Three years of precision farming research at Hepburn, Saskatchewan

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Abstract

A broad association between landform and distinctive pedological regimes, as influenced by the hydrological pattern of the hillslope is known to exist in glacial till landscapes of Saskatchewan, Canada. We used image analysis of aerial photographs to delineate different pedological regimes within a typical glacial till field in the thin Black soil zone. Three distinctive areas (upper, mid, and lower slope) were identified as "management units". Variable rate N and P fertility trials using wheat and canola as the test crops were initiated in 1996 and conducted over a three-year period. The data associated with the N treatments are discussed in this paper. Results indicated that the management units developed on the basis of the aerial photographs were agronomically meaningful. In particular, mean yields on upper slope positions were consistently less than yields achieved on upper slope positions. Moreover, N fertilizer application did not mitigate the impact of slope position on yield and it was concluded that moisture limitations on upper slope positions limited the extent to which wheat and canola responded to fertilizer application. On the basis of the results from this study, it was concluded that a meaningful variable rate program could be developed for canola whereas variable wheat yield responses and low financial returns limited the success of the variable rate fertilizer program for wheat.

Introduction

On the rolling plains of the western Canadian prairies, crop productivity can be highly variable within a field. The most pronounced variability usually occurs on hummocky or rolling terrain where upper slope positions are characterized by reduced crop yields as compared to lower slope positions. The productivity gradient has been attributed to loss and redistribution of topsoil (Gregorich and Anderson 1985; Pennock and de Jong 1990; McConkey et al. 1997) and moisture (Verity and Anderson 1990) from upper to lower slope positions. The challenge for implementing precision farming is to determine the specific pedological and hydrological factors that are responsible for productivity gradients and develop appropriate management strategies.

Materials and Methods

A three-year study was initiated in 1996 to investigate the agronomic and economic potential for the implementation of variable rate N and P fertilization in wheat (var. AC Barrie) and canola (var. Maverick). The study site was located 40 km north of Saskatoon, SK, Canada near the community of Hepburn (SW 7-40-5-W3 or 52°25'N, 106°41'W). The site was situated on a glacial till landscape (loam to clay loam) that is part of the Oxbow soil association (Acton and Ellis 1978). Soils at the site were dominantly Chernozemic with significant Gleysolic soils in the depressional areas. Slope gradients at the site ranged from 5 to 10%. Surface drainage at the site is local.

In each year of the study, two research experiments (i.e., wheat and canola) were established, each covering an area 250 m by 300 m. The sites encompassed several cycles within the knoll and depression landscape – one cycle extending from one knoll down into a depression and then to the top of the next knoll. The sites were extensively surveyed using a Total Station and analysis of aerial photographs was used to develop maps comprising three management units: 1) upper slope; 2) midslope; and 3) lower-slopes (McCann et al., 1996). Soils from within each landscape position were sampled (15 cm increments to 60 cm) and were subjected to a series of analytical procedures to determine characteristics including mineral N, total carbon, organic carbon, pH, electrical conductivity and moisture content.

A series of replicated (6 replicates) fertility treatments were imposed across a complete landform cycle within the study site. Nitrogen was applied as urea (46-0-0) at 5 rates (0, 0.5, 1.0, 1.5 and 2.0 times the recommended rate) and phosphorus was applied as monoammonium phosphate (11-55-0) at 3 rates (0, 1.0 and 2.0 times the recommended application rate for wheat and 0, 0.5 and 1.0 times the recommended rate for canola). Only the results from the N treatments are discussed in this paper. The recommended fertilizer rates were based on fall soil analysis (Enviro-Test Labs, Saskatoon), conducted according to standard practices, i.e., 10 individual soil cores taken from midslope positions were bulked and analyzed. Fertilizer treatments were seeded using a modified Morris air seeder (2.13m width with 30 cm row spacing). Fertilizer N was side-banded whereas P was placed in the seed furrow. Treatments were harvested using a small plot harvester (10m sections were harvested within each of the management units).

