LONG-TERM PHOSPHORUS STUDIES IN WESTERN CANADA

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ABSTRACT

An experiment that was established in 1982 to assess placement of P fertilizer on the yield of continuous barley was terminated in 2004, after annual application of P (30 kg ha^{-1}) was discontinued in all but one treatment in 2001. Total removal of P during the first 20 years of the experiment (615 kg P_2O_5 ha^{-1}) was virtually equal to total P application (600 kg P_2O_5 ha^{-1}); however, when removal by the control that was fertilized with N only was subtracted from the total removal, a residual P component of 474 kg P_2O_5 ha^{-1} was obtained as a result. In spite of this, discontinuing P fertilization after 20 years of annual application of 30 kg P_2O_5 ha^{-1} resulted in significant reduction in barley grain yield that was greater in the treatments that P was seedrow placed (21%) than either banded (12%) or 1/3 seedrow placed and 2/3 banded (15%).

INTRODUCTION

Application of phosphate fertilizer fulfills a dual role, i.e., it enhances crop yields and contributes to maintaining soil P levels in the soil. The recent increase in P fertilizer prices have resulted in farmers reconsidering their fertilization practices in order to maximize their profits and to ascertain whether there is a need to consider reducing or completely eliminating phosphorus (P) application.

Soil testing has been a pillar in deriving fertilizer recommendations. However, one has to consider that existing soil testing databases were developed based on the Law of Minimum and for that only soils that were not previously fertilized were used. Nowadays it is virtually impossible to find such soils and the behavior of P in a soil is quite different once the soil has been fertilized for a prolonged period of time. In a 1993 review of the macronutrient status on the P soil testing data from the three Prairie Provinces were compiled by the provincial laboratories for the period between 1965 and 1990 (Rennie et al. 1993). One common feature in these data was that average P soil test levels did not change much over that period (Figure 1).

Evaluation of residual effects from phosphorus (P) fertilization has been the subject of numerous studies in western Canada, which were summarized by Roberts and Stewart (1987). Residual P is expected to build in soil when removal of P by crops is lower than the P applied in the form of fertilizer or other sources, e.g., manure. However, numerous studies have demonstrated that recovery of P by crops in the year of application is very low. Independently of technique, fertilizer P recovery remains poor and can range up to 30% depending on soils, crop and management factors, however, most commonly is reported to be <10% on soils that were supplied with P (Withers et al., 2005). This means that knowingly or unknowingly annual use of P fertilizer contains a maintenance component. Also, prolonged P fertilizer use will result in well-supplied labile P pool (a pool containing all forms of potentially available P), so much so that agroeconomic benefits are derived with the first 15 to 20 lb P_2O_5 applied. However, does this warrant eliminating P fertilization altogether?

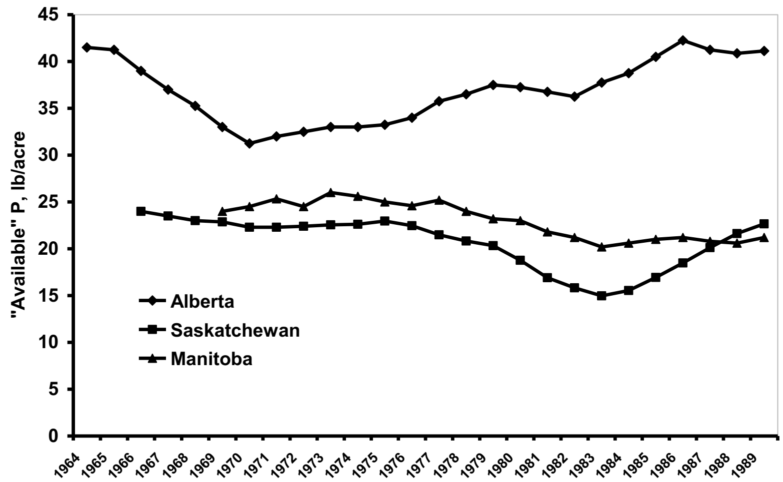

Figure 1. Five-year running average of soil testing data from the three Prairie Provinces over the period of 1965 to 1990. Differences in levels between provinces reflect differences in methodology amongst laboratories (Alberta: Miller and Axley 1956; Saskatchewan and Manitoba: Olsen et al. 1954).

The objective of this study was to assess residual effects from twenty annual applications of P to a Black Chernozemic soil in Alberta and the impact on succeeding crops that received no fertilizer P.

