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WHEAT, BARLEY AND CANOLA RESPONSES TO PHOSPHATE FERTILIZER IN ALBERTA

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ABSTRACT

The phosphorus supplying power of Alberta soils has been increasing as a result of frequent phosphate fertilizer additions in recent years. However, fertilizer trials conducted across Alberta from 1991to 1993 have demonstrated that wheat, barley and canola still significantly respond to added phosphate fertilizer. Results of 1991 to 1993 field trials show that 84.4% of wheat sites, 92.5% of barley sites and 82% of canola sites responded to added phosphate fertilizer. From an economic standpoint, approximately 70% of all wheat, barley and canola sites responded to 15 kg ha^{-1} of P_2O_5. Initial results of this project indicate that phosphate fertilizer remains an important input component for Alberta farmers.

INTRODUCTION

Most prairie soils are naturally low in crop available phosphorus (P). The benefits of seedplacing phosphate (P_2O_5) fertilizer with wheat sown on fallow soil were first observed in western Canada in 1927 by Mitchell (1932). Use of phosphate fertilizer became common during the 1950's and dramatically increased from the 1960's to 1980's. Today, phosphate fertilizer purchases in the three prairie provinces exceeds 300 million dollars each year.

In the1980's, it was recognized that the P suppling power of soils may have increased as a result of residual P fertilizer. McKenzie et al. (1987) found that less than 50% of irrigated grain and oilseed fields in southern Alberta were responding to added P fertilizer, presumably as a result of residual available P.

To develop an understanding of residual P, long-term crop rotation studies (O'Halloran et al. 1987; McKenzie et al. 1992a, 1992b) have been conducted. O'Halloran (1987) found that phosphate fertilizer additions had increased the labile inorganic phosphorus fractions of a Brown Chernozemic soil while labile organic phosphate fractions were unaffected. McKenzie et al. (1992a; 1992b) examined phosphorus fractions in both Chernozemic and Luvisolic soils. Their results showed that phosphate fertilizer had increased labile and moderately labile inorganic fractions. The combination of nitrogen (N) and P fertilizers positively affected the organic fractions compared to unfertilized treatments. Continuous cropping with both N and P fertilizer inputs had the most positive effects of increasing P availability at sites studied.

The lack of crop response to added phosphate on soils that tested low in plant available phosphorus led to questioning of soil test calibration. Could one test, based on one calibration curve, be used across the wide range of soil and climatic conditions found on the prairies? A growth chamber study, comparing four routine P test methods with wheat and canola uptake of P, was conducted by McKenzie et al. (1989) using 8 soils with different pedogenic, crop rotation and fertilizer use histories. Results confirmed that one calibration curve to predict P fertilizer requirements for a wide range of Alberta soils and crops is virtually impossible. However, when soil types and crops were separated, good

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correlation was obtained between soil test P and plant uptake. They concluded that to improve the prediction of crop response to phosphate fertilizer will require correlation trials using a number of crops and a wide range of soil types from across the prairies. Crop response must be correlated with various P soil test methods and take into account physical and chemical variables such as crop rotation history, P fertilizer history, soil zone, climatic zone, pH, % clay, % organic matter and $CaCO_3$ content.

McKenzie (1989) found that wheat and canola potentially use several mechanisms to take-up soil P. Acid phosphatase, an enzyme released from plant roots to hydrolize organic phosphorus, was evident in the rhizosphere of both wheat and canola, and levels increased over time. Microbial activity was higher in the rhizosphere of wheat than of canola. The acidic canola rhizosphere suppressed microbial activity. Wheat roots had an abundance of root hairs while canola roots were almost devoid of root hairs. In examining P decline in the rhizosphere of wheat and canola, approximately half of the total-P removed came from the plant available fraction, a quarter came from the labile and moderately stable fractions and a quarter came from stable P fractions. Canola frequently took up greater amounts of P from both the available and stable inorganic P fractions than wheat, indicating that canola had a greater ability to extract P from soil. The ability of plant roots to lower the pH within their rhizosphere, through preferential uptake of NH_4^+-N, was the probable mechanism for the decline of stable inorganic P in the rhizosphere. The acidification likely caused dissolution of acid soluble P forms resulting in substantial plant uptake. McKenzie (1989) found the forms and amounts of P removed varied between soils and were a function of soil type, crop, past crop rotation management and past fertilizer use. This partly explains why no one soil test has been found to work well on a wide range of soil types. It is possible that different soil P tests may have to be used for soil areas of western Canada.