Results and Discussion

Very strong management unit effects on seed yield were detected at the canola site in both 1996 (data not shown) and 1997 (Fig. 1) – the overall means increased from the upper slope through the mid slope to the lower slope. These results indicate that the management units delineated using image analysis of aerial photographs were agronomically meaningful. Moreover, response to N applications differed in the different landscape positions. Application of fertilizer N did not mitigate the impact of slope position for canola grown on upper slopes, suggesting that factors other than N fertility, such as moisture availability, limited yields.

In both 1996 and 1997, the seed yield response of canola to N application generally was curvilinear on both the upper- and mid-slope positions (Fig.1). In the lowerslope positions, however, seed yield responses to N tended to be linear, indicating that yield maximums were not achieved, even at the 2 × the recommended rate of N application. In 1998, canola was relatively unresponsive to N application, irrespective of landscape position (Figure 2). Lack of response to fertilizer application during the 1998 field season was a reflection of the severe drought experienced early in the growing season at this site.

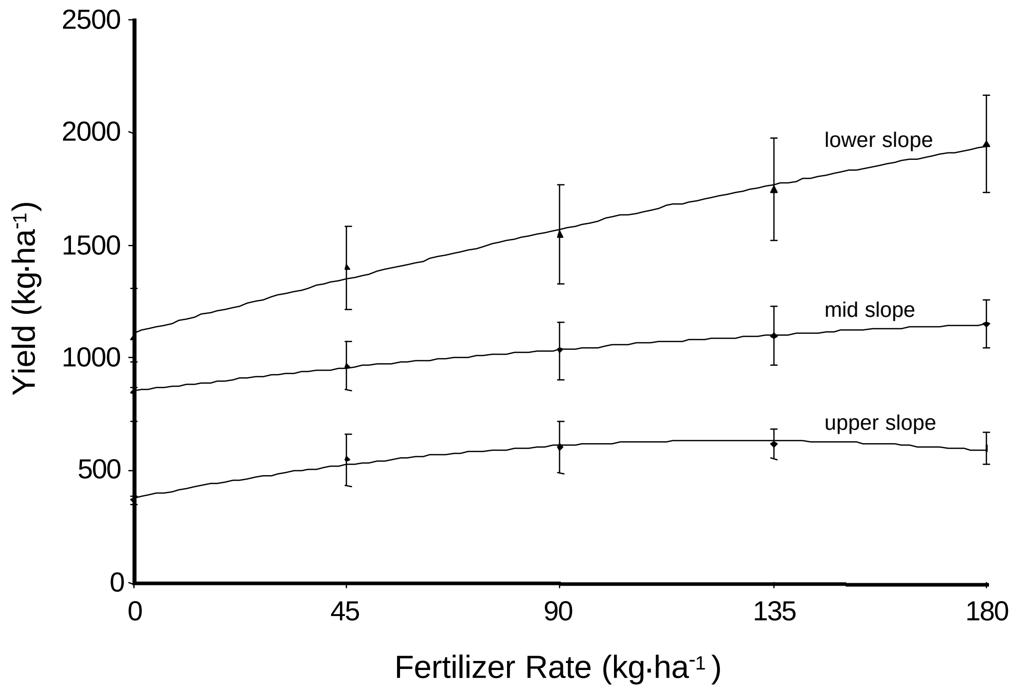

Figure 1. Response of canola, grown in 1997 at Hepburn, SK, to increasing increments of N fertilizer on upper, mid and lower slope units. The recommended rate of N fertilizer in 1997 was 90 kg ha^{-1}.

