PHOSPHORUS AND POTASSIUM FERTILIZATION OF ALFALFA

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Fertilizing alfalfa with phosphorus (P) and potassium (K) can increase yield and stand longevity. However, to maximize production and profitability, it is important to adjust fertilizer rates to meet the nutritional needs of plants in a field-specific manner. In this publication we first review important information regarding P and K deficiency symptoms, and current soil test recommendations. We then discuss recent results from Purdue University regarding fertilizer rates, importance of balanced fertility, timing of fertilizer application, and the influence of P and K fertility on alfalfa forage quality.

Phosphorus and K are Involved in Many Important Plant Processes

Both P and K are considered macronutrients and are required by plants in relatively high amounts compared to other nutrients. Both P and K are essential for plant growth. Potassium is involved in a number of important physiological processes in plants including activation of several enzymes, synthesis and degradation of carbohydrates, synthesis of protein, and opening and closure of stomata, the pores in leaf surfaces involved in gas exchange and photosynthesis. Phosphorus is found in many cellular constituents including nucleic acids (DNA, RNA), phospholipids, ATP, and other high-energy compounds in plant cells. These compounds are necessary for photosynthesis, energy transfer, carbohydrate and protein synthesis, and lipid metabolism (Rhykerd and Overdahl, 1982).

Deficiency Symptoms of P and K Can Sometimes be Seen in the Field

Potassium deficiency of alfalfa can appear as chlorotic (yellow) spots along the leaf margin (Figure 1). These symptoms are especially evident on older leaves because K is mobile in plants and is preferentially transported from old to young leaves when K availability is limited. These symptoms are very distinct and easy to recognize.

Deficiency in P appears as reduced growth, and dark green or purple colored leaves (Figure 2). Symptoms of P deficiency in alfalfa are more subtle than K deficiencies and may be difficult to recognize.

[1]Paper is being submitted as an Extension publication in the near future.

Figure 1. Potassium deficiency symptoms in alfalfa. Photo: J. Volenec

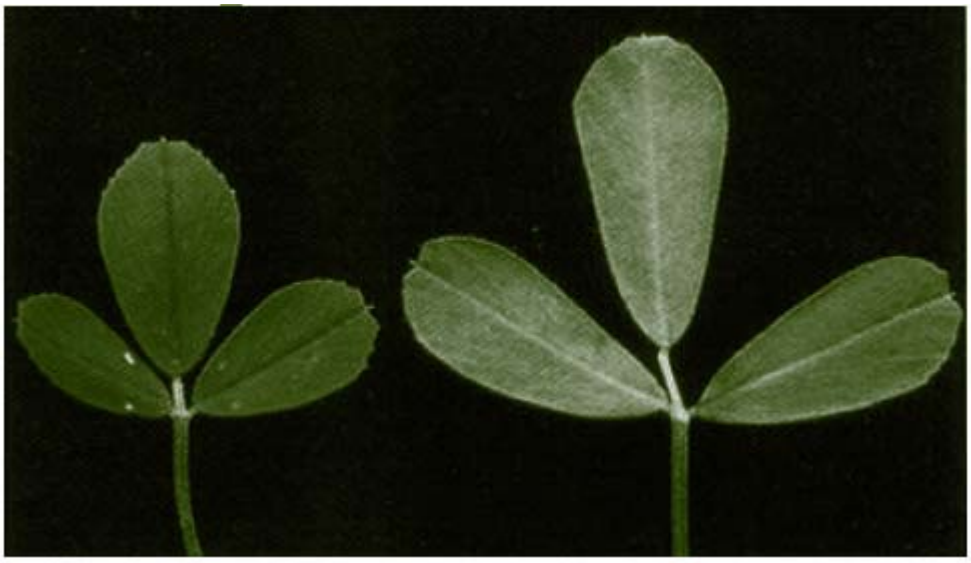

Figure 2. Phosphorus deficient alfalfa (left) versus P sufficient alfalfa (right). Photo: University of Montana. www.montana.edu/wwwpb/pubs/mt44499.pdf

Achieving and Maintaining High Alfalfa Yield Can Require P and K Fertilization

Alfalfa stands normally provide the highest yield in the first two to three production years and thereafter yield starts to decline. If the productivity of a stand decreases enough, it will be necessary to re-establish it. However, re-establishment involves additional costs, and therefore it may be more profitable to use improved management to keep stands high-yielding for more years. By adding sufficient amounts of P and K, alfalfa stands will persist better and remain high yielding longer.

