CORN RESIDUE HARVESTING EFFECTS ON YIELD RESPONSE TO N FERTILIZATION

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Introduction

Producers have many choices of diverse tillage practices for their corn (*Zea mays* L.) production systems. However, no-till has become an important soil management practice to help reduce water and wind erosion, as well as nutrient runoff, while conserving soil moisture for crop use. No-till systems also help farmers by saving labor and time, as well as reducing farm costs due to less equipment and fuel consumption. Nevertheless, no-till production is typically more successful and has higher crop yield on moderately to well drained medium-textured soils (Bitzer, 1998), compared to soils with poor internal drainage and high clay.

The increased use of corn biomass for livestock feed, bedding, or a bioenergy resource is an ongoing issue in the Midwest U.S. The removal of corn residue from fields reduces the amount of plant material remaining for soil surface protection, reduces carbon return to soil and potential soil organic matter, and alters the cycling of plant nutrients. This could potentially affect nutrient availability for crop use. Therefore, it is necessary to evaluate the short and long-term impacts of corn residue removal and residue return on soil properties and nutrient supply to crops. Concerns about nitrate (NO_3^--N) loss in drainage water as the major contributor of N loading to the Gulf of Mexico has also led to increasing efforts for alternative management practices to reduce NO_3^--N loss from corn fields in the Midwest U.S. Mehdi *et al.* (1999) discussed the importance of identifying tillage practices which maximize corn N uptake and the associated need to determine N fertilization recommendations tailored to those systems that minimize N loss. A similar need is required for systems where corn residue is harvested.

Compared to tillage, no-till may result in lower yield but not necessarily change response to N management practices (Vetsch and Randall, 2004). Also, corn residue removal can change yield response to tillage system, and optimal N fertilizer requirements (Coulter and Nafziger, 2008). The agronomic and environmental impacts of tillage and corn residue removal practices are still in debate. Effective N management needs to enhance N fertilizer efficiency without resulting in yield reductions due to inadequate N (Andraski and Bundy, 2008). The determination of optimal N fertilization rates for achieving optimal yields is difficult due to the complexity of N cycling, which can be altered with different soil tillage and cropping practices, such as grain or combination grain-residue biomass removal. The objectives of this study are to evaluate tillage system, corn residue removal rate, and N fertilizer rate on corn yield response and N fertilization requirement in continuous corn.

Materials and Methods

Field sites were established in the fall of 2008 at two Iowa State University research and demonstration farms representing contrasting regions, soils and drainage class, and climatic conditions. One site is located in central Iowa at the Agricultural Engineering and Agronomy Research Farms, Boone (Canisteo silty clay loam), with the soil having naturally poor drainage. The other site is located in southwest Iowa at the Armstrong Memorial Research and Demonstration Farm, Lewis (Marshall silty clay loam), with the soil being naturally well drained. The experimental design is a randomized complete block with three replicates, with the main plot tillage system (no-till and fall chisel plow with spring field cultivation), split plot corn residue removal rate (0, 50, and 100%), and split-split plot N fertilization rate (0 to 250 lb N/acre, in 50 lb increments) as early sidedress coulter-injected urea-ammonium nitrate (UAN) solution. Corn residue was removed by raking and bailing. Fig. 1 shows an example of the soil surface with the different tillage and residue removal levels.

In the fall of 2008, post-harvest profile soil samples (0-1, 1-2, and 2-3 ft) were collected to determine initial soil NO_3^--N. After establishment of the study sites, soil has been sampled in the spring (preplant) and early June in corn plots not receiving N fertilizer (0-1 and 0-2 ft), and post-harvest in the 0, 150, and 250 lb N/acre rates (0-1, 1-2, and 2-3 ft) to determine profile NO_3^--N. A Crop Circle ACS-210 (Holland Scientific, Lincoln NE) active canopy sensor was used to estimate the normalized difference vegetative index (NDVI) at the mid-vegetative (V10) corn growth stage. This index indicates corn canopy biomass and potential N stress. Corn grain yields were determined by harvest with a plot combine. Corn economic optimum N rate (EONR) and corn grain yield at EONR (YEONR) were determined at a 0.10 $/lb N:$/bu price ratio from regression models fitted to corn yield response to N rate.

Results and Discussion

2008 Initial Soil Nitrate

Initial soil profile NO_3^--N concentrations across sites and depths were low (< 5 ppm) (data not shown). This indicates little residual NO_3^--N and no clear trend by depth at each site. These samples were collected before any N treatment was applied, and therefore reflect background levels from the previous corn production.

Soil Nitrate

Across sites and years, tillage and residue removal did not affect soil profile NO_3^--N in the spring. A NO_3^--N concentration difference was measured between spring preplant and early June (Table 1), however, the difference was very small and could be an indication of low net mineralization or corn N uptake. All spring NO_3^--N concentrations were quite low (≤ 3 ppm). No fertilizer was applied to these plots, and the sites had above normal precipitation.

