A field-scale assessment of the rotation benefits of pea and canola

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Abstract

Producers and researchers have observed that higher cereal yields occur when oilseed and pulse crops are included in a cereal-intensive cropping system. A study was established in the spring of 1996 to compare the rotation benefit of a pulse crop (pea) with a second non-legume broadleaf crop (canola) to succeeding cereal crops. It is anticipated that the benefit of pea in a crop rotation is due largely to non-N related factors, and that other broadleaf crops could provide the same benefits. Pea-wheat-barley, canola-wheat-barley, and wheat-wheat-barley rotations, were established in two field-scale (10 acre; each plot 30-m by 80-m) sites. The expression of rotation benefits from pea and canola to wheat were compared in different management units (shoulder, footslope, and level landform complexes). The seed yield of wheat sown after pea or canola was 14% higher than wheat sown after wheat at the St. Louis and Birch Hills sites. Furthermore, the N content of wheat seed was improved in the pea-wheat and canola-wheat rotations compared with the wheat-wheat rotation. Wheat leaf disease severity in the pea-wheat and canola-wheat rotations compared with the wheat-wheat rotation was reduced by 17% at St. Louis and 30% at Birch Hills, whereas, common root rot incidence did not differ among rotations. The reduction in leaf disease severity accounted for a portion of the yield advantage associated with wheat grown in the pea and canola rotations compared with the wheat-wheat rotation. The relationship between leaf disease severity and the yield advantage associated with crop rotation was strongest at Birch Hills. The unexplained portion of the rotation benefit at St. Louis was not associated with differences in weed infestations among the different crop rotations. Common root rot and weed infestations were similar among rotations, and there was no evidence to suggest that there were significant differences in soil N availability among rotations. It appears that pea and canola provide similar benefits to a succeeding wheat crop. Unaccountable reasons for the rotation effect on the seed yield of wheat among rotation and the spatial variation affecting growing conditions in the different rotations the complexity of field-scale processes associated with rotation benefit of broadleaf crops to succeeding cereal crops.

Introduction

When producers include pulse and oilseed crops prior to a cereal in a relatively cereal intensive crop rotation, they generally observe a yield advantage-rotation benefit-in comparison to sowing the same cereal consecutively. For example, in northeast Saskatchewan Wright (1990) showed that seed yield of barley was 2 1% greater when a pulse crop preceded rather than barley. The rotation benefit can be separated into an N and non-N component. The N benefit is that portion of the rotation benefit that can be compensated for by N fertilizer. Wright (1990) found that the N benefit of pea to a succeeding barley crop was the equivalent of 100 kg N ha^{-1} of fertilizer. The remainder of the rotation benefit that cannot be compensated for by N fertilizer is the non-N benefit. Reductions in disease and weed problems are thought to be the main factors responsible for the non-N benefit (Bullock, 1992; Stevenson and Van Kessel, 1996). Although the non-N benefit of legumes has received little attention, this component of the rotation benefit can be significant. Reduced leaf disease severity and grassy weed infestation were related to 91% of the yield advantage in the pea-wheat rotation (Stevenson and Van Kessel, 1996). A 129 N kg ha^{-1} increase in the A value (soil N supplying power) was related to only 9% of the yield advantage in the pea-wheat rotation.

The development of variable rate technologies are driving the need for agronomic information regarding the spatial variation of crop productivity across a field. Topographic variation has been shown to interact with factors responsible for the rotation benefit of pea to a succeeding wheat crop (Stevenson and Van Kessel, 1996). A study was established in 1996 to further evaluate the effect of pea and canola on important crop production parameters in fields with variable topography.

Materials and Methods

Site description and research design

Research sites in the northern grainbelt of Saskatchewan were established near St. Louis (106” 45’ W, 52° 54’ N), and Birch Hills (105 ° 2’ W, 53 ° 3’ N) in 1996. The terrain at these sites varied from hummocky to undulating. Soils at St. Louis and Birch Hills are mainly Orthic Chemozems of the Hoey and Blaine Lake Associations, developed on a silty-textured lacustrine parent material with occurrences of Gleysolic and Regosolic soils. Cropping history at the sites included mainly wheat, barley, and canola in the years prior to the study, with barley grown as the most recent crop.

