P forms and levels in an acid Dark Brown Loam Soil after long-term fertilizer applications for wheat

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A three year fallow-wheat-wheat rotation study was initiated in 1912 on a Dark Brown Chernozemic Loam soil at the Experimental Farm, Scott, Saskatchewan. The soil is acidic, with a pH ($CaCl_2$) in the 0-15 cm depth of about 5.3, and an organic matter content of 4%. The rotation consists of three adjacent blocks, or plots, unreplicated, to which the cropping sequence has been applied.

During the period 1912 to 1930, no fertilizers were applied to the plots. In 1930, the plots were divided, and subsequently one-half of each plot received ammonium phosphate fertilizer for wheat on fallow, and the other half remains unfertilized. From 1930 to 1978, the fertilizer rate was 17 kg/ha P_2O_5. In 1978, the rate was increased to 28 kg/ha, and this rate has continued until the present time. During the course of the rotation up to 1987, the fertilized half of each plot has received a total of 19 applications of P fertilizer. The rotation plot arrangement is shown in Figure 1.

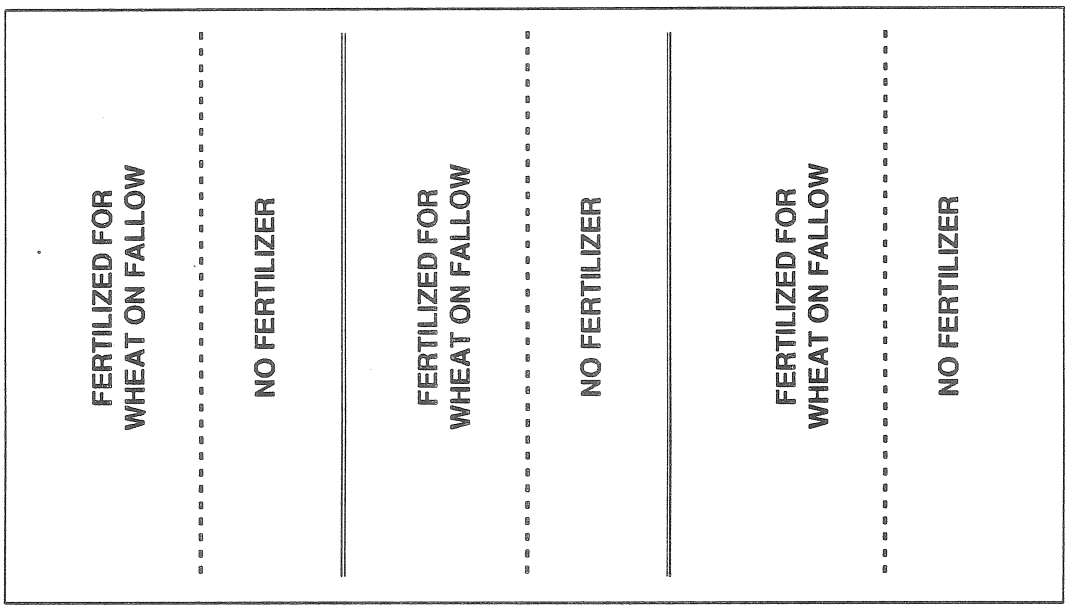

Figure 1. Fallow-wheat-wheat-rotation (Rotation C) at Scott, Saskatchewan.

Occasional soil sampling for available nutrient determination was carried out during the latter half of the rotation study period. Increased levels of $NaHCO_2$-extractable P have been observed in the fertilized portions of the plots. In the spring of 1974 the fallow plot was sampled just prior to seeding of wheat. The $NaHCO_3$-P levels in the fertilized and unfertilized portions of the plot are shown in Table 1. Application of P fertilizer did not increase wheat yields on this plot in 1974. It is evident that residual available P levels have increased substantially in the fertilized portions of these rotations plots, even though the rates of P fertilizer application have been relatively small.

Table 1. Available P levels in the fallow plot of the fallow-wheat-wheat rotation just prior to seeding in 1974.

Depth cm	0.5 N $NaHCO_3$-P (kg/ha) Fert.	Check
0-15	36	20
15-30	16	9

Other studies of crop rotations on similar, though non-acidic soils in Western Canada (O'Halloran, *et al.*, 1987; Stewart, *et al.*, 1989; Wager *et al.*, 1986) have shown that long-term applications of relatively low rates of P fertilizers, or large one-time incorporation of P fertilizer can significantly increase the levels of residual labile, plant available P levels in the soil.

This study was undertaken to determine the effect of the long-term applications of P fertilizers with the seed of wheat on fallow in this three-year rotation on the changes in P status and the forms of P and their relative proportions in Scott loam.