Soil Test Recommendations Depend on CEC and Expected Yield

Current fertilizer recommendations for alfalfa include applying P if soil test levels are 90 lbs/acre or less (Table 1). For very low soil tests (30 lbs P/acre or less) recommended applications range from 115 to 165 lbs/acre of P_2O_5 depending on yield expectations. Recommendations for K vary depending on the cation

exchange capacity (CEC) of the soil as well as the yield expectation (Table 2). At the same soil test level, a soil with a high CEC will need more K fertilizer than a soil with a low CEC. Fertilization with K should never exceed 300 lb K_20/A, regardless of CEC (Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa, 1996).

Table 1. Phosphate (P_2O_5) recommendations at different soil P test levels and yield expectations. (Adapted from Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa (1996), Table 17)

	Expected yield - tons per acre				
Soil test P (lbs/A)	**5**	**6**	**7**	**8**	**9**
	lbs P_2O_5 per acre				
30	115	130	140	155	165
40	90	105	115	130	140
50-80*	65	80	90	105	115
90	35	40	45	50	60
100	0	0	0	0	0

*Maintenance recommendations are given for this soil test range

Table 2. Potash (K_2O) recommendations at different soil K test levels, CEC, and a yield expectation of 5 T/A. (Adapted from Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa (1996), Table 22.)

	CEC (meq/100g)			
Soil test K (lbs/A)	**5**	**10**	**20**	**30**
	lbs K_2O per acre			
0-150	285*	300	300	300
151-200	150**	270*	300	300
201-250	40***	160†	270*	300
251-300	0	55‡	160†	270*
301-350	0	0	55‡	160†
351-400	0	0	0	55‡
400-	0	0	0	0

* For an expected yield of 6 T/A or more, apply 300 lbs/A

** For each additional ton, add 30 lbs/A, up to no more than 260 lbs/A

*** For each additional ton, add 10 lbs/A, up to no more than 70 lbs/A

† For each additional ton, add 30 lbs/A

‡ For each additional ton, add 10 lbs/A

Soil Test Recommendations May Need to be Re-evaluated

Purdue University researchers have shown that current recommendations regarding soil test P and K concentrations may be higher than necessary. With increasing fertilizer costs, a conservative approach to identifying fertilizer application rates may be more profitable than current recommendations that tend to be aggressive with respect to fertilizer application. Researchers from Purdue University are at this time collaborating with surrounding states with the objective of re-evaluating alfalfa fertilizer recommendations.

Highest Fertilizer Rates did not Always Result in Highest Yield

The amounts of fertilizer needed to provide high yield and good persistence of alfalfa depend upon the current nutrient status of the soil and yield expectations of the crop; the lower the initial soil test levels and the higher the yield expectations, the more fertilizer needed. However, over-applying fertilizer may not always result in higher yield. A study at Purdue University started out with low P (15 lbs/A) and medium K (140 lbs/A) soil test levels. Averaged across all of the years, highest yields were routinely obtained with applications of 50 lbs P_2O_5/A/yr and 300 lbs K_2O/A/yr, or 100 lbs P_2O_5/A/yr and 200 lbs K_2O/A/yr (Figure 3). Higher fertilizer applications did not result in significantly increased yield.

