CALIBRATION OF BICARBONATE-EXTRACTABLE PHOSPHORUS ON WHEAT

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ABSTRACT

Nine locations were selected throughout Saskatchewan so that a summerfallow an oilseed stubble and a wheat stubble experimental site were adjacent to each other. Each site was characterized by analyses carried out on a composite soil sample obtained from the whole site. A randomized complete block (RCB) design with three treatments (control, 10 lb P_2O_5/ac , and 20 lb P_2O_5/ac) and four replicates was established at all sites. Subsequently, composite soil samples from each plot were taken. Comparison between the two sampling schemes suggested that characterizing a site on the basis of one composite sample may not result in a true representation of the P fertility status of individual plots within the site. Analysis of variance for a RCB design resulted in non-significant response of spring wheat to P fertilizer application independent of previous crop history. However, examination of soil P levels in each plot of every experiment revealed that sites were extremely variable. Hence, comparison of mean grain yields in many cases was based on averaging "non-responsive" parts of the field with "responsive" ones. When the probability of grain yield response was plotted on a per plot basis, a 65%, 72% and 78% probability of positive response to P fertilization was obtained on the fallow, wheat stubble and canola stubble, respectively. Boundary-line analysis indicated that spring wheat had very small possibility of positive yield response to P fertilization when soil bicarbonate-P was over 25 lb/ac. Spatial variability of a site must be determined prior to carrying out an experiment and number of replications must reflect the differences sought.

INTRODUCTION

The current phosphorus soils test (0.5 M $NaHCO_3$) and fertilizer recommendation in Saskatchewan are not always effective in predicting when a crop will respond to P fertilizer application (Bullock et al., 1990). The weak link in making accurate P fertilizer recommendation to Saskatchewan farmer is the limited field calibration research data-base available on a specific soil and crop from which to make recommendation. The variability of soil testing results can be assigned to three sources: 1) sampling error, 2) sample processing error, and 3) analytical error. With the improvement of analytical techniques and instrumentation, analytical error can be minimized. Processing error can be reduced by careful sample handling. Sampling error in soil testing has been found to be of a much greater magnitude than other two types of error (Horneck et al., 1990). It has been found that coefficients of variation for P soil test levels within a small uniform field ranged from 20 to 40% (Kunkel et al., 1971). These results indicated the importance of soil heterogeneity on experimental data and the possible invalidation of results due to block treatment interactions.

Soil sampling is an integral part of soil testing. The heterogeneity of soil and a samples' failure to represent field condition can render analytical results useless. Addition of soil amendments and fertilizer increases soil heterogeneity, especially where fertilizers have been banded. A representative soil sample is therefore a prerequisite for meaningful analytical results and an accurate fertilizer recommendation. The objective of this study was to examine whether a composite soil sample from the whole experiment site can represent the P fertility status in individual plot.

MATERIALS AND METHODS

Field studies on wheat were conducted at nine locations throughout Saskatchewan in 1990. At each location, a summerfallow, an oilseed stubble and wheat stubble experimental site were adjacent to each other. The $NaHCO_3$-extractable P levels at these site varied from 10 to 38 lb ac^{-1} and phosphate recommendation, according to the Saskatchewan Soil Testing Lab criteria, ranged from 15 to 40 lb/ac. A randomized complete block (RCB) design with three treatments (control, 10 lb P_2O_5/ac and 20 lb P_2O_5 /ac) and four replicates was established at all sites. Plot size was 3m x 10m. Basal application of macro- and micronutrients were applied to each field site according to soil testing recommendation to ensure that available nutrients would not limit yield. All fertilizers were broadcasted and incorporated before seeding except P was seed-placed.

Two soil sampling schemes were carried out before fertilization, namely, one composite sample obtained from each site and one composite sample taken from each plot. Four 22mm in diameter cores were obtained for plot composite samples and 12 for site composite samples. All composite samples were taken to two depths (0-15cm, 15-30cm). Soil samples were air-dried at room temperature, ground and passed a 2-mm sieve before analyses. At maturity, a 2.0 m^2 area was harvested to measure grain yield in each plot.

