Soil Nitrogen Cycling Affected by Tillage and Crop Rotations

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Introduction

Crop residues, especially from cereal crops, have much higher carbon:nitrogen (C:N) ratios than optimal for the nutrition of soil microorganisms. Excessive amounts of available C in cereal residues result in microbial 'immobilization' of mineral N. Tillage management can influence nutrient availability (Martens, 2001). No-till is considered a sustainable practice in reducing soil erosion and organic matter degradation. Crop rotation is considered an effective practice to change residue C:N ratio and enhance N uptake of crops (Chen, 2014). This study investigated effects of different crop rotations and tillage practices on overwinter N release and winter wheat yields.

Methods

The experiment was conducted from 2004 to 2010 at the Central Agricultural Research Center. The soil is Judith clay loam, with shallow profile (~24 inches). The fields used were adjacent long-term no-till (LTNT, 15 years) and long-term sweep-tilled (LTST, >20 years) with the same crop and fertilization management history. The treatments included four crop rotations and four N rates with four replications. Crop rotations were fallow–winter wheat (F-WW), spring wheat–winter wheat (SW-WW), spring pea–winter wheat (SP-WW), and winter pea (for forage)-winter wheat (WP-WW). Wheat received 0, 40, 80, or120 lb N/acre but no N was applied to either pea or fallow.

"Fall" soil samples were taken mid-August to mid-September after crop harvest. Spring samples were taken in late April to early May before fertilization. Cores were divided into depth increments (0 to 6, 6 to 12, and 12 to 24 inches), air-dried, sieved (< 1 mm), and analyzed for nitrate-N (NO_3-N) concentrations. Winter wheat was harvested in August of 2006, 2008, and 2010.

Results

The yearly fall and spring NO_3-N for each crop rotation in the LTNT and LTST fields are given in Table 1. In the LTNT field, spring soil NO_3-N was greater than in the fall in all three rotation cycles for the SP-WW and WP-WW rotations, and two of the three F-WW rotations. An average 15 lb N/acre NO_3-N was released over the winter, likely from crop residues and soil organic matter decomposition. However, soil NO_3-N did not change much from fall to spring in the SW-WW rotation in any year. This is likely due to the slow decomposition of wheat residue which has a relatively high C:N ratio and, therefore, takes additional soil N for microorganism to decompose the residue. The NO_3-N in the LTST field followed a similar pattern as in the LTNT field, except the amounts of NO_3-N in the spring tended to be greater in LTST than in LTNT. Total NO_3-N in the spring tended to be less in SW-WW than in F-WW and WP-WW rotations in both LTNT and LTST. Spring soil NO_3-N in SP-WW was not consistently higher or lower than in the other rotations.

Lack of differences between fall and spring nitrate in 2009-10 are possibly a result of higher precipitation in 2009-10 (5.1 inches) than in 2005-06 (4.1 inches) and 2007-08 (3.5 inches), and possibly more related to precipitation timing than amount. Almost 3 of the 5.1 inches in 2009-10 fell in October, most likely as rain, compared to only about 1 inch in October in the other 2 years. This could have led to more leaching loss.

Winter wheat grain yields differed among rotations and N rates. Averaged over years and N rates, the F-WW and WP-WW rotations produced the most yields and the SW-WW rotation produced the least. Winter wheat yield in SP-WW was lower than in F-WW or WP-WW but greater than in SW-WW rotation (Figure 1).

The SW-WW produced the lowest yields

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Fertilizer Check-off

March 2014
Number 67

MONTANA STATE UNIVERSITY
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of all rotations at all N input levels and in both tilled and no-till fields. This was likely due to the continuous mono-cropping, perhaps causing root disease leading to a compromised root system. Introducing legumes, espeically winter pea forage, into winter wheat rotation greatly improved yield over wheat mono-cropping. The WP-WW rotation had similar yield to the F-WW rotation, which indicates that WP harvested for hay could release similar amount of N as summer fallow because the legume roots and nodules provided N after decomposition, while forage also produced revenue for the grower.