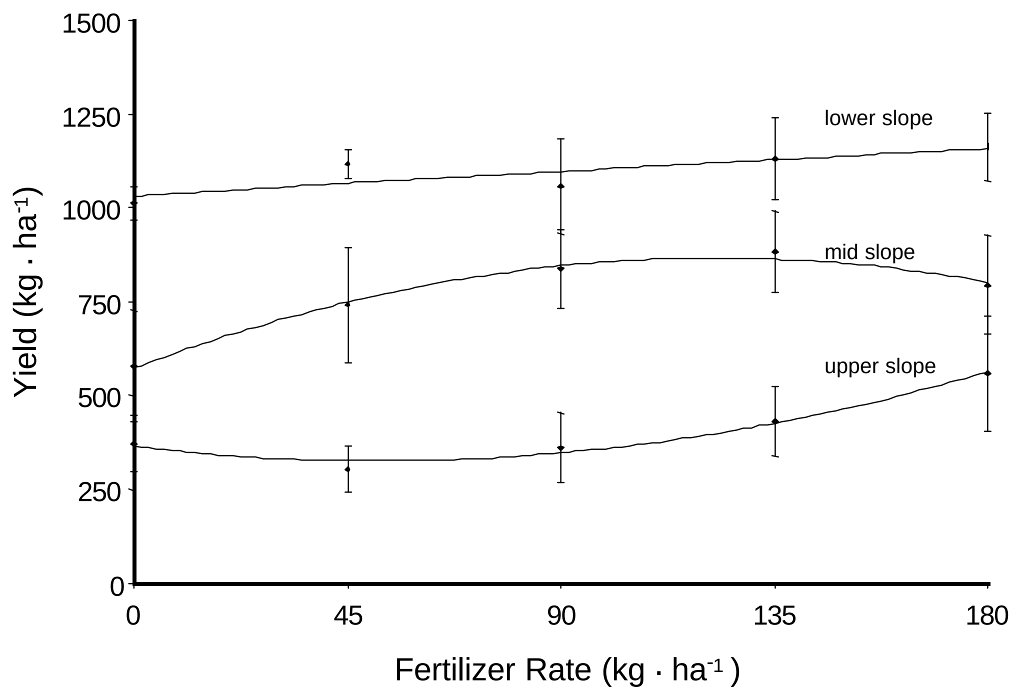

Figure 2. Response of canola, grown in 1998 at Hepburn, SK, to increasing increments of N fertilizer on upper, mid and lower slope units. The recommended rate of N fertilizer in 1998 was 90 kg ha^{-1}.

At the wheat site, yield responses to fertilizer N differed between years (Fig. 3 and 4, data not shown for 1998). In 1998, wheat was unresponsive to fertilizer N additions, irrespective of landscape position. The unpredictable nature of the wheat N response curves at Hepburn limited the potential for developing a successful variable rate N fertilizer strategy for this location. Clearly, the success of variable rate fertilizer application depends on our ability to predict crop response to inputs.

Although responses to N fertilizer were not consistent, some similarities in wheat yield responses to landscape existed. For example, wheat grain yields typically were lower on the upper slope units as compared to lower slope units.