All soil sample analyses were carried out at Saskatchewan Soil Testing Lab: NO_3-N and SO_4-S extracted with 0.001 M $CaCl_2$; P and K extracted with 0.5 M $NaHCO_3$; soil pH in 1:1 soil:water; texture estimated by hand.

RESULTS AND DISCUSSION

Phosphorus fertilizer is normally concentrated in a seed-row or band and does not move. Residual P levels can vary widely over a short distances within a field (Sable and Marx, 1987). This means that the P fertility status in the field can be very heterogeneous. Spatial variability of a site in the field must be determined prior to carrying out a experiment. The result of 12 subsamples from each site in this study indicated that the coefficients of variation ranged from 13 to 60% for P soil test levels (Table 1). The number of samples required to obtain an accuracy within ±3 lb/ac P ranged from 1 to 163. This indicates that some of the sites are quite homogeneous. One composite sample from one site could be representative. In the more heterogeneous sites, however, more than 100 subsamples from one site are needed to represent the P fertility status in the site. In most cases, 20 to 40 subsamples are needed to detect ±3 lb/ac difference.

Table 1. Ranges of mean (lb/ac) and Coefficients of Variation (CV) of $NaHCO_3$-extractable P in 9 locations in Saskatchewan.

Crop history	Summerfallow		Wheat stubble		Canola stubble	
Depth (cm)	0-15	0-30	0-15	0-30	0-15	0-30
Mean (lb/ac)	10-27	16-42	7-28	12-38	12-42	19-69
CV (%)	18-50	13-41	21-59	14-44	16-50	14-34
No required†	4-62	5-99	1-77	6-95	4-69	4-163

†. No required: Number of subsamples required to obtain accuracy within ±3 lb/ac P.

When the composite samples were sampled based on individual plots, a huge spatial variability of soil P test level was discovered and is illustrated in Fig. 1. From this information, it can be concluded that characterizing a site on the basis of one composite sample may not result in a true representation of P fertility status of individual plots within the site.

Analysis of variance for a RCB design resulted in non-significant (P =0.05) response of spring wheat to phosphorus fertilizer application for all sites and all previous crop history. Grain yield in two sites on Canola stubble responded to P fertilizer application at 10 % level (P = 0.09 and P = 0.08, respectively). The coefficients of variation of grain yield within treatment ranged from 4 to 88 % with the majority over 15 % (Table 2). The number of replicates required to detect a 5 % grain yield response ranged from 5 to more than 1000. The huge variation of grain yield within a treatment may be caused by extremely variable soil phosphorus levels in each site. Hence, comparison of mean grain yields in many cases was based on averaging "non-responsive" parts of a field with "responsive" ones.

Table 2. Ranges of average grain yield (kg ha^{-1}), coefficients of variation (CV)within treatment and number of replicates required to detect a 5 % yield response.

