RESIDUAL PHOSPHATE STUDIES[1]

J.W.B. Stewart, J.O. Moir and L.C. Tollefson
Saskatchewan Institute of Pedology
University of Saskatchewan
Saskatoon, Sask.

ABSTRACT

Data on yield and P uptake by flax and wheat is presented from the first year of an eight year residual phosphate (P) study located on the Kernen Farm of the University of Saskatchewan. Comparison of seed-placed (0, 5, 10, 20, and 40 kg P ha^{-1}) and broadcast P (0, 40, 80, 160, and 320 kg P ha^{-1}) treatments showed that there was a yield response to both types of P fertilizer application with maximum yields being obtained in wheat by either 40 kg P ha^{-1} seed-placed or by broadcast P application of 80 to 160 kg P ha^{-1}, and in flax by 5-10 kg P ha^{-1} side-banded or 80 kg P ha^{-1} broadcast. Laboratory studies related the prediction of fertilizer P response from seed-placed treatments to broadcast treatments by use of P sorption and P extraction techniques. P sorption isotherms were run on over 300 soil samples taken from the 0-15 cm layer of cultivated fields representing the majority of the cultivated soil associations in Saskatchewan. This data would suggest that rates of P broadcast should be four to eight times higher than recommended seed-placed or side-banded rates in the same soil zone with the same available P content.

INTRODUCTION

Previous studies on the residual effect of large application of P fertilizer to Chernozemic soils (Read et al., 1973, 1977; Bailey et al., 1977; Sadler and Stewart, 1974, 1975, 1977) have clearly demonstrated that the applied P will be available to crops in succeeding years. In addition, greenhouse evaluation of residual phosphate in neutral and calcareous soils have indicated (Bowman et al., 1978) that most of the residual P accumulated through years of fertilizing and manuring was available for P uptake and that specific lab procedures are excellent methods of assessing the P fertility as related to plant growth potential on these soils. These results have caused many farm operators to look seriously at the possibility of putting on one large amount of fertilizer phosphate (200 to 400 kg P ha^{-1}) and not adding further fertilizer phosphate for a period of up to eight years. This process has some advantages in the Canadian prairie environment where frost-free days range from 100-120 and speed is essential in the spring of the year once the operator can get on his land. Other advantages is that flax and rapeseed having small seeds and with basically tap root systems are susceptible to phosphate being placed with the seed and require very accurate banding techniques to obtain good yields. It could be argued that increasing the level of plant available phosphate in the complete plant rooting zone always would ensure maximum efficiency.

---

[1]Paper presented at the Soils and Crops Workshop, Feb. 18-19, 1980. Proceedings published by Sask. Advisory Council on Soils and Agronomy and Extension Division, University of Saskatchewan, Saskatoon. Research supported by Western Co-operative Fertilizers and the Natural Sciences and Engineering Research Council of Canada.

All recommendations made in Saskatchewan by the Soil Testing Laboratory are based on phosphate which has been seed-placed or side-banded and little information is available on the level of broadcast phosphate that would be required for similar yield increases. Earlier work has simply established that at least two to four times the seed-placed or side-banded application would be required as a broadcast phosphorus treatment to obtain similar yield increases. Predictions of the level of added phosphate required in the broadcast treatment may be extrapolated from data on P sorption and desorption. Fox and co-workers (1970, 1978) have fertilized the soil with added P until the phosphorus in the soil solution reached a high enough level for the specific crop concerned, while some other workers have fertilized with phosphate until the sodium bicarbonate extractable P level was above the level where phosphorus additions would give economic responses.

In 1979, two long term residual phosphate experiments were started on the Kernen Farm of the University of Saskatchewan and P sorption and desorption studies were carried out in soils representative of the major soil associations of major soil zones within Saskatchewan. The objectives of this program are: (1) to obtain maximum efficiency of use with lowest economic cost of fertilizer phosphate in Western Canadian soils, (2) to investigate the residual effects of large broadcast applications of fertilizer phosphate on productivity of cereals, rapeseed and flax grown at two rotations, (a) continuous wheat, (b) flax, wheat, rapeseed, wheat (a four-year rotation), and to compare these treatments with side-banded and seed-placed treatments, (3) to investigate analytical techniques that could be used in the laboratory to predict the level of broadcast fertilizer phosphate required for maximum yields.