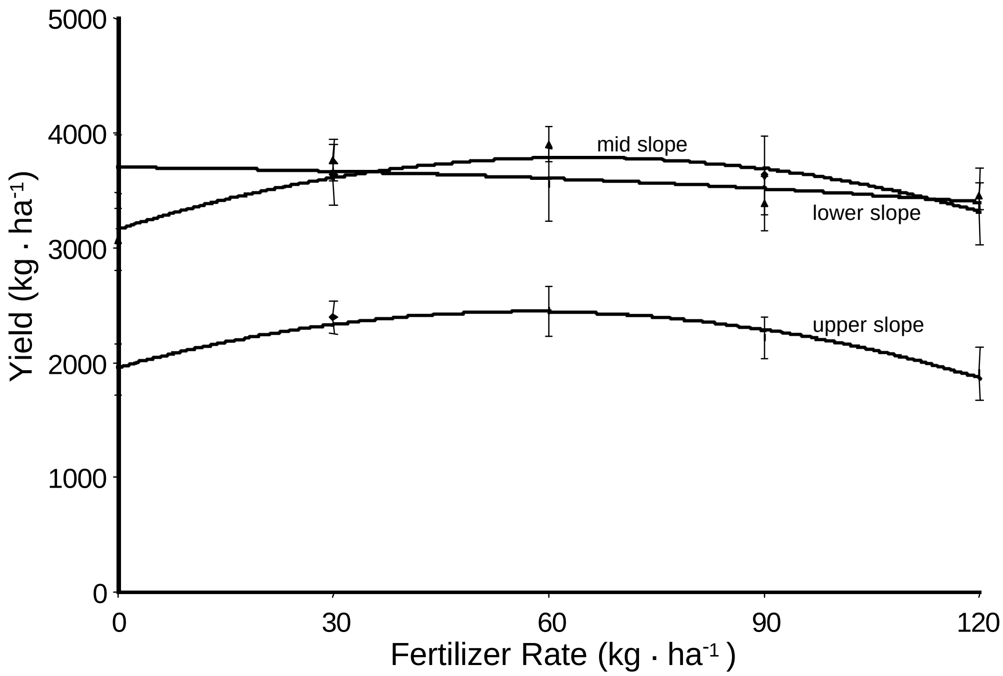

Figure 3. Response of wheat, grown in 1996 at Hepburn, SK, to increasing increments of N fertilizer on upper, mid and lower slope units. The recommended rate of N fertilizer in 1996 was 60 kg ha^{-1}.

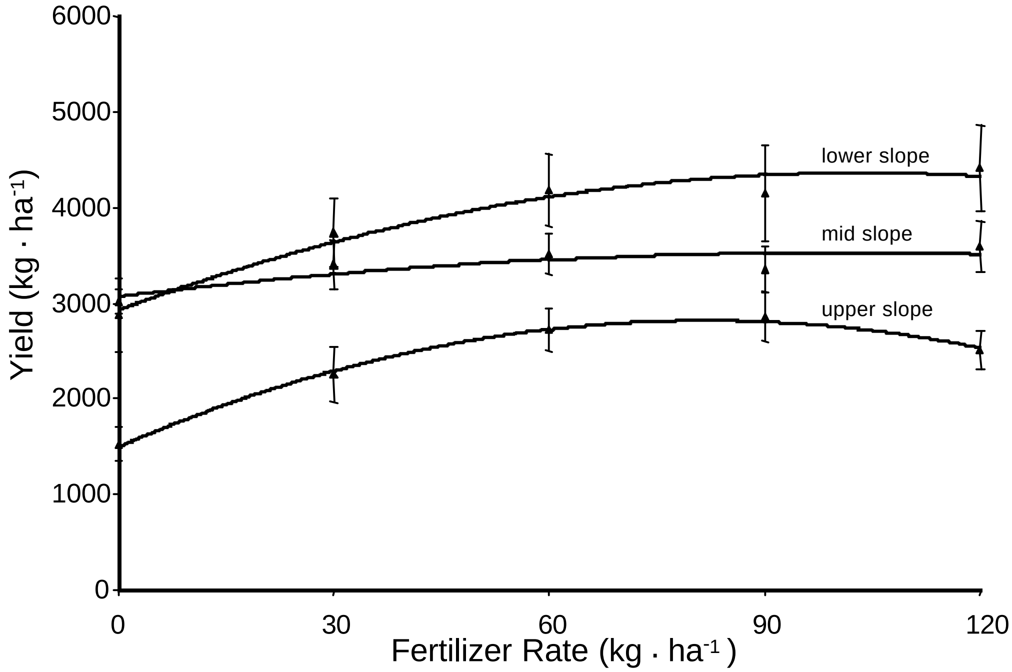

Figure 4. Response of wheat, grown in 1997 at Hepburn, SK, to increasing increments of N fertilizer on upper, mid and lower slope units. The recommended rate of N fertilizer in 1997 was 60 kg ha^{-1}.