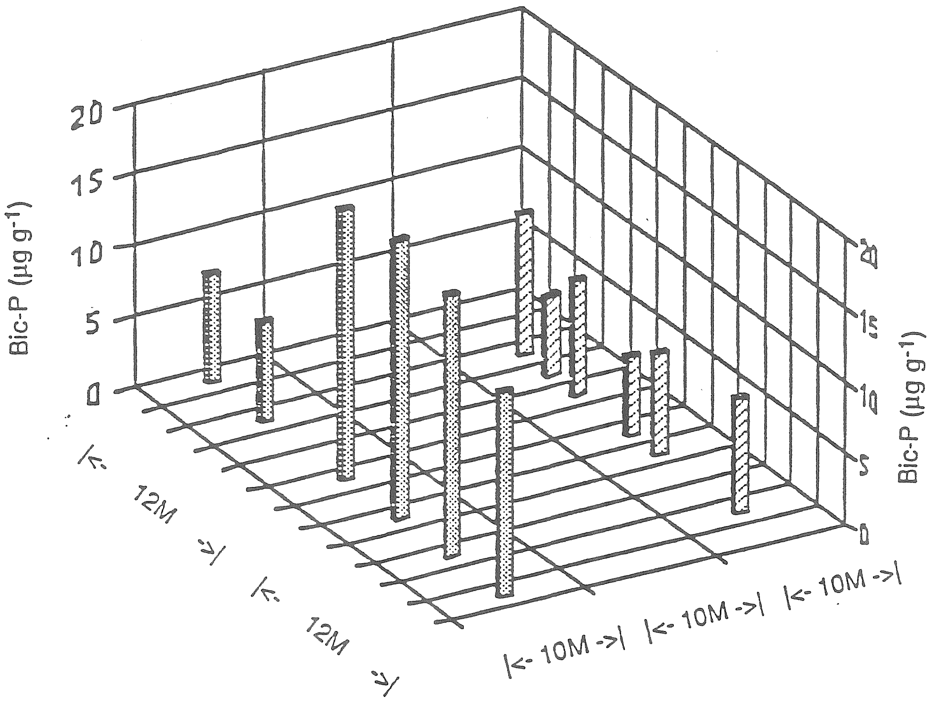
Crop history	Summerfallow	Wheat Stubble	Canola Stubble
Mean (kg ha^{-1})	1504 - 3088	1018 - 2712	320 - 2837
CV (%)	4 - 27	4 - 32	4 - 88
No. required†	5 - 294	6 - 410	7 - 3135

†. Number of replicates required to detect 5 % grain yield response.

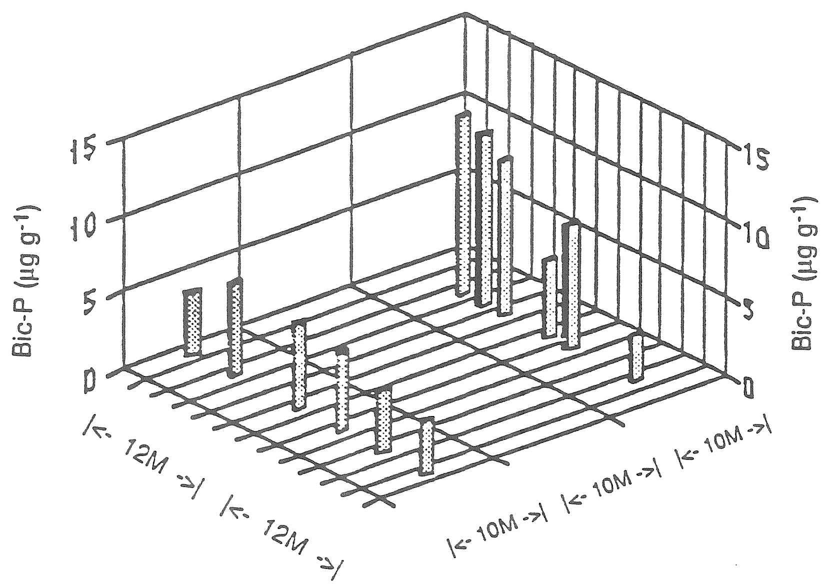
An alternative approach, ranked probability graph, was helpful for making yield comparisons between treatments (Flaten et al., 1988). Yield increases, defined as fertilized yield less check yield, were ranked from highest to lowest. Apparent yield decreases are included in this ranking. Then the probability for each yield increase was plotted on a per plot basis. A 65 %, 72 % and 78 % probability of a positive spring wheat yield response to phosphorus fertilization was obtained on summerfallow, wheat stubble and canola stubble, respectively (Fig.2).

The ranked probability approach is also useful in determining economic return from phosphorus fertilization. Based on the current P_2O_5 fertilizer cost ($0.60 /kg P_2O_5), the average rate of P_2O_5 applied (20 kg P_2O_5 ha^{-1}), the current price of wheat ($147 ton^{-1}), a farmer would require a 2.7 bu ac^{-1} yield increase in order to break even on the P_2O_5 fertilizer cost . In Fig. 2, the probability of a economic return would be approximately 45 % , 50 % and 57 % in summerfallow, wheat and canola, respectively.

