LANDSCAPE-SCALE CONTROLS ON THE AVAILABILITY OF PEA-RESIDUE NITROGEN FOR THE SUBSEQUENT WHEAT CROP

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ABSTRACT

Increased N uptake is a major mechanism responsible for the rotation benefit of a pulse crop to a succeeding cereal crop. The objective of our study was to determine the sources of N in pea-wheat vs. wheat-wheat rotation using a landscape-scale research approach. In 1993, a pea-wheat and wheat-wheat rotation were established in adjacent 1 ha sampling grids. Measurements were conducted in the second phase of the rotation. At the time of sowing in 1994, mineral N in pea-wheat rotation was 7 kg ha^{-1} greater than in the wheat-wheat rotation. Mean seed yield was 68% greater in the pea-wheat vs. wheat-wheat rotation-a 940 kg ha^{-1} rotation benefit. A 14% reduction in seed yield within the footslopes of the pea-wheat rotation was related to excessive resource availability and lodging. Compared to the wheat-wheat rotation, an additional 40 kg ha-1 of N yield in wheat residue and seed was measured in the pea- wheat rotation. A higher residue plus seed N yield in the pea-wheat rotation occurred from the soil N pool, since only 7 kg ha^{-1} was derived from pea residue N returned to the soil in 1993, and mean N derived from fertilizer N was 11 kg ha^{-1} and did not differ between the rotations. This extra soil N uptake was attributed, in part, to lower root and leaf diseases prevalence in the pea-wheat rotation. From our results it was estimated that =15% of the rotation benefit was related directed to the uptake of mineralized pea residue N. Processes indirectly increasing N availability in the pea-wheat rotation were thought to be the important mechanisms contributing to the remainder of the rotation benefit.

INTRODUCTION

When producers include pea or lentil in a crop rotation prior to a cereal, 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 21% greater when a pulse crop preceded rather than barley.

The rotation benefit can be separated into an N and non-N compt. The 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).

The N benefit of a pulse crop to the succeeding crop can be divided into a direct and indirect component that each has specific sources of N from which they are derived. The indirect N benefit results from the increased uptake of N from soil organic matter and N fertilizer rather than pulse residue. However, the indirect N benefit is not independent of the non-N benefit since any improvement in plant health that results from a non-N benefit should increase N uptake.

The N_2-fixing activity of a pulse crop has traditionally been associated with its rotation benefit. The objective of our study was to determine the sources of N in a pea-wheat vs. wheat-wheat crop rotation using a landscape-scale research approach. It was felt that this research approach would more accurately reflect processes controlling N availability in a producer's fields.

MATERIALS AND METHODS

We established a research site in a field with hummocky terrain at Birch Hills, SK, located in the Thick Black soil zone. In the spring of 1993, a pea-wheat and wheat-wheat rotation were established in two adjacent 1 ha areas. A 100 sampling point systematic grid was superimposed in the area encompassed by each rotation. Sampling points were characterized as shoulders, footslopes and levels using procedures given by Pennock et al. (1994) (Pig. 1). Results from levels were not included in this paper.

Figure 1. Spatial position of shoulders, footslopes and levels in two rotations at Birch Hills, SK.

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In 27 May 1993, 'Trapper' pea and 'Katepwa' wheat were sown to a 1 ha area and were managed following typical practices in the Black soil zone. Before sowing wheat, 80 kg N ha-1 as anhydrous ammonia was banded at a depth of =10 cm. Pre- emergent EDGE and post-emergent ASSURE were used to control weeds in pea. Post-emergent ASSERT was used to control grassy and broadleaf weeds in wheat.

On 22 June 1993, a 1 m^2 ^{15}N-enriched- fertilizer microplot was established at each sampling point in the area sown to pea. The ^{15}N-enriched aboveground biomass was harvested when pea reached maturity. Each sample was dried and threshed, the seed was discarded, and the residue (pods + straw) was coarsely ground in a Wiley mill. On 19 Oct. 1993, ^{15}N- enriched residue was returned to it's respective sampling point in a new 1 m^2 microplot that had not received ^{15}N-enriched fertilizer. The entire site was tandem disced on the same day.

Before sowing in 1994, ROUNDUP, at 1 L ha- 1, was sprayed on the entire research site. On 14 May, the entire site was tandem disced twice, 45 kg N ha^{-1} as urea fertilizer was banded at a depth of =7 cm, and 'Makwa' wheat was sown to the entire site. In both years, 5 kg N ha^{-1} and 26 kg P_2O_5 ha^{-1} as monoammonium phosphate was banded with the pea or wheat seed. Post- emergent ASSERT was used to control grassy and broadleaf weeds in wheat.