A field-scale research approach was used because it includes and quantifies the effect of topographic variation and soil-crop-pest interactions across a field, and can supply information to emerging precision agriculture technologies. Pea-wheat-barley, canola-wheat-barley, and wheat-wheat-barley rotations were established in a randomized complete block design in both research approaches. Experimental units were 30-m by 80-m and were allocated to five blocks (Fig. 1). A small-plot experiment was situated immediately adjacent to each landscape-scale experiment. A systematic grid with 10-m spacing was superimposed on the area encompassed by each landscape-scale experiment. A topographic survey was conducted at each grid point, a digital elevation model generated, and slope variables calculated. The slope variables were then used to identify distinct management units (shoulder, backslope, footslope and level landform elements complexes) within each site (Fig. 1). Grid points classified as levels with an above average elevation were reclassified as upper levels and those points with a below average elevation were reclassified as lower levels.

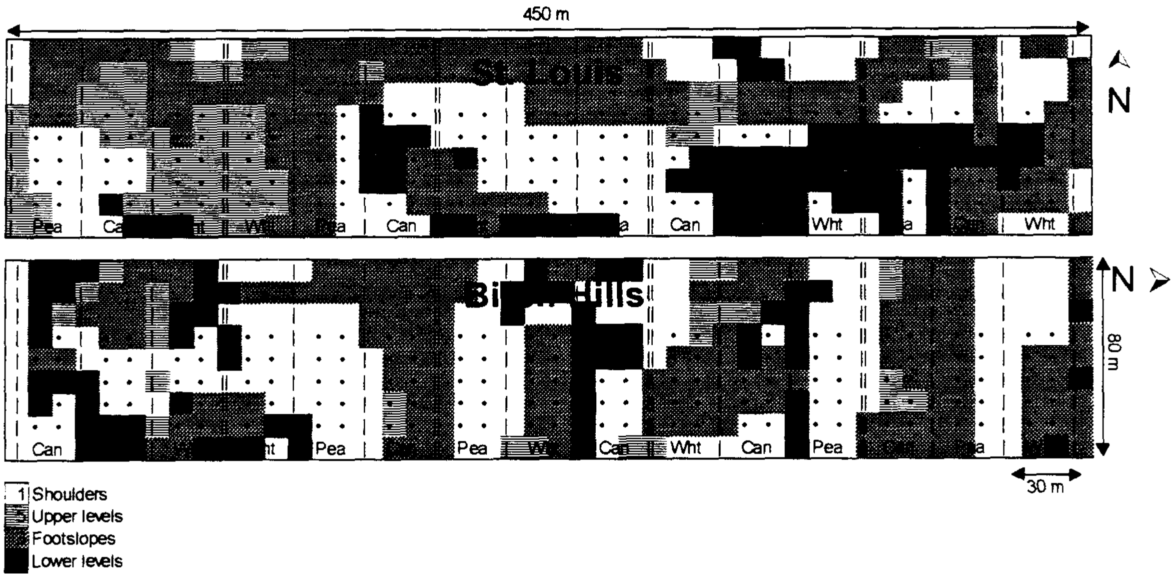

Fig. 1. Landform complex/sampling point maps for the two study sites.

Pre-seeding tillage operations in the first rotation phase included two passes with a cultivator followed by harrow packing just prior to sowing. In 1997, pre-seeding tillage included two passes with a tandem disc. The study sites were sown in the last week of May in both 1996 and 1997 with a 10 to 12.2-m hoe air-drill. Highlight' pea, inoculated with a commercial Rhizobium inoculant, and 'Pursuit Smart' Argentine canola were sown at all first rotation phase sites. 'Katepwa' hard red spring wheat was sown in 1996 and 'Teal' in 1997. Seeding rates were about 200 kg ha^{-1} for pea, 100 kg ha^{-1} for wheat, and 5 kg ha“ for canola. Urea was banded prior to seeding across the entire Birch Hills site in 1996 at a rate of 50 kg ha^{-1}. At St. Louis in 1996, urea was side-banded at seeding at a rate of about 60 kg N ha^{-1} in the canola plots and 50 kg N ha^{-1} in the wheat plots of the landscape-scale sites at St. Louis and Birch Hills. Urea was side-banded at seeding at a rate of 55 kg N ha^{-1} across the both sites in 1997. Five kg N ha^{-1} and 11 kg P ha^{-1} were applied as mono-ammonium phosphate during all seeding operations at all study sites.

