Soil Drainage, Tillage, And Crop Residue Management Impacts On Corn N Use Efficiency And Soil Health

FINAL REPORT 2022 Growing Season

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Background

A research site with 720 (10 by 30-foot) plots was established in 2011 to evaluate the effect of soil drainage [drained (tiled) and undrained (no tile)] conditions on soybean yield in a poorly-drained soils in south-central Minnesota in a corn-soybean cropping system. Starting in 2014, the effect of nitrogen rate and time of application on both corn and soybean was added as a variable. In 2017, tillage variables (conventional, strip-till, no-till) were added. More recently, in fall 2021 we added crop residue management variables [corn residue removed, cover crop planted in the fall/terminated in spring, traditional (residue left on the field)]. While both crops are present every year, this study evaluates N availability and corn response to N rates under the drainage, tillage, and crop residue variables described. We know all these variables impact soil health (soil carbon and total soil N) and can impact how much N is available to produce corn because they directly impact mineralization/immobilization and N loss (leaching and denitrification). However, little or no information is currently available in the Midwest to adjust N fertilization rates based on these conditions. Over the duration of this study, the variables established will allow us to evaluate corn N use efficiency and soil health.

Goals and Objectives

Some of the previous findings obtained from this research site clearly showed that corn yields are similar with drained and undrained conditions but the N rate needed in undrained conditions is greater to achieve the economic optimum regardless of tillage conditions. We have also observed that pre-plant applications work as good as or better than split applications in drained soils, but split applications are often superior for undrained soils. We have also evaluated soybean yield and grain quality in response to drainage and tillage and with regard to direct N application or residual N from the previous corn crop. Based on what we have learned from previous studies in this site, under long-term drainage conditions (established in 2011) and tillage conditions (since 2017) we are now ready to evaluate new concepts to refine N management and quantify their influence on soil health parameters for Minnesota farmers.

The objectives of this study are to evaluate the effect of N rate and crop residue management [corn residue removed, cover crop planted in the fall/terminated in spring, traditional (residue left on the field)] on 1) soil N availability for corn, and 2) corn grain yield and nitrogen use efficiency. Our goal is to refine N management accounting for soil conditions (drainage) and management practices (tillage and crop residue) normally encountered in Minnesota to improve N use efficiency, economic returns, environmental protection, and soil health and productivity.

Methods/Timetables

The study was conducted in a long-term research site established on a farmer's field near Wells in south-central Minnesota. Drainage conditions were established in 2011 with every plot having subsurface tile drains installed. The site was divided into eight blocks where four blocks were randomly assigned to be drained (control drainage structures fully open) and four were randomly assigned to be undrained (control drainage structures completely closed). Each of these blocks was subdivided to accommodate both corn and soybean crops that rotate every year. In 2017, three tillage treatments were imposed: 1) conventional, 2) strip-till, and 3) no-till. Starting in fall 2021 three levels of residue management were added where soil cover from plant materials increased in the order (1<2<3): 1) corn residue removed, 2) traditional (residue left on the field), and 3 cover crop planted in the fall and terminated in spring). Within each of these levels there are five 10x30 ft plots that receive 0, 130, or 260 lbs N/ac during the corn phase and the following year during the soybean phase they receive no nitrogen. The remaining two plots receive 130 lb N/ac during the corn phase and the following year during the soybean phase we are evaluating soybean seed treatment and plant population variables. Thus, the study has 360 10x30 foot plots in corn (2 drainage x 3 tillage x 3 residue management x 5 N rates x 4 replications= 360) and 360 plots in soybean for a total of 720 plots. The N rates in corn were selected to establish soil N supply (0N) and calculate N use efficiency for the 130N [near the economic optimum N rate (EONR)] and 2x the EONR (260N).

This report will only focus on the corn plots and will not discuss in detail the findings from the soybean crop or the data related to soil health, as those are objectives for a different research project. However, because all the treatments are followed by soybean and their residual effect will be measured in the corn plots we discuss the overall site management.

In the fall after harvest, tillage and residue management treatments were established. In the spring, the plots with cover crop were chemically terminated on May 18, 2022. Corn was planted on May 24, 2022 and N rate treatments were applied before emergence on May 31, 2022 as a broadcast application of Agrotain.