MATERIALS AND METHODS

A trial was established in the fall of 1981 at the University of Alberta Ellerslie experimental farm to assess methods of phosphorus (P) placement. A number of treatments were initiated in the fall of 1981 and spring of 1982 and were repeated annually until the spring of 2001. These treatments were arranged in a randomized complete block design (RCBD) with six replications and included:

(i) an unfertilized control,
(ii) a nitrogen (N) only treatment that received 80 kg banded N ha^{-1},
(iii) a treatment that received 80 kg banded N $ha^{-1}$and 30 kg seedrow applied P_2O_5 ha^{-1},
(iv) a treatment that received 80 kg banded N $ha^{-1}$and 30 kg seedrow applied P_2O_5 ha^{-1},
(v) a treatment in which both 80 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} were banded (dual banding),
(vi) a treatment that received 80 kg banded N $ha^{-1}$and 30 kg P_2O_5 ha^{-1} split 1/3 in the seedrow and 2/3 in the band.

Banded N and P (at a depth of 12.5 cm) and broadcast and incorporated N fertilizer treatments were applied in the fall of the previous year; seedrow placed P was applied at seeding time. Phosphorus in all treatments was applied as triple super phosphate (0-45-0), whereas N was in urea (46-0-0) form. Fertilization in all treatments but one was discontinued starting in the fall of 2001 and the experiment was terminated after the 2004 growing season; all treatments other than the control still received 80 kg banded N ha^{-1} according to the original schedule.

Barley was grown in all but one year (1995 – canola). Every spring, both parts were tilled to a depth of two (2) inches and then sown to a depth of approximately 2.5 cm using a six-row double disk seeder with 17.5-cm spacing. Seeding rates varied from 263-354 seeds m^{-2} depending on thousand kernel weights of the seed lots used and averaged 314 seeds m^{-2}. Crops were harvested at early maturity using a Wintersteiger Nurserymaster Elite experimental plot combine. The seed weight per plot was measured immediately following harvest and again after being dried by forced air at 60 °C to constant weight and was assayed for total P. The seed yield per plot was calculated with moisture content corrected to 13.5 and 10 % for cereals and canola, respectively. Grain yield and P removal data were subject to ANOVA for a randomized complete block design using SYSTAT 8.0 (SPSS 1998) and effects were separated via least significant differences ($LSD_{0.05}$).

Composite soil samples from 0-15 cm depth of the control treatments were collected on an annual basis either in the fall after harvest and/or spring prior to sowing each year. Soil samples were analyzed for "available" P using the bicarbonate (Olsen et al. 1954) method.

Detailed sampling of all plots of Part B and treatment (vi) of Part A (the one receiving 30 kg P_2O_5 ha^{-1} in 2002-2004) was carried out in the fall of 2005 according to the protocol depicted in Fig. 2. Samples were taken from 0-4 inch (10.16-cm) and 4-8 (10.16 to 20.32-cm) depth along a 15-foot (4.57-m) transect crossing two rows in each plot. The transect was drawn at an angle, so that when projected on a line vertical to the direction of the seeding rows, the distance between sampling points was 1 inch (2.54-cm). Fourteen such sampling points were duplicated in each plot and the two corresponding sub-samples for each point were composited into one, thus resulting in 14 samples per plot per sampling depth. All sub-samples were analyzed for "available" P using the bicarbonate method (Olsen et al. 1954).

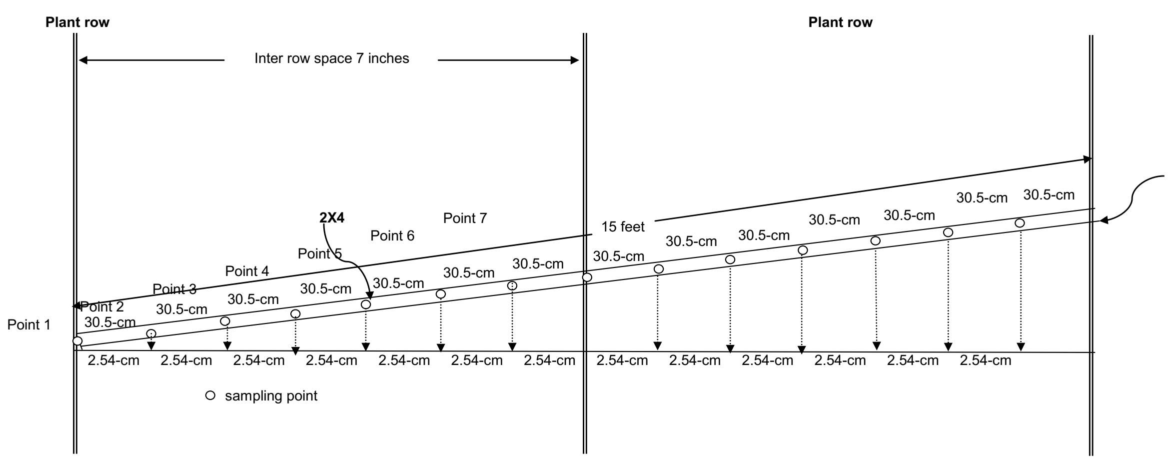

Figure 2. Soil sampling protocol for detailed site sampling in the fall of 2005.