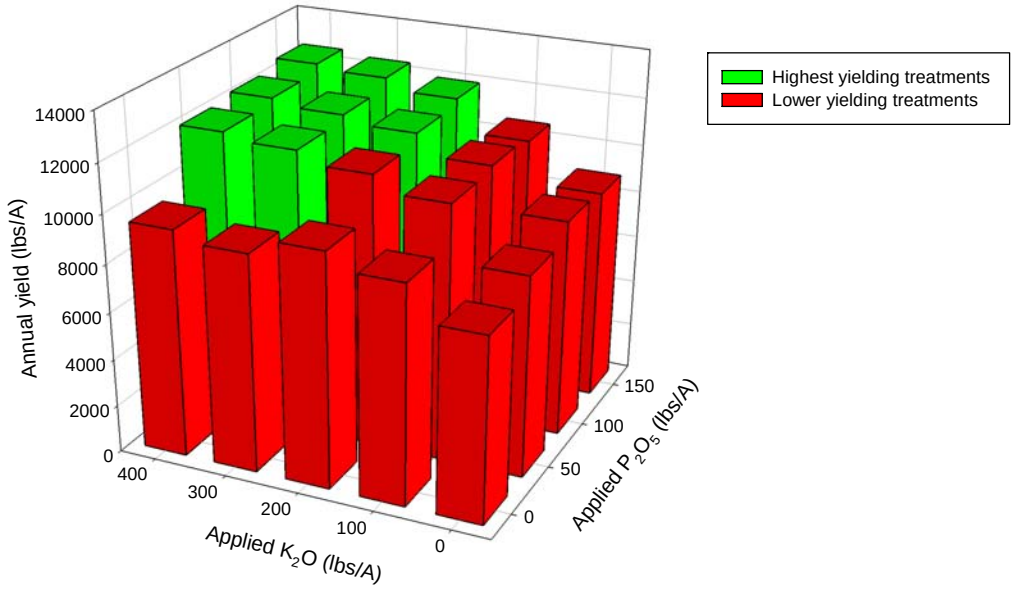

Figure 3. Highest yield was received when alfalfa was fertilized with 50 lbs P_2O_5/A/yr and 200 lbs K_2O/A/yr or more. There was no significant increase in yield when rates higher than 50 lbs P_2O_5/A/yr and 200 lbs K_2O/A/yr were applied (adapted from Berg et al., 2005, 2007).

Providing Both P and K Fertilizers is Critical for Plant Persistence

When fertilizing alfalfa it is essential to consider plant needs for both P and K. By testing the soil for P and K, and fertilizing accordingly, balanced soil fertility will be ensured. In the study at Purdue University, researchers found

Purdue University researchers showed that an alfalfa stand fertilized with 50 to 150 lbs P_2O_5/A/yr and 200 to 400 lbs K_2O/A/yr) had higher yields than unfertilized stands (Figure 5). Adequate fertilizer slowed yield decreases over time, resulting in progressively greater yield advantages due to P and K fertility as stands became older.

that alfalfa stands that were fertilized with P but not K yielded less than unfertilized stands. Some plots provided imbalanced fertility rates experienced complete stand loss, while unfertilized plots and those provided low rates of both P and K persisted, but were low-yielding (Figure 4).

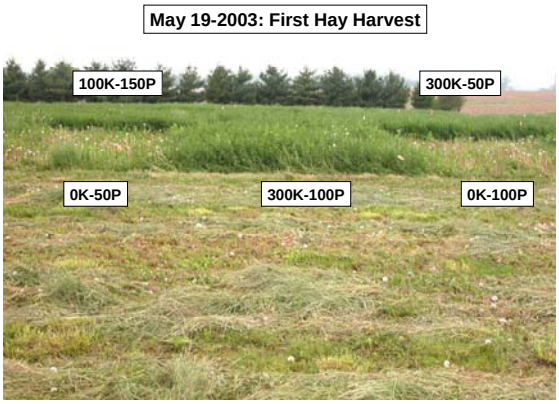

Figure 4. Photo of Purdue University study site. Note the two dead (0 K_2O, 50 P_2O_5 and 0 K_2O, 100 P_2O_5) plots with imbalanced fertility. All fertilizer applications are given as K_2O and P_2O_5 (lbs/A/year). Photo: J. Volenec.