Regression equation for soil test calibrations are both site and season specific. One has been forced to repeat such work both in space and time in order to represent a range of the uncontrollable variables. An alternative approach to analyzing the data set is provided by boundary-line analysis as described by Webb (1972), Walworth et al. (1986), Flaten et al. (1988). This would then represent the ultimate soil test calibration. The value of the soil test parameter where the maximum yield is obtained represent the level of the particular nutrients that would be optimal under any conditions. By interpolation, one could establish the maximum yield that might be obtained at any particular soil test level or alternatively, establish the minimum soil test level for a given required yield. Since soil test P is only an index of the labile P pool and is not quantitatively equivalent to fertilizer P, only soil test P



Glenavon (Fallow)



StarCity (Wheat Stubble)

Figure 1. Spatial distribution of NaHCO3-extractable P in 0-15 cm for two sites (Glenavon-summerfallow and StarCity-wheat stubble).

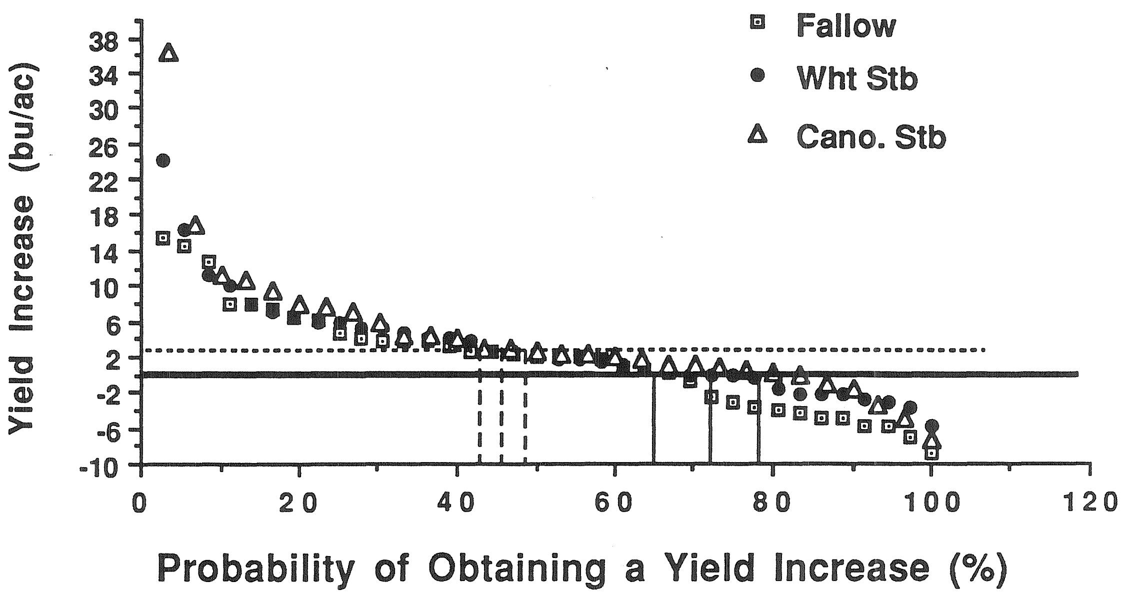


Figure 2. Probability of obtaining a yield increase of spring wheat to P fertilizer.

was used in this analysis.

In this analysis a curve is drawn through the uppermost points in a plot of yield against soil test P. It is assumed that points on this line represent the maximum possible yield for a given value of the soil test P, whereas points below this line represent yield limited by other variable for which boundary-line curves are also determined. A data set consisting of soil bicarbonate extractable P and grain yield of spring wheat on individual plots from nine locations and three crop histories is present in Fig. 3. It can be seen that most points occur in the center of the plot. This indicated that in most cases other growth factors besides available P limited grain yield. A point to lie on the boundary line required that the levels of all other growth factors be at or very near the optimum . When soil bicarbonate P is over 25 lb/ac in 0-15 cm, very little possibility of spring wheat yield responded to P fertilization. If soil bicarbonate P is less than 15 lb/ac, most possibly, spring wheat yield would respond to P fertilization. Soil bicarbonate P levels between 15 to 25 lb/ac can be taken as marginal level.