MATERIAL AND METHODS

Field Plot Research

Two 3.5 acre plots were located on the Kernen Crop Research Farm (Univ. of Saskatchewan). Both plots received bulk applications of triple superphosphate (0-45-0) at rates ranging from 0, 40, 80, 160 to 320 kg P ha^{-1} on subplots which were 45 by 110 feet in a 5 x 5 latin square design on each of the two major blocks of land. On the first block, a continuous wheat rotation was started and on the second a rotation of flax-wheat-rapeseed-wheat was initiated (Fig. 1). Within each subplot (45 x 110 feet) seed-placed or side-banded treatments ranging from 0, 5, 10, 20 to 40 kg P were applied at seeding (Fig. 2). The plots were located in a relatively uniform area of the farm where the dominant profiles were Rego Dark Brown Sutherland and Orthic Dark Brown Sutherland, and in the area where the plots were located the texture is silty clay, approximately 38% clay and 45% silt. Initial $NaHCO_3$ extractable P levels within the plot area where less than 5 ug g^{-1}. In 1979 soil test analyses for other nutrients (N, K, and micronutrients) showed that extra fertilizer was not needed. Neepawa wheat was seeded on May 26th and harvested on August 22nd, with intermediate sampling on June 27 and July 12. Dufferin flax was seeded on May 29th and harvested on September 5th, with intermediate samplings on June 27

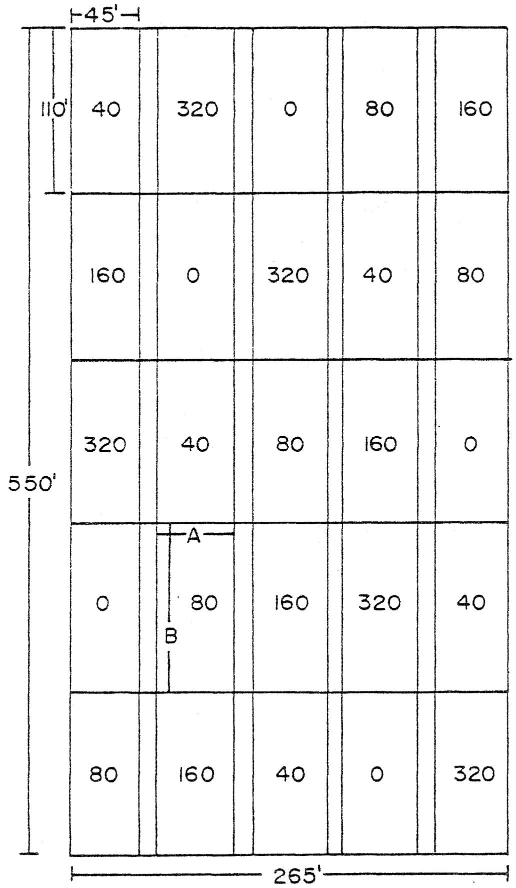

Fig. 1. Field plot layout at Kernen Farm. P applied at designated rates as triple superphosphate (0-45-0) in the spring of 1979 to two blocks, one of which was seeded to wheat and the other to flax.

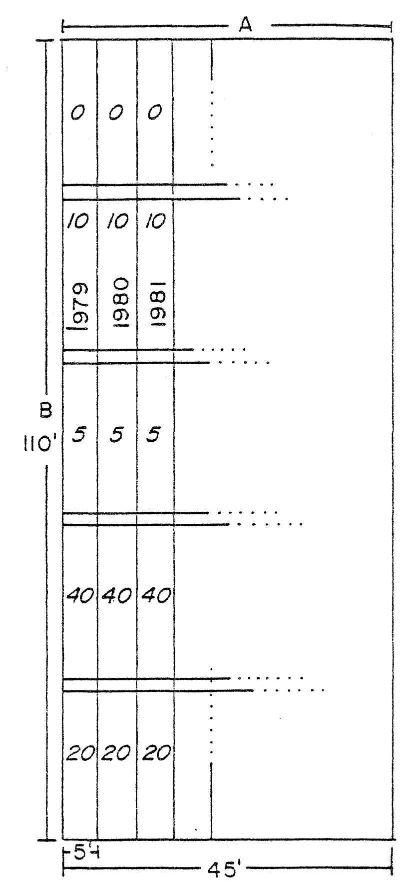

Fig. 2. Details of a 80 kg ha^{-1} treatment (designated area AB in Fig. 1). P was seed-placed with wheat (side-banded with flax) at rates 0, 5, 10, 20 and 40 kg ha^{-1} in one strip 5 feet wide in 1979. In 1980, the seed-placed P was applied to a 10 foot strip that included the 1979 5 foot strip. In 1982 a 15 foot strip will be used.

and July 12. At each sampling date, specific length of rows were sampled to enable conversion to a hectare basis and plant analysis were carried out for P and Zn on above ground plant material. Percent N was also determined on the final harvest samples of grain and straw.

Laboratory Studies

P sorption and desorption studies were carried out in 300 different soils representative of 63 soil associations of the major soil zones in Saskatchewan. The technique used was equilibration of eight samples of each soil with increasing amounts of calcium phosphate ($CaH_4(PO_4)_2H_2O$) in 0.01 M calcium chloride solution and to measure the amounts of P left in solution. The samples were centrifuged then washed with NaCl to remove excess P from solution before extracting them with 0.5 M sodium bicarbonate (pH 8.5) as outlined by Olsen et al. (1954). The P sorption method was similar to that used by Fox et al. (1970).

Analytical Methods

Plant digests 0.2 g of oven-dry plant tissue were weighed into block digestor tubes and wet digested using a H_2SO_4-H_2O_2 digestion procedure (Thomas et al., 1967). The N and P in solution were measured colorimetrically using an autoanalyzer (Technicon Autoanalyzer Method No. 324-74W and 94-70W). The Zn in solution was analyzed using atomic absorption spectrometry.