Materials and Methods

In 1987, soil samples were taken from the fallow-wheat-wheat rotation at Scott for fractionation analysis. The fertilized and unfertilized portions of each of the three plots were sampled separately. Samples were taken from five locations on each of the fertilized and unfertilized portions of the three plots at depths of 0-7.5, 7.5-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm. The five subsamples were combined for a composite at each depth. The samples were thoroughly air dried and mixed, and finely ground for chemical analysis. The samples were analyzed by the P fractionation procedure of Hedley *et al.* (1982).

Results and Discussion

For presentation, the data have been averaged over the three plots of the rotation.

Inorganic P (Pi) fraction levels are shown in Table 2. The application of P fertilizer for wheat over the years of the rotation has r esulted in a substantial increase in Resin-Pi and

Table 2. Inorganic P fraction levels (μg/g) in fertilized and unfertilized sub-plots of the fallow-wheat-wheat rotation on Scott loam.

Depth	Resin-Pi		Bicarb-Pi		NaOH-Pi		HCl-Pi	
cm	Fert.	Check	Fert.	Check	Fert.	Check	Fert.	Check
0-7.5	29.5	19.8	20.9	14.1	50.1	42.1	107.9	105.1
7.5-15	20.2	11.5	14.6	9.7	39.8	30.1	98.1	92.6
15-30	7.3	4.7	5.7	3.9	21.3	16.2	101.7	93.8
30-45	5.8	4.3	4.2	3.0	13.8	10.6	133.4	127.2
45-60	4.1	3.0	2.8	2.6	6.2	4.7	179.6	212.2
60-75	3.2	1.7	1.8	1.8	4.0	2.7	273.5	310.1
75-90	2.1	1.2	1.3	1.2	3.2	2.2	277.3	339.8
LSD (.05)	*		**		N.S.		N.S.	

Bicarb-Pi, the relatively labile, plant-available forms of P. The largest increases occurred in the 0-15 cm depth, but it appears that Resin-Pi has increased in smaller amounts to the depth of sampling, and Bicarb-Pi to 45 cm depth. There was also a considerable increase in NaOH-Pi in the fertilized portion of the plots, although not statistically significant when analyzed using plots of the rotation as replicates. The increases in inorganic P forms below 15 cm in the fertilized plots could be an indication of movement downward by leaching or root action (biocycling). Richards and Belanger (1989) also found evidence of some movement of P to 60 cm depth in an acidic loam cropped to timothy, and suggested leaching to be the probable cause. The total

increases in Pi in the Resin and Bicarb fractions in the fertilized soil would raise the "available" P to sufficient levels. Available P determinations for fertilizer recommendations are usually done on soil samples taken to 15 cm depth in Western Canada. P fertilizer applications increased the Resin-Pi levels by 59% and Bicarb-Pi levels by 49% in the 0-15 cm soil in these rotation plots.

There is no increase in the HCl-Pi fraction from fertilizer use. At the lower depths in the fertilized soil there appears to be a decrease in HCl-Pi. It is rather doubtful that increased root activity at depth in fertilized plots would decrease the levels of this P form. The organic fractions (Bicarb-Po and NaOH-Po) are slightly lower in the 0-15 cm depth and slightly higher below this depth in the fertilized soil (Table 3).

Table 3. Organic P fraction levels (µg/g) in fertilized and unfertilized sub-plots of the fallow-wheat-wheat rotation on Scott loam.

Depth cm	Bicarb-Po		NaOH-Po	
	Fert.	Check	Fert.	Check
0-7.5	57.9	66.8	135.2	152.0
7.5-15	41.7	56.7	131.4	137.5
15-30	24.2	18.9	88.9	81.2
30.45	9.4	7.5	44.7	38.4
45-60	3.5	3.2	16.3	13.9
60-75	1.9	0.9	6.9	4.1
75-90	1.0	0.9	3.6	1.9
LSD (0.05) Fert.		N.S.		N.S.

Residual and total P levels are shown in Table 4. There was no apparent influence of fertilizer on residual-P levels, and total P levels do not reflect any consistent change due to fertilizer application.

Table 4. Residual and total P (µg/g) in fertilized and unfertilized sub-plots of the fallow-wheat-wheat rotation on Scott loam.

Depth cm	Residual P		Total P	
	Fert.	Check	Fert.	Check
0-7.5	221	209	622	609
7.5-15	230	224	576	563
15-30	225	223	474	442
30.45	185	176	396	367
45-60	143	147	396	386
60-75	126	118	418	440
75-90	113	109	402	456
LSD (0.05) Fert.	N.S.		N.S.	

The effects of P fertilizer application at fairly low rates over a period of 57 years on the Scott loam soil, on P forms and relative distribution in surface soil, are similar to results reported by O'Halloran *et al.* (1987) and Stewart *et al.* (1989) on other chernozemic soils. A substantial amount of the residual fertilizer P apparently moved into relatively labile forms in this soil.

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