This data set present here is only from one year experiments. More growing season data are needed to represent the variable growth factors between growing seasons. Any type of field experiment that is capable of generating variability supplies particularly useful information to data banks for use in boundary line interpretations. Appropriate experimental design in this category would be complete and partial, preferably not replicated, but rather used as single replication at a number of sites. It is important to select sites likely to be responsive to P fertilizer application.

SUMMARY

Comparing two sampling schemes, it can be concluded that one composite sample from a site can not characterize the true P fertility status of individual plots within the site. Coefficients of variation of $NaHCO_3$-extractable P in individual site ranged from 16 to

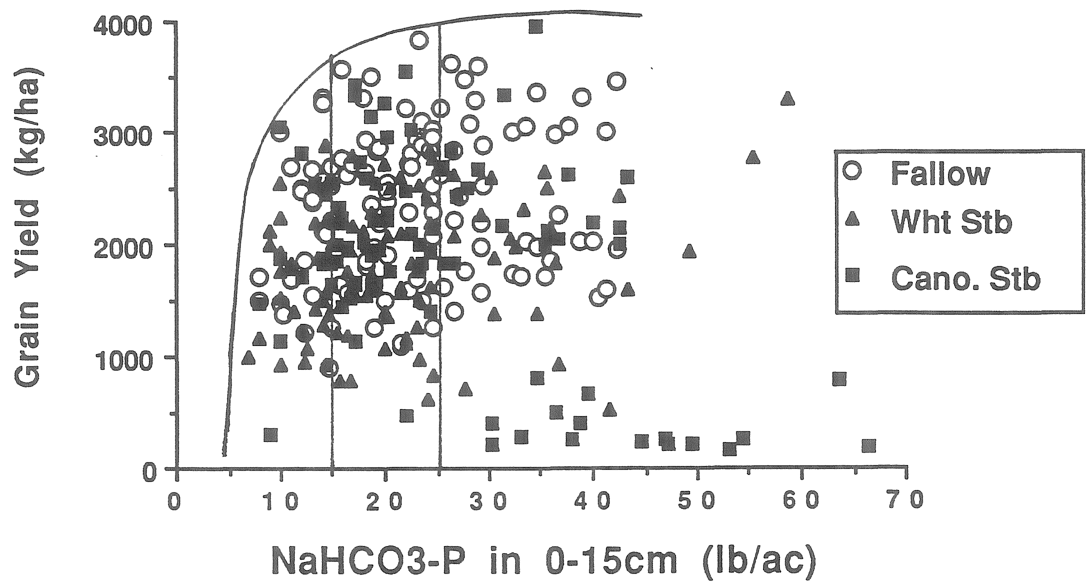


Figure 3. Scatter diagram together with confining boundary line for the relationship between soil test P and spring wheat grain yield.

60%. The spatial variability of soil test P is so large that the number of subsamples required to detect ± 3 μg P g^{-1} soil usually ranged from 10 and up to 100 for a site. This may be the reason why there were no significant responses to P fertilizer application at any site when the sites were examined as a whole. This suggested that comparison of mean grain yields in many cases was based on averaging "non-responsive" parts of field with "responsive" ones. Using the ranked probability graph approach, a 65 %, 72 % and 78 % probability of positive response to P fertilization on per plot basis was obtained on fallow, wheat stubble and canola stubble, respectively. In practice, the probability of obtaining an economic return would be approximately 45 % , 50 % and 57 % for summerfallow, wheat stubble and canola stubble, respectively, when the marginal yield over marginal cost approach is utilized. When soil bicarbonate P in 0-15 cm is over 25 lb/ac, very little possibility of spring wheat yield response to P fertilization from spring wheat would be expected. All these results indicated that spatial variability of a site must be determined prior to carrying out an experiment and number of replications must reflect the differences sought.

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