Post-harvest soil samples collected in the fall of 2009 and 2010 did not show an effect of tillage system or residue removal rate on soil profile NO_3^--N concentrations (Fig. 2). This is a similar result as for the spring sampling. Soil NO_3^--N concentrations were low each year and at each depth. The concentrations decreased with depth, and were only increased with the highest N rate in 2009 (250 lb N/acre). These low residual NO_3^--N concentrations would be a result of the wet conditions each year, and the corn yield response to high N rates (described later).

Corn Response to Nitrogen Application

Canopy NDVI values indicated N stress with no and low N rates each year, and also indicated the plant biomass increase and reduction in N stress with increasing N rate (Fig. 1). In each year, corn had higher NDVI values at the V10 growth stage when residue was removed, with similar response for both tillage systems. This residue removal effect was greatest in 2010. In addition, NDVI was intermediate with 50% removal in 2010 and 2011, but not different than with 100% removal in 2009. The N rate where the NDVI values plateaued was lower with residue removal (data not presented, but shown in Fig. 3). These results indicate increased plant biomass and lower N rate stress with full or partial corn residue removal, and is likely a reflection of changes in soil conditions with residue removal that influence early season crop growth; such as differences in N fertilizer availability, soil temperature, and soil N mineralization and immobilization associated with decomposition of high C:N ratio corn stover.

Corn grain yield increased with N application at each site each year, and yields were greater in 2009 than 2010. At the time of this report, corn yields were not available for 2011. Tillage system had no effect on corn yield in 2009 (Fig. 4 and Table 2). In 2010, the chisel plow system resulted in an average (across N rate) 13 bu/acre higher yield and an 8 bu/acre higher YEONR compared to no-till. Removing residue increased corn yield (Fig. 5). In 2009, residue removal resulted in average across N rate 7 and 11 bu/acre grain yield increase for the 50 and 100% removal, respectively (Fig. 5), but no difference in YEONR (Table 2). In 2010, the difference was greater than in 2009, with average across N rate corn yield increase of 14 and 20 bu/acre for 50 and 100% residue removal, respectively, and a 5 bu/acre higher YEONR for each removal rate. These yield results reflect the canopy NDVI values measured at mid-vegetative growth and the lower corn plant stress when residue was removed.

Tillage system had no differential effect on N response or EONR in 2009, but EONR in 2010 was lower with chisel plow tillage (Table 2). The EONR with the 50 and 100% residue removal was lower in 2009 by approximately 25 lb N/acre. In 2010, no difference in EONR could be determined between the 0% and 50% residue removal as the N response was to the highest applied rate; however, the EONR for the 100% removal was 216 lb N/acre. The EONR each year and site was quite high due to continuous corn and years with above normal rainfall.

Results indicate that residue removal increased corn yield and reduced the needed N fertilization rate. Chisel plow tillage also increased corn response to N compared to no-till, but the impact was smaller than that associated with residue removal. With increased time, the tillage differences may become greater, as could differences in response to residue removal between the tilled and no-till systems.

Summary

In this continuous corn system, removing crop residue increased corn early growth each year (canopy NDVI values); and averaged across tillage systems, sites, and years increased corn yield at the EONR an average of 6 bu/acre (3%) with 100% removal, decreased EONR by 27 lb N/acre (11%) with 50% removal and 41 lb N/acre (17%) with 100% removal, and had no effect on early season soil NO_3^--N. This indicates a change in short-term conditions with residue removal that influences corn growth, yield, and N response. Likely factors include soil N availability, N

immobilization/mineralization, residue decomposition, and soil temperature. The measured residue removal effects on corn growth, yield, and N response were similar in both tillage systems; with a 6 bu/acre lower yield with no-till and no difference in EONR (224 lb N/acre) between tillage system. Study across a long-term period will help confirm crop and soil responses to residue removal and needed change in corn N fertilization requirement.