A number of soil test P methods have been used to make phosphate fertilizer recommendations to prairie farmers. The Alberta Agricultural Soils and Animal Nutrition Lab has always used the Miller-Axley method (0.03N NH_4F+ 0.03N H_2SO_4)(Miller and Axley 1956). Until 1991, the Saskatchewan and Manitoba Soil Testing Labs used the Olsen method (0.5M $NaHCO_3$)(Olsen et al. 1954). The B.C. Soil Testing Lab began using the Kelowna method (0.25N HOAc + 0.015N NH_4F)(van Lierop 1988) in the late 1980's. In 1989, Norwest Labs began using a modified form of the Kelowna method (0.25N HOAc + 0.015N NH_4F+ 1.0N NH_4OAc) (Ashworth and Mrazek 1989). In 1992, the Saskatchewan Soil Testing Lab (renamed Plains Innovative Lab) began using a modification of the Kelowna method (0.25N HOAc + 0.015N NH_4F+ 0.25N NH_4OAc)(Qian et al. 1991). Also in 1992, the Manitoba Soil Testing Laboratory was taken over by Norwest Labs, resulting in a change in soil test P to their modified Kelowna method.

The result is that a large percentage of phosphate fertilizer recommendations are based on the Kelowna method or modifications of this method. The Kelowna method preformed well when correlated with wheat and canola dry matter yield in a growth chamber study by McKenzie et al. (1989) and in a greenhouse study by Perl et al. (1991). However, extensive field correlation of the Kelowna method or modifications of the Kelowna method had not been been undertaken prior to laboratories switching to newer methods. Laboratories that have switched to using new methods must correlate the new method to older methods. This can potentially pose a problem for making accurate phosphate fertilizer recommendations to farmers. For example, if an old method had an r^2 correlation value of 0.6 to predicted crop response to P and the r^2 correlation value of the old method to a new method was 0.8, the r^2 correlation of the new method to the original field research maybe as low as 0.48. If a new method is not directly correlated to crop response in the field, a reduction in making accurate fertilizer recommendations may result.

The first objective of this study was to evaluate the responsiveness of wheat, barley and canola to phosphate fertilizer on a wide range of soil types across Alberta. The second objective was to correlate seven soil test P methods with crop response to identify the preferred analytical methods for available P over a wide range of Alberta soils, and on a case specific basis by defining and delimiting soil characteristics that could be used to select the most effective tests under a variety of circumstances. Field research will examine the effects of soil test P, increasing rates of seed-placed P fertilizer, spring soil moisture and growing season precipitation on the level of yield increase of each crop at approximately 50 locations throughout Alberta in 1991 to 1993. The purpose of this paper is to examine preliminary trends observed in the study.

MATERIALS AND METHODS

Locations, Experimental Design and Treatments

To meet the first object of establishing P rate trials at a number of locations, the province was divided among four research groups. Plot sites were coordinated by R.H. McKenzie in southern and south-central Alberta; J. Harapiak and N. Flore in central Alberta; D.C. Penney and E. Solberg in central and north-central Alberta; and G. Coy in the Peace River region.

Soils at each site were characterized by soil series and sites were located on the dominant soil type in each area. Sites were on level, uniform land and were not located in corners of fields to avoid previous double fertilizing. Each cooperator was asked to estimate how much P fertilizer had been applied to the site in the past 10 years (or more).

At each location, the best rated crop varieties were used. Plots were replicated six times in a randomized complete block design. Four phosphate treatments for each crop were used including: control, 15, 30 and 45 kg ha^{-1} of P_2O_5 seed-placed except the 45 kg ha^{-1} rate for canola, which was split 30 kg ha^{-1} seed-placed and 15 kg ha^{-1} banded prior to seeding. Nitrogen and any other required fertilizers were banded prior to seeding. In 1991, in the southern sites also had phosphate rates banded prior to seeding.