On 18 June 1994, 45 kg ha^{-1} of ^{15}N-enriched fertilizer was applied to a 1 m^2 microplot established at each sampling point in both rotations.

Soil mineral N was measured from 0 to 60 cm at all sampling points just prior to sowing in 1994. Common root rot incidence was rated at selected sampling points and leaf disease severity was rated at all sampling points just after wheat was headed (Bailey et al., 1992). Wheat seed and residue yields were determined at each sampling points in both rotations in 1994. Percent N and atom % ^{15}N seed were measured in the ^{15}N-enriched-fertilizer microplots at each sampling point in both rotations. Seed N, and N derived from fertilizer were calculated from these numbers. Atom % ^{15}N of residue and seed was measured in the ^{15}N-enriched-residue microplots at each sampling point in the pea-wheat rotation. Nitrogen derived from pea residue was calculated from these numbers. The approach given by Huggins and Pan (1993) was used to calculate the N and non-N components of the rotation benefit.

RESULTS AND DISCUSSION

Average mineral N in the footslopes was greater than in shoulders, especially in the pea-wheat rotation (Table 1). Also, mineral N availability was 7 kg ha^{-1} greater in the pea-wheat compared to wheat-wheat rotation. Results of a study conducted in 1993 showed that pea preferred to use soil N rather than fixing it's own N (Stevenson et al., submitted). This would suggest that the additional mineral N in the pea-wheat rotation was not due to the sparing of soil N by pea. Therefore, processes other than N_2 fixation and N sparing by pea influenced mineral N status between the rotations.

Table 1. Mean mineral N and wheat seed yield in two landform complexes and two rotations at Birch Hills, SK.

Rotation/landform complex	Mineral N	Seed yield
Pea-wheat	kg ha^{-1}	
Shoulders	12.9	2870
Footslopes	27.3	2480
$LSD_{0.05,98}$	4.2	260
Wheat-wheat		
Shoulders	9.6	1680
Footslopes	16.5	1710
$LSD_{0.05,72}$	3.8	240

Mean seed yield in the pea-wheat rotation was 68% greater than in the wheat wheat rotation-a rotation benefit of 940 kg ha^{-1} (Table 1) . In the pea-wheat rotation, mean seed yield in the footslopes was lower than in the shoulders while mean seed yield in wheat-wheat rotation did not differ between landform complexes. From spatial patterns of mineral N it was expected that seed yield in the footslopes should be at least as great as in the shoulders, especially in the pea-wheat rotation . However, wheat in most of the footslope sampling points in the pea-wheat rotation lodged in later July and August. It was speculated that this impaired seed development in these areas in the pea-wheat rotation.

Mean percent N derived from ^{15}N-enriched pea residue in the residue and seed of wheat was 6% and consistent between shoulders and footslopes (Table 2). Sixty four kg N ha^{-1} was returned as ^{15}N-enriched pea residue in the fall of 1993 Therefore; the N use efficiency of pea residue N was 11%. Mean percent N in wheat residue and seed derived from ^{15}N-enriched fertilizer was 11% and consistent between rotations and landform complexes (Table 2). This was paralleled by an average fertilizer use efficiency of =25%.

Table 2. Mean N yield and N sources in wheat residue and seed in tw landform complexes and two rotations at Birch Hills, SK.

Rotation/Landform complex	N yield	N sources: Residue	Fertilizer	soil
Pea-wheat		kg ha^{-1}		
Shoulders	107	**8**	12	**95**
Footslopes	134	**6**	11	**123**
$LSD_{0.05,98}$	16-t	**2**	2	**16**
Wheat-wheat				
Shoulders	73	NA	13	61
Footslopes	88	NA	9	79
$LSD_{0.05,72}$	17		2	16

†LSD error df was 96 for N derived from residue.
NA = not available.

There was a **40** kgha^{-1} increase in wheat residue and seed N yield in the pea-wheat compared to wheat-wheat rotation (Table 2). This increase was greatest in the footslopes of the pea-wheat rotation. Pea-residue-N and fertilizer-N use did not appear to explain this increase in N uptake. As a result, N derived from the soil made up the difference in N uptake.

Both root and leaf diseases were less prevalent in the pea-wheat rotation (Table 3). In addition, grassy weeds were considered a significant problem in the wheat-wheat rotation. Perhaps, the reduction in pest pressure in the pea-wheat rotation may have increased the demand for N. This might explain the extra soil N uptake observed in the pea-wheat rotation. However, mineralization of pea root N and rhizodeposited N (not accounted for in our study) might be responsible for a portion of the increase in N uptake between rotations (Senaratne and Hardarson, 1988; Sawatsky and Soper, 1991).

Table 3. Mean wheat root incidence and leaf disease severity in tw landform complexes and two rotations at Birch Hills. SK.