Acknowledgments

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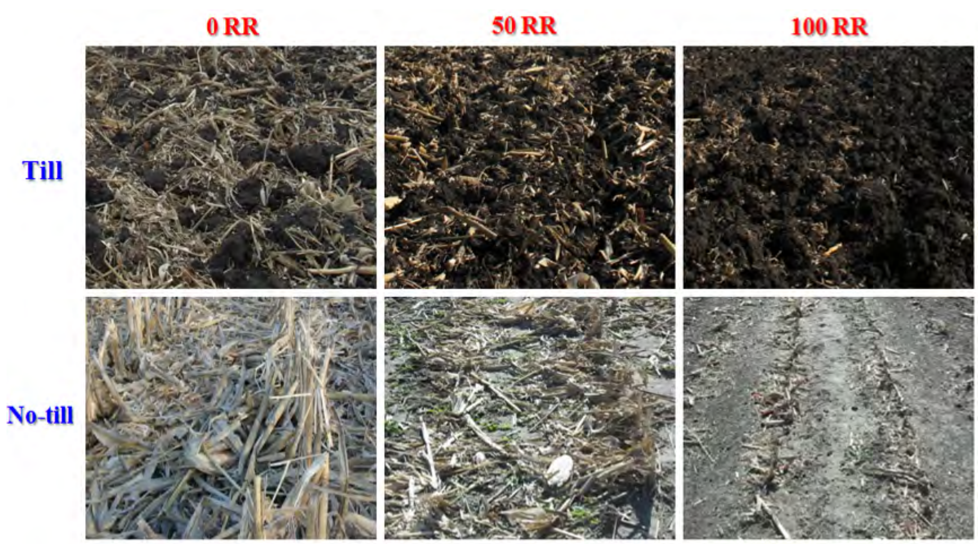

Figure 1. Pictures of the soil surface after tillage and residue removal (RR).

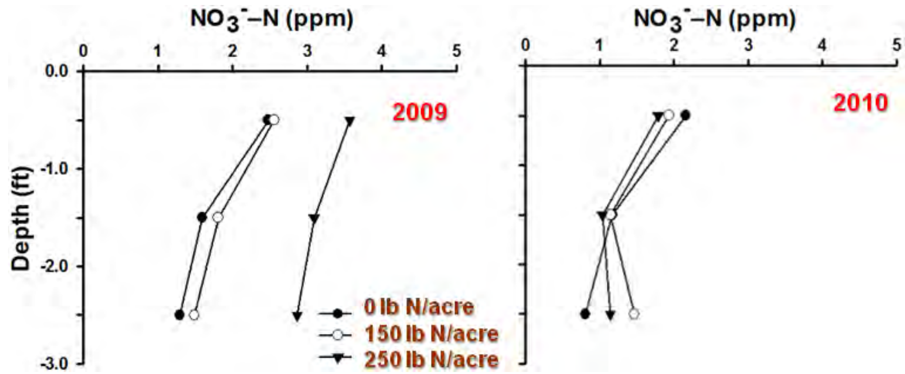

Figure 2. Post-harvest soil profile NO_3^--N concentration (0-3 ft) across sites, tillage system, and residue removal.

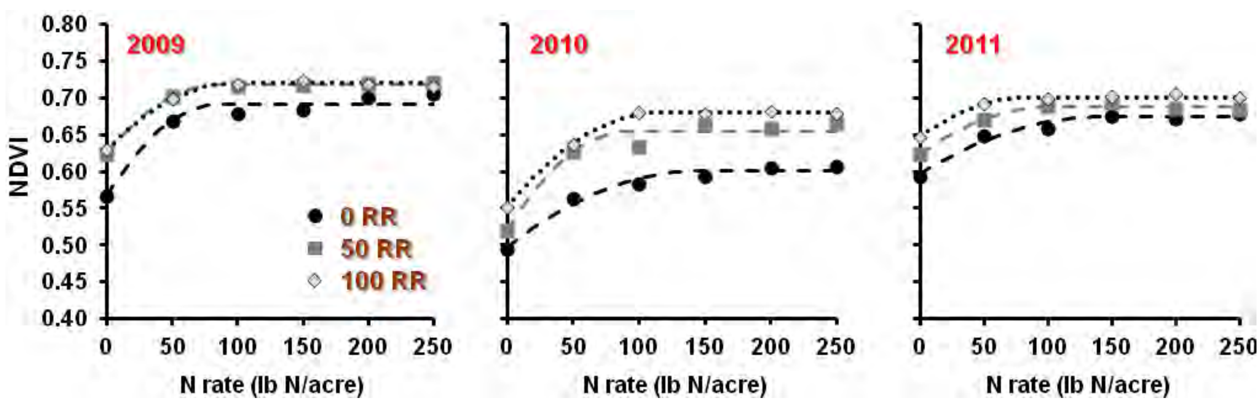

Figure 3. Corn plant canopy NDVI across sites and tillage system as affected by residue removal and N rate.

