Do We Need More Phosphorus Calibration Work?

By T.L. Roberts

About 75 percent of soils in the Canadian prairies test low in available phosphorus (P). Despite this, responsiveness to P fertilization and soil P analysis are being questioned because routine analysis doesn't detect the residual soil P that has built up over years of fertilizer use. This paper reviews recent P calibration studies and discusses the validity of existing P benchmark data.

PRAIRIE SOILS in western Canada have lost 40 to 50 percent of their organic matter since they were first brought under cultivation at the turn of the century. Much of this occurred within the first 20 years of breaking sod. The initial loss of soil fertility prompted early investigators to conduct fertilizer trials and to conclude that P, at that time, was the most likely nutrient to limit plant growth. Plant available P has been, and continues to be, low in most prairie soils. A recent survey suggested 75 percent of the Canadian prairie soils contain less than 20 parts per million (ppm) soil test P.

Although available P remains marginal in most prairie soils, it's commonly accepted that prairie soils are now less responsive to P fertilization due to buildup of residual P from past fertilization practices. Crop responses to residual P fertilizer application have been well documented in western Canada. However, routine analysis does not detect residual forms of fertilizer which are able to supply P to plants. Because of this, use of the "old" P response curves has been questioned.

Past Calibration Studies

Historic P calibration studies conducted in western Canada clearly demonstrated crop response to P fertilization decreased as available soil P increased. Based on these early studies, John Mitchell, a Saskatchewan soil scientist, stated: "Soils showing an availability of less than 20 parts per million phosphorus seem likely to give very substantial increases from phosphate applications." A soil test less than 20 ppm P is still considered marginal, and responsive, by most labs today.

Wheat response in early P calibration experiments varied with location and year. Typical yield increases in response to applied P are shown in **Table 1**.

Table 1. Average wheat yield increases in a Saskatchewan P trial (1939-1943).

P_2O_5, lb/A	Yield increase, bu/A Mean	Yield increase, bu/A Range	Yield increase, % Mean	Yield increase, % Range
7	4.6	2.5-5.3	20	14-22
12	6.0	2.4-8.6	25	14-32
17	7.8	3.9-10.7	33	22-40
24	9.3	3.7-12.7	39	21-48

Source: Mitchell (1946)

In these Saskatchewan wheat trials, yield increases over the control ranged from 2.5 to 12.7 bu/A or 14 to 48 percent. Significant response occurred in 215 of 299 sites. Poorest response occurred in years when moisture was in short supply. On average the greatest increases occurred with the highest application rates.

Table 2 summarizes Saskatchewan P response data for wheat. Average Saskatchewan wheat yield response was about 5.2 bu/A prior to 1970 and 2.5 bu/A since

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Table 2. Wheat response (bu/A) to applied P in Saskatchewan trials.

	Prior to 1970			Since 1970		
	Trials	Control	Fertilized	Trials	Control	Fertilized
Stubble	238	20.8	23.9	130	30.4	31.9
Fallow	636	23.8	29.7	122	31.6	35.6

Source: Cowell and Doyle (1993)

1970. Comparable responses to P fertilization have been observed in other calibration studies throughout the prairies.

Prior to 1970, the probability of obtaining a P yield response in Saskatchewan wheat was 92 percent on stubble and 96 percent on fallow. After 1970 these dropped to 70 and 90 percent, respectively. More recently, yield responses in P fertility trials have appeared more difficult to find. For example, only 50 percent of irrigated trials in southern Alberta responded to P fertilization in a 1987 study, and only 15 percent of P fertility trials showed significant response in a Saskatchewan study in 1990. This type of reduced response has been attributed to improved fertility of P deficient soils due to a build up of residual fertilizer P and increased cycling (release) of organic P. Perhaps more important, the lack of response on soils that were expected to respond to P fertilization has caused the predictability of the P soil test to be questioned.

Current Calibration Studies

Few current P fertility experiments are ongoing in western Canada. However, recent studies have suggested that western Canadian prairie soils continue to be responsive to P fertilization and that P soil tests being used in western Canada do a fairly good job of indicating the need for supplemental P.

An extensive study was recently initiated in Alberta to assess the responsiveness of cereal and oilseed crops to P fertilization and to correlate crop response with the different P soil tests.

Wheat response to P fertilization occurred in 78 percent of the sites in 1991, 89 percent of the sites in 1992, and 82 percent of the sites in 1993 (**Table 3**). Yield increases ranged from about 3 to more than 5 bu/A. A similar or greater response occurred with barley and canola.

Phosphorus benchmarks were recently evaluated in Saskatchewan over a range of available soil test P (STP) levels using a direct seeded semi-dwarf wheat. Seven sites (including one irrigated site) with varying amounts of soil test P were selected.

