

## Agroeconomics of Phosphate Fertilizer in Manitoba

Rigas E. Karamanos

Western Cooperative Fertilizers Limited, Box 2500, Calgary AB T2P 2N1

E-mail: r.karamanos@westcoag.com

### Abstract

The recent increase in P fertilizer prices have resulted in farmers reconsidering their fertilization practices in order to maximize their profits and if 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 behaviour of P in a soil is quite different once the soil has been fertilized for a prolonged period of time. A compilation of yield data from 155 experiments showed that when soil test levels were less than 10 lb P/acre (deficient), not all crops responded to P fertilization in all cases. At the same time when soil test levels were greater than 30 lb P/acre (sufficient) still a number of crops were responding to high P levels. Although the frequency of responses was higher at lower soil test P levels, there were no clear trends, which would suggest that response to phosphate fertilizer is indeed affected by factors other than the soil test level and in any event application of P would be necessary almost at any soil test level. A long-term (23-year) showed that elimination of P fertilization results in immediate yield losses. The maintenance portion of P fertilization can be forgone in years of high fertilizer and low commodity prices on the understanding that prolonged removal of that portion from the fertilizer plan will inadvertently results in increasing soil P deficiency.

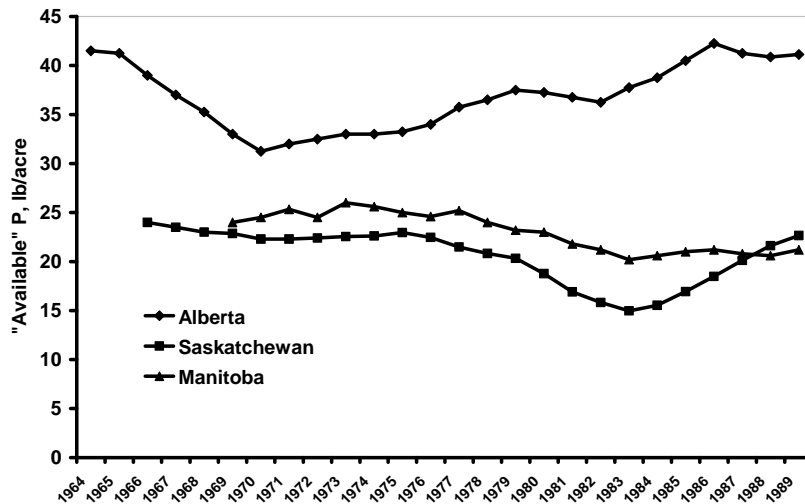
### Introduction

To put the P fertilizer question in perspective we need to consider that farm operating costs are essentially divided into five categories: essential (seed), enhancement (fertilizer and seed), maintenance (fertilizer and herbicide), protection (herbicide, insecticide and fungicide), and insurance (herbicide, insecticide, fungicide and fertilizer). The benefit from all these inputs is not additive and that any gains in yield can only be achieved via better quality seed and fertilization; therefore, a producer must derive maximum economic benefit from these two operating inputs in order to cover some of the remaining costs. Application of phosphate fertilizer fulfills a dual role, i.e., enhancement and maintenance.

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 behaviour 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).

## Enhancement Component of Fertilizer P

Recently, a compilation of yield data from 222 experiments in western Canada (Karamanos et al. 2002) based on four soil testing categories (<10, 10 - 20, 20 - 30 and >30 lb P/acre) of bicarbonate extractable P levels (Schoenau and Karamanos, 1993) allowed assessment of current soil testing criteria. When soil test levels were less than 10 lb P/acre that are considered very deficient, not all crops responded to P fertilization in all cases (see Table 1). At the same time when soil test levels were greater than 30 lb P/acre that are considered close to sufficient still a number of crops were responding to high P levels (see Table 2). Responses in the intermediate range of soil tests were variable.



**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: Schoenau and Karamanos, 1993).

**Table 1.** Proportion (%) of phosphate fertilizer rates at which maximum yield was obtained for each crop when soil test was less than 10 lb P/acre.

