How to Profit from Phosphorus Fertilizer Use

By J.W. Bauder and B.E. Schaff

Montana farmers applied nearly 66,500 tons of P as fertilizer in 1996. That amounts to approximately 15 lb of P for every acre of cropland in the state, representing a significant cost to growers of small grain. Yet most admit that the rate they apply is routine; oftentimes, they never even take a soil sample to determine what that rate should be.

Recent Montana research sheds new light on significance of phosphorus (P) soil tests and periodic P fertilizer additions, even on some soils testing high in Olsen-extractable soil P. The greenhouse study tested response of sordan to P applied to calcareous soils.

Current findings show that the specific properties of the soil along with the soil test P level can have a dramatic effect on crop responses to fertilizer P. Past research has shown that some soils initially high in P still show good yield responses to P fertilizer. The study reported here found that soil test P level may have a greater effect on yield than the amount of fertilizer applied.

To determine just how important soil testing is with regard to P fertilizer rates, researchers at Montana State University conducted a study in cooperation with farmers and ranchers along the Powder River in southeast Montana. The purpose of the investigation was to determine how a crop (sordan, a sorghum-sudan hybrid) would respond to various P fertilizer rates when applied to soils with increasing soil test P levels. Three different soils, each with a relatively low soil test level, were collected from cropped fields: Gay Ranch in Powder River County, Griffin Ranch in Custer County, and Foulger Ranch in Prairie County (**Table 1**).

Typical Montana soil test levels range from 1 or 2 parts per million (ppm) to 20 or more ppm. Researchers currently recommend P additions when Olsen extractable levels are less than 18 ppm (approximately 36 to 40 lb/A). Recommended P_2O_5 rates generally range from 10 to 60 lb/A.

TABLE 1. Description of test soils and pre-experiment test levels.

Source	Soil series	Olsen P level, ppm	pH	EC, mmhos/cm	OM %	$CaCO_3$ %
Foulger Ranch	Glendive fsl[1]	2.4	8.3	1.04	1.2	2.5
Griffin Ranch	Havre l	7.2	8.3	2.61	2.3	3.6
Gay Ranch	Heldt sic	3.0	8.1	0.78	2.5	6.1

[1]fsl = fine sandy loam; l = loam; sic = silty clay

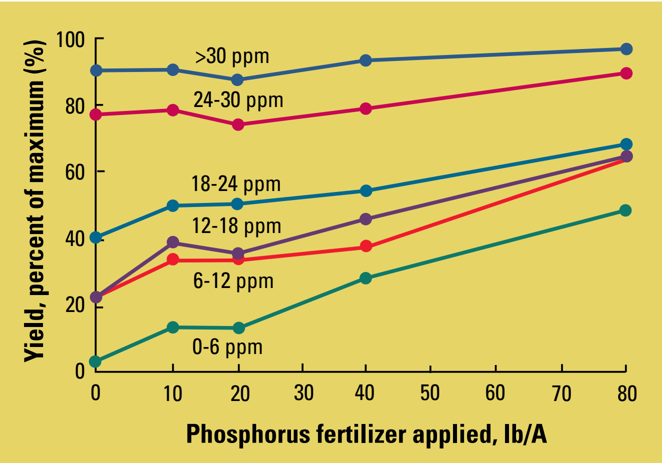

Figure 1. Composite response of sordan to P fertilizer additions when Olsen soil test P level was in the range of 0-6, 6-12, 12-18, 18-24, 24-30, and over 30 ppm.

tional P rate. The yield continued to increase each time more P was added, as long as the soil test P level was less than 30 to 40 ppm.

Current P fertilizer recommendations imply that responses will be minimal at soil test P levels above 18 ppm. The results of this study indicate that for a forage crop such as sordan, yield increases are nearly linear in response to the P applied, up to a soil test P level of approximately 30 ppm, at least on some soils. However, the greatest responses for each unit of fertilizer applied occurred when the soil test level was at its lowest. Response on the Gay site indicated that yield response decreases as the intial soil test P level increases. At a soil test level of 3.2 ppm, the yield increased steeply with each increment of P added. The same was true at an initial soil test P level of 13.2 ppm. However, by the time the soil test level increased to 29.0 ppm, there was almost no change in yield among the various P fertilizer rates.

After initially testing the soil, each of the original soils in the study was divided into five samples. The P soil test level of each sample was adjusted to create five levels (from very low to very high) for each soil. This procedure also provided an opportunity to see how the P soil test level would change with different P additions.

After the five soil test levels were created for each soil, P was added at rates equivalent to 0, 10, 20, 40 and 80 lb/A. Three crops of sordan were then grown on each soil. Sordan was used as the test crop partly because of its similarity in behavior to small grains, and partly because three successive crops could be grown and harvested without the need to replant between crops. Total yield from each harvest was recorded, and measurements were made of the soil test P level after all fertilizer additions.

Researchers hoped to determine the maximum fertilizer rate that still generated crop responses. To that end, they found that the pattern of yield response to P was similar across all three soils. If the soil test level was relatively low, yield response kept increasing with each addi-

When everything else is uniform, specific properties of the soil and the soil test P level can have a dramatic effect on crop responses to fertilizer P. On the Glendive soil, the research team observed no response to P additions at rates less than about 40 lb/A when soil test P level was greater than approximately 18 ppm. At the higher levels of soil test P (about 40 ppm or above), there was little or no response to each additional P rate. For example, with the Heldt soil at the highest soil test P level, yield did not increase at all between the point where no P was applied and where 80 lb/A rate of P_2O_5

was applied. Similarly, the yield increases on the Glendive and Havre soils were only 7 and 2 percent, respectively, at the high soil test levels.