All seven sites responded to P fertilization. **Figure 1** shows that the greatest response occurred at the lower soil test P levels. Yield increases in the fertilized treatments were as high as 93 percent and ranged from 5 to 31 bu/A. These increases

Table 3. Wheat response in Alberta P calibration trials (1991-1992).

	Number of sites		
	1991	1992	1993
Responsive (yield increase >5 bu/A)	25	25	25
Marginally responsive (yield increase 2-5 bu/A)	12	20	15
Total sites	48	51	49

Source: McKenzie, et al (1994)

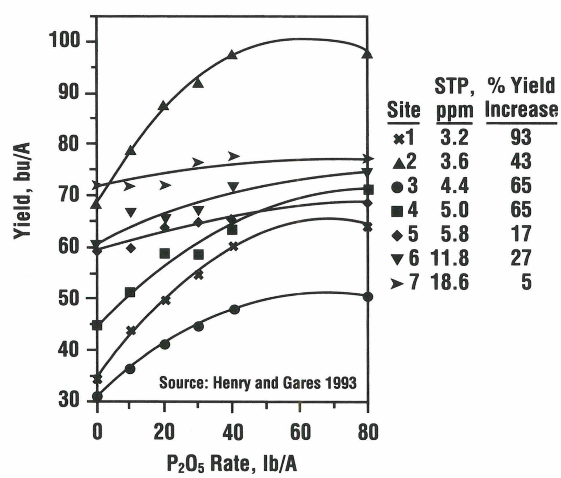

Figure 1. Wheat response to applied P at different soil test P levels in Saskatchewan soils.

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were considerably higher than those obtained in previous P calibration studies using hard red spring wheat. However, semi-dwarf wheats usually yield about 25 percent more than hard red spring wheat and are perhaps more responsive to P fertilization.

Although many believe western Canadian soils are not as responsive to P fertilization as they once were, and that P soil tests now in use are not as effective as they once were, the recent studies in Alberta and Saskatchewan would suggest otherwise.

If crops grown on P deficient soils still respond to P fertilization, why haven't recent studies been more consistent in their observations and conclusions? Part of the explanation is likely due to residual fertilizer P. In addition, because there are fewer P fertilizer experiments, the chances of obtaining variable results are greater, especially if crop responses are smaller because base-line available P levels have increased.

With fewer P fertilizer trials being conducted, researchers need to take greater care to ensure responsive events are recognized. Natural variability in fields and plot areas can easily mask smaller crop response. **Table 4** shows results from a recent P rate study in Saskatchewan where wheat was grown on summerfallow. Composite soil samples were taken from each site and from each plot within sites to assess P variability.

The large variability in grain yield within treatments was attributed to the variability in soil P levels at each site.

Table 4. Range in means of soil test P (lb/A) and wheat yields (bu/A), and variability at 9 locations in Saskatchewan.

	$NaHCO_3$ Extractable P, lb/A	Wheat yield, bu/A
Mean	10-27	22-46
Coefficient of variation,%	18-50	4-27
Number required[1]	4-62	5-294

Source: Liang et al (1991)

[1] Number of subsamples required to obtain a soil test P accuracy within ±3 lb/A or number of replicates required to detect a 5 percent grain yield response.

Although statistical analysis showed response was not significant at any site, when considered on a per plot basis, the probability of a positive P response ranged from 65 to 78 percent. Possible responses to P fertilization were masked because comparisons of mean yields were based on averaging "responsive" areas with "non-responsive" areas. This demonstrates that spatial variability of a site must be determined prior to carrying out an experiment and the numbers of experimental replications must reflect the yield differences being sought.

Past fertilization practices are also complicating soil P variability, particularly in no-till systems. When tillage is reduced, there is minimal disturbance and mixing of soil. And because P is relatively immobile, differences between row and interrow areas will become greater, making proper soil sampling even more important in predicting P response.

Yield increases in semi-dwarf wheats suggest they are potentially more responsive to P fertilization than traditional hard red spring wheat, and differential P response within varieties is also possible. North Dakota researchers have demonstrated faster growing, earlier maturing varieties of wheat require more P fertilizer for adequate tillering and grain yield than slower growing varieties.

Summary

Soil test P levels remain marginal in many prairie soils, and although residual fertilizer P is difficult to account for using routine soil analysis, crops continue to respond to P fertilization when soil test P is low. Albeit, the responses to P fertilizer may not be as great as when P was first applied to prairie soils, that does not invalidate past P calibration work.

Recent calibration studies in Alberta and Saskatchewan show that crop response to P fertilization is widespread and can be substantial. They also show P soil tests are still effective at predicting response. However, because of the changing nature of soil P and the introduction of newer crop varieties and cropping systems, P soil tests and P calibration curves need constant refining to better reflect today's cropping needs. ■