Soil Sampling and Analysis:

Each block was soil sampled separately before fertilizer application. Samples were taken at 0-15 and 15-30 cm depths and ground to pass a two mm sieve. Analysis conducted by Alberta Agricultural Soils and Animal Nutrition Laboratory (ASANL) in Edmonton included: N, K, S, pH, E.C. and hand texture. Phosphorus soil test methods included: Miller-Axley, Kelowna, Norwest modified Kelowna as well as 0.01 M CaCl with 40 g soil and 50 ml solution to estimate solution P. On a composite soil sample of each site the Hedley P fractionation procedure is used to characterize the various P fractions. Also, micronutrients, % organic matter and mechanical analysis for soil texture is be determined. Samples were also sent to the Plains Innovative Laboratory for the Olsen and modificated Kelowna P analysis.

Site Monitoring:

Soil moisture was determined by gravimetric sampling at time of seeding using 15 cm increments to a depth of 90 cm. Crop growth was recorded weekly. Rainfall was recorded either daily or weekly at each site. Crops were sprayed for weeds as required. Tissue samples were taken from each treatment, for each crop.

Yield, protein and P in grain, and oil content in canola were determined on harvested samples. Soil moisture at the site was also measured to determine soil moisture use efficiency.

RESULTS AND DISCUSSION

A total of 46 rate trials were conducted as originally planned by Alberta Agriculture and Westco researchers in 1991. At all wheat and barley sites, germination and emergence was good to excellent. Canola emergence was good at most sites. The last two weeks of

May and all of June were wetter and cooler than normal at almost all sites. In mid-June, response to P fertilizer was observed at a number of locations in both wheat and barley. At most locations, visual differences were difficult to see by mid-July. Typically, cereal crops take up to 70% of their P requirements in the first 40 days after emergence. Furthermore, soil P is less available to crops under cool wet conditions.

Based on visual observations in June, yield response to added P fertilizer was anticipated at a number of sites. In 1991, from Table 1, 78% of wheat sites, 89% of barley sites and 82% of canola sites responded to added phosphate fertilizer (Table 1).

In southern and south central Alberta, positive yield responses by wheat and barley were more frequent on fallow than on stubble sites (Table 2). Yield responses to phosphate tended to be greater on fallow than stubble for all three crops. In some cases, yield increased in response to phosphate on summerfallow but not on stubble (Figure 1). Treatments included both banded and seed-placed phosphate in 1991 in southern Alberta. Seedplaced phosphate produced higher yields than banded phosphate in thirty-three of fifty-five responsive sites (Table 2). Banded phosphate was superior to seed-placed phosphate at only eight of the 55 sites. This point is illustrated in Figure 2 which compares wheat yield response to seed-placed versus banded phosphate at High River and barley response at Strathmore.

In 1992, germination and emergence was good to excellent at most sites. The exceptions were several sites in the Brown soil zone. In southern Alberta, weather was drier than normal in April, May and early June. However, the last two weeks of June and all of July were wetter and cooler than normal in both southern and central Alberta. The growing season was drier than normal in the Peace River region. In mid-June, response to P fertilizer was observed at a number of locations in both wheat and barley in central Alberta and the Peace River region. At most southern locations visual responses were not obvious. At most locations, visual differences were difficult to see by mid-July. In 1992, from Table 3, 89% of wheat sites, 96% of barley sites and 77% of canola sites responded to added phosphate fertilizer. The high number of responsive sites was similar to 1991.

In 1993, germination and emergence was also good to excellent at most sites. In southern Alberta, precipitation was near normal in April and May, however, was much wetter than normal in July to September. April to mid-June were drier than normal in north-central Alberta but by late June turned cool and wet for the rest of the growing season. Growing season precipitation was variable in the Peace River region. In mid-June, response to P fertilizer was observed at a number of locations in both wheat and barley in central Alberta and the Peace River region. At most southern locations visual response was not obvious. At most locations, visual differences were difficult to see by mid-July. In 1993, from Table 4, 82% of wheat sites, 91% of barley sites and 89% of canola sites responded to added phosphate fertilizer. The high number of responsive sites was similar to previous years.

A summary of the three years of phosphate fertilizer response trials (Table 5) shows that wheat, barley and canola response occurred at 84.4, 92.5 and 82.0 % of the research sites.