Lower yield in the LTNT field compared to LTST in this study indicates no-till may need different N management than sweep-till, such as increased N rates or possibly N placement below the surface. Bono and Alvarez (2013) reported that soil organic matter supplied 51 lb N/acre mineral N in tilled wheat fields, which was 44% higher than in no-tilled fields (35 lb N/acre), and mineralized N was about double for buried residues compared with residues left on the surface in a semiarid region.

Fertilizer Facts

- Considerable amount of NO_3-N (~15 lb N/acre) was released from the late summer/early fall to spring.
- SW-WW rotation released less NO_3-N over-fall and winter than F-WW, SP-WW, and WP-WW rotations.
- The WP-WW rotation had a similar wheat yield as the F-WW rotation.
- No-till appears to require more N input than sweep-till but can be offset by including pea in rotation.

Acknowledgment

We thank the Montana Fertilizer Advisory Committee for funding this research.

References

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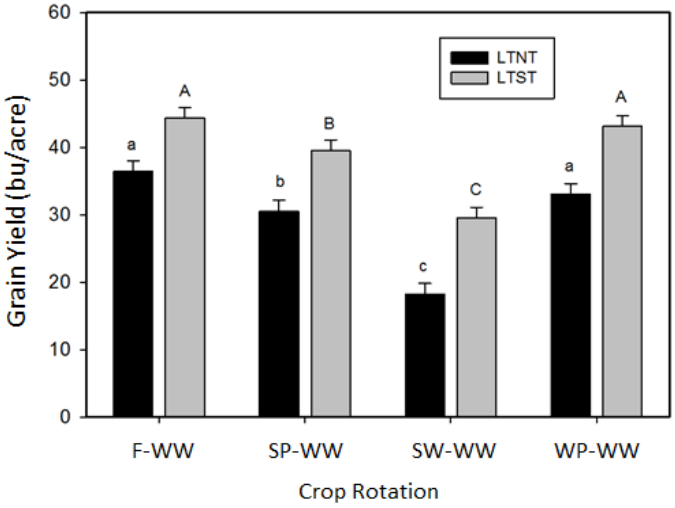

Figure 1. Winter wheat yield under different crop rotations in no-till (LTNT) and sweep-tilled (LTST) fields averaged over 2004, 2006 and 2010. Letters indicate 95% probability of differences among rotations within LTNT (lower case) or LTST (upper case).

Table 1. Soil NO_3-N (lb N/acre) in top 2 feet measured in the fall and spring and the difference at Moccasin, MT, under different crop rotations in a long-term no-till (LTNT) and sweep-tilled (LTST) field.

Tillage	Rotation	2005-2006			2007-2008			2009-2010		
		Fall	Spring	Diff	Fall	Spring	Diff	Fall	Spring	Diff
LTNT	F-WW	48.8	69.6	20.8*	31.4	43.7	12.3*	42.6	31.9	-10.6
	SP-WW	27.3	60.7	33.4*	8.4	23.8	15.4*	19.3	26.3	6.9
	SW-WW	34.1	34.4	0.3	4.8	9.0	4.2	27.4	21.8	-5.7
	WP-WW	28.7	63.4	34.7*	15.0	28.7	13.7*	31.3	42.8	11.5
LTST	F-WW	38.8	101.8	62.9*	25.8	52.8	27.0*	59.1	53.3	-5.7
	SP-WW	31.3	58.9	27.6*	8.4	27.3	18.8*	37.3	36.7	-0.6
	SW-WW	30.2	30.8	0.6	7.1	14.5	7.4	21.7	18.6	-3.1
	WP-WW	44.0	92.9	48.9*	13.1	36.3	23.2*	77.8	56.9	-20.9

* significant difference between the late summer/early fall and spring soil NO_3-N with 95% confidence

Edited by Clain Jones, Extension Soil Fertility Specialist, and Kathrin Olson-Rutz, Research Associate