YIELD RESPONSE AND ECONOMIC IMPLICATIONS OF SEED-PLACED PHOSPHORUS ON STUBBLE AND SUMMERFALLOW SPRING WHEAT AND DURUM

P.L. Flaten, E. de Jong and N.J. Livingston
Innovative Acres Project, Department of Soil Science
University of Saskatchewan, Saskatoon, Sask.

Abstract

Several growing seasons data on phosphorus responses of stubble and summerfallow crops have been summarized. Spring wheat and durum wheat show a 85% and 65% probability of a positive response to seed-placed phosphorus on fallow and stubble, respectively. At 1987 prices, the probability of an economic response to P fertilization is less than 50% on fallow and less than 35% on stubble.

Boundary line analysis was used to determine the relationship between crop yield and available spring soil water, rainfall, soil + fertilizer nitrogen and soil phosphorus. A curve was drawn through the uppermost points in a plot of yield against a single independent variable and it was assumed that this line represents the maximum possible yield for a given value of the independent variable. Points below this line represent yields limited by other variables for which boundary line curves were also determined. It was assumed that the limiting factors were multiplicative. This analysis accounted for almost 80% of the variability in yield.

Introduction

Innovative Acres is a project of the Soil Science Department of the University of Saskatchewan, funded by the Saskatchewan Government through the Agriculture Development Fund. The focus, since the Program's inception in 1981, has been towards on-farm demonstrations and research across the province. This paper will summarize the response to seed-placed phosphorus fertilizer by spring wheat and durum wheat as measured on field strip trials since the beginning of the project. Since mycorrhizal infections in low P soils may decrease the P response on stubble crops relative to the response of summerfallow crops (Khan, 1975; Kucey, 1980), a comparison has been made between stubble and summerfallow yield responses.

Materials and Methods

The data used are from 56 summerfallow and 61 stubble crops. Included in the summerfallow data are 21 data points from the Palliser Project of the 1970's. Stubble fields have not been sorted according to previous crop, i.e. oilseed vs. cereal stubble. However, the vast majority of the data points are from fields of cereal stubble. The main field at each location was fertilized to Saskatchewan Soil Testing Laboratory recommendations, and a check strip in which no phosphorus fertilizer was left. Yield samples (10 samples of 1 m^2 per treatment) were then taken on either side of the dividing line.

Most of the comparisons are from the Brown and Dark Brown soil zones, with fewer data points from the Black soil zone. The soil texture varied from sandy loam to heavy clay, but most of the sites were loam and clay loam. Generally, the fields used for this study have a long-term history of phosphorus fertilization. Growing conditions varied greatly both geographically and on a year-to-year basis.

Results and Discussion

Table 1 summarizes growing conditions and results of the study. The data was analyzed in three ways: by linear regression, ranked probabilities and boundary-line analysis.

Table 1. Growing conditions and yield responses of spring wheat and durum wheat to seed-placed P fertilizer.

	Fallow	Stubble
Number of comparisons	56	61
Growing season precipitation, cm	16.7±6.4	20.1±8.3
Available soil water at seeding, cm	11.7±5.3	10.1±4.3
Available soil P, kg P/ha	17.0±10.6	20.5±11.9
Applied fertilizer P, kg P_2O_5/ha	28.3±6.6	28.8±8.7
Soil and fertilizer N, kg/ha	95.4±44.7	92.7±29.9
Check yield, kg/ha	2224±763	1988±767
Fertilized yield, kg/ha	2400±811	2046±747
Yield increase, kg/ha	176±182	58±239

Linear Regression

The results of the regression-line approach show responses to be random, on both summerfallow and stubble crops. Attempts to correlate yield increases to soil phosphorus, fertilizer phosphorus, soil zone, soil texture, growing season rainfall and available spring soil moisture were unsuccessful.

Ranked Probability Graph

Yield increases, defined as fertilized yield less check yield, were ranked from highest to lowest. Apparent yield decreases are included in this ranking. Then the probability for each yield increase was plotted. Figure 1 indicates that summerfallow crops have an 80% probability of obtaining a positive yield increase, while stubble crops have only a 55% probability of obtaining a positive yield response to phosphorus fertilizer. The average (50%) yield increases were 175 and 50 kg/ha on fallow and stubble, respectively.