At a few selected sites, plant counts were conducted in the 0 and 45 kg ha^{-1} treatments (Table 6). The number of barley plants m^{-2} increased in the high P treatment, versus the control. The number of canola plants m^{-2} decreased in the high P treatment, versus the control. Generally, there was little difference in plant counts between the two P treatments.

Table 1. Summary of responsive, marginally responsive and non-responsive sites by soil zone in 1991.

Crop	Type of Response†	Brown	Dark Brown	Thin Black	Black	Gray Wooded (Central)	Gray Wooded (Peace R.)	Total Sites
Wheat	Response	3	6	5	5	2	4	25
	Mar. Resp.	1	4	3	0	2	2	12
	No response	2	4	2	2	0	1	11
Barley	Response	3	10	7	5	4	5	34
	Mar. Resp.	2	1	3	1	0	2	9
	No response	1	0	1	2	0	0	4
Canola	Response	5	2	3	1	1	5	17
	Mar. Resp.	0	6	1	2	3	2	14
	No response	1	3	1	1	0	1	7

†Response-yield increase greater than 5 bu/ac.
Marginal response-yield increase between 2 and 5 bu/ac.
No response-less than 2 bu/ac yield increase.

Table 2. Wheat, barley and canola response to seed-placed versus banded phosphate fertilizer in southern Alberta in 1991.

	Wheat		Barley		Canola	
	Fallow	Stubble	Fallow	Stubble	Fallow	Stubble
No. of sites	7	17	7	19	7	15
P Responsive sites	6	10	6	13	6	14
Seed-placed > banded	4	6	4	8	5	6
Banded> seed-placed	2	3	1	0	0	2
Seed-placed ~ banded	0	1	1	5	1	7

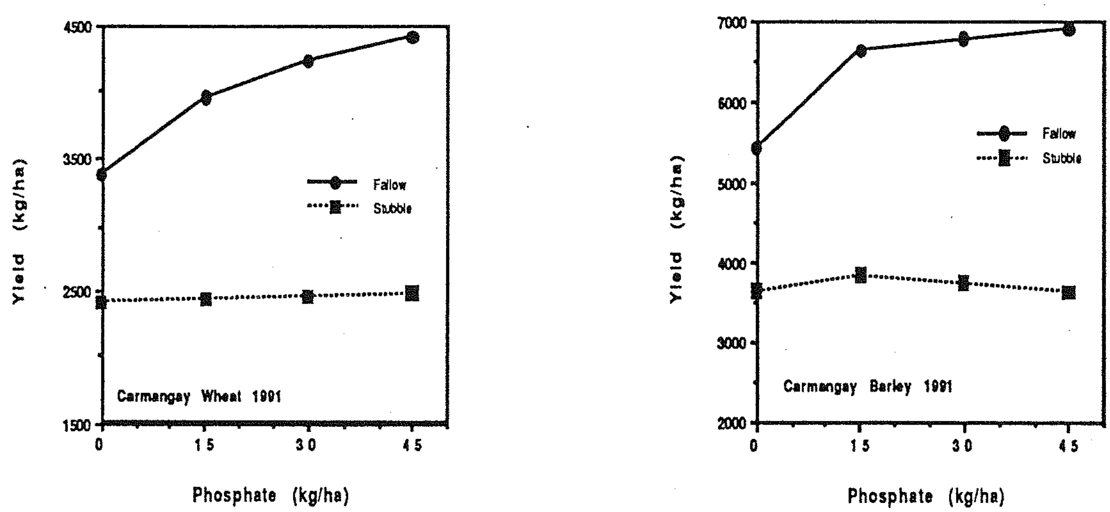
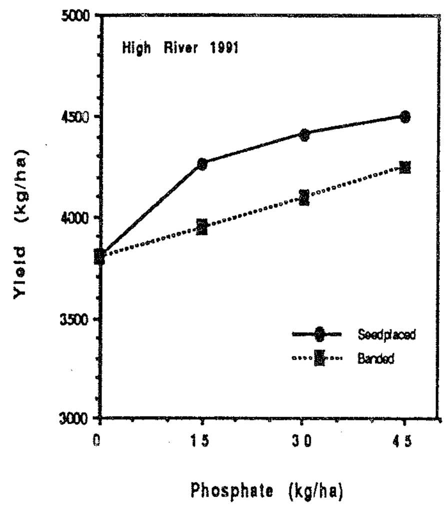


Figure 1. Response of wheat and barley on stubble and summerfallow to seed-placed phosphate at Carmangay in 1991.