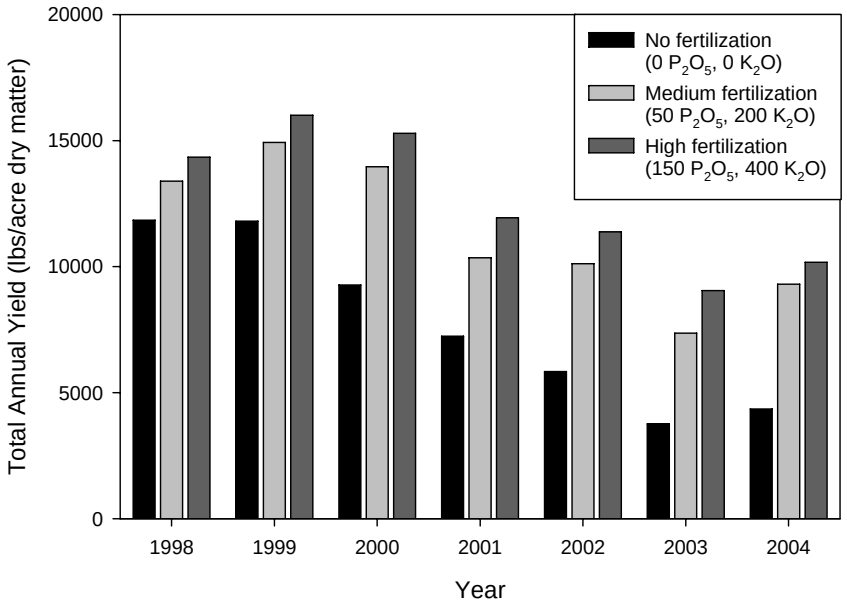

Figure 5. Influence of P and K fertilization on total annual yield. Soil test P and K concentrations averaged 15 and 140 lbs/A, respectively at stand establishment (Lissbrant et al., unpublished).

Fertilizers Should be Surface-Applied after the First and Last Forage Harvest of the Season

The Purdue University study has shown that applying P, and especially K fertilizer, in early spring before the first harvest often does not increase forage yield. At our location in west central Indiana, soils released considerable amounts of K over winter; a result we believe was due to freezing-thawing action of this soil. The released nutrients are generally used by plants during the initial growth in spring, and application of additional P and K after first harvest is recommended. A second application is recommended after the last harvest of the growing season. The most important reason for this is that increased availability of K may improve winter hardiness and alfalfa survival.

If more fertilizer is applied to the soil than what is removed by the plants, the risk of movement of nutrients to surface waters can increase. Phosphorus levels in the soil can especially increase by adding more P than required by the plants (Figure 6). Potassium levels in the soil are more difficult to increase (Figure 7). This is because “luxury consumption” of K by alfalfa can occur, meaning that plants take up K from the soil in excess of plant need. This often results in elevated K concentrations in plant tissues, increased removal of K from the field, and reduced economic returns.

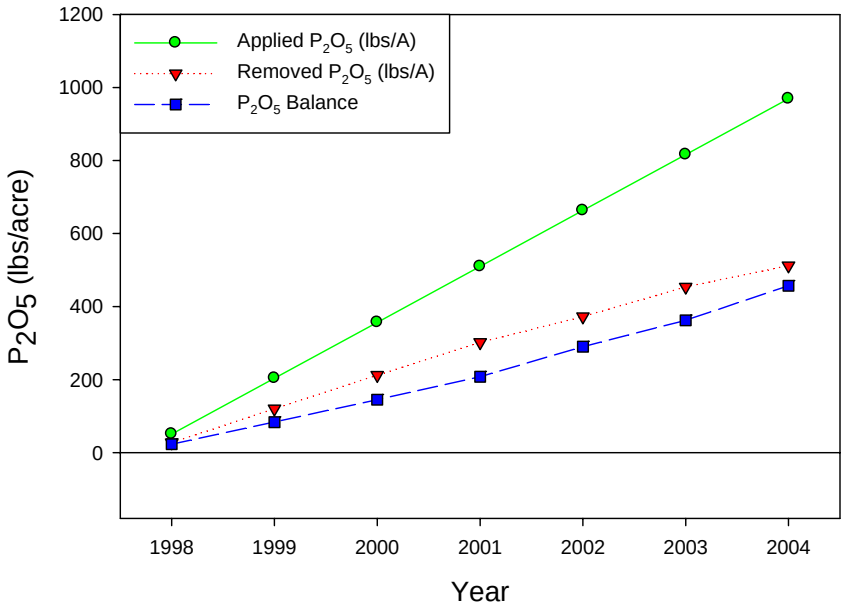

Figure 6. Applied P_2O_5, removed P_2O_5 in forage, and P_2O_5 balance (applied minus removed P) of a high fertility (150 P_2O_5, 400 K_2O lbs/A/year) plot. The balance is positive indicating that soil P levels are increasing (Lissbrant et al., unpublished).