To show just how important the soil test level is for determining the benefits of adding P, researchers adjusted and combined the yield data from all three soils to come up with one figure. **Figure 1** shows the yield (as a percent of the maximum yield) after applying increasing amounts of P to each soil at various soil test levels.

TABLE 2. Olsen P soil test levels of each soil following P fertilization.

P added, lb/A	Olsen P level after fertilizing, ppm Glendive fsl	Havre l	Heldt sic
0	3.0	7.2	2.4
10	4.0	7.7	3.7
20	6.1	8.9	6.5
30	6.0	15.4	9.1
40	8.9	13.0	8.9
60	9.9	14.5	11.3
80	18.0	18.3	19.3
120	32.3	31.8	26.3
240	61.5	56.0	51.9

In general, yield responses were similar for all soils testing up to 18 to 24 ppm (similar slopes for response curves). There was less response to any additional P when soils tested higher than this. These results provide additional evidence that a soil test is a good index to determine if the soil has adequate P for cereal production. An important result is that soils which had low soil tests never did yield as much, even at 80 lb/A of applied P, as those testing above 24 ppm and with no additional P. **Results suggest that it may be a good soil management strategy to gradually build up P soil test level, rather than applying small annual applications which are barely adequate for each year's crop.**

It was interesting to note that the way yield increased with each increase in P rate was slightly different for each of the soils. In all three, however, yield continued to increase up to a P rate as high as 80 lb/A.

Table 2 and **Figure 2** show soil test P levels after fertilizer was applied to each of the soils. Soil test P levels continued to increase, up to almost 60 ppm, when an equivalent of 240 lb/A of P was applied. In general, about 4 lb/A of P (10 lb/A P_2O_5) was needed to raise the soil test P level 1 ppm. Regardless of whether the initial soil test P level was low or high, it still took about 4 lb P/A to raise the soil test level 1 ppm.

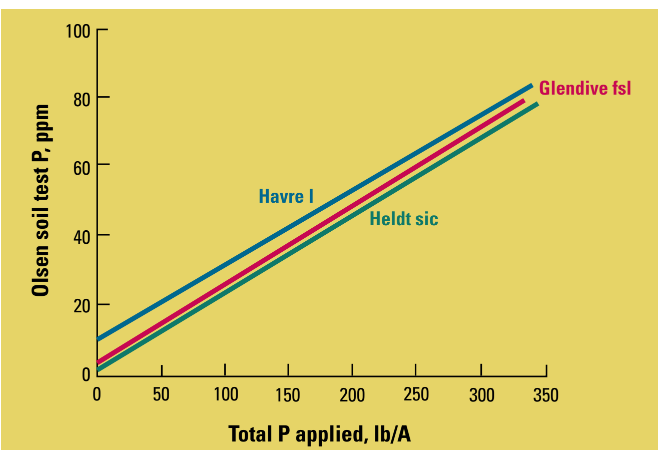

Figure 2. Change in soil test P level of three eastern Montana soils receiving increasing rates of P fertilizer (source was 0-45-0).

The study revealed that if a soil tested at 8 ppm (Olsen method) to start with, and a farmer wanted to raise the level to 18 ppm, he would calculate: [18 ppm (desired level) minus 8 ppm (starting level) x 4] = 40 lb of additional P needed per acre. Since fertilizer such as 18-46-0 is 46 percent P_2O_5 and P_2O_5 is 43 percent P, it would take the equivalent of about 200 lb of actual fertilizer material to raise the soil test level from 8 to 18 ppm.

Researchers only looked at short-term effects; it is likely that over a longer period, greater amounts of P would be "fixed" by the soil and more P would be needed to raise test levels. Data do not show what happens to soil tests over long periods of wetting and drying, freezing and thawing. Other research results indicate that the newly established soil test level would probably decrease somewhat for a few weeks or months.

In summary, keep in mind that all of the soils used in this study were from eastern Montana; the pH of each soil was greater than 8.0 (alkaline), and the lime (calcium carbonate level) ranged from 2.5 to 6.1 percent. Also remember that this study was conducted in the greenhouse under ideal conditions: plenty of water and all other nutrients were supplied abundantly. Under actual field conditions, other factors such as available water and temperature would probably limit yields so that a continued response to P at very high rates would probably not occur.

Observations:

- There does not seem to be any one soil test level at which response to fertilizer stops. However, when the soil test P level was above 30 ppm, the crops showed nearly no response to additional P additions.
- Two different approaches to P fertilization strategy can be seen here. They are: 1) build the soil test level and then supply only low amounts of P annually; or 2) maximize the return on each dollar spent on P fertilizer on your farm by applying higher rates of fertilizer on fields with low testing soils, and lower rates of fertilizer on fields with high testing soils.
- Finally, the value of a soil test for helping make wise P fertilizer decisions cannot be over-emphazised.

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Information Agriculture Conference

The 1997 InfoAg Conference at the University of Illinois-Urbana attracted about 800 participants August 6-8. The three days of educational sessions and workshops featured more than 80 speakers and presenters. Over 50 exhibits displayed products and services related to precision agriculture. The 1997 event, organized by PPI and the Foundation for Agronomic Research, was the third Information Agriculture Conference.