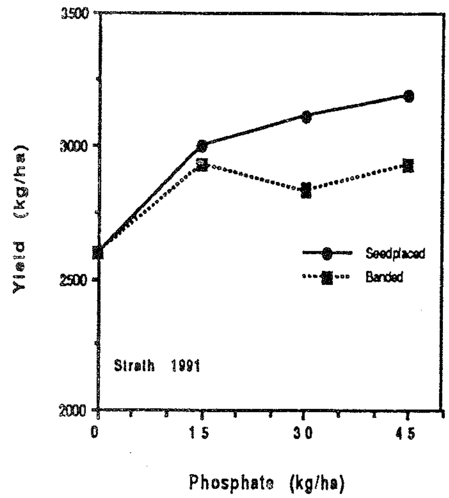


Figure 2. Seed placed versus banded phosphate with wheat at High River and barley at Strathmore in 1991.

Table 3. Summary of responsive, marginally responsive and non-responsive sites by soil zone, in 1992.

Crop	Type of Response†	Brown	Dark Brown	Thin Black	Black	Gray Wooded (Central)	Gray Wooded (Peace R.)	Total Sites
Wheat	Response	2	7	5	6	1	4	25
	Mar. Resp.	2	5	4	3	3	3	20
	No response	2	1	1	1	0	1	6
Barley	Response	3	6	9	12	4	6	40
	Mar. Resp.	3	3	4	0	0	2	12
	No response	0	2	0	0	0	0	2
Canola	Response	0	1	2	6	3	3	15
	Mar. Resp.	4	5	4	2	1	2	18
	No response	2	3	1	2	0	2	10

†Response-yield increase greater than 5 bu/ac.
Marginal response-yield increase between 2 and 5 bu/ac.
No response-less than 2 bu/ac yield increase.

Table 4. Summary of responsive, marginally responsive and non-responsive sites by soil zone in 1993.

Crop	Type of Response†	Brown	Dark Brown	Thin Black	Black	Gray Wooded (Central)	Gray Wooded (Peace R.)	Total Sites
Wheat	Response	3	4	6	7	3	2	25
	Mar. Resp.	0	4	4	3	1	3	15
	No response	1	4	0	3	1	0	9
Barley	Response	3	4	10	11	4	5	37
	Mar. Resp.	0	2	2	0	0	0	4
	No response	1	0	1	1	1	1	5
Canola	Response	0	1	1	5	3	2	12
	Mar. Resp.	4	3	6	3	2	2	20
	No response	0	2	0	2	0	0	4

†Response-yield increase greater than 5 bu/ac.
Marginal response-yield increase between 2 and 5 bu/ac.
No response-less than 2 bu/ac yield increase.

Table 5. Summary of responsive, marginally responsive and non-responsive sites by soil zone for the three years of the project.

Crop	Type of Response†	Brown	Dark Brown	Thin Black	Black	Gray Wooded (Central)	Gray Wooded (Peace R.)	Total Sites	
Wheat	Response	8	17	16	18	6	10	75	
	Mar. Resp.	3	13	11	6	6	8	47	82.4
	No response	5	9	3	6	1	2	26	
Barley	Response	9	20	26	28	12	16	111	
	Mar. Resp.	5	6	9	1	0	4	25	92.5
	No response	2	2	2	3	1	1	11	
Canola	Response	5	4	6	12	7	10	44	
	Mar. Resp.	8	14	11	7	6	6	52	82.0
	No response	3	8	2	5	0	3	21	

†Response-yield increase greater than 5 bu/ac.
Marginal response-yield increase between 2 and 5 bu/ac.
No response-less than 2 bu/ac yield increase.

Table 6. Effect of P treatments on wheat, barley and canola plant populations at selected sites in 1992 and 1993.