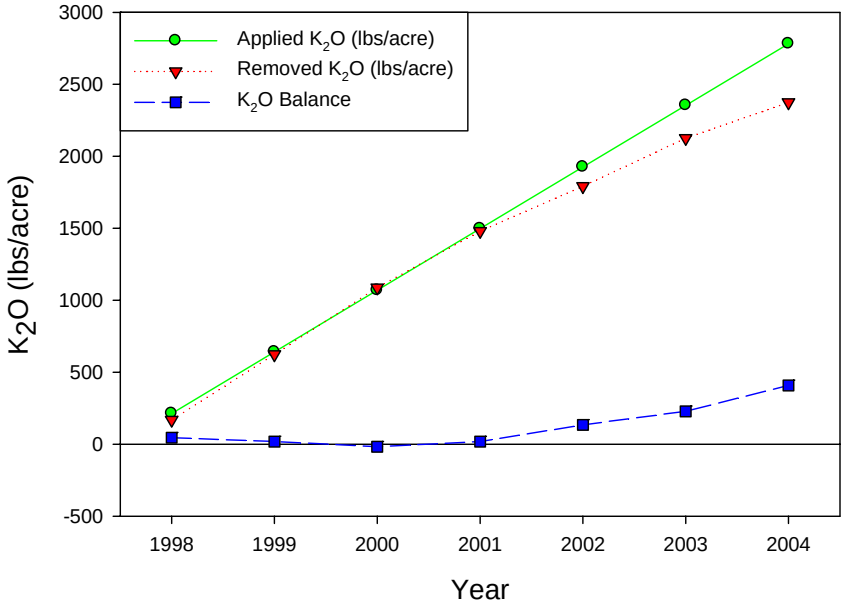

Figure 7. Applied K_2O, removed K_2O in forage, and K_2O balance (applied minus removed K) of a high fertility (150 P_2O_5, 400 K_2O lbs/A/year) plot. Even though K applications are high, the removal is equally high, resulting in a K balance close to 0 (Lissbrant et al., unpublished).

While fertilizer placement may be of importance in other crops, it is not possible to use deep placement or tillage to apply fertilizer to established alfalfa stands due to the risk of damaging the roots and crowns of plants. With broadcast application of P and K, most of the nutrients will remain in the top few inches of the soil since neither K nor P move vertically in most soils. Research at Purdue University has found that this is not a concern since most of the fine roots that are active in nutrient uptake, are located in the upper-most two inches of the soil (Figure 8). This root density pattern was similar in all fertility treatments.

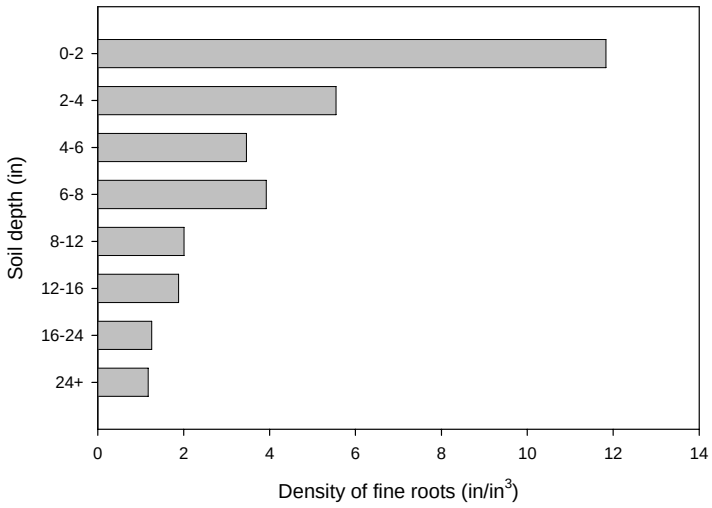

Figure 8. Vertical distribution of fine alfalfa roots with soil depth (Volenec and Brouder, unpublished).

