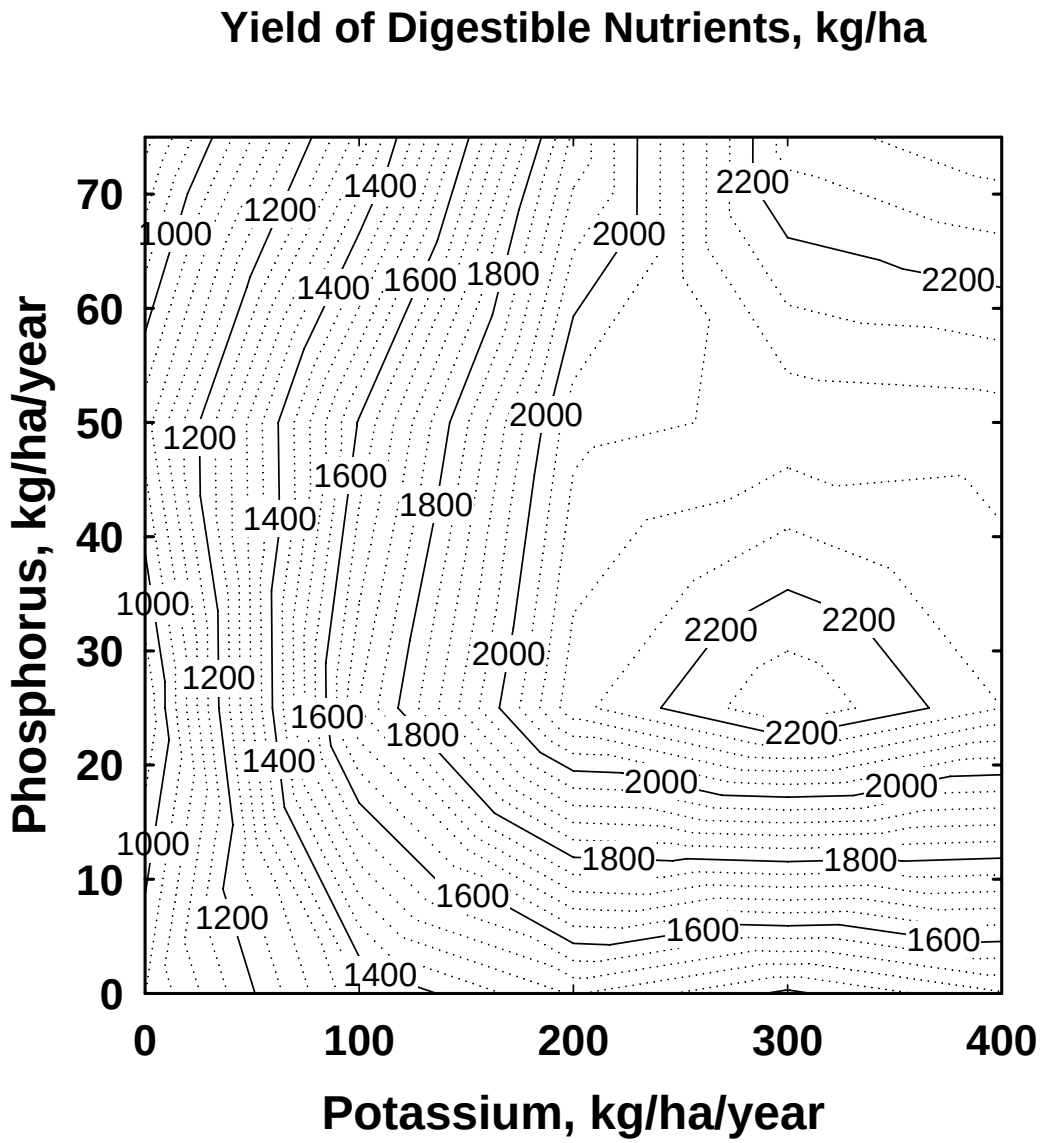
least 25 kg P/ha had the highest forage yields at this harvest (Figure 4), but forage IVDMD values of approximately 82% (Figure 3).

Figure 4. Influence of P and K application on forage yield (dry weight) of alfalfa. Numbers in contour lines are yields in kg/ha and can be converted to lbs/A using calculations provided in Figure 1.



In order to understand the impact of the trade-off between forage IVDMD (Figure 3) and forage yield (Figure 4), we calculated the yield of digestible nutrients per acre. This is simply the product of forage yield x IVDMD (using the decimal value instead of percent; for example, 0.82 for 82% IVDMD). These data are plotted in Figure 5 and clearly show the importance of forage yield in influencing yield of digestible nutrients per acre in this study. The highest IVDMD yield was in plots provided both P and K at moderate to high application rates (Figure 5). This pattern was virtually identical to the pattern observed for forage yield at this harvest and underscores the importance of forage yield in driving nutrient production per acre.

Figure 5. Influence of P and K application on yield of digestible nutrients of alfalfa. Numbers in contour lines can be converted to lbs/A using calculations provided in Figure 1.



Conclusions

1. Balanced P and K nutrition is important for maintaining high alfalfa yields.
2. High rates of K fertilization alone result in high plant densities, but only moderate yield because the P-limited plants have small shoots.
3. High rates of P fertilization without K result in poor plant persistence and low forage yield.
4. Forage quality is highest in low yielding plots that are deficient in K, and have received only moderate P fertilizer rates.
5. Maximum yield of nutrients per acre is closely associated with yield.
6. Under most circumstances producers should manage for high forage yield, and not be concerned about the slight reduction in forage quality that might result under high-yielding conditions.