RESULTS

Field Plots

As all the fertilizer P was applied in the spring of 1979, the results obtained from the field plots can only be used to compare broadcast with seed-placed or side-banded application of P. Information on residual P will be obtained in 1980 and succeeding years.

The effect of seed-placed P on the yield of wheat grown on the plants which had received broadcast P applications of 0, 40, 80, 160 and 320 kg ha^{-1} of P is shown on Fig. 3. These results show that a maximum yield without seed-placed P was obtained by broadcast addition of 160 kg P ha^{-1}. This yield was higher but not significantly different from the yield obtained by seed-placed P at 40 kg P ha^{-1}. A seed-placed P treatment of 40 kg P ha^{-1} provided approximately 200 kg ha^{-1} increase in grain yield on the plot which did not receive broadcast P. On the 40, 80 and 160 kg P ha^{-1} broadcast P treatments, small yield increases were obtained with 5 kg P ha^{-1} seed-placed P.

The effects of side-banding P on flax yields did not show a significant effect on the 0 broadcast P plots but did appear to show an increase at the 5 kg P ha^{-1} on the broadcast P treatments of 40, 80 and 160 kg P ha^{-1}. The highest yield obtained where P was not side-banded was on the broadcast P treatment at 320 kg P ha^{-1} (Fig. 4). When all the side-banded treatments were averaged for each broadcast P plot, the yields (Fig. 4) showed a significant increase up to 80 kg P ha^{-1} and no significant increase at higher rates.

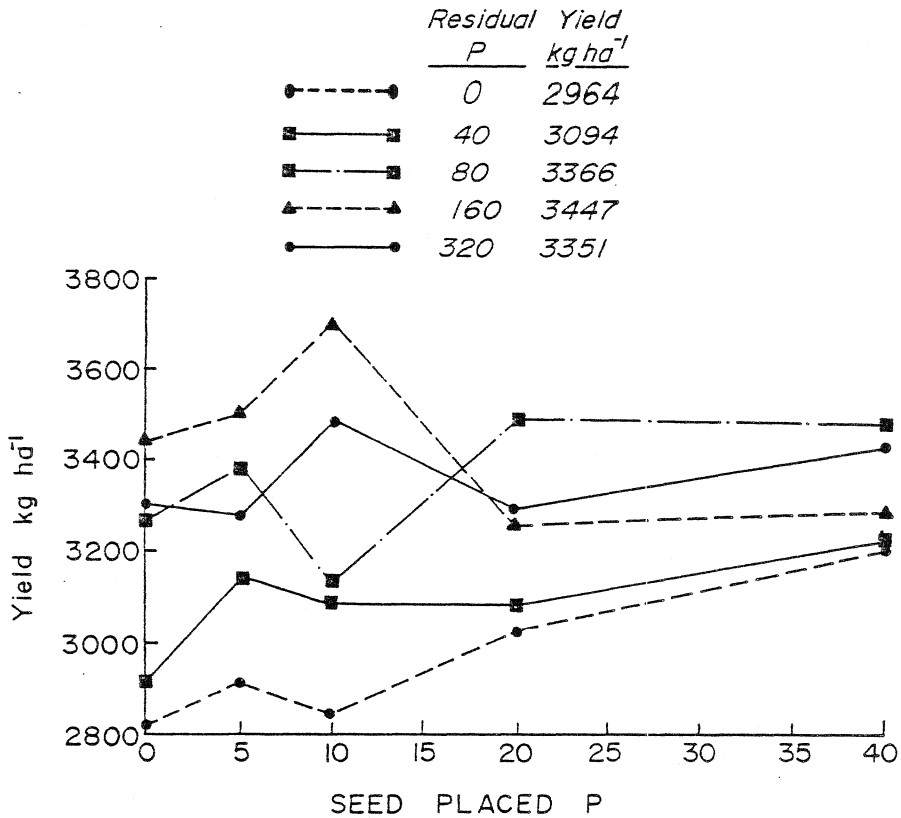

Figure 3. Effect of Broadcast P and seed placed P on Wheat yields.