Fertilizer Application Resulted in Slight Reductions in Forage Quality

As fertilizer is added to alfalfa and the yield increases, the morphology and physiology of the plants may be altered in ways that impact forage quality. Shoots get taller and thicker and the amount of leaves relative to the amount of stem tissue (leaf-to-stem ratio) often decreases in response to P and K application. With decreased leaf-to-stem ratio forage quality often declines. Table 3 shows an example of how digestibility decreased as yield increased with P and K application.

To compare the benefits and constraints caused by P and K fertilization of alfalfa we calculated the amount of digestible nutrients produce per acre. This is done by multiplying the percent digestibility by the forage yield to get the digestible nutrient yield.

Digestible Nutrient Yield = % Digestibility/100 x Yield

When comparing the digestible nutrient yield from different fertility treatments, Purdue University researchers found that higher yield easily compensated for slightly reduced digestibility of the forage in the high fertility plots (Table 3, Figure 9).

Table 3. Digestible nutrient yield for alfalfa fertilized with contrasting rates of P and K (Lissbrant et al., unpublished).

Treatment	Yield	Digestibility*	Digestible Nutrient Yield
	lbs/acre	%	lbs/acre
0 K_2O 0 P_2O_5	1087	86	927
200 K_2O 50 P_2O_5	2324	83	1915
400 K_2O 150 P_2O_5	2542	81	2063

* Values adjusted for organic matter (ash content removed)

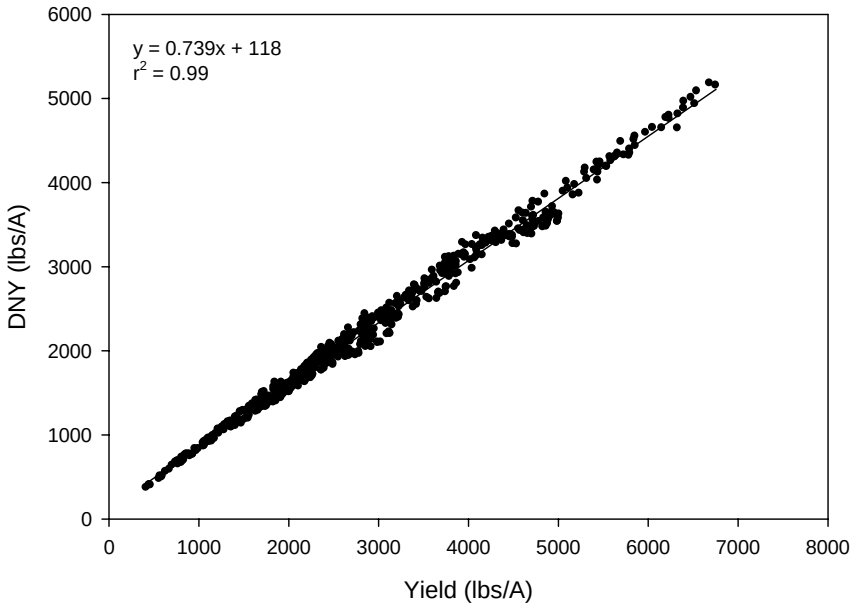

Figure 9. Relationship between yield and digestible nutrient yield (DNY) (Lissbrant et al., unpublished).

Animals differ in their protein requirements. Depending on the use of the alfalfa, it may be of interest to regulate the amount of protein in the forage. Soil fertility and fertilizer regimes can affect forage protein concentration, resulting in higher protein concentration in low P and K fertility fields and lower protein concentration in high fertility fields (Figure 10). Nevertheless, research at Purdue University showed that the high fertility - high yielding stands provided sufficient protein concentration to satisfy the protein requirements of dairy cows in lactation, and only slightly less than the requirements for dairy cows in early lactation. The small reduction in protein

concentration resulting from P and K fertilization were more than offset by the large difference in forage yield. Factors such as cutting management will have greater influence on forage quality than will fertility.