Grassy and broadleafweeds in the pea and canola plots were controlled with either imazethapyr (Pursuit) or imazamox (Odyssey). Imazethapyr was tank-mixed with clethodim at St. Louis in 1996 for more complete control of wild oats and volunteer cereals. A number of different herbicides were used to control grassy and broadleaf weeds in the wheat plots in 1996 and 1997. Herbicides were applied with a high-clearance sprayer at the study sites.

A number of measurements were made in the second rotation phase wheat crop in 1997. Nitrogen- 15 fertilizer was surface applied in 1 -m^2 microplots just after sowing. Root and foliar diseases were rated between anthesis and harvest in all plots in the second rotation phase. At crop maturity, a 1-m^2 area was harvested from each sampling point and then the aboveground biomass was threshed to determine seed yield. A three to five plant sample was harvested from the middle of each ^{15}N microplot at the same time the crop yield samples were harvested. Plant samples were threshed and ground, and the N and ^{15}N content of the seed tissue was determined.

Results and Discussion

The rotation benefit in 1997

The inclusion of pea or canola in the crop rotation provided a similar yield advantage to the succeeding wheat crop. A 14% increase in seed yield occurred when wheat was sown after either broadleaf crop rather than after wheat, when averaged across both sites (Table 1). Furthermore, the N content of wheat seed also was higher in the pea-wheat and canola-wheat rotations compared with the wheat-wheat rotation at both sites (Table 1).

Table 1. The effect of crop rotation on wheat seed yield and N content at the two sites in 1997.

Preceding crop	Yield		N content	
	kg ha^{-1}		%	
St. *Louis*				
Pea	2489	60†	2.63	0.05
Canola	2390	57	2.45	0.05
Wheat	2065	63	2.26	0.05
Birch Hills				
Pea	2088	122	2.71	0.19
Canola	2055	56	2.62	0.09
Wheat	1871	66	2.17	0.11

† Means are followed by SE.

The yield advantage of sowing wheat on broadleaf crop stubble was smaller than that observed in a previous study, conducted in the same region of the province, where the seed yield of wheat sown on pea stubble was 40 to 60% greater than that sown on wheat stubble (Stevenson and Van Kessel, 1996). Wright (1990) also found that the yield advantage of sowing barley after a pulse crop rather than a cereal can vary considerably — the rotation benefit was highly dependent on the environmental conditions. The inclusion of pea and canola in a crop rotation apparently will not provide consistent benefits, which is not surprising considering the fact that prairie climatic conditions are highly variable.

Reasons for the rotation benefit: N and non-N effects

Previous studies suggest that the N component of the rotation benefit is relatively small compared with the non-N component — the rotation effect on soil N availability is to small to have significant effects on seed yield (Stevenson and Van Kessel, 1996). The A value is a ^{15}N methodology that measures of the size of the plant-available N pool integrated over time and is expressed in equivalents of an added "N-labeled fertilizer, with the ^{15}N:^{14}N ratio of the plant tissue varying inversely with the A value. The A value can be used to assess the *relative N* contribution of different crops to a succeeding cereal crop. In this study, the A value was 30% lower in the pea-wheat rotation compared with the canola-wheat rotation at St. Louis (Table 2). The A value in the wheat-wheat rotation was intermediate to estimates in the other two rotations. At Birch Hills, the A value was 23% lower in the pea-wheat rotation compared with wheat-wheat rotation, and intermediate in the canola-wheat rotation. It is likely that more ^{15}N was immobilized into microbial biomass of soil in the wheat-wheat rotation compared with the pea-wheat or canola-wheat rotations, thus reducing N availability in the wheat-wheat rotation. Covariance showed that the rotation effect for the A values was not associated with the rotation effect on seed yield (Table 3).