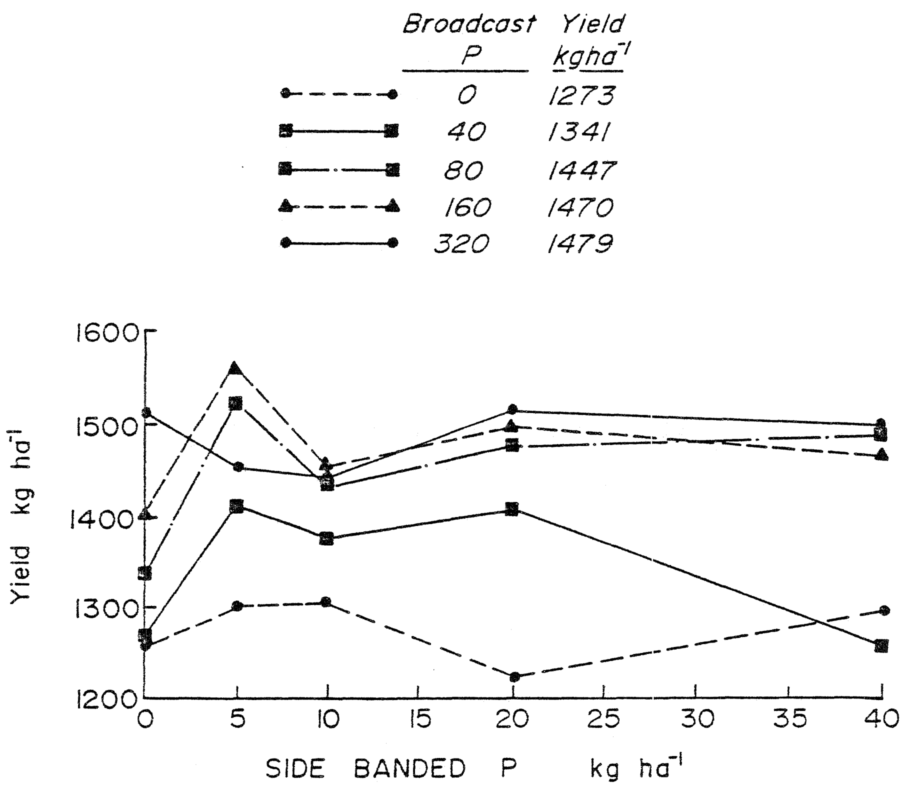

Figure 4. Effect of Broadcast P and sidebanded P on Flax yields.

The uptake of P by wheat with time from seeding at different seed-placed and broadcast P treatments is shown in Fig. 5. Comparison of Fig. 5a, 5b and 5c show the effect of seed-placed P treatments on P uptake on the plots that had received broadcast applications of 320, 80 and 0 kg P ha^{-1}. It can be seen that on the 320 and 80 broadcast P treatments the uptake of P was much more rapid and reached a maximum earlier in the season than on the 0 P broadcast treatments. Seed-placed P did not overcome this initial effect although it has been previously noted that the yields were not significantly different. This effect is clearly shown in Fig. 5d which portrays the uptake of phosphorus on the various broadcast P treatments.

Summary of the flax results presents the uptake of P with time from seeding at different side-banded and broadcast P treatments (Fig. 6). Fig. 6a shows the effect of side-banding P on P uptake on the plots that had received 320 kg P ha^{-1} and it can be seen that at all side-banded treatments the phosphorus uptake was higher on this plot than on the 80 kg P ha^{-1} broadcast treatment and much higher again than the uptake from the side-banded treatment at 0 broadcast P. In comparison to the P results however for wheat, the uptake of phosphorus by flax proceeded over the whole season and did not reach maximum uptake at approximately six weeks from seeding as had been noted with wheat (wheat at this growth stage was at the flag leaf stage), but increased at each sampling date until harvest.

Laboratory Results

At the time of presentation of this paper, some initial results on P sorption and desorption were available. These results enabled comparison to be made between seed-placed recommendations and broadcast recommendations. Broadcast recommendations were based on the Fox and co-workers approach that the final concentration of P in solution should be 0.1, 0.2 or 0.3 μg P g^{-1}. The value used would depend on the crop to be grown and its rooting distribution and P uptake pattern. The second approach simply fertilized the soil until the $NaHCO_3$ extractable P level reached a level where response to added P was not common and values of 15, 20 and 25 μg P g^{-1} were used (corresponding to soil test values of 30, 40 and 50 $NaHCO_3$ extractable P in lbs $acre^{-1}$ or kg ha^{-1}).

The results in Table 1 show initial results from low and medium testing soils in various soil zones and much more information is needed from field plot data to make a full interpretation. These results would suggest that anywhere from 4 to 8 times the seed-placed recommendations (Sask. Soil Testing Lab) may be required. However, there is no general agreement between the methods to predict broadcast P requirements. This disagreement is illustrated in Figures 7 and 8 which represent the greatest difference observed between two soils.

A second initial analysis of the results looked at the effect of texture on the comparison between broadcast recommendations and seed-placed values (Table 2), but no significant correlation with texture could be observed. Ongoing research is examining reasons for the discrepancy.