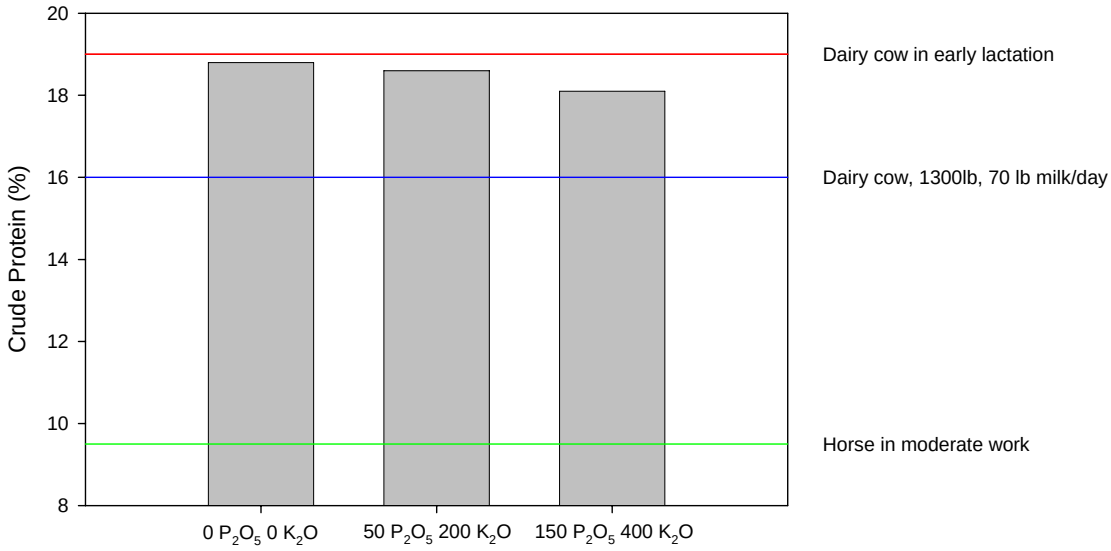

Figure 10. Protein concentrations for alfalfa fertilized with contrasting rates of P and K fertilizer (Lissbrant et al., unpublished). The reference lines indicate the dietary protein requirements for horses in moderate work, lactating dairy cows producing 70 lbs of milk per day, and dairy cows in early lactation (Perry et al., 2003).

Adding excessive K can reduce economic returns because of wasted fertilizer, but can also lower the value of the forage. If the concentration of K in the forage exceeds 3% of dry weight the animals consuming it may become afflicted with milk fever which is caused by hypocalcemia (low blood calcium). This potentially fatal disease is most prevalent in cows shortly after calving. By monitoring soil test levels and applying fertilizers as split applications, the risk for excess K in the forage and milk fever can be reduced.

The forage can be tested for P and K concentrations if sampled and sent for analysis. This is a good way of checking the nutrient status of the forage, especially if there is suspicion of low or high P and K levels. Table 4 provides general guidelines regarding deficient, sufficient, and excessive tissue P and K concentrations.

Table 4. Deficiency, sufficiency, and excess concentrations of P and K in alfalfa plant tissue. (Adapted from Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa (1996), Table 24).

	Deficient	Sufficient	Excess
Phosphorus (%)*	<0.25	0.26-0.70	>0.71
Potassium (%)*	<2.0	2.01-3.5	>3.51

*Top 6 inches sampled prior to initial flowering

Key Points to Remember

- P and K positively influence alfalfa yield and stand persistence
- Balanced nutrition is essential for high yield and persistence of alfalfa
- Apply P, and especially K, in split applications after first and last harvests in order to enhance productivity and avoid luxury consumption of K
- Broadcasting applications of P and K fertilizer work well since fine roots of alfalfa are abundant near the soil surface
- Fertilize for high yield; do not worry about forage quality. Higher yield will compensate for a slight reduction in forage quality
- Be careful not to over-apply K; luxury consumption occurs and high tissue K concentrations may increase the risk of milk fever

Where to Send Soil and Tissue Samples for Analysis

For contact information about ACP certified commercial laboratories, visit Purdue Extension at http://www.agry.purdue.edu/ext/soiltest.html

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