Table 2. The effect of crop rotation on the *A* value of the soil and wheat diseases at the two sites in 1997.

Preceding crop	*A* value†		Root rot		Leaf disease	
	kg N ha^{-1}		0–4 scale‡		0–11§	
St. Louis						
Pea	267	23¶	1.3	0.1	2.9	0.1
Canola	374	23	1.2	0.1	2.8	0.1
Wheat	325	25	1.1	0.1	3.5	0.1
Birch Hills						
Pea	406	99	1.5	0.1	2.7	0.3
Canola	469	46	1.3	0.1	3.1	0.1
Wheat	531	59	1.2	0.1	4.1	0.2

† *A* value of the soil estimated with wheat seed.
‡ Common root rot incidence rated with a O-4 scale.
§ Leaf spot complex severity rated with a O-l 1 scale.
¶ Means are followed by SE.

Table 3. Covariance analysis explaining the effect of the A value, and leaf and root diseases, on the rotation effect for wheat seed yield at the two sites in 1997.

	St. Louis	Birch Hills
	P	
Variables		
A value†	0.173	0.598
Leaf disease severity	0.503	0.213
Root rot	0.308	‡
Contrasts		
Pea vs. wheat	0.002	0.086
Canola vs. pea	0.293	0.776

† *A* value of the soil estimated with wheat seed.
‡ Root rot was not affected by crop rotation.

Common root rot incidence did not differ among rotations at St. Louis and Birch Hills (Table 2). Wheat leaf spot disease severity was 30% lower in the pea-wheat and canola-wheat rotations compared with the wheat-wheat rotation at Birch Hills. A similar but smaller rotation effect occurred for leaf diseases at St. Louis. Covariance analysis showed that a unit increase in leaf spot disease severity resulted in a 27 kg ha^{-1} decrease in seed yield at St. Louis and 64 kg ha^{-1} decrease at Birch Hills (Table 3). Further analyses showed that the density of the most abundant weed species at St. Louis did not differ among rotations (Table 4). At Birch Hills, the pea rotation actually had higher weed densities than the canola and wheat rotations. Therefore, leaf disease severity may be a moderately important component of the rotation benefit in certain instances (e.g., Birch Hills) , but in other instances (e.g., St. Louis) may be due to factors soil P availability which was not measured in this study.

Table 4. The effect of crop rotation on the weed densities at the two sites in 1997.

	St. Louis							
Preceding crop	Quackgrass		Wild oat		Volunteer barley		Birch Hills?	
	plants m^{-2}‡							
Pea	0	0.06§	4	0.16	1	0.12	13	0.34
Canola	0	0.06	6	0.15	1	0.11	2	0.15
Wheat	0	0.07	3	0.16	2	0.12	7	0.20
	P							
Contrasts								
Pea vs. wheat	0.035		0.166		0.192		0.794	
Canola vs. pea	0.008		0.395		0.525		0.002	

† The median is used as a measure of central tendency. The density of all weed species was presented for Birch Hills data.

‡ Data were log-transformed.

§ Means are followed by SE.

Crop rotations and precision agriculture

Distinct spatial patterns for seed yield, leaf disease severity, and the A value were apparent when the residuals from ANOVA including the effect of crop rotation were mapped (Fig. 2). The spatial patterns for seed yield were somewhat related to the A value at **St.** Louis — increased N availability in the low-lying areas improved seed yield- and leaf disease severity at Birch Hills — increased leaf diseases in the upper-slope positions reduced seed yield. The statistical analysis, however, could not confirm that the spatial patterns for seed yield were due to the A value or leaf diseases in the different rotations at either site (results not shown).

