Alfalfa Hay and Soil-Test Phosphorus Responses to Long-term Phosphorus Fertilization Strategies

RFR-A12104

Antonio Mallarino, professor
Department of Agronomy
David Rueber, farm superintendent

Introduction

A long-term experiment was established at the ISU Northern Research Farm, Kanawha, Iowa, in 1998 to study phosphorus (P) fertilization of alfalfa. Alfalfa has higher P demand than corn or soybean, and soil-test P interpretations and P fertilization guidelines in Iowa State University extension publication PM-1688 (A General Guide for Crop Nutrient and Limestone Recommendations in Iowa) are based on research more than 30 years old.

Materials and Methods

The experiment was established on an area with Webster soil that initially tested very low in P. When it was established, the trial consisted of three years of alfalfa in rotation with one year of corn. It included several phases that began with different crops of the rotation. Five treatments applied a total of 0, 120, 180, 240, or 300 lb P_2O_5/acre over the three years of alfalfa, with rates distributed differently between initial and top-dressed applications. All plots were split to grow corn with or without starter P. The four lower rates were replicated four times and no N was applied. The high rate was applied to eight plots (replications), and in the corn year four plots had no N applied and four plots received 50 lb N/acre. Results for two complete alfalfa-corn rotation cycles were summarized in a 2009 report for this farm.

This report summarizes the recent years of this long-term study, for which the initial treatments were changed. After the last corn year of rotations summarized in the previous report, the previous set of P treatments was discontinued, the corn year was dropped, and the objectives changed to evaluate alfalfa yield as affected by the different soil-test P levels created by the old treatments. An annual rate of 120 lb P_2O_5/acre was applied to four of the eight plots that had received the highest P rate to have one treatment where P was not yield limiting. Because the study began with several phases for different crops of the rotation, the alfalfa seeding year for the new study occurred in different years for different phases. Therefore, by the end of the study there has been continuous alfalfa for a different number of years.

Results and Discussion

Soil-test P. The range of P fertilizer treatments applied during the first portion of this experiment resulted in different initial soil-test P levels for the new study. Table 1 shows that on average across the previous five P treatments, the initial soil-test P level ranged from 5 to 44 ppm by the Bray-1 method. Data not shown for the Olsen method ranged from 4 to 25 ppm. The soil P level for the treatment that had received no broadcast P since the late 1990s did not decrease because levels already were extremely low and yields were very low. The other soil P levels decreased significantly, which was expected due to crop removal.

By the end of the study (Table 1), the Bray-1P level of the plots that received no P ranged from 4 to 21 ppm (and 2 to 9 ppm by the Olsen method). However, Bray-1 P level of plots that received 120 lb P_2O_5/acre per year increased to 67 ppm (34 ppm by the Olsen method).

Alfalfa hay yield. The varying initial soil-test

P values resulted in different alfalfa yield levels (Table 1). The yield of oat hay in the seeding year was low, which is typical. On average, the yield of first-year oat hay for the lowest initial soil P level of 5 ppm was 1.50 ton/acre, and the initial level of 11 ppm maximized yield (1.78 to 1.90 ton/acre). However, the annual application of 120-lb P rate on average increased yield slightly to 1.97 ton/acre.

The varying initial soil P levels produced a wider range of responses for alfalfa after the seeding year. With few exceptions, yield without the annual P application increased from the lowest initial soil P level (5 ppm) to the highest initial level (44 ppm). On average across all years, hay yield increased from 2.14 ton/acre to 4.72 ton/acre. This large yield response to such a high initial soil P level occurred because soil P without P application declined over time due to removal with harvest, and the highest final average soil P level was 21 ppm. The annual application of 120 lb lb P_2O_5/acre to plots that had the highest initial soil P level increased yield further (by 0.59 ton/acre).

Relationship between yield and soil P. Figure 1 shows the relationship between soil-test P and alfalfa relative yield response to P fertilization. Each data point in the graphs represents an average across four replications for each different trial phase for each year (excluding the seeding years). The graphs for both Bray-1 and Olsen methods show the characteristic curvilinear increase in yield relative to the maximum achieved with fertilizer (from plots receiving the 120-lb rate). The yield increases are large at low soil P levels and become smaller as soil P increases. Calculations for the Bray-1 method using the equation for the fit line indicated that 95 and 99 percent of the maximum yield was achieved with 22 and 32 ppm, respectively. For the Olsen method, 15.0 and 23.5 ppm achieved 95 and 99 percent yield, respectively.

The results support the Optimum soil-test category that publication PM 1688 suggests should be maintained based on P removal by alfalfa hay. This category is defined by 21 to 25 ppm for the Bray-1 method and 15 to 17 ppm for the Olsen method. The coincidence is remarkable, because the current guidelines were based on decades old research, primarily from neighboring states.