On the basis of the N fertilizer response curves for canola, the economically optimum rate of fertilizer N was identified for the upper-, mid- and lower-slope positions and a variable N rate scenario or "prescription" was developed. The economically optimum rate of fertilizer application was considered to be the point on the production function where one more unit of fertilizer N added the same amount to revenue as to cost. The returns of the variable rate scenario (1.0 × recommended N rate on the upper slopes, 1.5 × the recommended rate in the midslopes and 2.0 × the recommended rate in the lower slope units) were compared to a single blanket application of fertilizer N applied according to soil test recommendation for each year (Table 1). In both 1996 and 1997, the variable rate scenario provided better returns than the blanket application of the recommended N rate. However, it is important to note that the variable rate scenario resulted in more fertilizer N being applied to the entire field as compared to the recommended N rate. Implementation of the variable rate scenario resulted in a loss in 1998 as compared to the blanket 1.0 × N recommendation because the canola was relatively unresponsive to fertilizer N due to the extremely droughty conditions. Over the three years of the study, implementation of the variable rate scenario resulted in an increase in the returns of \$13.94 ha^{-1} as compared to the recommended rate of fertilizer N. These results are encouraging as they suggest that an economic potential exists for the application of variable rate technology for canola production. However, one might argue that these returns, although positive, may not warrant the major expense required to purchase the equipment required for full implementation of variable rate technology.

Table 1. Comparison of the returns from the variable rate scenario to a blanket application of the recommended rate of N for the three study years for the canola sites.

	Upper	Mid	Lower	Whole Field
	Rate of N Fertilizer Application			
	1.0 ×	1.5 ×	2.0 ×	
Year	Returns ($/ha) of variable rate versus constant N fertilizer (1.0 × rate)			
1996	0.00	23.05	76.52	33.60
1997	0.00	-0.94	100.57	29.00
1998	0.00	-27.30	-25.73	-20.78
3-year Average				13.94

The development of a variable rate scenario for the production of wheat at Hepburn was hampered by the variation in the response of wheat to N fertilizer application from year to year. Indeed, the best combination of rates varied between years and was largely unpredictable. Using a variable rate N fertilizer scenario similar to that proposed for canola, implementation of variable N fertilizer rate application resulted in a loss in returns as compared to using a blanket application of the recommended rate of N (Table 2).

Table 2. Comparison of the returns from the variable rate scenario to a blanket application of the recommended rate of N for the three study years for the wheat sites.

	Upper	Mid	Lower	Whole Field
	Rate of N Fertilizer Application			
	0.5 ×	1.0 ×	1.5 ×	
Year	Returns ($/ha) of variable rate versus constant N fertilizer (1.0 × rate)			
1996	6.01	0.00	-23.79	-4.45
1997	-25.20	0.00	-9.62	-4.92
1998	19.16	0.00	-19.72	-0.14
3-year Average				-3.17

SUMMARY

Results from this study indicate that management units (upper-, mid- and lowerslope) developed on the basis of black and white aerial photographs were agronomically meaningful for both wheat and canola production. Of particular importance is the observation that mean yields on upperslope units were consistently less than yields achieved on lowerslope units. Moreover, yield responses to N fertilizer on upperslope units were limited by moisture, as evidenced by the curvilinear response curves, whereas canola, in particular, continued to respond to increasing increments of fertilizer N on lowerslope units. Thus, producers wanting to implement variable rate fertilization should consider increasing fertilizer inputs in the most responsive areas of the field; namely the lowerslope positions.

A simple economic analysis revealed that increased economic returns were associated with the variable rate scenario developed for canola as compared to a blanket application of the recommended rate of N fertilizer. However, the three-year average return of the variable rate scenario as compared to a blanket application of the recommended N rate (\$13.94 ha^{-1}) suggests that economic returns may be limited and may not warrant the expenses associated with full implementation of variable rate fertilizer application. The variablility in the wheat yield responses to fertilizer N limited the potential for developing a variable rate scenario. Data suggested that implementation of a variable rate scenario for wheat at Hepburn would have resulted in a net loss in returns as compared to a blanket application of the recommended rate of N fertilizer.

Many factors determine overall crop productivity in a given year. The variability of nutrients other than N and P, such as S or various micronutrients can be critical for certain crops; competition from weeds may be greatest in the lower slope positions; or in a wet year, problems with water-logging or root rot in lower slope positions may lower the yields. Through a combination of research trials on non-level fields and producer trials of different fertility-weed control scenarios, a more complete understanding of the management of variable productivity conditions will emerge.

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