At physiological maturity (R6 development stage) corn plants were collected and partitioned into cobs and the rest of the plant. Dry biomass was calculated for each sample. The vegetative tissues were ground and analyzed for total N content. Plots were harvested on October 4, 2022 and grain yields was calculated. A grain subsample was ground and analyzed for total N content. After harvest, on October 20, 2022 soil samples were collected from the corn plots in 1-ft increment down to 3-ft.

Soil fertility (other than N rates) and agronomic practices followed University of Minnesota guidelines to optimize agronomic productivity.

Data were statistically analyzed and this report will present the preliminary results for the year of the report.

Results and Discussion

During the 2022 growing season precipitation amounts in April were adequate, which was important to reduce the water deficit created by the droughty conditions in 2021 (Table 1). However, most of the growing season (May-July) was drier and hotter than normal. Because of these conditions, corn grain yields were limited by water in addition to the variables designed for testing in this study. Thus, results from this year should be viewed in light of the weather limitations.

While a significant four-way interaction is the most important to explain results, it is often easier to discuss lower level interactions or main effects before explaining the more complicated interaction (Table 2). Corn grain yield was affected by tillage, cover crop/residue management and nitrogen rate (Table 2). Drainage had no effect on corn response and the average yield average across variables was

170 bu/ac for drained and 167 bu/ac for undrained conditions. The same was true in N removal in grain (Table 3). Tillage had a significant effect on corn yield, which decreased as the amount of tillage decreased from conventional tillage (180 bu/ac) to strip-tillage (165 bu/ac) to no-till that had the lowest yield of 160 bu/ac (Fig. 1). Removal of nitrogen in grain followed a similar pattern, though only the conventional tillage system removed greater amount than the other two tillage systems. Similar to tillage (since greater tillage results in lower crop residue on the surface), corn yield decreased as residue cover increased (Figure 2). The highest yield was obtained for the variable where crop residue was removed (177 bu/ac), second for the variable where the residue was left in the field (traditional practice) (168 bu/ac), and the lowest yield (160 bu/ac) was for the variable with the most soil cover (crop residue left in the field plus rye cover crop). However, there were no differences due to this variable in nitrogen removal in the grain (Table 3). Corn yield was also impacted by nitrogen rate, where yield increased from 133 to 190 bu/ac from the 0N check to the highest nitrogen rate of 260 lbs N/ac (Fig. 3). A similar pattern was observed in response to nitrogen rate in grain nitrogen removal (Table 3).

As mentioned, 4-way interactions are often difficult to explain fully. In addition to capturing what was already discussed for the main effects, the 4-way interaction helps us understand how these main effects interact with each other (Table 2). In the drained system as soil cover decreased, grain yield increased regardless of N rates in conventional and strip-tillage (Fig. 4). In no-till there was also an increase in yield with less soil cover, but only when the residue was removed in the 130 and 260 rates. In the drained system the 0N check in no-till had the highest yield when the crop residue was left on the field. The same was observed for the 0N check in conventional and strip-tillage under the undrained soil conditions. Under undrained conditions when N was applied (130 and 260N rates), in general corn grain yield increased with less soil cover regardless of tillage variable except for the 260N rate in conventional tillage where there was no difference due to soil cover management.

Table 1. Monthly cumulative precipitation and monthly mean air temperature for the 30-yr normal, the 2022 growing season and calculated departure from the normal for the 2022 season.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
							Inch						
Normal	0.7	0.7	1.6	3.4	4.5	5.6	4.9	4.2	3.8	2.7	1.4	1.1	34.6
2022	0.8	0.3	1.7	4.7	4.1	1.7	3.4	5.9	1.4	0.3	1.2	1.6	27.0
Departure	0.1	-0.4	0.1	1.3	-0.4	-3.9	-1.5	1.6	-2.3	-2.4	-0.2	0.5	-7.6
							°F						
Normal	14.3	18.5	31.7	45.5	58.2	68.5	72.3	69.6	62.5	48.8	34.0	20.8	45.4
2022	8.8	12.3	32.1	39.6	59.7	70.5	73.0	70.0	63.1	48.4	34.2	17.0	44.1
Departure	-5.5	-6.2	0.4	-5.9	1.5	2.0	0.7	0.4	0.6	-0.4	0.2	-3.8	-1.3

Normal precipitation is for 1990 to 2019, temperature is for 1993 to 2019 as there is no earlier record. The weather information was collected from Wells MN. https://www.dnr.state.mn.us/

Table 2. Statistical analysis of main (fixed effects) and their interactions and probability level for corn grain yield.