RESULTS AND DISCUSSION

Total removal of P during the first 20 years of the experiment (615 kg P_2O_5 ha^{-1}) was virtually equal to total P application (600 kg P_2O_5 ha^{-1}); however, when the P_2O_5 removed in the control treatments (412 in the unfertilized control and 489 when only N was applied) was accounted for in the removal a large "residual" P_2O_5 pool was calculated (474 kg ha^{-1}). As a result an 'apparent P recovery (FPUE) of between 21.2 and 31.4% for the 20-year period from

1982 to 2001 was obtained (Figure 7). The lowest recovery rate was obtained when N was broadcast and incorporated and P was seedrow placed. This reflects the lower fertilizer N use efficiency (FNUE), as it has been already demonstrated that N fertilization results in increased P uptake and, consequently, higher P recovery in crops (Halvorson and Black 1985).

In spite of this, interruption of P fertilization led to significant yield decreases with average losses over a three year period (2002-2004) being greater (21%) when 30 kg P ha^{-1} was being seed-placed for the first 20 years and lesser with 1/3 seed-placed and 2/3 banded (15%) and banded (12%) (Fig. 4). “Available” P levels extracted with bicarbonate (Olsen et al., 1954) virtually showed no differences between “available” P levels on the row and in the inter row spaces (Table 1) with the exception of the 10-20 cm depth of N+P banded treatment, in which bicarbonate-extractable P levels on the row were 2 mg kg^{-1} greater than in the inter row spaces, reflecting accumulation of fertilizer P at that depth. Lack of differences in the remaining treatments would appear logical, since the surface soil layer above the depth of banding was being disturbed and redistributed every year prior to seeding. Further, there was a difference of up to 4 mg kg^{-1} on the row and 3 mg kg^{-1} in the inter row spaces of the 0-10 cm layer between the P fertilized treatments and the unfertilized controls (Table 1).

Table 1. Basic statistics for detailed sampling of two rows of every plot of Part B in 2005.

	Depth (cm)	Min.	Max.	Mean	On row A (kg P ha^{-1})	Between rows B	Delta A-B
No Fertilizer	0-10	10.2	12.0	11.2	10.8	11.2	-0.5
	10-20	6.0	8.2	7.2	6.9	7.3	-0.4
N Banded, no P	0-10	10.4	12.7	11.4	11.1	11.5	-0.4
	10-20	5.6	8.2	7.0	6.1	7.1	-1.0
N Banded, P seed-placed	0-10	11.6	14.0	12.8	13.0	12.8	0.2
	10-20	6.9	9.1	7.6	7.2	7.7	-0.5
N B&I, P seed-placed	0-10	12.4	14.7	13.5	13.8	13.5	0.3
	10-20	6.0	8.0	6.9	6.6	6.9	-0.4
N+P Banded	0-10	12.9	16.2	14.3	15.3	14.1	1.2
	10-20	7.6	12.2	9.3	11.2	9.0	2.2
N+2/3 P Banded+1/3 P Seed-placed	0-10	11.3	15.1	12.8	12.4	12.8	-0.4
	10-20	6.2	8.0	7.3	7.2	7.3	0.0
Minimum	0-10	10.2	12.0	11.2	10.8	11.2	-0.5
	10-20	5.6	8.0	6.9	6.1	6.9	-1.0
Maximum	0-10	12.9	16.2	14.3	15.3	14.1	1.2
	10-20	7.6	12.2	9.3	11.2	9.0	2.2
Mean	0-10	11.5	14.1	12.7	12.7	12.7	0.1
	10-20	6.4	9.0	7.5	7.5	7.5	0.0

“Available” P levels ion the 0-10 cm layer are considered very low (McKenzie et al., 2003; Saskatchewan Agriculture and Food, 2006) to low (Manitoba Agriculture, Food and Rural Initiatives, 2001). Hence, a greater than 75% probability of response to P based on the above sources should be anticipated. However, differences in the extractable P levels of previously P fertilized treatments were not sufficiently wide to fully explain the observed yield losses.

