THE EFFECT OF TILLAGE ON SPRING WHEAT N RESPONSE

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ABSTRACT

For economic and environmental benefits, more and more producers have adopted no-till practices in Montana, but the nitrogen (N) recommendations for various no-till crop rotation systems have not been well established. The objectives of this study were: 1) to investigate the effects of tillage, number of years of tillage, previous crop, and N input on winter wheat yield, and 2) determine the fertilizer-N needs and establish fertilizer recommendations for Montana growers to produce optimum winter wheat yield under various tillage and crop rotations. This report summarizes the first phase of the rotation study. Spring wheat was planted in the fields that have been in 1) long-term no-till, 2) one-year no-till, 3) long-term conventional tillage, and 4) newly transitioned to conventional tillage. Four levels of N fertilizer at 0, 45, 90, and 134 kg N ha^{-1} were applied. Spring wheat yield responded differently to N fertilizer under different tillage treatments. Conventional tillage reached a yield plateau at lower N level than no-till. Yield and harvest index declined at higher N levels due to summer drought. Residual NO_3 ranged from 20-40 kg N ha^{-1} at lower N levels (0 and 45 kg N ha^{-1}) to 58 to 82 kg N ha^{-1} at higher N level (134 kg N ha^{-1}).

INTRODUCTION

Adoption of no-till cropping systems offers a practical means of preserving soil productivity and reducing the cost for crop production (due to less fuel consumption for tillage). Benefits of no-till systems also include increased amounts of crop residue remaining after harvest to protect surface soil from erosion and increased water infiltration (Papendick and Miller, 1977), increased snow trapping and moisture conservation, reduced wind speeds and evaporative demand for water, and altered microclimate for improved water use efficiency during the growing season (Cutforth and McConkey, 1997; Cutforth et al., 2002). However, no-till systems may require higher rates of N fertilizer to maintain yield potential due to N sequestration in crop residue and surface soil. Nitrogen fertilizer needs are determined by crop response to N, available water, and expected yield.

Pea and lentil are leguminous crops which are able to fix N biologically from the atmosphere making it available to the legumes. Therefore, growing pea and lentil in rotation with cereal crops can reduce N fertilizer inputs. In addition, N released in association with legume residues can be used by the subsequent cereal crops (Badaruddin and Meyer, 1994; Walley et al., 2005). Rotating legumes with cereals also provides biological interruption of pest cycles established in continuous cereal crops (Derksen et al., 2002; Krupinsky et al., 2002); therefore, enhancing the subsequent cereal crop yield.

Nitrogen recommendations likely need to be adjusted based on the cropping system with different tillage systems and rotations. For example, the N recommendation should be different between summer fallow and continuing cropping systems, type of rotation and the previous crop.

The number of years of no-till likely also affects the organic matter content, which will affect the N mineralization, availability, and fertilizer input. Short term no-till can increase the amount of fertilizer N need to achieve optimal yields. Bronson et al. (2001) reported that 19 to 38 kg ha^{-1} additional N was needed with conservation tillage than with conventional tillage practices. Howard et al. (2001), however, found different responses of N in different types of soils with no-till. Therefore, there is a demand for information regarding the management of no-till systems in the Great Plains. Because of the interactions of tillage, previous crop, rotation, and duration of no-till, fertilizer recommendations for Montana soils published earlier may need to be re-examined and modified. The objectives of this study were: 1) to investigate the effects of tillage, number of years of tillage, rotation, previous crop, and N input on winter wheat yield; and 2) to determine the fertilizer-N needs and establish fertilizer recommendations for Montana growers to produce optimum winter wheat yield under various tillage and crop rotations.