Conclusions

This study provided a useful research update about soil-test P needs for alfalfa hay. No research on P fertilization of alfalfa had been conducted in Iowa since the 1970s. Results confirmed the adequacy of the Optimum soil-test range of ISU guidelines for alfalfa in publication PM 1688 concerning soil test P values to be maintained based on harvest removal. The portion of this long-term experiment summarized was not designed to investigate P fertilization rates for deficient soil-test P (such as for the categories Very Low and Low). However, the early portion of the study summarized in a previous report showed that the P rates suggested in the current guidelines are adequate. The useful results of this study confirmed the value of long-term soil fertility experiments at research farms.

Acknowledgements

Funding for the summarized study was provided by the Iowa State University College of Agriculture and Life Sciences and the Research and Demonstration Farms.

Table 1. Initial and final soil-test P values and alfalfa hay yield.

			Alfalfa hay yield†						
Initial soil P‡	P Rate	Final soil P‡	1st year	2nd year	3rd year	4th year	5th year	6th year	Avg.§
ppm	lb P_2O_5/a	ppm	tons/acre						
5	0	4	1.50	2.53	2.44	2.11	1.53	2.09	2.14
11	0	6	1.89	3.63	3.75	3.32	2.81	3.17	3.34
21	0	10	1.90	4.88	4.42	4.26	3.44	3.45	4.09
35	0	18	1.78	5.17	4.48	4.24	4.10	3.80	4.36
44	0	21	1.78	5.44	5.00	4.71	4.14	4.32	4.72
44	120	67	1.97	5.61	5.67	5.55	4.90	4.81	5.31

†Air dry based yield.
‡Bray-1 method, 6-in. depth.
§Average excluding the 1st year.

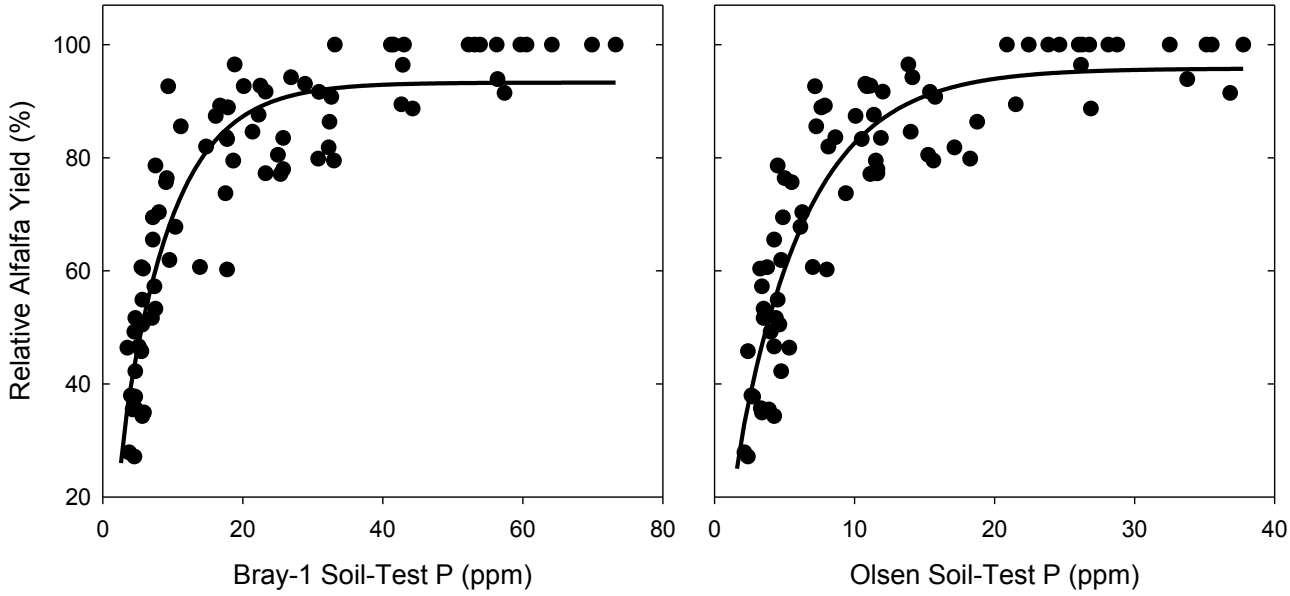

Figure 1. Relationship between soil-test P and alfalfa hay relative yield (air dried basis) response to P fertilization. Each point represents an average across four replications for each different trial phase for each year (excluding the seeding years).