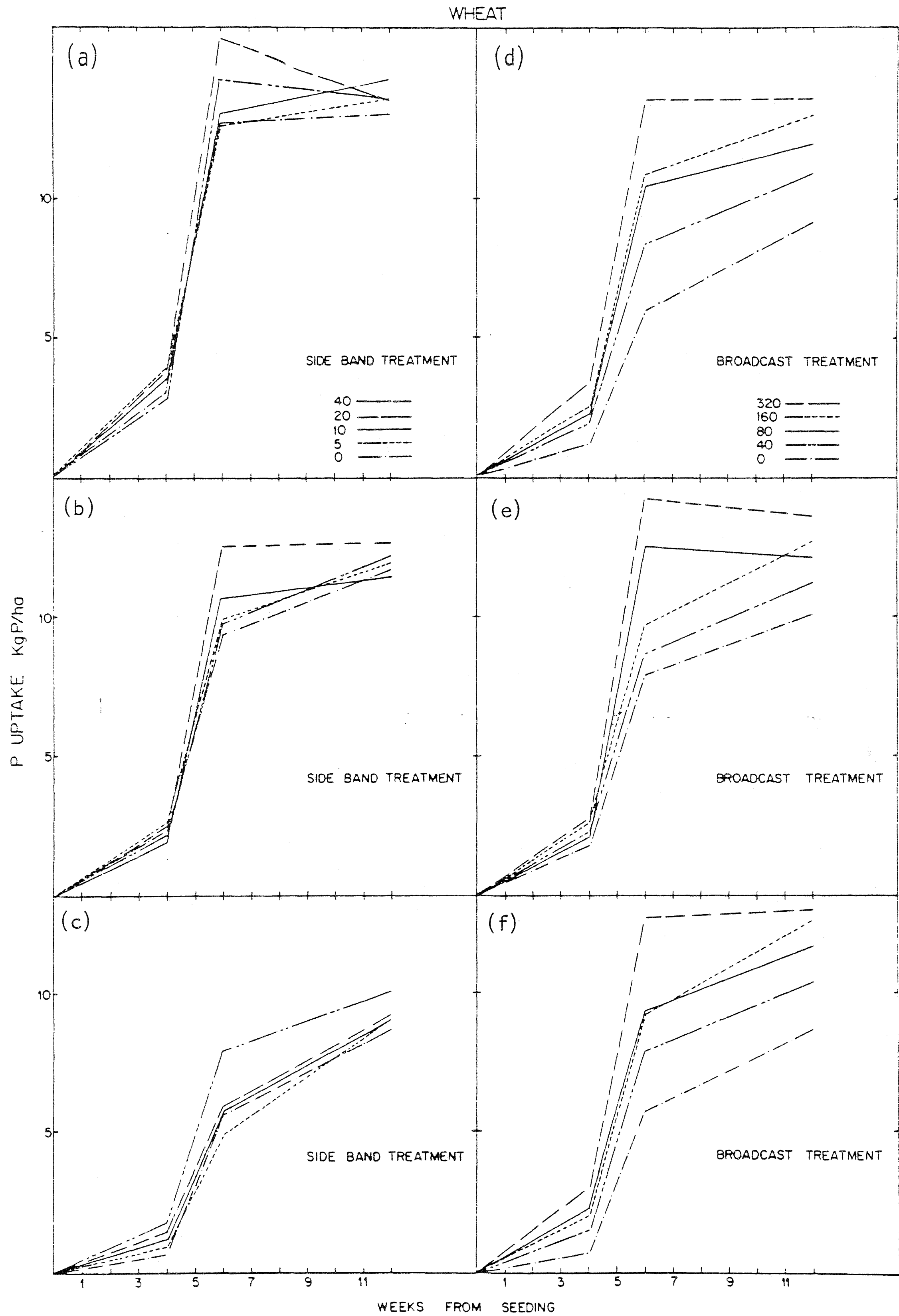

Fig. 5. The uptake of P by wheat with time from seeding at different seed-placed and broadcast P treatments. Fig. 5(a,b and c) show the effect of seed-placed P treatments on P uptake on the plots that had received 320, 8 and 0 kg P ha^{-1}, respectively. Fig. 5(d) show the effect of the broadcast P treatments on P uptake averaged over all seed-placed treatments, 5(e) on the 40 kg P ha^{-1} seed-placed P treatment and Fig. 5(f) at 0 kg ha^{-1} seed-placed P.