MATERIALS AND METHODS

The study was conducted at the Central Agricultural Research Center, Moccasin, MT. The experiment was carried out in a field that has been split into till and no-till since 1996. The study was designed to have four tillage treatments, four crop rotations, and four nitrogen levels. The four tillage treatments were 1) no-till since 1996 (NTNT); 2) no-till since 2005 (CTNT); 3) conventional sweep tillage since 1996 (CTCT); 4) conventional sweep tillage since 2005 after nine years no-till (NTCT). The four crop rotations were 1) fallow–winter wheat (F–WW); 2) spring wheat–winter wheat (SW–WW); 3) spring pea (seed)–winter wheat (SP(s) –WW); 4) winter pea (hay)–winter wheat (WP(h)–WW). The four nitrogen levels were 1) 0 kg N ha^{-1}; 2) 45 kg N ha^{-1}; 3) 90 kg N ha^{-1}; and 4) 134 kg N ha^{-1}.

The experimental design was a split-split-plot design with four replicates. The tillage treatments were main plots, and rotation was split-plots with N treatments randomized within each rotation treatment. The sampling and measurements for each plot included:

1) *Soil NO_3 and potentially mineralizable N (PMN)* Soil samples were taken before planting and after harvest of spring wheat to determine background and residual NO_3, and PMN changes.

2) *Yield and harvest index (HI)* After harvesting the spring wheat, yield and HI were determined. HI was determined by dividing the grain yield by the total biomass.

Analysis of variance (ANOVA) was performed for spring wheat yield and HI, and residual N affected by tillage and N fertilizer using SYSTAT 10.2 (SYSTAT Software Inc, Richmond, CA) for a split-plot model.

RESULTS AND DISCUSSION

Soil Background Analysis

There was no significant difference in soil organic matter content and potentially mineralizable N in the top 30 cm of soil after nine years no-till compared to sweep tillage. Sweep tillage undercut the soil at 15 cm depth and had relatively low disturbance.

Table 1. Soil organic matter (O.M.) and potentially mineralizable N (PMN) at 0-15 cm depth. The same letter in a column indicates no significant difference between treatments (P=0.05).

Treatment	O.M. (%)	PMN (kg N ha^{-1}) April 2005	PMN (kg N ha^{-1}) August 2005
NTNT	3.10 ± 0.09a	56.0 ± 9.5a	46.7 ± 8.5a
CTNT	3.07 ± 0.09a	52.0 ± 9.5a	51.6 ± 8.5a
CTCT	3.18 ± 0.09a	49.8 ± 9.5a	41.3 ± 8.5a
NTCT	2.89 ± 0.09a	54.5 ± 9.5a	42.6 ± 8.5a

Spring Wheat Yield and Harvest Index

Results of ANOVA showed that tillage did not affect spring wheat yield and HI in 2005, but spring wheat yield was affected by N fertilizer levels (Table 2). Although the effect of tillage x N-level interactions was not significant, wheat grain yield response to N slightly differed between tillage treatments. Conventional tillage reached a yield plateau at lower N levels than no-till (Fig. 1), which indicates that no-till may conserve more water and require more N fertilizer to reach the yield plateau, or that more fertilizer N is immobilized in NT due to high surface residue. Yield declined at higher N levels because of terminal drought. The yield reduction caused by water stress can be explained by the harvest index. When too much N was applied, the wheat crop produced a larger vegetative biomass at early growth stages, but then soil water was depleted and less grain was produced, resulting in a decreased HI (Fig. 2). The NTNT and NTCT treatments appeared to have higher HI than CTCT and CTNT at 90 kg ha^{-1} N level, but the cause for this difference is not clear before further analysis is completed.

