Does Crop Residue N Influence Soil N Availability?

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Abstract

A landscape study was conducted near Biggar, Saskatchewan, to study the influence of crop residues on the availability of soil N in the second phase of crop rotations. In order to compare leguminous and cereal residues, chickpea (Cicer arierinum) and wheat (Triricum *aestivm)* residue were used. The results showed that plant N derived from soil (Ndfs), added nitrogen interaction (ANI) and N recovery from chickpea residue were higher than from wheat residue in footslopes, but not in the shoulders. Chickpea residue increased soil N availability and crop production, whereas wheat residue decreased crop production in the footslopes, but there was no difference between these two residues in the shoulders, indicating that the impact of crop residues was variable and dependent on landscape position.

Introduction

It has been observed that fertilizer N uptake efficiency measured by difference method is higher than that measured by ^{15}N uptake method, likely indicating that there is more organic nitrogen mineralized in fertilized plots. Bingeman et al. (1953) suggested that this phenomenon of enhanced N mineralization be referred to as 'priming effect'. Jenkinson et al. (1985) introduced the term 'added nitrogen interaction' (ANI) to describe any increase (positive ANI) or decrease (negative ANI) in the mineralization of native soil N following fertilizer application.

Nitrogen, released from residue decomposition, will be subject to such processes as denitrification, leaching and microbial immobilization. As a result, only part of the N released from residue decomposition is available to plants. It was found that ^{15}N recovery from labeled residues and N benefits of crop rotations were low (Bremer and van Kessel 1992; Stevenson 1996). The low ^{15}N recovery from labeled residue was hypothesized to be caused by the ANI, e.g., pool substitution. Thus, estimates of mineralized N from residue based on availability of N to subsequent crop may be low. The objective of this study was to investigate the influence of crop residues on the availability of soil N in a natural landscape. In order to compare leguminous and cereal residues, chickpea and wheat residue were used.

Materials and Methods

The study field was located in the Dark Brown soil zone near Biggar, Saskatchewan. The hummocky field was surveyed and stratified into different landform element complexes, i.e., shoulders and footslopes (Pennock et al., 1994). The field was divided into six 14-m by 200-m adjacent transects. Two crop rotations, i.e., chickpea-wheat and wheat-wheat, were established in 1996 and 1997, and randomly arranged among the six transects (i.e., each rotation with three transects).

Fourteen sampling points were established in each transect with a sampling distance of 14-m. Two treatments, i.e., control and labeled residue, were established in 1997 (the second phase of the rotations) at each sampling point.

Control treatment: After harvest in 1996, one 1.5 m by 1.5 m microplot was established at each sampling point, crop residue within the microplot was removed.

Labeled residue treatment: After seeding the chickpea and wheat in 1996, one unconfined 1-m^2 microplot was established and atom 10% $^{15}NH_4{}^{15}NO_3$ applied as a solution at a rate of 20 kg N ha^{-1} for residue labeling. After harvest in 1996, another 1-m^2 microplot was established at each sampling point, crop residue within the microplot was removed and ^{15}N labeled residue was applied inside the microplot.

At harvest in 1997, subsamples of wheat plants were taken from control and labeled residue microplots at each sampling point and total N and ^{15}N content were determined. Wheat yield of control and labeled residue treatment was also determined. Soil samples (0- 15 cm) were taken at each sampling point and microbial N and ^{15}N content were measured by the chloroform fumigation-extraction method (Voroney and Winter 1993).

N derived from soil (Ndfs) was calculated as follows:

Ndfs = (1 - %Ndfr) x N uptake, where Ndfr = N derived from labeled residue

ANI was calculated as follows:

ANI = Ndfs (labeled residue) – Ndfs (control) (Jenkinson et al., 1985)

Results and Discussion

There was no difference in Ndfs between residue and control treatment for chickpea residue in both shoulder and footslope positions (Table 1). Negative ANI value in the shoulders suggests that chickpea residue decreased soil N availability, although the impact of the residue was not statistically significant. The opposite was true on the footslope positions. Wheat residue increased soil N availability in the shoulders, but not in the footslopes. The ANI value was relatively low compared with Ndfs values, likely because pool substitution can only occur if labeled and unlabeled N occupy the same pool at the same time (Jenkinson et al., 1985). The labeled residue was applied to soil surface because minimum tillage was practiced in the study field; thus, strong pool substitution was unlikely. It has been reported that the decomposition of residue on the soil surface was slower than the residue incorporated into soil (Christensen, 1986); thus, only part of residue N was involved in the pool substitution.