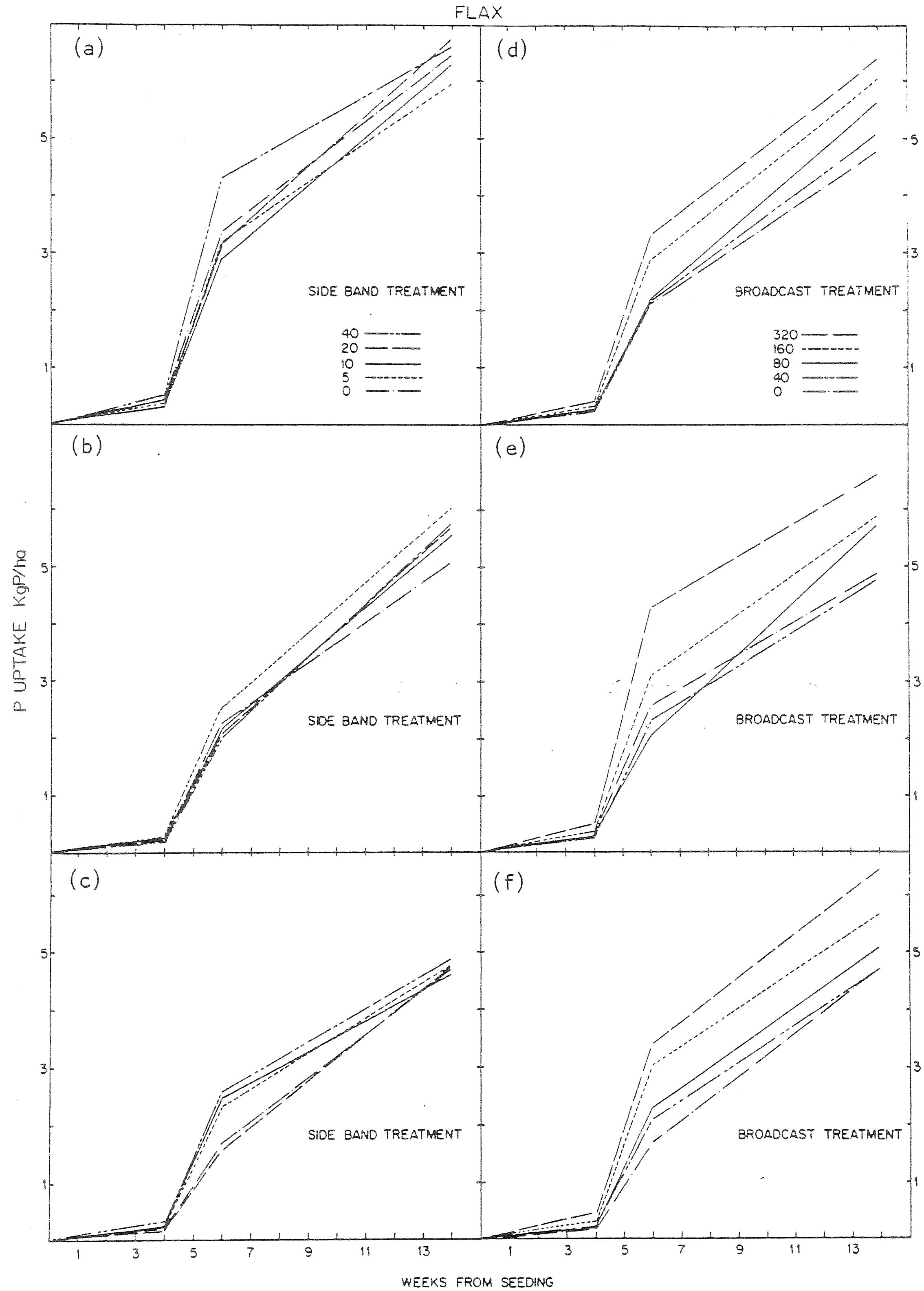

Fig. 6. The uptake of P by flax with time from seeding at different side-banded and broadcast P treatments. Fig. 6 (a,b and c) show the effect of side-banded P on P uptake on the plots that had received 320, 80 and 0 kg P ha^{-1}, respectively. Fig. 6(d) show the effect of broadcast P on the P uptake averaged over all side-banded treatments, Fig. 6(e) on the 40 kg ha^{-1} side-banded treatments and Fig. 6(f) at 0 kg ha^{-1} side-banded P.

Table 1. Comparison of broadcast recommendations obtained by two P sorption approaches.

Soil zone	Soil test value $NaHCO_3$-extractable P	Seed-placed recommendation	Broadcast recommendations: From P sorption to provide P concentration in solution of 0.1	0.2	0.3	From $NaHCO_3$-extraction to give values of 15	20	25
	———	———	———	$\mu g\ P\ g^{-1}$ soil	———	———	———	———
			Soils with low soil test values					
Brown	4	6.6	24	27	29	22	30	38
Dark Brown	3	8.7	33	48	61	25	35	44
Thin Black	4	8.7	17	22	34	28	40	52
Gray Black	4	8.7	16	40	50	27	38	48
			Soils with medium soil test values					
Brown	9.5	6.6	22	38	49	21	31	42
Thin Black	9.0	4.4	30	43	52	17	30	42
Gray Black	9.5	6.6	21	37	47	23	38	52
Gray Wait-ville	9.5	6.6	24	35	41	16	27	37

Table 2. The effect of texture on the comparison of broadcast recommendations obtained by two P sorption approaches.

Texture % clay	Soil test value $NaHCO_3$-extractable P	Seed-placed recommendation	Broadcast recommendations: P sorption 0.1	0.2	0.3	$NaHCO_3$-extraction 15	20	25
	———	———	———	$\mu g\ P\ g^{-1}$ soil	———	———	———	———
			Brown Soil Zone					
<15	3	6.6	24	27	29	22	30	38
<20	4	6.6	26	36	42	25	33	40
<27	4	6.6	22	38	52	24	34	44
<35	3	5.5	13	31	42	22	31	41
>40	3	6.6	28	43	55	28	43	55
			Gray Black Soil Zone					
<15	5	8	30	49	59	30	43	55
<20	4	8	20	31	39	26	36	49
<27	5	8	37	51	64	24	36	48
>40	6	8	30	50	65	21	32	42