Residual NO_3 in 60 cm Soil Profiles

Due to summer drought, soil moisture decreased and spring wheat did not take up all the N applied nor convert the N into yield at the higher N levels. Residual N was 20-40 kg ha^{-1} at the 0 and 45 kg N ha^{-1} levels, which is equivalent to the background level tested in April 2005 (data not shown). The residual N was 30-60 kg N ha^{-1}, and 58-82 at the 90 and 134 kg N ha^{-1} levels, respectively. The amount of residual N was similar in NTNT and NTCT treatments, and was less than in the CTCT and CTNT treatments. The CTNT treatment seemed to have the greatest amount of residual N in the profile (Fig. 3); several samples that had extremely high levels of residual N are waiting for a confirmation from the chemical laboratory. The cause for the differences in residual NO_3 under different tillage treatments are not clear, but the mass balance for N uptake by spring wheat will be calculated after we receive the N content data for plant tissue from a chemical laboratory. This paper only reports the preliminary data for the first phase of study. Further results will be presented in the future.

Table 2. ANOVA table for spring wheat yield, harvest index (HI), and residual NO_3 in 60 cm soil profile as affected by tillage and fertilizer N.

Source	Yield	HI	Soil NO_3
Block	7.6E+03§	6.7E-04	7.2E+02
Tillage (A)	*P>0.25*† *(3,9)*‡	*P>0.10 (3,9)*	*P<0.05 (3,9)*
	5.4E+04	3.3E-04	1.6E+03
Error A (Block*A)	6.6E+04	2.2E-04	3.4E+02
N level (B)	*P<0.01 (3,9)*	*P<0.05 (3,9)*	*P<0.05 (3,9)*
	8.2E+05	1.3E-03	6.0E+03
Error B (Block*B)	2.2E+04	2.2E-04	9.9E+02
Tillage*N level (A*B)	*P>0.10 (9,27)*	*P>0.10 (9,27)*	*P>0.10 (9,27)*
	3.2E+04	2.2E-04	2.5E+02
Error AB (Block*A*B)	3.4E+04	1.9E-04	4.1E+02

Data in each column represent: §mean-square from the ANOVA, †significant level, and ‡degree of freedom for F-test.

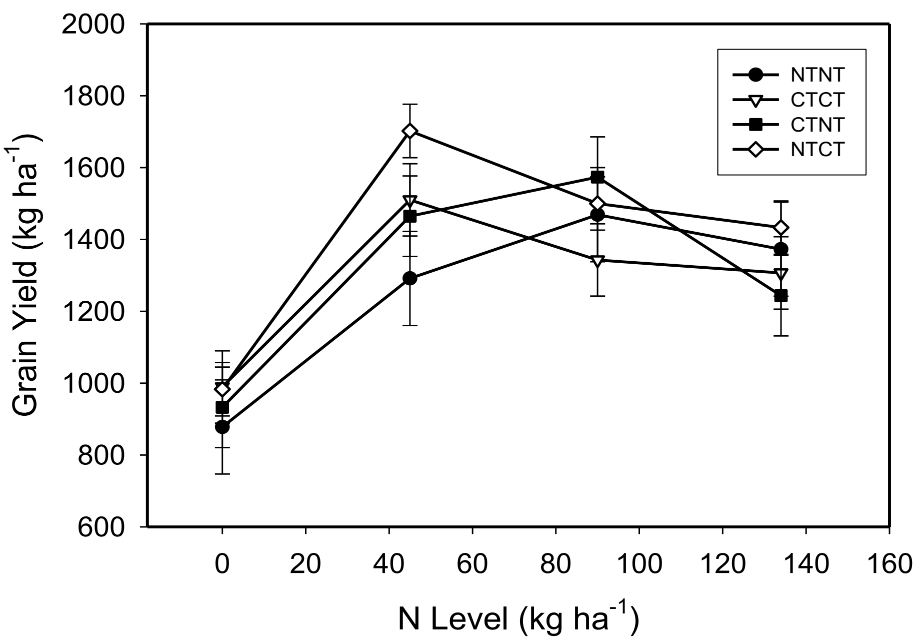

Fig. 1. Spring wheat grain yield response to nitrogen fertilizer under different tillage treatments. The error bars in the graph represent ±1.0 standard error.