Mean 'apparent' recovery of previously applied P from 2002-2004, i.e., after P fertilization was discontinued, ranged from 5.5 to 12.2% (Fig. 5); similarly to mean annual values, the lowest recovery rate was obtained when N was broadcast and incorporated and P was seedrow placed and the highest when it was banded. Hence, overall recovery ranged between 26.7 and 43.6% (Fig. 3 and 5).

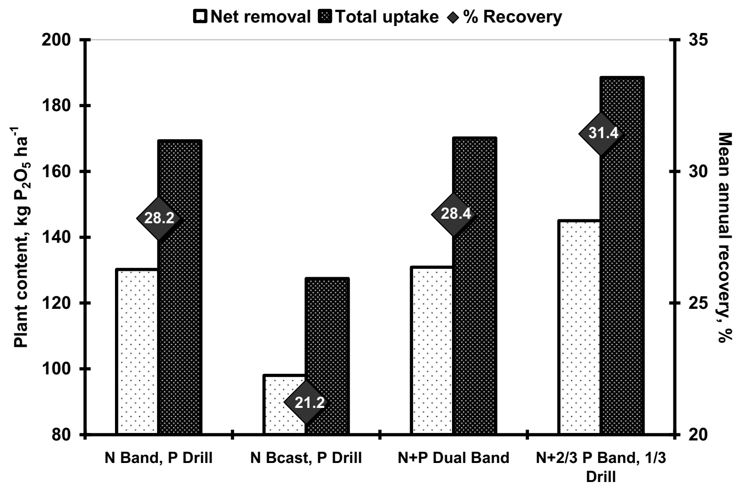

Figure 3. Total net removal, uptake and 'apparent' P recovery after 20 annual applications of 30 kg P_2O_5 ha^{-1} in the form of triple super phosphate (0-45-0).

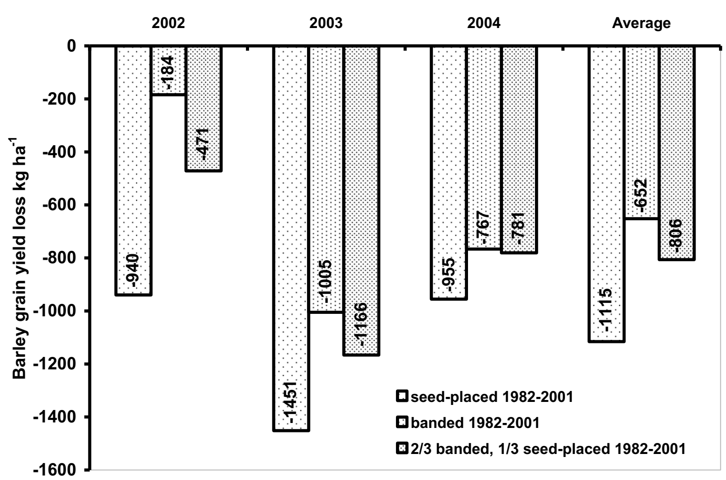

Figure. 4. Barley grain yield loss resulting from discontinuing P application after 20 years of annual application of 30 kg P_2O_5 ha^{-1} as 0-45-0.

CONCLUSION

Residual P from long-term P fertilization was not sufficient to alone provide all the P requirements of barley grown in a monoculture system after P fertilization was discontinued; therefore, a minimum of 15 to 20 kg P_2O_5 ha^{-1} should be applied to meet crop demand.

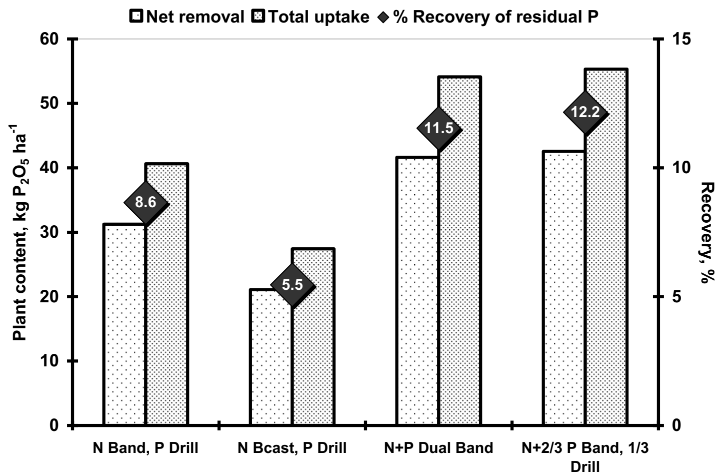

Figure 5. Total net removal, uptake and 'apparent' P recovery of residual P from 20 annual applications of 30 kg P_2O_5 ha^{-1} in the form of triple super phosphate (0-45-0) after three consecutive barley crops grown without P fertilization.

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