Rate of applied P lb P <sub>2</sub> O <sub>5</sub> /acre	% of tests that responded to P			
	Barley	Canola	Wheat	Peas
0	5	25	11	0
15-20	28	75	47	0
30-40	50	0	37	67
45-60	17	0	5	33

Although the frequency of responses was higher at lower soil test P levels, there were no clear trends, which would suggest that response to phosphate fertilizer is indeed affected by factors other than the soil test level and in any event application of P would be necessary almost at any soil test level.

**Table 2.** Proportion (%) of phosphate fertilizer rates at which maximum yield was obtained for each crop when soil test was greater than 30 lb P/acre.

Rate of applied P lb P <sub>2</sub> O <sub>5</sub> /acre	% of tests that responded to P			
	Barley	Canola	Wheat	Peas
0	27	50	48	86
15-20	53	38	26	0
30-40	20	13	26	14
45-60	0	0	0	0

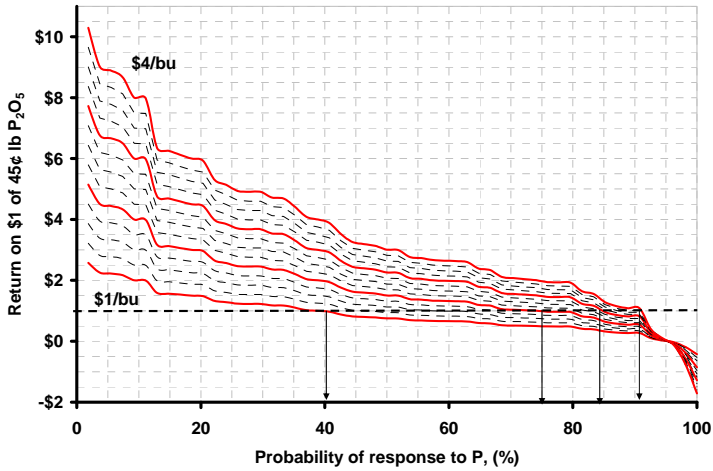
As a rule, the greater the severity of phosphorus deficiency the greater the recommended rate of phosphate and the greater the response to its application. Table 3 shows the average responses one can anticipate based on the recommended P rate.

**Table 3.** Average yield increase in bu/acre depending on application rate.

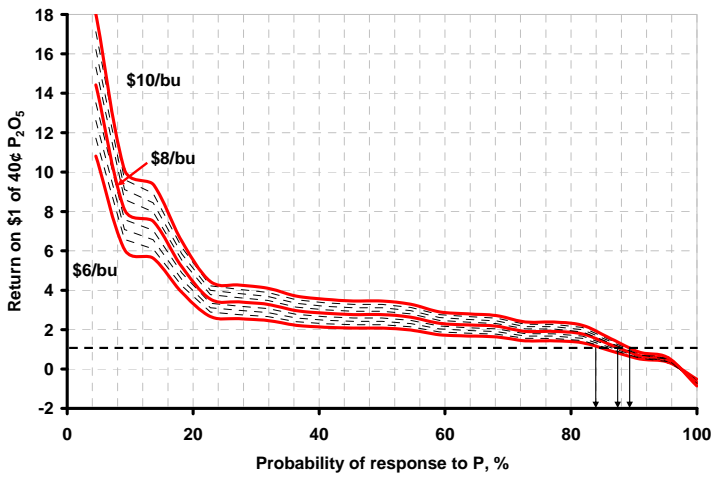
Crop	Recommended Phosphate fertilizer rate, lb P <sub>2</sub> O <sub>5</sub> /acre		
	<20	20-30	>40
barley	3	11	20
wheat	3	5.5	10
canola	2	4.5	Insufficient data

A series of experiments (155; 54 with barley, 22 with canola and 79 with wheat) have been used to demonstrate the agronomic and economic returns to P fertilizer application. Both crop and fertilizer prices have increased in recent years, which begs the question of whether the “fundamentals” of fertilizing crops have indeed changed and if a need exists for considering a fertilizer rate change (reduction), shift in ratios of usage of various fertilizer products (e.g., N vs. P<sub>2</sub>O<sub>5</sub>), etc.

