Landscape-scale variation in yield and N uptake of the second wheat crop in a lentil-wheat-wheat rotation

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Introduction

The benefits accrued from incorporating legumes in crop rotations include increased N availability to and uptake by the subsequent crops. The increased N availability may be due to indirect factors such as enhanced N mineralization and spared N in the preceding legume crop; or the direct N contribution from the decomposing leguminous residue (Karlen et al., 1994). These benefits have been observed even in the second or third subsequent non-leguminous crops (Ladd et al., 1983; Jensen, 1994). However, the degree of N availability decreases with time due to several factors affecting N cycling in the soil. At a landscape scale, N cycling and movement are controlled by water redistribution factors. Thus, N availability varies with slope position (Pennock et al., 1987), resulting in variation in grain yield and protein content across the landscape. Hence, the objective of this study was to determine landscape-scale variation in yield and N uptake of and N availability to the second wheat (Triticum aestivum L.) crop in a lentil (Lens culinaris Medikus) -wheat-wheat (LWW) rotation compared to a wheat-wheat-wheat (WWW) monocrop.

Materials and methods

A landscape-scale study was conducted at Dinsmore in the Dark Brown soil zone. The soils at the site are classified as Elstow-Weyburn loam - clay loam A 2-year fallow-wheat system had been followed at the site for many years. The field was summerfallowed the previous year - 1993.

In the spring of 1994, a 100 x 200 m area was separated into two 100 x 100 m areas, each with 100 10 x 10 m grid cells. These two areas were surveyed using a theodolite total station for subsequent digital elevation model and landform element derivation. This information was used to classify the landscape into the landform elements and complexes as described by Pennock et al. (1987, 1994). Lentil was seeded in one area and wheat in the other. In the lentil area 1 x 1 m microplots of lentil and wheat were established in each grid cell and fertilized with an 15N double-labeled 15NH415NO3 for the subsequent determination of N2 fixation by lentil (15N isotope dilution method). The labeled lentil residue was retained after harvest and applied back into new 1 m² microplots in the fall for the determination of lentil residue N in the subsequent years. The labeled residue was lightly incorporated in the
top 2-4 cm to avoid drift and loss of material over the winter and in the spring. Wheat was planted to both areas in 1995 and 1996. Thus, the lentil-wheat-wheat (L-W-W) and the wheat-wheat-wheat (W-W-W, crop rotations were established. Results for the first year and second year were reported in these proceedings (Mooleki et al., 1995; 1996). Although four landform complexes were classified, two of them (shoulder and upper level) which had shown similar effects on various crop variables in the first year were combined into one landform complex and simply designated “shoulder” as shown in Figure 1.

Various soil and plant variables were measured in the third year. These included; spring moisture and available soil N (O-60 cm), N derived from lentil residue (Ndfr) in the soil and the crop as well as grain yield and protein content.

Ten experimental units were selected in each complex within a rotation (Figure 1) and measurements taken subjected to a two-way ANOVA with rotation and landform complex as factors (Stevenson and van Kessel, 1996).

Results

Differences in gravimetric moisture content were observed between the two rotation systems (Figure 2). The shoulder complex in the WWW rotation had lower gravimetric moisture content than the footslope and lower level complexes. No differences in gravimetric moisture content were observed in the LWW rotation among landform complexes. The difference in spring moisture content was attributed to topographical differences rather than the imposed crop rotation.

Available soil N in the spring of 1996 was higher in the LWW rotation than in the WWW rotation (Figure 3) indicating that the N benefits obtained from incorporation of lentil
in the cropping system extended beyond the first subsequent crop. In the LWW rotation, the footslope landform complex had the highest available soil N whereas in the WWW rotation the lower level had the highest available soil N (Figure 3).

Available soil N derived from lentil residue (Ndfr) in early spring was higher on the footslope than on the shoulder and lower level (Table 1). No difference in Ndfr were observed between the shoulder and the lower level complexes. Wheat grain yield was higher on the lower level and footslope than on the shoulder in both the LWW and the WWW rotation (Figure 4). However, g-rain yield was higher in both the lower level and footslope complexes for the WWW rotation than for the LWW rotation. The shoulder complex on the LWW rotation had higher grain yield than the shoulder complex on the WWW rotation.

No difference in N yield (in straw and grain) was observed between the LWW and WWW rotations on either the footslope or the lower level complexes (Figure 5). Lower N yield was observed on the shoulder complexes of both rotations. N yield on the shoulder complex of the LWW rotation was higher than on the shoulder complex of the WWW rotation.
No difference in wheat grain protein was observed between the LWW and the WWW rotations on either the footslope or the lower level nor between the two landform complexes within each rotation (Figure 6). Wheat grain protein content on the shoulder in the LWW rotation was significantly lower than that on the footslope or lower level of the same rotation. Grain protein content on the shoulder of the WWW rotation was the lowest. No differences occurred in Ndfr in the grain, straw or total aboveground biomass of the second wheat crop (Table 1).

These results show that inclusion of lentil in the rotation enhanced N availability to the second wheat crop. However, significant variations in N availability were observed among landform complexes. The actual amount of Ndfr in the second wheat crop was small, indicating that the indirect factors associated with the inclusion of lentil (or legumes in general) in a rotation are more important in increasing N availability to subsequent crops than the direct contribution of N from aboveground residue. Among the indirect factors that could help increase N availability in a system that incorporates a leguminous crop is enhanced N mineralization and immobilization turnover which result from enhanced microbial activity. However, the effect of increased N availability on grain yield and protein content was low in the third year, allowing other factors (e.g., water redistribution) to dominate. Removing the

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<th>Available soil Ndfr in spring</th>
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<td></td>
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<td>1.1</td>
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<td>Lower level</td>
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advantage of water (as seen on the shoulder) results in higher grain yield and protein content of the second wheat crop in the LWW rotation than in the WWWW rotation.

Results of this study show, that although the amount of N fixed by lentils in semiarid regions such as southern Saskatchewan are small compared to other leguminous crops, the overall potential of increasing the N fertility of the soil and the subsequent reduction in N fertilizer application is high. Harris et al. (1994) showed that a larger soil microbial biomass existed in a cropping system incorporating a legume crop than in fertilizer-based system. This large soil microbial biomass is responsible for the greater soil-N supplying power of the legume-based system. In a long term study in the Brown soil zone of southern Saskatchewan, Campbell et al. (1992) found that lentil straw may supply 50% more N to the soil organic matter pool than well-fertilized wheat stubble. With time, this N slowly builds up and eventually enhances the net N mineralization. The topographic variations on N availability also show the potential for increased N losses in the lower areas, especially if blanket fertilizer rates are applied.

References