Rotation/Landform complex	Root	Leaf
Pea-wheat	0-4†	o-1 1†
Shoulders	1.2	6.5
Footslopes	1.0	5.7
$LSD_{0.05,98}$	**0.5‡**	**0.5**
Wheat-wheat		
Shoulders	1.9	9.4
Footslopes	1.9	9.0
$LSD_{0.05,72}$	**0.9‡**	**0.5**

† The appropriate scale for the respective disease ratings.
‡ LSD error df was 18 for roto disease ratings.

The direct N benefit of pea residue N was estimated to be =15% of the rotation benefit (Fig. 2). The overlap of the seed yield curves for the pea-wheat and wheat-wheat rotations in Fig. 2 meant that a non-N benefit was not directly responsible for the rotation benefi (Huggins and Pan, 1993). Therefore, the remaining rotation benefit was due to an indirect N benefit. However, it was speculated that the reduction in pest pressure resulted in a non-N benefit manifested through the indirect N benefit. These results suggest that the short-term rotation benefit of pea to a succeeding wheat crop is due to processes other than pea N_2 fixation and the mineralization of pea residue N.

Figure 2. Direct and indirect rotation benefits of pea-wheat vs. wheat-wheat rotation at Birch Hills, SK.

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The rotation benefit of pea to the succeeding wheat crop at our site was within the range (-470 to 1300 kg ha-l) observed by Wright (1990) for a pulse-barley rotation at five different sites It is . speculated that the cropping history and climatic conditions at the Birch Hills site were responsible, in part, for the large rotation benefit. But, Campbell and Noe (1985) discussed the importance of sampling design with regards to the spatial development of plant diseases Therefore, it is not inconceivable that the processes controlling the rotation benefit may have been accentuated in the large 1 ha rotations.

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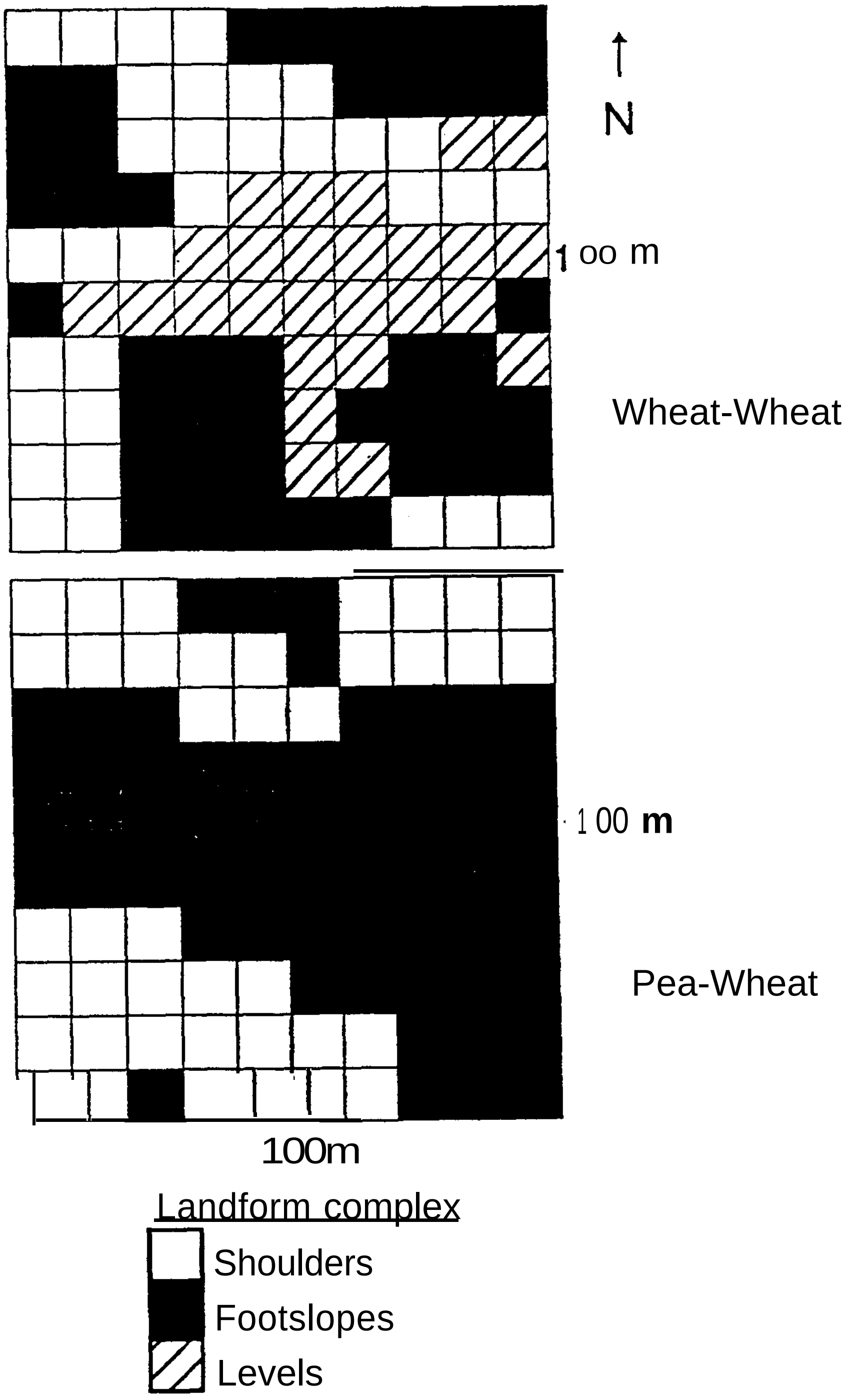