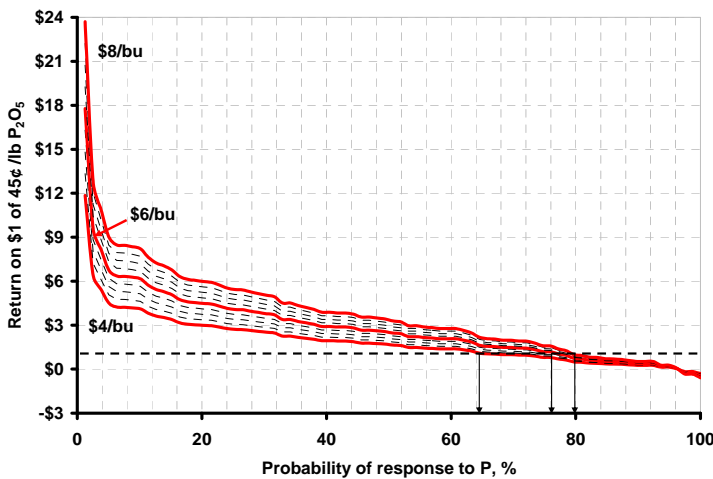
Probability ranking of the economic return to the application of phosphate fertilizer was derived from these experiments. At current prices of approximately 45¢ for one lb of P<sub>2</sub>O<sub>5</sub> return to \$1 of fertilizer can be derived for barley, canola and wheat from Figures 2, 3 and 4. The graphs show the break-even points (\$1 return for \$1 spent on fertilizer) for different commodity prices. For example, the break-even point for \$2 per bushel of barley in these experiments occurred 75% of the time, whereas that for \$4 per bushel 92% of the time.



**Figure 2.** Probability of obtaining a return on \$1 based on four prices of barley for 45¢ /lb  $P_2O_5$ .



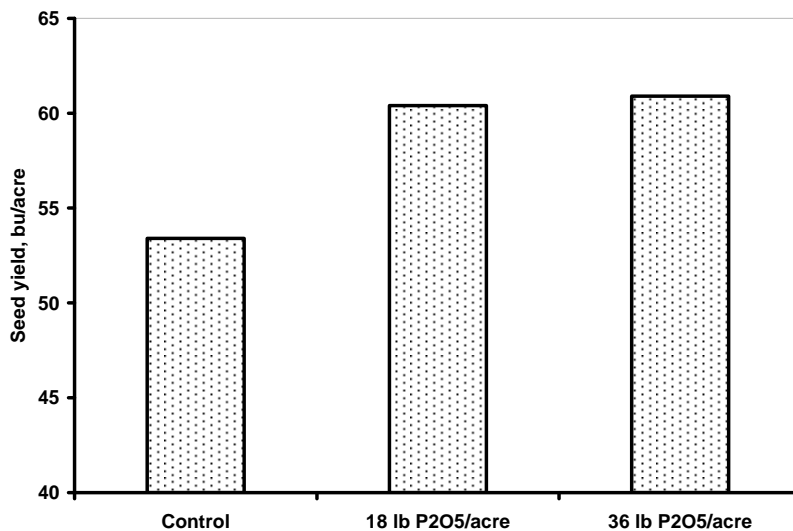
**Figure 3.** Probability of obtaining a return on \$1 based on four prices of canola for 45¢ /lb  $P_2O_5$ .