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Drainage (D)	1	159	1.67	0.1979
Tillage (T)	2	159	31.82	**<.0001**
Cover/Residue (C)	2	159	19.98	**<.0001**
N Rate (R)	2	159	260.49	**<.0001**
D*T	2	159	1.37	0.2578
D*T	2	159	0.26	0.7736
D*R	2	159	0.95	0.3889
T*C	4	159	0.37	0.8268
T*R	4	159	0.33	0.8547
C*R	4	159	1.54	0.1918
D*T*C	4	159	1.29	0.2757
D*T*R	4	159	0.81	0.5178
D*C*R	4	159	0.65	0.6305
T*C*R	8	159	0.83	0.5802
D*T*C*R	8	159	2.08	**0.0411**

Table 3. Removal of nitrogen in corn grain in response to main variables.

Main Variable	Grain N (lb N/ac)
Drained	113a
Undrained	111a
Conventional tillage	123a
No-tillage	105b
Strip-tillage	108b
Cover crop	112a
Residue removal	113a
No residue removal	111a
0 N	77c
130 N	119b
260 N	126a

Within main variable, means followed by the same letter are not significantly different at p=0.05.

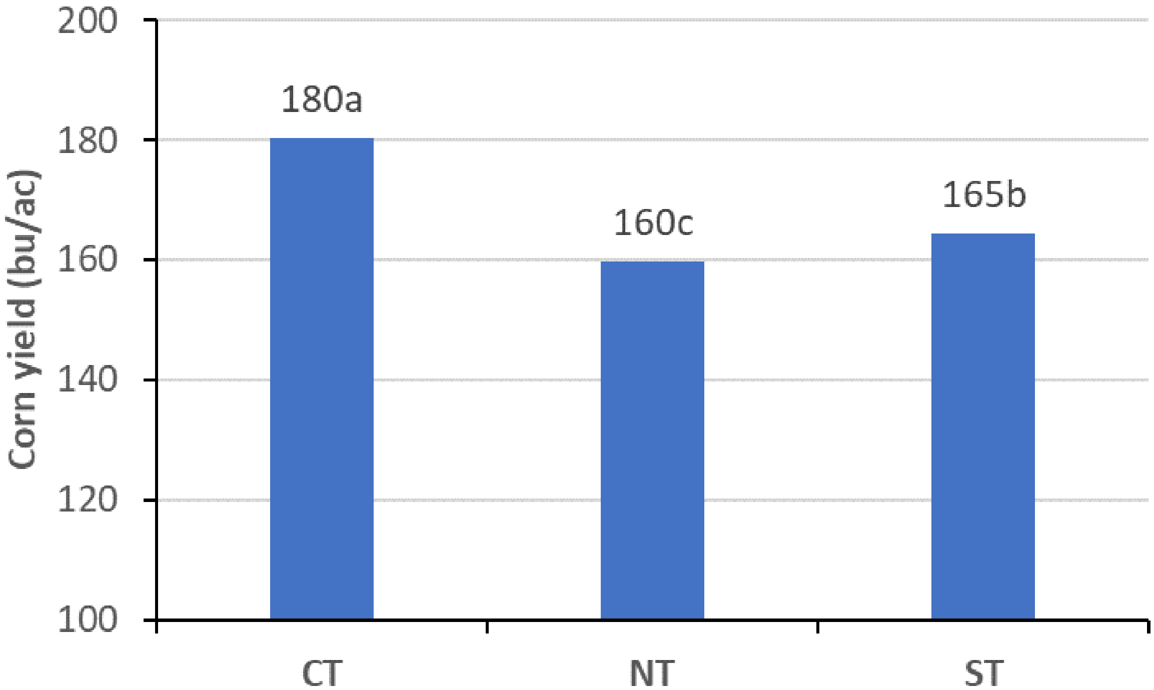

Figure 1. Corn grain response to tillage variable: conventional (CT), no-till (NT), and strip-till (ST). Means followed by same latter are not significantly different at p=0.05.

