Improved Phosphorus Management Enhances Alfalfa Production

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Improved alfalfa yield with P fertilization has been documented, but little is known of how this essential nutrient promotes increased growth and stand longevity. Complex P-soil mineral interactions and fertilizer costs make effective P acquisition and utilization vital.

Research in Indiana shows that nutrient imbalance ...adding phosphorus (P) without potassium (K)...has more severe consequences for alfalfa survival than anticipated.

In plants, P has many essential functions, including nitrogen (N) fixation, protein synthesis, carbon partitioning (production of starches and sugars), cell division (DNA synthesis), and production of cellular energy as ATP, to name but a few. Although P is involved in a tremendous number of plant processes, the mechanisms responsible for P-induced increases in forage yield of alfalfa are not yet known.

An alfalfa study established in 1997 at the Throckmorton Purdue Agronomy Center near West Lafayette, Indiana, had initial soil test K and P concentrations of approximately 90 parts per million (ppm) and 5 ppm in the top 8 in., respectively. Five K treatments (0, 100, 200, 300, and 400 lb K_2O/A) and four P treatments (0, 50, 100, and 150 lb P_2O_5/A) were applied annually in a split application. Half of the specified amount was applied after the first hay harvest in May and the remainder after the last hay harvest in September. Forage was harvested four times annually. Roots were dug in May and December to monitor plant populations over time and to confirm whether plant death occurred in summer

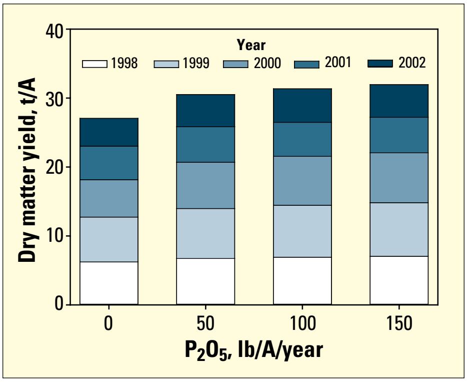

Figure 1. Yield as influenced by P fertilization rate. Data averaged over the K fertilizer rates.

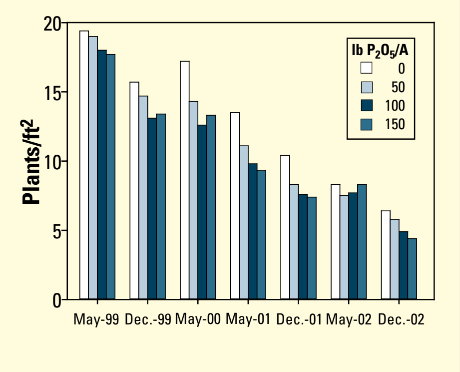

Figure 2. Plant population as influenced by P fertilization rate. Data averaged over the K fertilizer rates. Plants/ft² declined with addition of P from May 1999 to the present.

(May to December) or during winter (December to May). Shoot and root concentrations of P and K were determined, and P and K uptake calculated.

Addition of P dramatically increased yield in each year of the experiment. Application of 150 lb P_2O_5/A/year increased alfalfa yield by 1,640, 2,520, 3,600, 560, and 1,440 lb forage/A over control plots where no P application occurred in 1998, 1999, 2000, 2001, and 2002, respectively (**Figure 1**). In total, the dry matter yield increase resulted in an additional $560/A of return (considering $100/t value for alfalfa) when supplied triple superphosphate at 0.82 t/A ($200/A using $240/t cost for triple superphosphate) in the 5 years.

Alfalfa yield results from the interaction of three yield components: (plants/area) x (shoots/plant) x (mass/shoot). Understanding increases in forage yield in response to P fertilization should begin with understanding how individual yield components are affected by P applications. Plant populations (plants/area) have declined since the experiment was initiated in 1997 [Berg et al., Enhancing alfalfa production through improved potassium management. *Better Crops* 87(1): 8-11, 2003]. Phosphorus fertilizer applications have influenced plant population, but in an unexpected manner. Increased P fertility has resulted in decreased plants/ft^2 at each sampling since May 1999, except for plant counts obtained in May 2002 (**Figure 2**). Addition of P greatly increased alfalfa growth and development, which enhanced interplant competition when compared to plots where no P was added. Plants provided P characteristically attain greater crown and root size (**see photo**), which intensified competition for light, water, and nutrients. This greater size and increased competition likely led to the demise of slower growing, less competitive plants in the stand.