**Figure 4.** Probability of obtaining a return on \$1 based on four prices of wheat for 45¢ /lb  $P_2O_5$ .

## Maintenance Component of Fertilizer P

Phosphorus fertilizer use efficiency is fairly low and is crop dependent. For examples for cereals it can range between 15 and 30%, whereas for tap rooted plants (e.g., canola) it can be as high as 50%. 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 agro-economic benefits are derived with the first 15 to 20 lb  $P_2O_5$  applied. An example of this is shown in Figure 5 with the results of a canola experiment carried out at Olds, Alberta with a soil test of 25 lb P/acre. Maximum yield (60 bu/acre) of a canola hybrid was obtained with 18 lb  $P_2O_5$ /acre in spite of the crop removing some 47  $P_2O_5$ /acre. Application of an additional 18 lb  $P_2O_5$ /acre did not influence the yield.

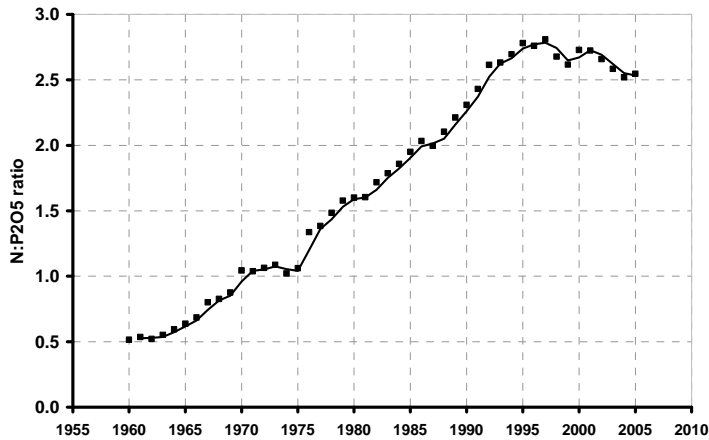


**Figure 5.** Impact of fertilizer P rates on the yield of hybrid canola on a soil that has received long-term P fertilization.

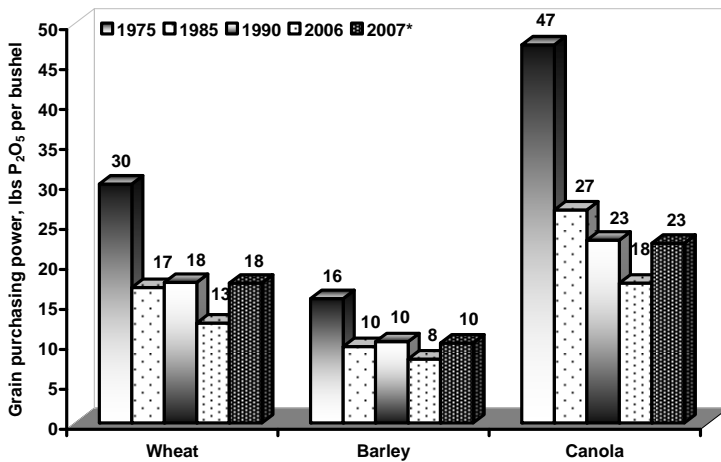
## Fertilizer Economics of N: $P_2O_5$ Ratios

A historical perspective of the change in N: $P_2O_5$  usage in western Canada is presented in Figure 6. A steady widening of the N: $P_2O_5$  ratio from 0.5 to 2.8 between the sixties and early nineties was followed by a stabilization in the ratio and actually a slight drop to 2.6 in the last couple of years. The drop is related to a proportionally greater drop in N compared to  $P_2O_5$  usage.

A steady increase in fertilizer prices with proportionally unchanged crop prices has led to erosion in the fertilizer “grain purchasing power”, or the amount of fertilizer purchased by one bushel of grain for  $P_2O_5$  (Figure 7), although a reversal in trends was observed in 2007.