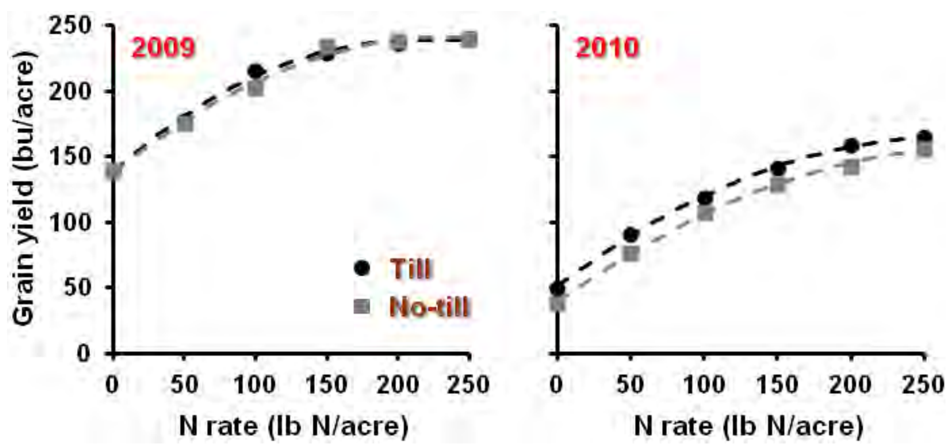

Figure 4. Corn grain yield N response across sites and residue removal rate as affected by tillage system. Regression models given in Table 2.

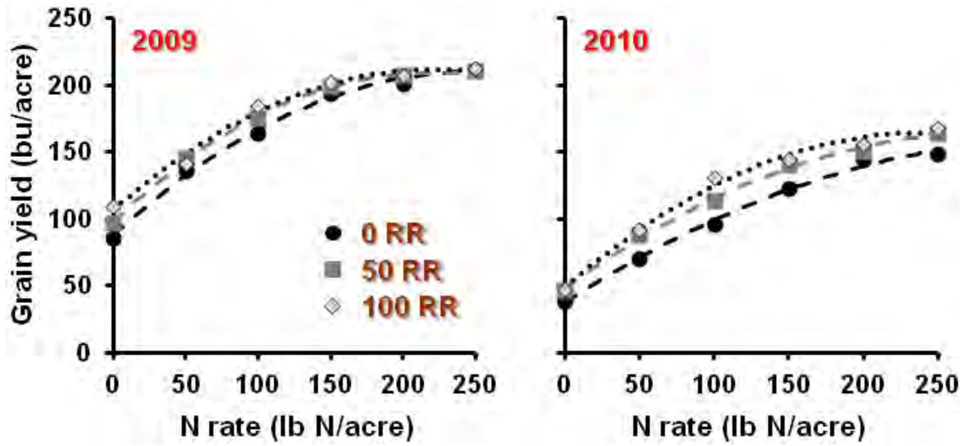

Figure 5. Corn grain yield N response across sites and tillage system as affected by residue removal rate. Regression models given in Table 2.

Table 1. Spring preplant and early June soil profile NO_3^--N in the corn not receiving N fertilizer (0 lb N/acre), across sites, years, tillage system, and residue removal.

Depth	Preplant	Early June	Mean
ft	----------------	NO_3^--N (ppm)	----------------
0-1	3.1	3.2	3.2a[†]
1-2	2.1	2.7	2.4b
Mean	2.6b	3.0a	

[†] Means followed by the same letter are not statistically different ($p \leq 0.05$).

Table 2. Effect of tillage and residue removal rate on corn grain yield and economic optimum N rate across sites.

Year	Main effect		EONR[†]	YEONR[†]	Regression model[‡]	Joint point[§]	Plateau	R^2	p > F
			lb N/acre	bu/acre		lb N/acre	bu/acre		
2009	Tillage	Till	206	210	$y = 100.0 + 0.966x - 0.0021x^2$	230	211	0.995	<0.001
		No-till	204	208	$y = 95.0 + 1.010x - 0.0022x^2$	226	209	0.999	<0.001
	Residue removal	None	222	209	$y = 87.9 + 0.986x - 0.0020x^2$	247	210	0.995	<0.001
		50%	194	208	$y = 98.0 + 1.031x - 0.0024x^2$	215	209	0.999	<0.001
		100%	198	211	$y = 106.5 + 0.950x - 0.0021x^2$	221	212	0.988	0.001
2010	Tillage	Till	238	164	$y = 50.8 + 0.848x - 0.0016x^2$	>250	165	0.999	<0.001
		No-till	>250	156	$y = 38.8 + 0.809x - 0.0014x^2$	>250	157	0.999	<0.001
	Residue removal	None	>250	158	$y = 37.6 + 0.722x - 0.0011x^2$	>250	160	0.995	<0.001
		50%	>250	163	$y = 47.8 + 0.815x - 0.0014x^2$	>250	165	0.997	<0.001
		100%	216	163	$y = 48.9 + 0.960x - 0.0020x^2$	241	165	0.992	<0.001

[†] EONR, economic optimum N rate; YEONR, yield at economic optimum N rate.

[‡] For regression model, x is the applied N rate (lb N/acre), and y is the corn grain yield (bu/acre).

[§] Nitrogen rate at which corn grain yield joins the plateau.

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