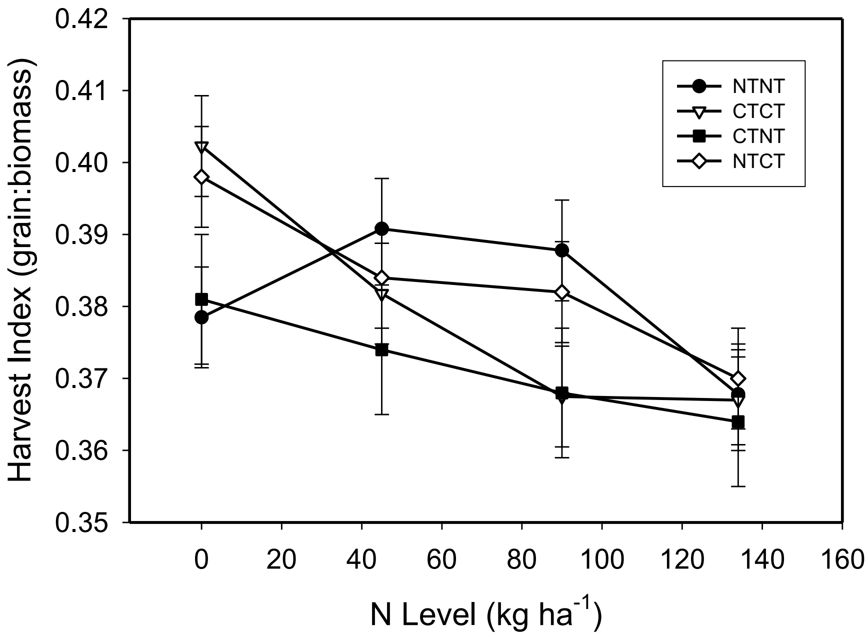

Fig. 2. Spring wheat harvest index response to nitrogen fertilizer under different tillage treatments. The error bars in the graph represent ±1.0 standard error.

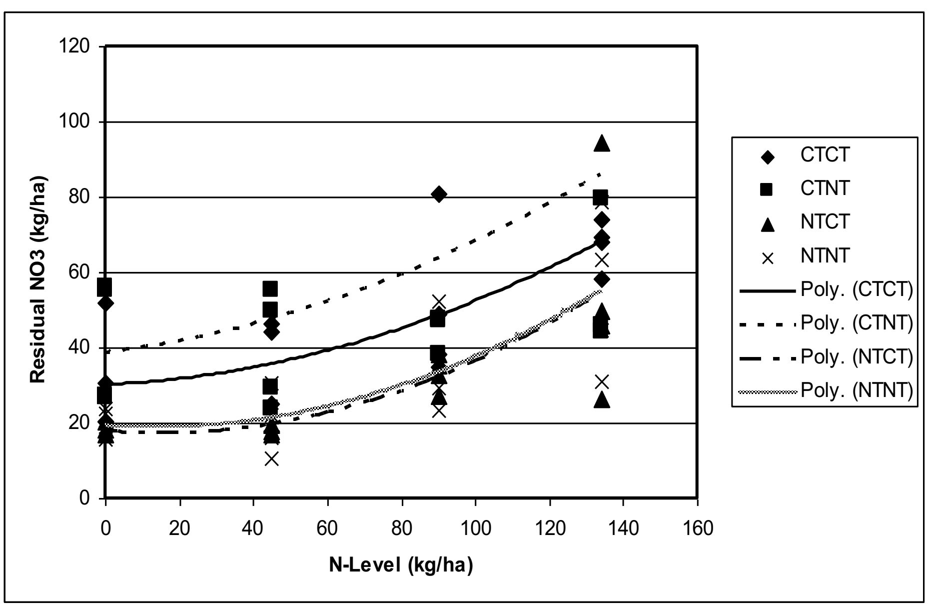

Fig. 3. Residual NO_3-N in 60 cm soil profile after harvesting spring wheat. The lines in the graphs are the best-fit curves using polynomial function (Poly.) for each of the tillage treatments.

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