Location	P treatment (kg/ha)	Wheat 1992	Wheat 1993	Barley 1992	Barley 1993	Canola 1992	Canola 1993
Athabasca	0	87.3	97.4	68.1	89.9	104.8	107.7
	45	83.1	80.7	72.8	96.9	105.5	66.4
Bear Hills	0	86.6	127.4	102.6	106.8	82.9	259.8
	45	88.3	126.7	109.2	114.6	81.9	120.0
Camrose (1992)	0	105.3	123.0	69.4	102.8	132.8	127.4
Calmar (1993)	45	101.8	123.5	83.4	112.7	117.3	93.2
Hylo	0	72.8	128.9	70.4	118.7	99.9	141.0
	45	74.8	126.2	67.4	123.5	106.3	80.7
Lamont	0	91.3	108.5	78.0	108.7	89.3	266.2
	45	89.3	122.5	76.3	115.1	61.5	159.7
Legal	0	102.8	114.1	82.4	93.5	98.6	222.1
	45	102.8	112.9	89.4	90.5	91.5	163.8
Millet	0	81.7	144.2	84.1	120.5	94.2	233.9
	45	84.1	153.5	85.1	124.5	95.7	169.5
Rimbey	0	68.9	120.5	99.1	108.7	79.5	159.9
	45	75.8	111.7	95.4	114.4	58.1	139.5
Thorsby	0	-	87.3	64.5	77.0	-	87.8
	45	-	96.9	70.8	85.1	-	83.4
Wainwright (1992)	0	80.4	115.4	79.7	107.7	35.7	107.7
Ryley (1993)	45	80.7	118.8	77.7	88.1	46	88.1

Of greatest concern to farmers is whether or not added phosphate fertilizer will economically increase crop yield. Our data suggests significant yield increase may frequently occur with added phosphate fertilizer, however, there are times when it may not be economic.

To evaluate this concern with the 1991 and 1992 data, we assumed that 15, 30 and 45 kg of phosphate had a value of \$3.15, \$6.30 and \$9.45, respectively. Wheat, barley and canola were assumed to have values of \$4.00, \$2.50 and \$5.00 per bushel. It was also assumed that to be economic the added fertilizer must have a 2:1 ratio of return for each dollar spent. Results of these economic analysis (Table 7) suggest that approximately 70% of all wheat, barley and canola sites responded to 15 kg ha^{-1}.

Table 7. The number of economically responsive and non-responsive sites to seed-placed phosphate fertilizer application in 1991 and 1992.

			Phosphate Rate (kg ha-1)					
			15		30		45	
Region	Year	Crop	No Response	Response	No Response	Response	No Response	Response
Southern Alberta	1991	Wheat	8	11	10	9	11	8
		Barley	8	14	11	11	14	8
		Canola	6	13	12	7	11	8
	1992	Wheat	4	19	5	18	10	13
		Barley	8	15	13	10	14	9
		Canola	7	11	15	3	14	4
Central Alberta	1991	Wheat	3	17	6	14	8	12
		Barley	5	16	6	15	5	15
		Canola	2	8	4	6	2	8
	1992	Wheat	4	17	8	13	10	11
		Barley	4	21	1	21	6	18
		Canola	8	12	10	15	9	11
Peace River	1991	Wheat	5	3	3	5	4	4
		Barley	2	6	5	3	4	4
		Canola	4	5	3	6	4	5
	1992	Wheat	2	6	3	5	3	5
		Barley	4	4	5	3	4	4
		Canola	5	2	5	2	3	4

SUMMARY

This province wide phosphorus fertilizer and soil test correlation project being conducted in Alberta has clearly demonstrated that wheat, barley and canola significantly respond to added phosphate fertilizer. Once data from the third year of the project is compiled, correlation of yield results with the various soil tests will be conducted to determine which soil tests are most effective at predicting crop response to added fertilizer. Also, predictive models will be developed for each crop, in each soil zone, for each soil test method for making phosphate fertilizer recommendations to prairie farmers. Results should be available for the spring of 1995.

Until our study is completed, it is our opinion that farmers should consider adding a maintenance application of phosphate fertilizer each year to replace the P that is removed by the crop. This will ensure that good soil P levels are maintained and that crops won't run short of phosphate during the growing season.

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