There was no difference in Ndfs between chickpea and wheat residue in the shoulders (Table 2), however, Ndfs of chickpea residue was significant higher than that of wheat residue in the footslopes indicating that chickpea residue increased the availability of soil N in this landscape position. Similarly, there was no difference in AN1 between chickpea and wheat residue in the shoulders, but ANI of chickpea residue was significantly higher than wheat residue in the footslopes, probably due to greater immobilization of native soil inorganic N during the course of wheat residue decomposition. Consequently, N recovery from wheat residue was lower than from chickpea residue in the footslopes. There was no difference in N immobilized and residue N recovery between chickpea and wheat residue in the shoulders.

Table 1. Median values and results of Mann-Whitney U test of Ndfs and ANI in each landform element complex (unit: kg N ha-‘).

Treatment	Chickpea residue		Wheat residue	
z	Ndfs	ANI	Ndfs	ANI
Shoulder				
Residue	18.5a	-1.22	18.5a	2.27
Control	20.2a		15.6b	
Footsiope				
Residue	32.4a	1.80	21.4a	-0.82
Control	28.9a		23.8a	

Note: within the column in each landform element complex, median values followed by the same letter are not significantly different (a = 0.20).

Table 2. Comparison of chickpea and wheat residues: median values and results of Mann-Whitney U test of Ndfs, ANI, residue N immobilized and residue N recovery by wheat in each landform element complex.

	Ndfs	ANI	N immobilized	N recovery
	(kg N ha^{-1})			(%)
Shoulder				
Chickpea residue	18.5a	-1.22a	1.11a	2.22a
Wheat residue	18.5a	2.27a	1.13a	2.84a
Footslope				
Chickpea residue	32.4a	1.80a	0.84a	3.14a
Wheat residue	21.4b	-0.82b	1.68b	1.72b

Note: Within columns in each landform element complex, median values followed by the same letter are not significantly different (a = 0.20).

The AN1 was significantly correlated with crop production (seed plus straw yield, $P < 0.05$), residue N recovery ($P < 0.01$) and soil C/N ratio ($P < 0.10$). ANI (or pool substitution) is a biochemical process and connected to the N cycles in the soil, and influenced by residue quality and soil properties. The AN1 was not significantly correlated with residue C/N ratio

(P = 0.10) in this study probably because C/N ratio is not a good indicator of residue quality (Fox et al. 1990).

There was no yield difference between residue and control treatment in both rotations in the shoulder positions (Table 3). In the footslope positions, seed yield was unaffected by the applied residue in chickpea-wheat rotation, but a higher straw yield was achieved. This observation likely was due to higher Ndfs and positive AN1 (Table 1). On the other hand, there was no difference in wheat yields in the wheat-wheat rotation in the shoulders and no difference in straw yield in the footslopes, but the wheat seed yield was significantly lower in the labeled residue treatment than in the control treatment, probably due to more soil N immobilization during the course of wheat residue decomposition (negative ANI). The results presented here represent a single study year, however, the residue effect on soil N availability and crop production might be long-term, i.e., the residue will help build up soil organic matter pool (Ladd et al. 1981) and improve soil properties (Morachan et al., 1972).

Table 3. Comparison of wheat yield: median values and results of Mann-Whitney U test of wheat yield between labeled residue and control treatment in each landform element complex (unit: kg ha-‘).

Treatment	Chickpea-wheat		Wheat-wheat	
	Seed	Straw	Seed	Straw
	Shoulder			
Residue	749a	1033a	695a	985a
Control	728a	915a	676a	957a
	Footslope			
Residue	1113a	1640a	781a	1225a
Control	1024a	1381b	817b	1208a

Note: within the column in each landform element complex, median values followed by the same letter are not significantly different ($\alpha = 0.20$).

The difference in measured parameters between chickpea and wheat residue was found only in the footslope positions, indicating that the influence of residues on the soil N availability and crop production was largely controlled by soil properties and environmental conditions. Dryland farming requires adequate growing season precipitation and sufficient storage of soil water to ensure successful crop production (Hanna et al. 1982). De Jong and Rennie (1969) reported that inadequate growing season rainfall induced moisture stress in plants earlier on upper slopes than lower slopes. There was only 12 mm precipitation during 1997 growing season, and the daily average soil moisture content was consistently higher in footslopes than shoulders (data not shown), thus plants on shoulder positions suffered more from moisture stresses. Soil moisture plays an important role in plant growth, nutrient uptake, residue decomposition and nitrogen transformation processes. Schomberg et al. (1994) found that rate coefficients of residue decomposition increased linearly with water applied. The reason why Ndfs, ANI, residue N recovery and crop yield between chickpea and wheat residue were not different in the shoulders was probably due to the dryness of soil.

Summary

Chickpea and wheat residue influenced soil N availability and subsequent crop production. However, the differences in measured parameters between chickpea and wheat residue were found only in the footslope positions, indicating that residue and soil properties controlled soil N availability.

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