**Figure 6.** Ratio of N to P<sub>2</sub>O<sub>5</sub> usage in Western Canada. (Sources: Western Cooperative Fertilizers Limited and Canadian Fertilizer Institute)



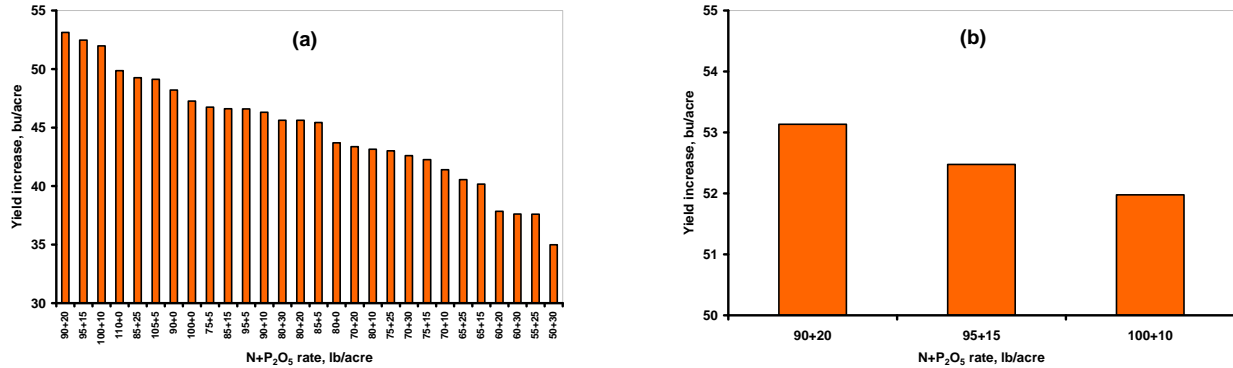
**Figure 7.** “Grain purchasing power” of phosphate fertilizer.

The impact of crop and fertilizer prices on the return from fertilizer was examined by analyzing fifteen experiments with barley (eleven on stubble and four on fallow) and five with wheat on fallow that were carried out between 1988 and 1994. The experimental design consisted of five rates of “total” product (0, 80, 90, 100 and 110 lb/acre) that were applied in their entirety as N (except the controls, of course) or with 5, 10, 15, 20, 25 and 30 lb P<sub>2</sub>O<sub>5</sub>/acre substituting the equivalent amount of N in the “total” products, thus resulting in 28 different combinations, each replicated six times. Two sets of prices, namely 26¢/lb and 42¢/lb for N and 27¢/lb and 32¢/lb for P<sub>2</sub>O<sub>5</sub> and three prices for barley (\$1.50, \$2.00 and \$2.50 per bushel), were used for the economic analysis, which consisted in calculating return less fertilizer expense as follows:

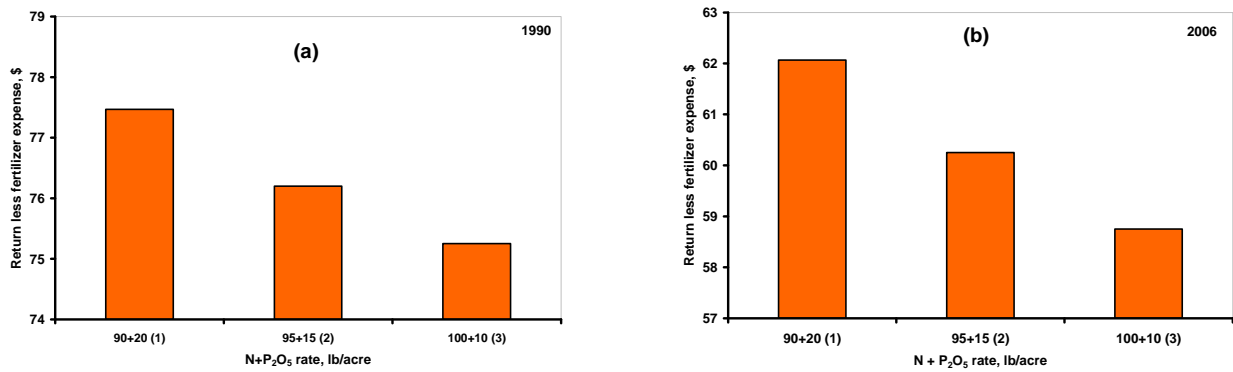
$$\text{Yield increase (bu/acre)} \times \text{price per bushel (\$/bu)} - \text{Fertilizer rate (lb/acre)} \times \text{Price per lb (\$/lb)}$$