As alfalfa population decreases with stand age and P fertilizer application, increased shoots/plant is thought to compensate for plant loss to sustain high yields. Plant counts, yield information, and mass/shoot data obtained at Harvest 1 in May permit us to calculate shoots/plant at this harvest. Although forage yield has increased and plant populations have decreased with P fertilizer application, shoots/plant has not changed significantly as a result of P fertilizer application. However, shoots/plant did increase by two between May 2000 and May 2001, perhaps due to the loss of plants over time (**Figure 3**).

In the first five years, increases in alfalfa yield have occurred primarily because of increased mass/shoot of plants in P-fertilized plots (**Table 1**). Neither of the other

Increased crown and root size resulting from P fertilization enhanced competition between plants and resulted in greater plant losses in P-supplied plots (see **Figure 2**).

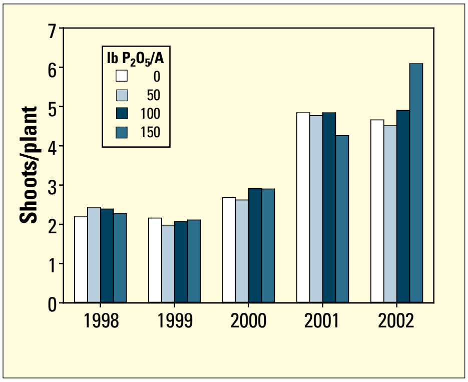

Figure 3. Shoots/plant as influenced by P fertilization. Data averaged over the K fertilizer rates and are for the May forage harvest of the year indicated.

TABLE 1. Mass/shoot (g/plant) as influenced by P fertilization. Data averaged over K fertilizer rates.

P_2O_5, lb/A/year	2000 H1	2000 H2	2000 H3	2000 H4	2001 H1	2001 H2	2001 H3	2001 H4	2002 H1	2002 H2	2002 H3	2002 H4
0	0.86	0.76	0.55	0.42	0.59	0.51	0.61	0.32	0.63	0.61	0.43	0.36
50	1.34	0.96	0.71	0.56	0.70	0.64	0.73	0.39	0.87	0.81	0.48	0.44
100	1.46	0.95	0.72	0.61	0.79	0.63	0.73	0.44	0.89	0.81	0.50	0.46
150	1.47	0.99	0.73	0.65	0.91	0.69	0.77	0.44	0.92	0.81	0.51	0.48
$LSD_{0.05}$	0.15	0.10	0.08	0.06	0.09	0.06	0.09	0.05	0.09	0.11	0.05	0.07

yield components has increased with addition of P, and plants/area has actually declined with P fertilization. Increased shoot mass with P fertilizer applications is a result of two different mechanisms: rapid initiation of regrowth immediately following hay harvest, and increased rate of stem elongation (**see photo**). Increased initiation of regrowth may be a result of enhanced mobilization of stored reserves in taproots following cutting.

Very extensive stand losses have occurred recently that are associated with specific fertility treatments, prompting detailed examination of the physiological basis for plant death in these plots. On the poorest fertility soils, severe stand decline occurred where P had been applied without K. These stand losses were even greater than those observed in plots where no P and K fertilizer had been applied for 6 years.

Responses of the 0K plus P plots were compared to those of plots provided 200 lb K_2O/A/year with the same P rates. The 200 lb K_2O/A/year rate provided good agronomic performance at moderate P application rates, and several of the 200K plus P plots were immediately adjacent to the 0K plus P plots that suffered extensive stand loss.