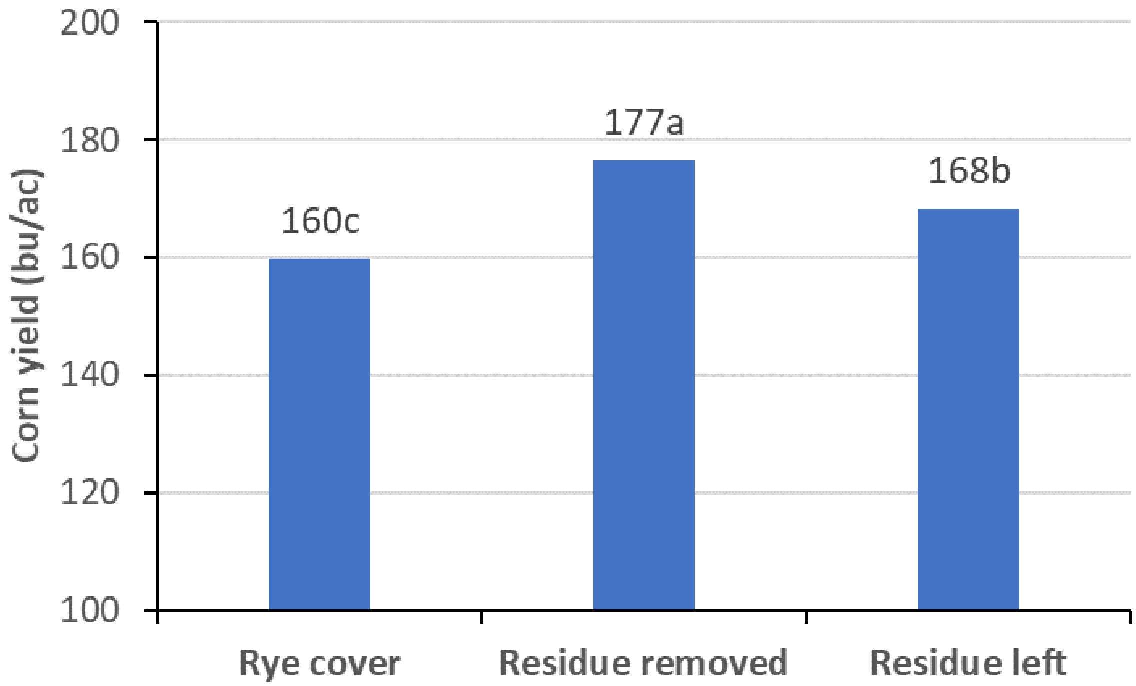

Figure 2. Corn grain response to residue management. Means followed by same latter are not significantly different at p=0.05.