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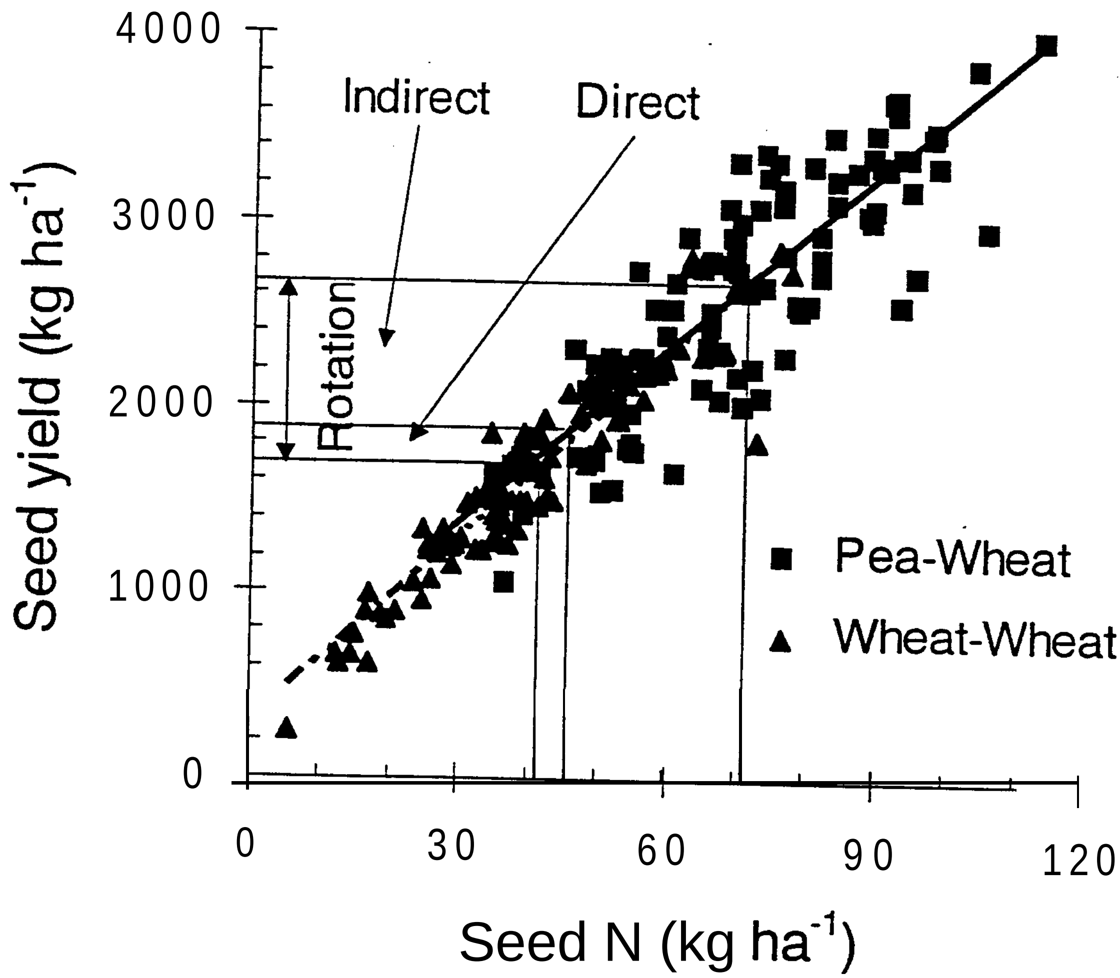

Fig. 2. Direct and indirect rotation benefits of pea-wheat vs. wheat-wheat rotation at Birch Hills, SK.