A ranking of all these treatments is shown in Figure 7. Agronomically, the top treatments (90:20, 95:15 or 100:10) included a relatively high total rate with wide (4:1 to 5:1) N:P<sub>2</sub>O<sub>5</sub> ratio.

Economically, the top three agronomic treatments ranked in the same order in spite of the dramatic difference in N prices (26¢ vs. 42¢/lb of N) between two selected years (Figure 8). However, this most likely should be interpreted as indicating that a relatively low rate of P<sub>2</sub>O<sub>5</sub> (10-20 lb P<sub>2</sub>O<sub>5</sub>/acre) is required to obtain maximum yield rather than that there is a need for adherence to a certain N:P<sub>2</sub>O<sub>5</sub> ratio.



**Figure 7.** Ranking of all possible (a) and the top three (b) N+P<sub>2</sub>O<sub>5</sub> combinations of barley yield.



**Figure 8.** Top three ranking treatments for \$2/bu barley on stubble based on 1990 (a) and 2006 (b) N and P<sub>2</sub>O<sub>5</sub> fertilizer prices.

### Fertilizing Based on P Removal by Crops

The recommended rate is tied to the soil test level for P. However, a number of people fertilize with P based on the anticipated yield and subsequent removal of P by a crop. So, it is possible that not all fertilizer P will be consumed by the crop to provide maximum agro-economic yield. Examples with wheat and canola are presented in Table 4, in which application of fertilizer P to replace P<sub>2</sub>O<sub>5</sub> removal is split into the portion of the applied fertilizer P that goes towards maximum agro-economic yield (sufficiency) and the portion that goes towards maintenance. The maintenance portion of P fertilization can be forgone in years of high fertilizer and low commodity prices on the understanding that prolonged removal of that portion from the fertilizer plan will inadvertently result in increasing soil P deficiency.

**Table 4.** When replacing P removed by a crop by applying equal amounts of fertilizer P, all fertilizer P may not go towards sufficiency depending of soil test levels.

Soil test P (lb/acre)	Sufficiency rate (lb P <sub>2</sub> O <sub>5</sub> /acre)	Maintenance rate (lb P <sub>2</sub> O <sub>5</sub> /acre)				
		Target yield (bu/acre)				
		30	40	50	60	70
CWRS wheat						
10	35	0	0	0	0	5
20	30	0	0	0	5	10
30	20	0	0	10	15	20
40	20	0	0	10	15	20
50	20	0	0	10	15	20
60	15	0	5	15	20	25
Canola						
10	35	0	0	10	20	30
20	30	0	5	15	25	35
30	20	7	15	25	35	45
40	20	7	15	25	35	45
50	20	7	15	25	35	45
60	15	12	20	30	40	50

Karamanos et al. (2006) showed that interruption of P fertilization after 20 years (1982-2001) led to significant yield decreases with average losses over the following three years (2002-2004) of greater (21%) when 27 lb P/acre was being seed-placed for the first 20 years and lesser with 1/3 seed-placed and 2/3 banded (15%) and banded (12%) (Figure 9). This demonstrates that residual P from long-term P fertilization was not sufficient to alone provide all the P requirements of a barley crop.

## Conclusions

Fertilizing with phosphorus serves a dual purpose. It supplies the crop's phosphorus requirement for the year of application and supplies "residual" P to maintain soil P levels for future crops. When crops have been fertilized for a prolonged period of time, agro-economic benefits are derived with the first 15 to 20 lb P<sub>2</sub>O<sub>5</sub>/acre; however, abrupt elimination of P fertilization can result in serious yield losses.

## References

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