The ranked probability approach is also useful in determining the likelihood of obtaining economic returns from phosphorus fertilization. By using the current P_2O_5 fertilizer cost ($0.60/kg P_2O_5) and the average rate of P_2O_5 applied (approximately 30 kg P_2O_5/ha), the average P_2O_5 fertilizer cost is $18/ha. At the current price of wheat ($100/t),

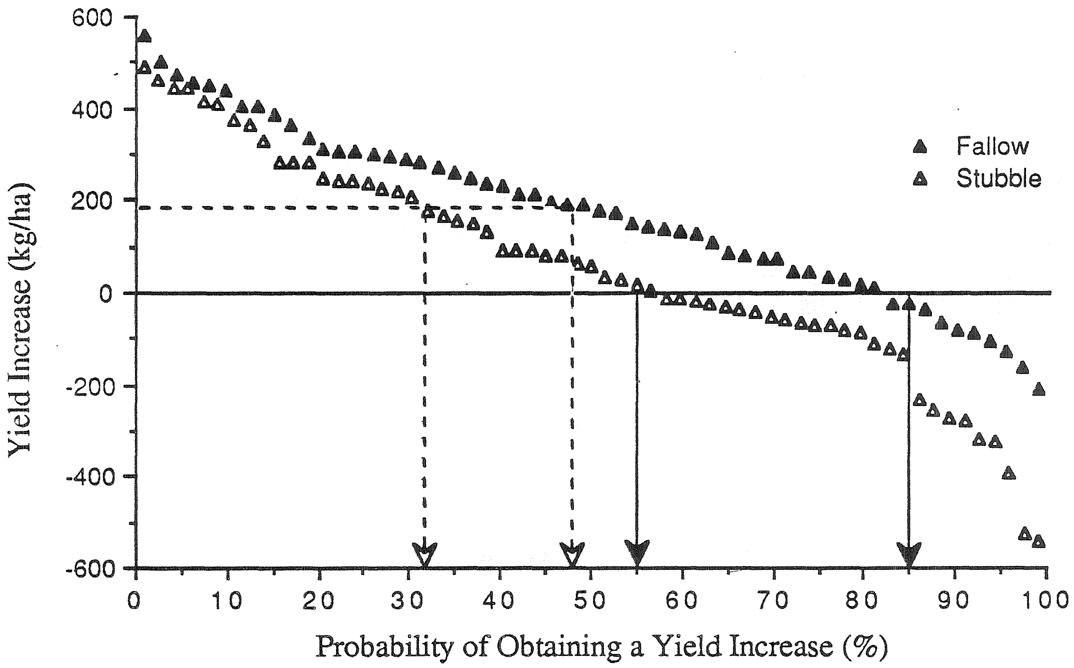

Figure 1. Probability of obtaining a yield increase of spring wheat and durum to seed-placed P fertilizer (Innovative Acres, 1982-1987).

a farmer would require a 180 kg/ha yield increase in order to breakeven on the P_2O_5 fertilizer cost. In Figure 1 the probability of obtaining that yield increase would be approximately 32% and 48% in a stubble crop and summerfallow crop, respectively. Benefits of earlier crop maturity are not directly considered.

Boundary-line Analysis

An alternative approach to analyzing the data set is provided by boundary-line analysis as described by Webb (1972) and Livingston and Black (1987). The same data was used, but stubble and fallow crops were combined. Since soil test P is only an index of the labile P pool and is not quantitatively equivalent to fertilizer P, only soil test P and check yield were used in this analysis.

In this analysis a curve is drawn through the uppermost points in a plot of yield against a single independent variable. It is assumed that points on this line represent the maximum possible yield for a given value of the independent variable, whereas points below this line represent yields limited by other variables for which boundary-line curves are also determined. Boundary-line analysis was performed to determine the relationship between yield and growing season precipitation (R), available spring water (A), soil phosphorus (P) and soil and fertilizer nitrogen (N). All variables were considered to act independently but multiplicatively so that:

$$\text{Yield} = \text{Yield}_{max}\, f(R)\, g(A)\, h(P)\, j(N)$$

where $Yield_{max}$ is the maximum yield and f, g, h and j are the function that describe the boundary-line curves for the relationship between yield and each variable. In determining boundary-line curves for the variables an attempt was made, whenever possible, to use general forms of relationships already established in the literature.

Figure 2 shows the relationship obtained when $Yield/Yield_{max}$ is plotted against season rainfall and indicates that other variables besides rainfall limit yield. The equation describing the response is given in Table 2. The relationships between $Yield/Yield_{max}$ and A, P and N are given in Figures 3, 4 and 5, respectively. The equations describing these responses are given in Table 2.

Table 2. Equations describing the boundary-lines for the relationship between yield and available spring soil water (A), growing season rainfall (R), soil and fertilizer nitrogen (N), and soil phosphorus (P).

