Oklahoma Research

Using Phosphorus Fertilizers to Maintain Wheat Forage and Grain Yields on Acid Soils

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Oklahoma research continues to emphasize the value of seed-placed phosphorus (P) for wheat on acid soils. Data indicate that applied P lowers concentrations of aluminum (Al) in the soil solution, allowing seedling establishment. Response to applied P occurred despite high P soil tests.

WINTER WHEAT is the main cultivated crop in Oklahoma and is grown for forage and/or grain. If livestock graze the wheat and are removed by early March, both forage and grain may be harvested.

Wheat and Beef

Harvest of wheat forage by beef cattle can be a significant source of income for producers in the state and region. Low returns from grain in poor yielding years can be offset by the value of beef gains produced on the forage.

Intensive management and harvest of high yields over an extended period of time have increased surface soil acidity in many fields in north central Oklahoma. This region also extends into Kansas where soil pH values have declined to levels approaching 4.0. At soil pH levels of 4.3, some fields in this area have failed to produce a grain crop. Maintaining acceptable forage and grain yields under these conditions requires that producers make critical management decisions relative to their specific situations.

Oklahoma Conditions

Past research in Oklahoma indicated that Al toxicity to seedling wheat was a major cause of crop failure at extremely low soil pHs. Soil acidity problems in Oklahoma initially reduce wheat forage yields. If the pH drops below a critical level, grain yields can also be affected to the extent of crop failures. High concentrations of harmful Al species in soil solution result in poorly developed wheat root systems, intensifying the effects of other environmental stress factors.

In many areas, liming has been an effective and economical solution to wheat production problems resulting from soil acidity. However, because lime sources are frequently 50 to 100 miles away and lime application is very expensive, some producers do not lime fields when soil tests indicate the need. Also, under conditions of continuous monocultural wheat production, the incidence of the root disease complex (including take-all) can be increased if the soil pH is raised above pathogen threshold levels by liming. Unlike severe nutrient deficiencies that may often be recognized by symptomatic tissue color changes, yield losses on acid soils may initially occur without dramatic changes in crop appearance.

A common practice among producers who have successfully grown wheat on very acid soils has been to apply P

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OKLAHOMA studies have illustrated the importance of fertilizer P for wheat on acid soils. Despite high P soil tests, growth responses to P banded with the seed (left) have been spectacular.

fertilizers with the seed at planting. Aluminum and P react in acid soils to create a 'fixed' or unavailable form of P. This reaction is responsible for decreasing P fertilizer efficiency in acid soils. However, when P is fixed, so too is Al, since each is part of the unavailable Al-phosphate complex. This 'fixing' of Al in acid soils explains why producers who apply P fertilizer with the seed can produce normal crop yields without liming.

Research Results

Recent research in Oklahoma has focused on utilization of P as a short-term alternative to liming. Two experimental sites were selected in central Oklahoma. Sites 1 and 2 had initial surface soil pH values of 4.7 and 5.0, respectively, with exchangeable soil Al being greater in the more acid soil. However, both locations have neutral subsoils beneath the plow layer and soil pH increases rapidly with depth. In order to obtain normal production from liming, a rate of about 1.2 tons/A of effective calcium carbonate equivalent (ECCE) lime would be required. Mehlich III soil test P index values were 155 (very high) and 66 (high) at sites 1 and 2, respectively. These soil test indices were high enough that under normal soil pH conditions, no nutritional P response was expected. Phosphate fertilizer sources used included APP (10-34-0), MAP (11-52-0), and DAP (18-46-0). However, only data for APP will be presented (generally no differences among sources were recorded). Three P fertilizer rates (30, 60 and 90 lb P_2O_5/A) were banded with the seed at planting. A 60 lb/A P_2O_5 rate was broadcast preplant (data for this comparison not shown). An unfertilized check was also included.

Figure 1 illustrates the effect of several rates of APP applied with the seed at planting on wheat forage yields during the three year period 1990-1992. Forage yields were increased by a factor of 4 at site 1 and were nearly doubled at site 2. Banding of the P fertilizer with the seed was more effective for increasing forage yield than P applied broadcast preplant.

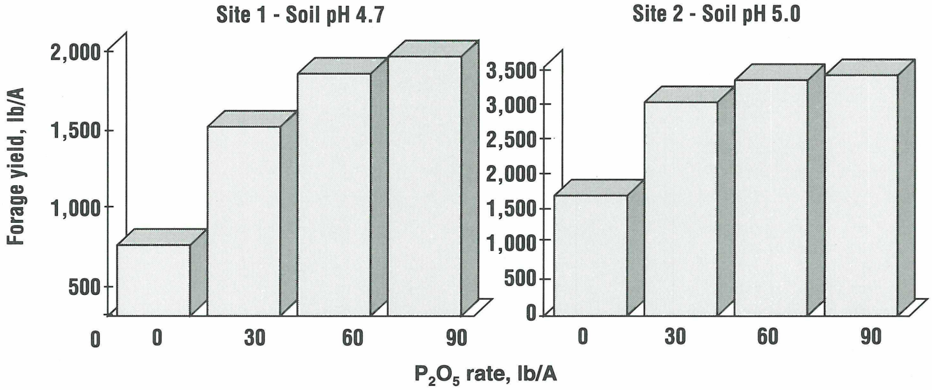

Figure 1. Applied P had dramatic effects on wheat forage yields over a 3-year period at two acid soil sites. Phosphorus as APP was banded with the seed at planting.