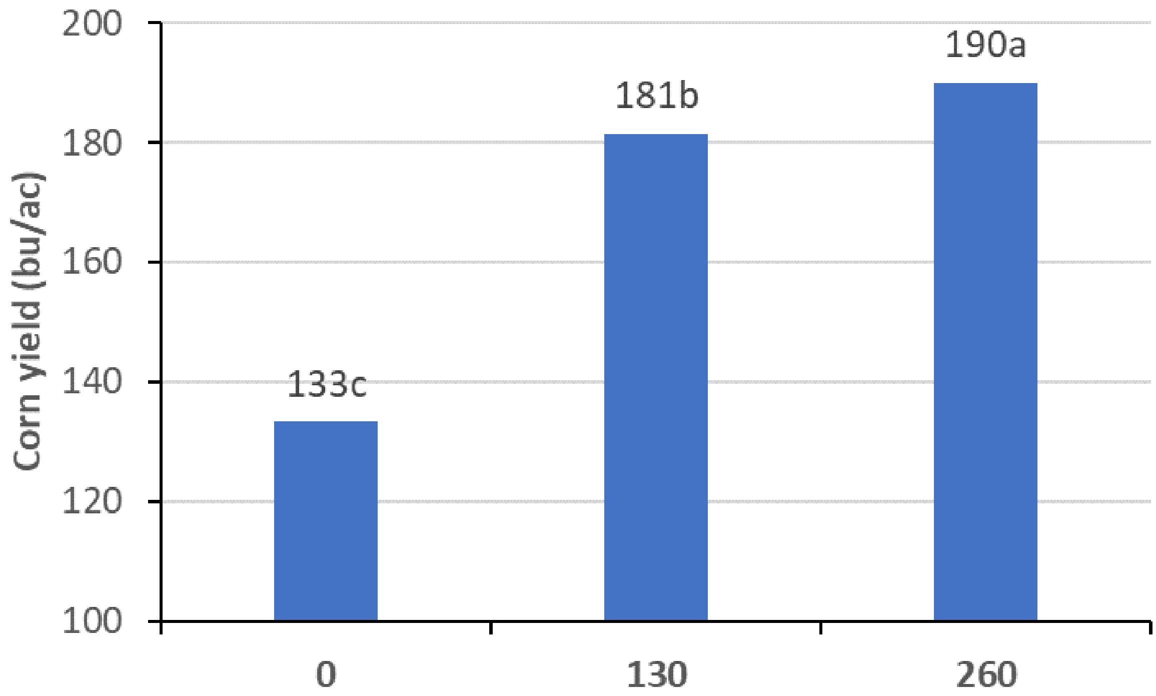

Figure 3. Corn grain response to nitrogen rate (lbs N/ac). Means followed by same latter are not significantly different at p=0.05.

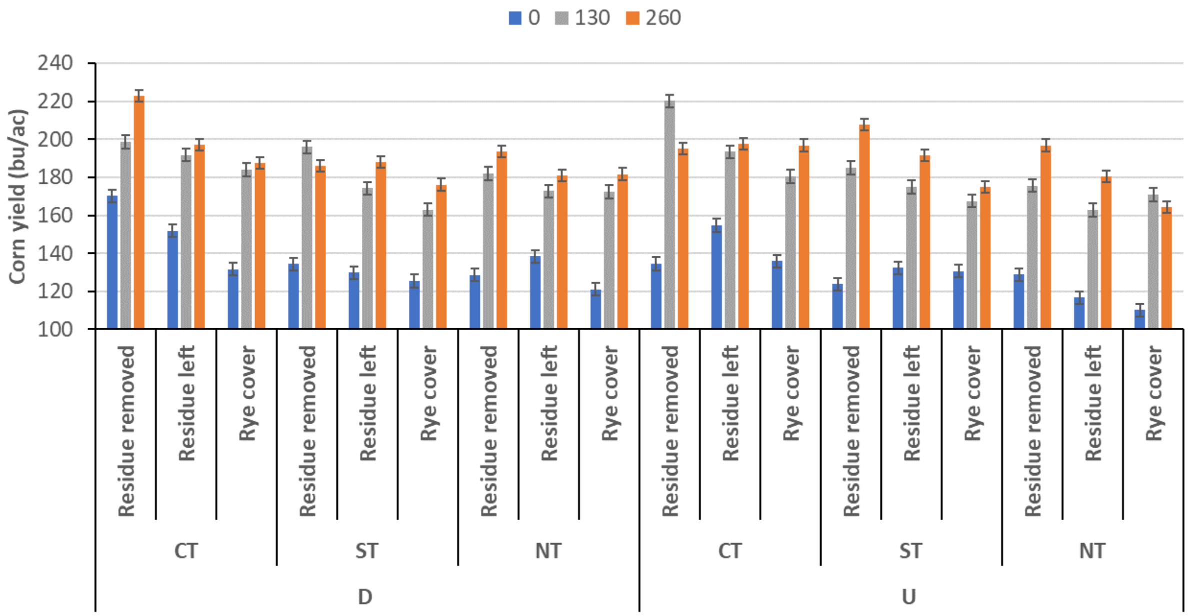

Figure 4. Corn grain response exploring the significant 4-way interaction. Error bars represent standard error of the mean.