Variable	Equation
R	$Yield = Yield_{max} * [1-\exp(-0.267 (R - 4.75))]$
A	For $R \leq 20$ cm, $Yield = Yield_{max} * (A / (A + 1.25)$ $R > 20$ cm, $Yield = Yield_{max} * (0.83 + 0.006A)$
N	$Yield = Yield_{max} * [1-\exp(-0.021 N)]$
P	$Yield = Yield_{max} * [1-\exp(-0.21 P)]$

No single variable accounted for more than 42% of the variability in yield, with soil phosphorus only accounting for 3%. However, when combined, the variables accounted for almost 80% of the variability (Table 3). Figure 6 compares measured yields on stubble and fallow fields with those calculated using the above equation. The slope and intercept of the regression line do not significantly differ from 1 and 0, respectively, and show that there was no bias in the yield predictions.

Table 3. The variance of yield on stubble and fallow fields explained by boundary-line analysis using the functions of the individual variables of: available spring soil water (A), growing season rainfall (R), soil and fertilizer nitrogen (N), soil phosphorus (P), and the combination of the functions (i.e. Equation 1).

Variable	% of variability explained
R	42
A	17
N	9
P	3
A,R,N,P	78

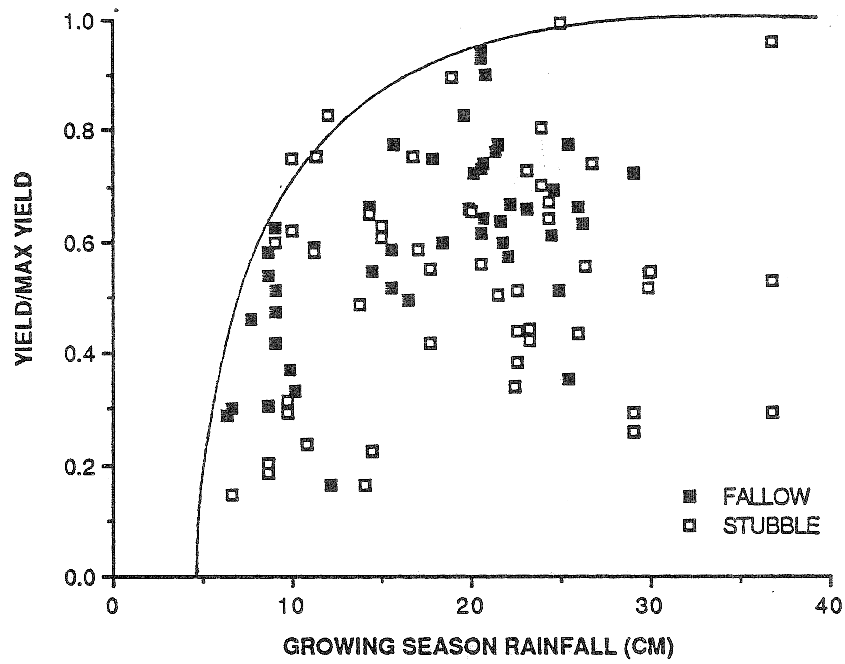

Figure 2. Yield/Yield Max vs Growing Season Precipitation

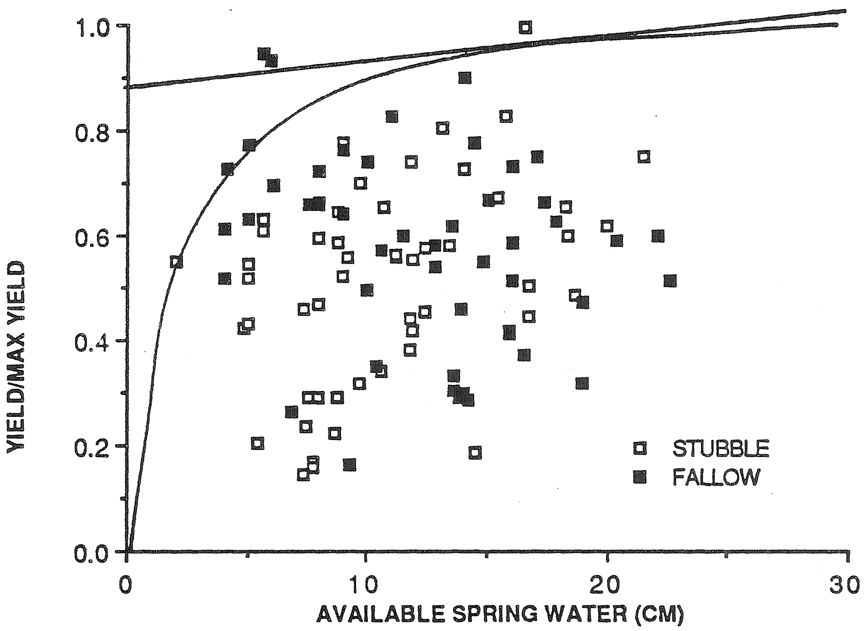

Figure 3. Yield/Yield Max vs Available Spring Water

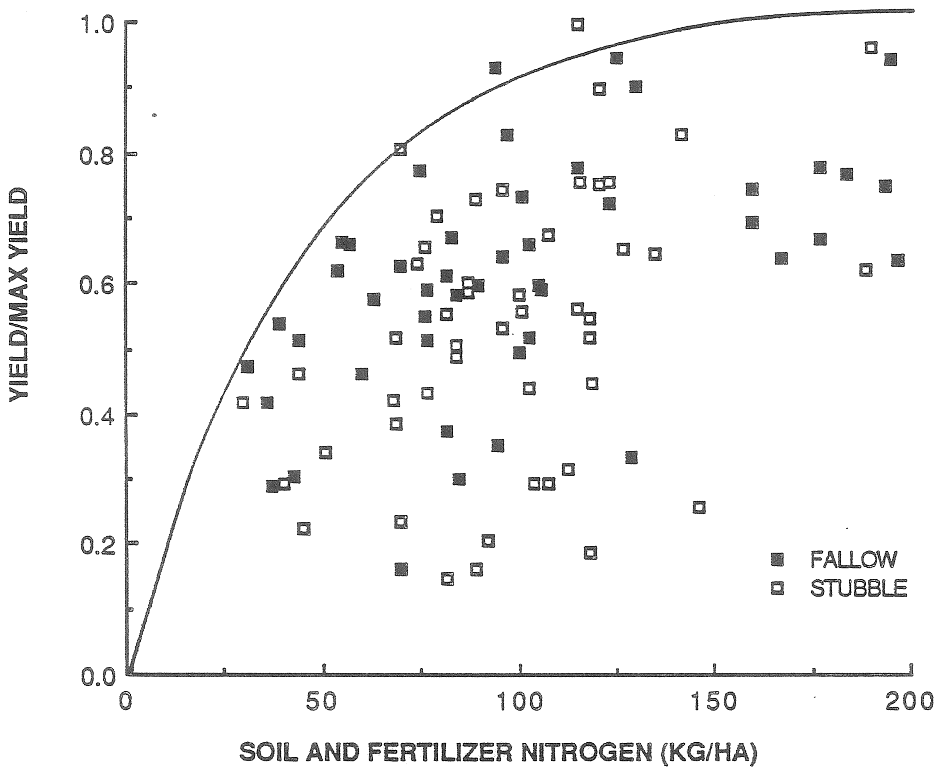

Figure 4. Yield/Yield Max vs Total Nitrogen

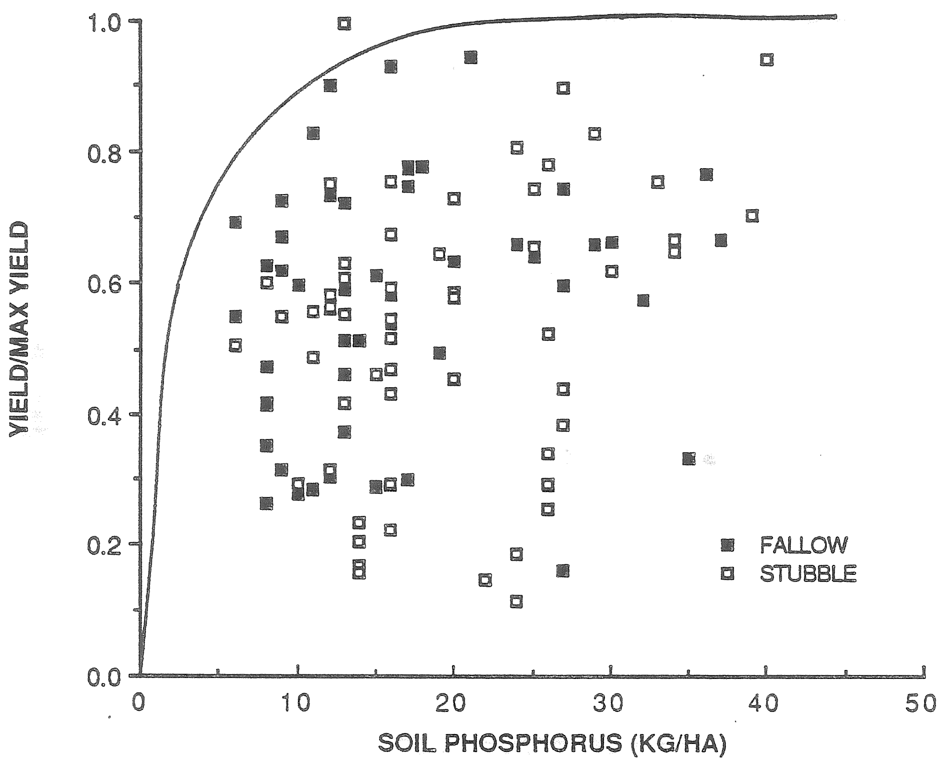

Figure 5. Yield/Yield Max vs Soil Phosphorus

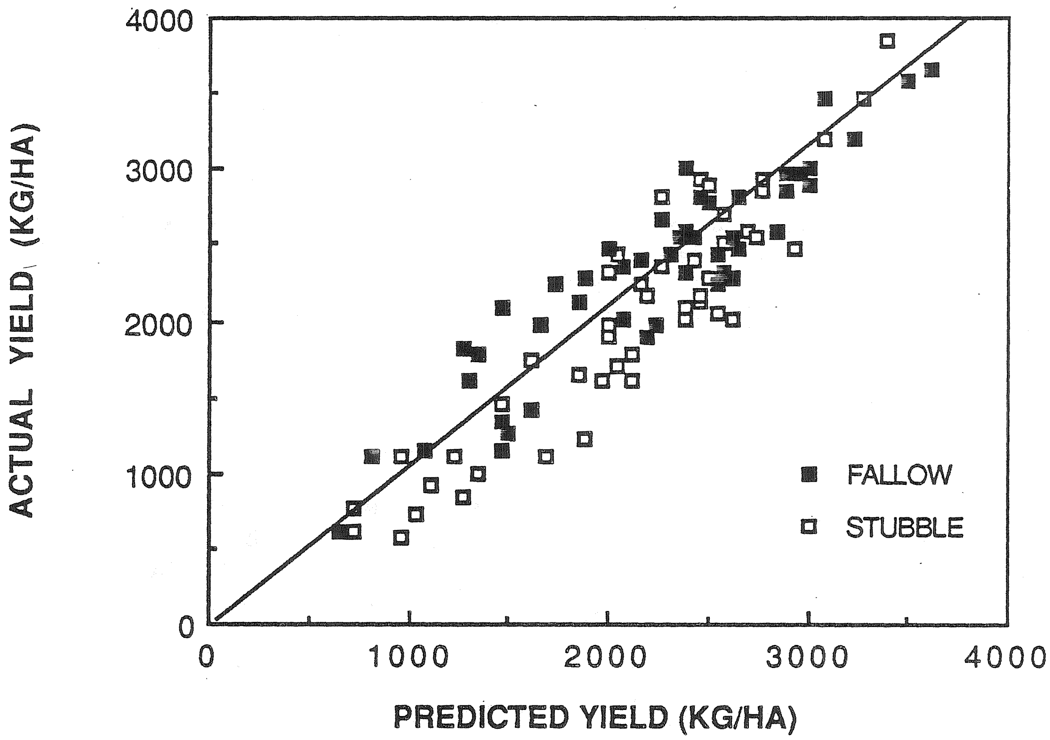

Figure 6. Comparison of yields calculated using eq.1 with measured yields.

Conclusions

Responses of spring wheat and durum to seed-placed monoammonium phosphate averaged 175 and 60 kg on summerfallow and stubble fields, respectively. No relationships between yield response and soil available phosphorus and environmental conditions were evident. One reason for this may be the long-term P_2O_5 fertilizer history on most of these fields. The random yield response to several factors considered in the regression-line approach proved this method of analysis to be inadequate in explaining the variability in yield. Two alternate methods were then used.

The ranked probability approach demonstrated that summerfallow crops are more responsive to P_2O_5 fertilizer applications than stubble crops, with probabilities of obtaining a yield increase being 85% and 50%, respectively. Economically, the probability of breaking even on P_2O_5 fertilizer costs at 1987 prices is less than 50% on both summerfallow and stubble crops.

Boundary-line analysis using only four variables (available spring soil moisture, growing season rainfall, soil + fertilizer N, and soil phosphorus) accounted for 78% of the variability in check yields, for stubble and fallow crops. Most of the variability was explained by water, in the form of available spring soil moisture and growing season rainfall.

References

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