Grain yields at site 2 did not increase significantly from P application during the three-year period. However, on the more acid soil at site 1, grain yields were increased in 1990 and 1991 (**Figure 2**). Method of P application was not important in 1990, but the banded treatment was more effective in 1991.

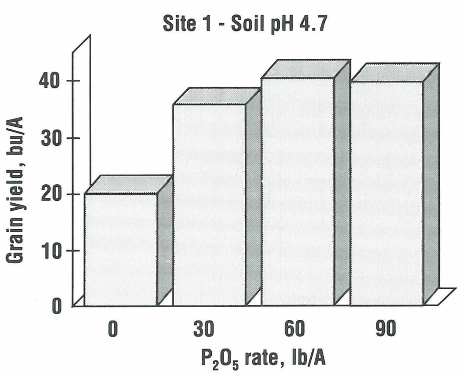

Figure 2. Banded P with the seed (APP) had significant effects on wheat grain yield when soil pH was low and P soil test was high.

Because field soil sampling techniques utilized in the first year of the experiment were inadequate to characterize the relationship of P to Al in the applied fertilizer band, a laboratory experiment was initiated. The objectives were to observe changes in soil solution composition with respect to time following the simulated banding of 0, 30, 60 and 90 lb P_2O_5/A in the strongly acid soil at site 1.

Soil solution was collected by high speed centrifugation at various times after application of fertilizer-P and analyzed for pH, Al, manganese (Mn), P and other constituents. Increased levels of fertilizer P resulted in decreased concentrations of Al, Mn and other cations in soil solution. These differences were still significant 70 days after fertilization. **Figure 3** shows relative Al concentrations over the 70-day period.

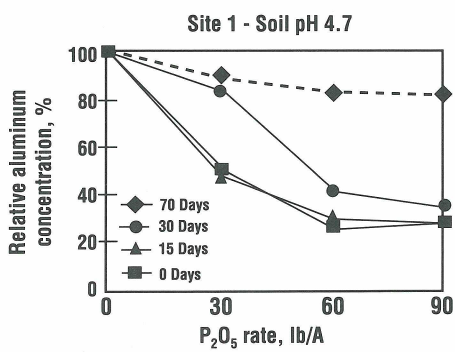

Figure 3. Relative concentration of Al in the soil solution of a P fertilizer band at 0, 15, 30, and 70 days after fertilizer application.

PHOSPHORUS banded with the seed (left) was much more effective on acid soils. The plot at right received 60 lb/A P_2O_5 broadcast compared to 30 lb/A banded (left).

FERTILIZER P sources had identical effects on wheat grain and forage yields. The area at left received ammonium polyphosphate (APP), that on the right diammonium phosphate (DAP) at the same rate of 60 lb/A P_2O_5. Monoammonium phosphate (MAP) was also included.

The GEOCHEM-PC computer model was used to assess Al speciation in the soil solution. The model showed that the sharp decrease in harmful Al was due to complexation with various P forms. The 60 lb/A P_2O_5 rate was enough to reduce the concentration of the harmful species of Al, as higher P fertilizer rates did not result in greater reductions. This finding coincided with field forage yields which were usually maximized at the 60 lb/A P_2O_5 rate. It is likely that P fertilizer is removing enough Al from soil solution near the roots to enable the developing crop to establish a better root system, thereby reducing seedling stress. Once the wheat plants become rooted below the extremely acid soil layer, the effects of Al toxicity from acidity in the surface soil are minimized.

Summary

Data from these studies show that wheat forage yields were increased by seed placement of P on acid soils with high P tests. The relative magnitude of forage yield response was greater on the more acid soil. Grain yields responded in a similar fashion, with yield responses occurring on the more acid soil, and were maximized at the 60 lb/A P_2O_5 rate.

Compared to the control, P placed with the seed was economic, even with high P soil tests. Figuring P_2O_5 at a cost of $0.25/pound and wheat at a conservative $2.50 per bushel, a grain yield increase of 15 bu/A from a 30 lb/A P_2O_5 application would have a value of $42.50, more than a 5 to 1 return from P application costs. The increase in forage production from 60 lb/A P_2O_5 at a cost of $15.00/A would produce about 140 lb/A of beef gain worth at least $70 and approximately the same 5 to 1 return for investment in P fertilizer. Remember that a well-fertilized, well-managed wheat crop can produce BOTH beef and grain for the same investment in P fertilizer. Expense for nitrogen (N) will be higher to replace that removed in the beef, but overall net returns are improved and returns per dollar invested in P will be closer to 6 to 1 or 7 to 1.

A lime requirement of about 1.2 tons of ECCE/A for these acid soils would have represented a cost of about $30/A and would last approximately 5 years. Maintaining maximum yields for 5 years using P placed with the seed would cost about $37.50/A for grain production and $75/A for forage production. Phosphorus fertilizer placed with the seed is then an effective alternative to liming strongly acid soils for winter wheat production. Use of P instead of lime is economical when lime costs are high and when considered on a short-term basis. In most instances, particularly when soil P levels are high, standard liming practices combined with provision of adequate fertilizer nutrients will be more economical for long-term management strategies. ■