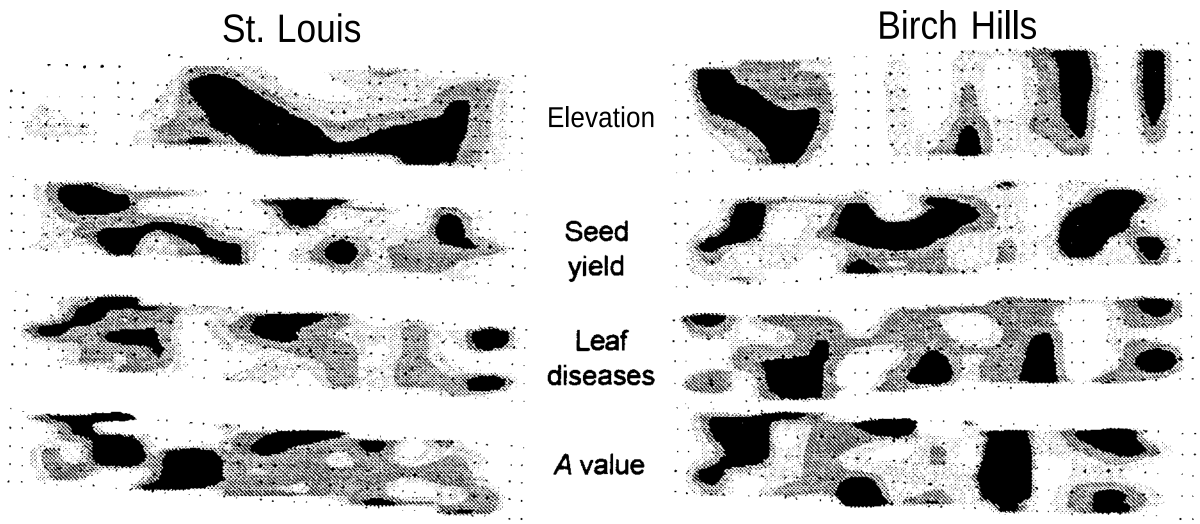

Fig. 2. Maps demonstrating spatial patterns for elevations and crop production parameters for the two study sites in 1997. Darker shading indicates increasingly higher elevations. Darker shading for the crop production parameter maps indicate increasingly greater residuals from ANOVA.

The adoption of variable rate technologies can be envisioned to alleviate unexpected yield reductions in certain areas of fields. For example, lowering N fertilizer rates in areas with excessive resource availability, or targeting pesticide applications to infested areas, may improve problems with lodging, delayed maturity, or pest damage. A clear understanding of the factors affecting growing conditions across a field in all types of cropping systems is needed to implement the technologies. Past research showed that the factors responsible for different seed yields among landform complexes also differed between a pea-wheat and wheat-wheat rotation (Stevenson and Van Kessel, 1996). The high potential productivity associated with crops grown after pea rather than wheat, in conjunction with excessive soil resource availability in the footslopes, caused adverse effects on seed yields in the footslopes. On the other hand, when wheat was grown after wheat, grassy weed infestations in the footslopes were responsible for adverse effects on seed yield. Preliminary findings from this study did not clearly show these types of field-scale controls. Perhaps, the relatively large study sites (10 acres) may have resulted in multiple field-scale controls for seed yield across the site. This type of spatial variation would be difficult to demonstrate with the statistical analysis or visually recognize with maps. Therefore, it is not clear whether crop rotation will affect factors that control the spatial variation of growing conditions across a field.

Concluding Remarks

Preliminary findings suggest that pea and canola provide a similar rotation benefit to a succeeding cereal crop. Thus, it must be recognized that the benefit from including legumes in a cereal intensive rotation is primarily the result of non-N effects and not the contribution of N to the succeeding crop as is often thought. However, a similar rotation benefit for pulse and oilseed crops should not undermine the agronomic and environmental advantages of cultivating legume crops that derive a large portion of their N requirements from the atmosphere. Further investigation will be necessary to determine if topographic variation interacts factors responsible for the rotation benefit of pea and canola to a succeeding wheat crop.

References

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