Trends in plant populations for these treatments were similar to those observed for the entire study, with plants/ft^2 declining from 15 to approximately 10 between May 2000 and May 2002 (**Figure 4**). Extensive stand loss occurred in all plots between May and December 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/ft^2, below the 4 plants/ft^2 minimum generally used to define an "acceptable" alfalfa stand.

The rapid decline in plant population found in the 0K plus P plots also had a substantial effect on total forage yield in 2002.

Increased mass/shoot found in P-supplied plants primarily resulted from rapid initiation of shoot regrowth after hay harvest. Seven days after harvest, plants supplied P had substantially greater herbage regrowth than did plants not supplied P.

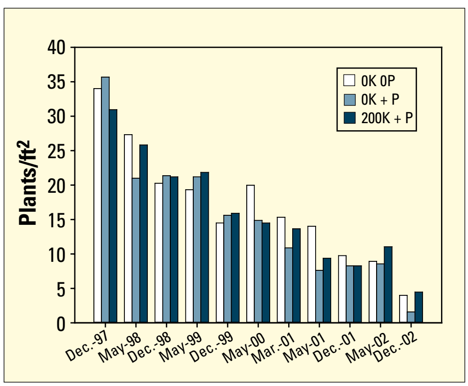

Figure 4. Changes in alfalfa stand between December 1997 and December 2002 as influenced by P and K fertilization. In the 0K plus P plots, plant populations declined below the critical density of 4 plants/ft^2 in December of 2002.

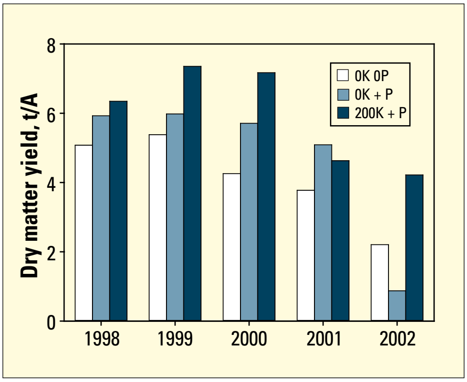

Figure 5. Yield as influenced by P and K fertilization of selected treatments. See **Figure 4** heading for definition of the treatments.

In the first 4 years of the study, the 0K plus P plots had yields comparable with the 200K plus P plots; both of these treatment groups consistently out-yielded the 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. 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 the 0K 0P plots are still economical and yield determinations will continue into 2003.

Clearly, nutrient imbalance (adding P without K) has more severe 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 as recommended to meet yield goals set for their alfalfa stand.** BC

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Meeting K Needs for Pacific NW Grass Seed Production *(cont. from p. 19)*

application rates should be adjusted to replace the amount removed in the straw.

In addition to meeting the total seasonal nutritional requirements, an adequate nutrient supply must be available for uptake to meet periods of peak demand. As a result of intensive plant sampling, both biomass and tissue K accumulation were found to be fairly constant during the growing season (**Figure 3**). This is in contrast with N accumulation, where the majority of the nutrient was taken up in the first half of the growing season. As adequate nutrient supply is essential for top yields, it must be present at both the correct time and in the proper quantity for the plant.

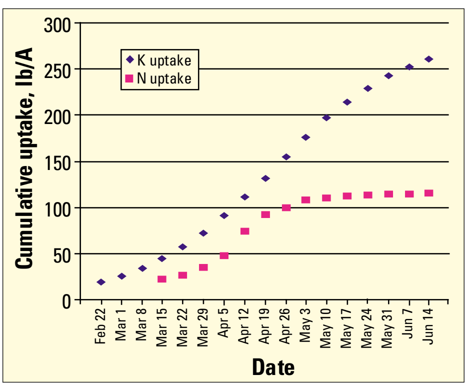

Figure 3. Accumulation of K and N by tall fescue during the growing season.

These results suggest that the removal of K from grass seed fields has greatly increased since the straw is now routinely removed from the field. Potassium removal is as much as five times greater when straw is removed in addition to the seed. Soil test K concentrations should be maintained above 100 ppm in the surface 6 in. and replacement of removed nutrients should be part of an ongoing soil fertility program. BC

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