Crop Responses at High Soil Test Phosphorus Levels

By W.K. Griffith

Despite the perception that high soil test levels preclude responses to applied nutrients, a survey of recent research indicates that many other conditions influence plant response to applied phosphorus (P), even at high soil test levels. This article summarizes some of the results.

RESPONSES to applied P are usually highest on low P testing soils. However, recent research on a number of crops has shown responses to applied P on high P testing soils.

There may be several reasons why these P responses seem to be occurring with greater frequency. They include: (1) higher crop yields than were obtained in the original calibration studies, (2) increased use of minimum tillage in some form, (3) use of some equipment and management practices which tend to increase soil compaction and restrict root growth, (4) earlier planting dates when soil temperatures are cooler, (5) inadequate attention to proper soil pH levels for optimum nutrient efficiency.

An incomplete review of recent P research has identified numerous studies that produced a significant response to applied P, even when soil test levels were high or very high.

Cotton

Louisiana researchers compared applications of 6 and 10 gallons of surface-applied 11-37-0 (liquid) for cotton at planting in a 3-inch band over the row on a high-P testing soil. Lint yields were increased more than 100 lb/A by these surface-band applications. According to the researchers, the cost of the treatments would be approximately $6 and $10 per acre. Net returns increased as much as $64 per acre from the starter applications containing nitrogen (N) and P (**Table 1**).

Table 1. Yield and profits from applying P to cotton in Louisiana.

Surface band applied 11-37-0, gal/A	Lint yield, lb/A	Yield increase, lb/A lint	Net return from starter, $/A
None	949	—	—
6	1,030	81	42.60
10	1,073	124	64.40

Cotton: $0.60/lb lint High P soil test.

Field studies were conducted in four North Carolina environments to determine the effects of planting date on cotton response to side-banded starter fertilizer. Ammonium polyphosphate (APP) starter was applied at a rate of 15 lb N and 51 lb P_2O_5/A on soils testing high to very high in available P. Lint yield was increased significantly, by an average of 9 percent, across the four locations from the starter applications. Yield response to starter was consistent although overall yields declined as planting date was delayed.

Arkansas studies have shown that additional P increases yield and proportion of cotton harvested during the first pick on soils testing high in extractable P. The early first pick is important because of machine harvest and early removal of a quality product from the field. Both yields and percentage of first pick cotton were higher when P was applied to a high P-testing soil compared to medium P-testing soil (**Table 2**). Note the yield advantage of maintaining a high soil test P level, regardless of the annual P application.

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Table 2. Effects of increasing P rates on seed cotton yield and proportion of the crop harvested during first pick in Arkansas.

P_2O_5 Rate, lb/A	High P soil Yield 1st pick, lb/A	High P soil % of Crop	Medium P soil Yield 1st pick, lb/A	Medium P soil % of Crop
0	1,402	67	987	45
30	1,555	71	1,205	51
60	1,638	75	1,398	61

Corn

North Carolina researchers reported the use of a starter fertilizer with a 1:1 ratio of N to P_2O_5 to be an excellent practice for high yield corn. They noted that soil P test levels are often high to very high for irrigated corn production in North Carolina, but concluded that it is important to include P in the starter for highest yields and profits.

Studies showed that P_2O_5 in the starter for irrigated corn lowered grain moisture 2.7 percent at harvest and increased yields 11 bu/A over the no P treatment when soil P test levels were high (**Table 3**). To a farmer, that decrease in grain moisture would mean as much to his profit potential (drying and/or dockage cost) as an increase in grain yield.

PHOSPHORUS response in corn shown here (at left) was on a high P testing soil. Cold, wet soils, often associated with conservation tillage systems, require supplemental P for rapid early growth, leading to higher yields.

The importance of starter placement in corn responses to P on high P-testing soils was emphasized in several South Dakota studies. In that area, corn (dryland) tends to respond much more dramatically to P after fallow than if the land is cropped the preceding year. Loss of mycorrhizal activity during the fallow may have contributed to these responses. Starter placement has had a highly significant effect on P responses during cool growing seasons (**Table 4**). Regardless of tillage system, starter placement for corn following small grain was much more effective than broadcast, knifed, or surface stripped application.

Table 3. Starter P_2O_5 increased irrigated corn yield and lowered grain moisture on a high P Coastal Plain soil in North Carolina.

Starter P_2O_5, lb/A	Yield, bu/A	Grain moisture, % at harvest	Gross return, $/A
0	191	20.7	380.09
58	202	18.0	429.25
Difference	11	2.7	49.16
	Difference for yield:		23.38
	Difference for moisture:		25.78

Corn price=$2.25/bu Soil test P=High
Dockage=$0.05/bu for each percent above 15.5% moisture

Corn yield responses to applied P are often quite large on high P testing soils when soil temperatures are low at planting. The value of P placement close to the seed can not be over-emphasized in reduced tillage on cold soils for both row crops and small

Table 4. Influence of placement on corn responses to P in South Dakota.

Soil test level, Bray-1, ppm	Check	Broadcast	Starter	Knifed	Surface strip
	Placement				
	yield, bu/A				
Low (15)	110	125	139	115	122
Medium (19)	123	127	145	122	124
High (22)	124	129	145	122	127
Average	120	127	143	119	125

Rate=25 lb P_2O_5/A
Average of moldboard, chisel, and no-till systems.

grains. Wisconsin studies emphasized the value of small amounts of row-applied P for corn under such conditions (**Table 5**).

Table 5. Row applied-P significantly increased yields in this Wisconsin corn study with high P soil test.