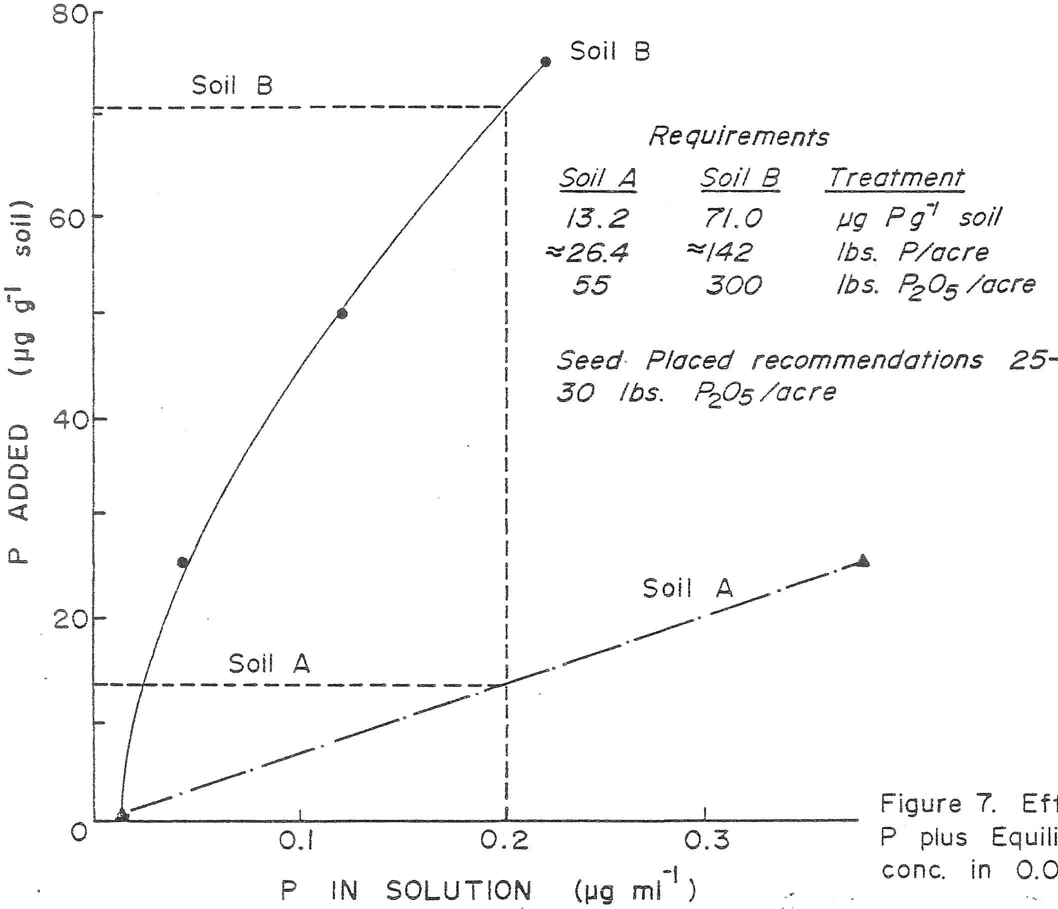

Figure 7. Effect of added P plus Equilibration on P conc. in 0.01M $CaCl_2$ solution.

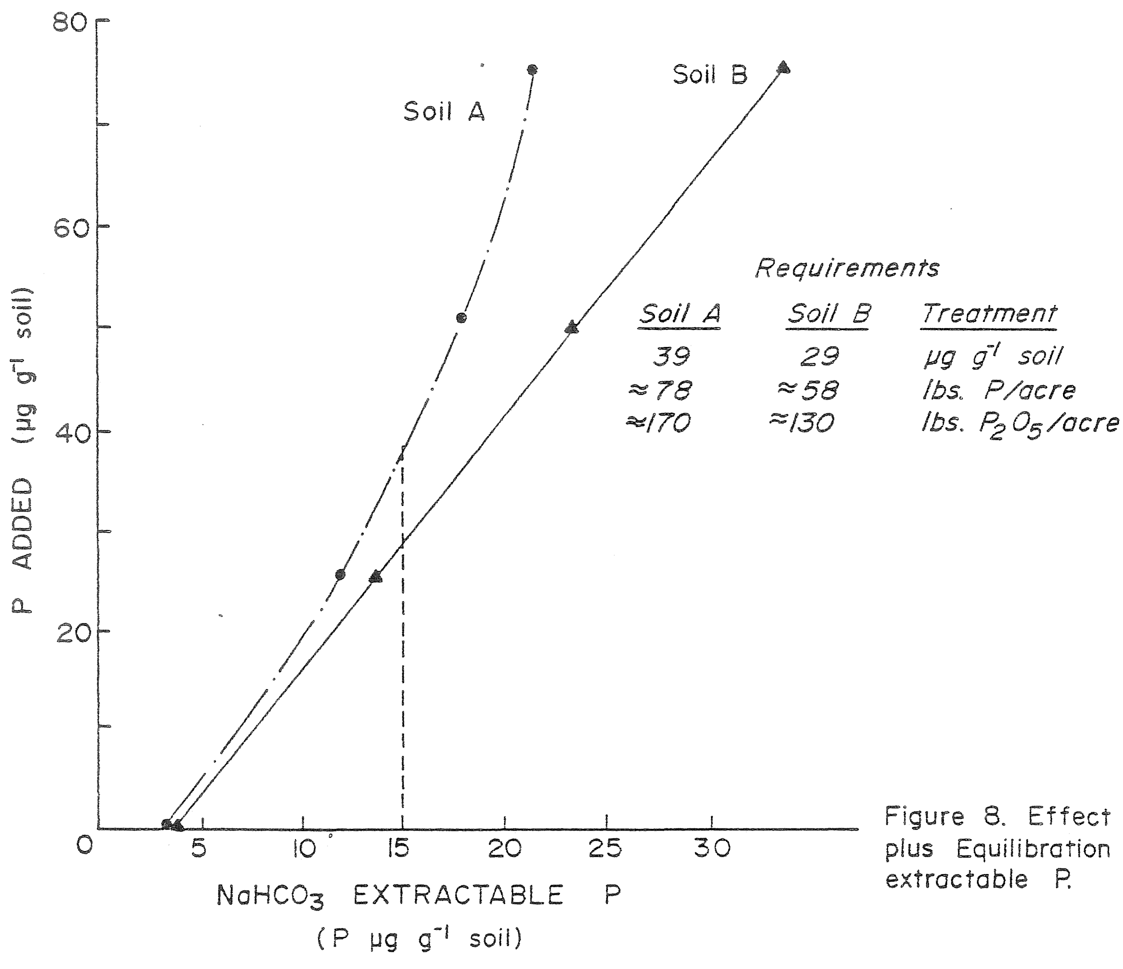

Figure 8. Effect of added P plus Equilibration on $NaHCO_3$ extractable P.

Correlation Between Broadcast and Seed-placed Recommendations from Laboratory Methods and the Results Obtained at the Kernen Farm in 1979

P sorption data on the soil from the Kernen Farm plots predicted that additions of 60 kg P ha^{-1} was required to give a soil solution concentration of 0.1 $\mu g\ g^{-1}$ and approximately 100 kg P ha^{-1} to give a soil solution concentration of 0.2 μg P. The yield data from this preliminary year would suggest broadcast treatments of 80 kg P ha^{-1} give optimum yields. Soil test P requirements were predicted from the $NaHCO_3$-extractable P values to be approximately 20 kg P ha^{-1} seed-placed P for wheat.

CONCLUSION

Preliminary laboratory and field data suggest that optimum broadcast P treatments for wheat will be 4 to 8 times the seed-placed recommendations of the Sask. Soil Testing Lab. Ongoing studies and attempting to refine these recommendations.

REFERENCES

Bailey, L.D., E.D. Spratt, D.W.L. Read, F.G. Warder and W.S. Ferguson. 1977. Residual effects of phosphorus fertilizer II for wheat and flax grown on Chernozemic soils in Manitoba. Can. J. Soil Sci. 57: 263-270.

Bowman, R.A., S.R. Olsen and F.S. Watanabe. 1978. Greenhouse evaluation of residual phosphorus by four phosphorus methods in neutral and calcareous soils. Soil Sci. Soc. Am. J. 42: 451-454.

Fox, R.L. and E.J. Kamprath. 1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soils. Soil Sci. Soc. Am. Proc. 34: 902-906.

Jones, J.P. and R.L. Fox. 1977. Phosphate sorption curves as a soil testing technique: a simplified approach. Commun. Soil Sci. Pl. Anal. 8: 209-219.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939.

Peasleas, D.E. and R.L. Fox. 1978. Phosphate fertilizer requirements as estimated by phosphate sorption. Commun. Soil Sci. Pl. Anal. 9: 975-993.

Read, D.W.L., E.D. Spratt, L.D. Bailey and F.G. Warder. 1977. Residual effect on phosphorus fertilizer. I. For wheat grown on four Chernozemic soil types in Saskatchewan and Manitoba. Can. J. Soil Sci. 57: 255-262.

Read, D.W.L., E.D. Spratt, L.D. Bailey, F.G. Warder and W.S. Ferguson. 1973. Residual value of phosphatic fertilizer in Chernozemic soils. Can. J. Soil Sci. 53: 389-398.

Sadler, J.M. and J.W.B. Stewart. 1974. Residual fertilizer phosphorus in Western Canadian soils: a review. Saskatchewan Institute of Pedology Pub. No. 136, Saskatoon.

Sadler, J.M. and J.W.B. Stewart. 1975. Changes with time in form and availability of residual fertilizer phosphorus in a catenary sequence of Chernozemic soils. Can. J. Soil Sci. 55: 149-159.

Sadler, J.M. and J.W.B. Stewart. 1977. Labile residual fertilizer phosphorus in Chernozemic soils. I. Solubility and quantity/intensity studies. Can. J. Soil Sci. 57: 65-73.

Thomas, R.L., R.W. Sheard and J.R. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus and potassium analysis of plant material using a single digestion. Agron. J. 59: 240-243.