Soil Test P, ppm		Row P_2O_5, lb/A		
		0	20	40
Year 1	Year 2	--------- bu/A	---------	
30	35	103	137	134
33	31	119	134	144
80	56	122	142	149

Withee silt loam soil.

Conservation tillage systems are an important management practice to reduce erosion and conserve moisture and are being widely advocated as an important part of the conservation management plans being implemented across the U.S.

Adequate P is a management tool which must be considered for these conservation tillage systems to ensure rapid early growth and high yields. Minnesota studies illustrate the relative importance of starter P on high P testing soils when conservation tillage systems are compared to other practices (**Table 6**).

Table 6. Response of corn to starter P fertilization on very high P testing soils in south central Minnesota.

Tillage system	Starter P applied No (Corn yield, bu/A)	Starter P applied Yes (Corn yield, bu/A)	Response to starter, bu/A
Moldboard	142	147	5
Chisel plow	128	139	11
Ridge plant	133	140	7
Disk	134	142	8
No-till	89	100	11

Bray P-1=22 ppm. Corn in rotation with soybeans.

Small Grains

Scientists at Montana State University recently completed a recalibration of the Olsen (sodium bicarbonate) P soil test for winter wheat on fallow. Rates of P_2O_5 applied with the seed ranged from 10 to 50 lb P_2O_5/A at 19 locations. Actual yields in the 3-year study varied from 12 to 77 bu/A, and P response trends were similar, regardless of the yield potential. The Olsen P soil test levels among the sites

PHOSPHORUS starter responses can occur on a wide range of soil test levels and are affected by a number of other soil conditions.

ranged from 10 to 35 ppm. These studies determined that the critical Olsen P level was 24 ppm (48 lb/A), a value much higher than the current critical levels used by many soil testing labs in the region. Phosphorus responses were smaller as P soil test increased, but responses did occur at levels which would formerly have been classified in the high range. This points out the dynamic nature of critical P soil test levels depending upon the management system in place.

The importance of starter P for wheat as a management tool on acid soils high in available P has been demonstrated in recent research in Oklahoma and Kansas. Under very acid soil conditions, high aluminum (Al) availability dramatically decreases wheat forage and grain yields. However, application of starter P in direct seed contact at rates of up to 60 lb of P_2O_5/A dramatically increases both forage and grain yields and is a practical management consideration when liming is difficult and expensive (**Table 7**). Kansas studies produced similar results, empha-

Table 7. Starter P is extremely important for wheat forage and grain yields on acid, high P soils.

P_2O_5 rate, lb/A	Forage yield, lb/A 1990	Forage yield, lb/A 1991	Grain yield, bu/A 1990
0	298	378	23
30	988	1,657	41
60	1,713	1,994	41
90	1,704	2,204	41

Mehlich III soil test P index=155 (very high)
Soil pH=4.5 Oklahoma

sizing the importance of P placement and variety selection on acid, high-P soils. The Oklahoma and Kansas studies do not suggest that banded P on high P soils is a permanent solution to soil acidity, but do underscore how other cultural conditions affect responses to applied P.

The importance of high soil test P values and annual fertilizer P applications for barley yields were indicated in New York studies. Fertilized barley headed earlier, withstood winter stress better and produced higher yields (**Table 8**). Note that high soil test P levels resulted in higher yields in either of the other P test categories regardless of annual P applications. Highest yields were obtained with the highest annual application rate (80 lb P_2O_5/A) and at the high soil test P level.

Table 8. Annual P fertilization and high P soil tests combine for higher barley yields.

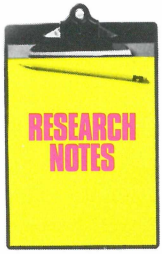
P_2O_5 rate, lb/A	Soil test P level: Low	Medium	High
	---------	yields, bu/A	---------
0	7	26	70
20	14	34	89
40	15	40	95
80	21	46	100

New York

Summary

In the final analysis, soil testing is an important best management practice (BMP) to monitor soil fertility levels and to aid in crop recommendations for the future. The probability of a profitable response to P fertilization is much greater on soils that test low in available P compared to soils with high P tests. However, the possibility of a profitable response from additional P applications at high P soil tests is relatively good when other production factors are optimum or when soil, climate and management factors impose stress early in the growing season.

The increasing adoption of conservation tillage practices, accompanied by lower soil temperatures at planting, higher soil moisture content, increased possibilities of soil compaction, and accumulations of soil acidity near the surface, emphasize the need for the use of starter fertilizers containing P to enhance early seedling growth and reduce seedling stress. There is an increased need for soil test P calibration research with new tillage practices and higher yield potentials to be sure that this nutrient is not a limiting factor for yields, profits, and environmental protection through input efficiency. ■



Alabama

Calcination Effect on the Agronomic Effectiveness of Apatitic North Carolina Phosphate Rock

A GREENHOUSE study investigated the effect of calcination . . . to increase the total phosphorus (P) content of apatitic phosphate rock (PR) . . . on the solubility and agronomic effectiveness of apatitic North Carolina PR.

A silt loam soil with a pH of 4.8 was used, with four rates of P being applied. Corn was the test crop and was grown for four weeks for each of two crops.

Results showed that the degree of carbonate substitution for phosphate in the apatite was decreased after calcination, along with citrate soluble P. Both dry matter (DM) yield and P uptake were reduced. Across the range of P rates in the two crops, DM yield reduction averaged 77 percent, compared to uncalcined PR.

Researchers concluded that apatitic PR used for direct application should not be calcined, even though the process increases total P content of the mineral. ■

Source: S. H. Chien and L. L. Hammond. 1991. Soil Sci. Soc. Am. J. 55:1758-1760.