RESPONSE OF CORN TO RESIDUE MANAGEMENT AND NITROGEN FERTILIZATION

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Abstract

Interest in the production of cellulosic fuel production for bioenergy has identified corn (*Zea mays* L.) as a suitable option. However, residue removal can affect the growth and yield of a following corn crop and its response to N fertilizer. Residue removal may also influence the optimal tillage system with regard to yield and N-use efficiency. In southern Minnesota, concern about yield reductions due to cool, wet soil conditions, partially attributed to high amounts of crop residue, have limited the adoption of reduced-tillage systems for continuous corn. In the fall of 2008, a high-yield continuous corn study was established at the University of Minnesota Research and Outreach Center at Waseca on a Nicollet-Webster clay loam soil complex to investigate the effects of residue removal (full vs. no removal), tillage system (disk-chisel, strip-till, and no-till), and N fertilizer (six rates ranging from 0 to 269 kg N ha^{-1}) on continuous corn growth and yield. Residue removal increased corn extended leaf height at the eight leaf-collar stage, NDVI, vegetative biomass yield, grain yield, and grain N content. In most cases, tillage system did not adversely affect crop growth and yield. While residue removal increased yield in the short-term and did not affect the response of corn grain yield to N, long-term residue removal without organic additions could potentially reduce long-term soil productivity and corn yield potential.

Introduction

Corn residue is an abundant source of cellulosic biomass that could be used for large-scale bioenergy production (Wilhelm et al., 2004; Perlack, 2005). However, residue removal can potentially affect the growth and yield of a following corn crop and its response to N fertilizer. Stover removal may also influence the optimal tillage system with regard to yield and N-use efficiency. In southern Minnesota, concern about yield reductions due to cool, wet soil conditions under high amounts of crop residue have limited the adoption of reduced-tillage systems for continuous corn.

While corn residue can potentially serve as an additional income source for producers, sustained removal can potentially lead to decreased soil quality through soil organic matter decline and increased erosion susceptibility (Blanco-Canqui et al., 2006; Wilhelm et al., 2007). Continuous corn cropping systems, which fundamentally return high amounts of crop residue to the soil, may be the cropping systems best suited for corn residue removal practices in order to minimize soil degradation. Research is necessary in order to identify the threshold level of residue removal that, at minimum, maintains soil quality. Furthermore, it is important to determine whether N fertilizer rates should be adjusted if residue is removed. Therefore, the objective of this study was to quantify how corn residue removal, N fertilization, tillage, and their interactions affect corn growth and yield.

Materials and Methods

Research plots were established in the fall of 2008 on a Nicollet –Webster clay loam (fine-loamy, mixed, superactive, mesic Typic Endoaquolls) soil complex at the Southern Research and Outreach Center at Waseca, MN. The experimental design was a split plot arrangement in a randomized complete block design. Residue removal and tillage treatments were main plots in a complete factoral arrangement, measuring 18.3 m wide by 7.0 m long. Residue removal consisted of no- and full removal. Removal occurred in fall following grain harvest through chopping, raking, and baling. Tillage methods consisted of conventional, strip-tillage, and no-tillage. Conventional tillage include fall disk-chiseling at a depth of 25 cm in the fall and spring field cultivation at depth of 9 cm in the spring. Strip-tillage occurred in fall following harvest at depth of 20 cm. Nitrogen fertilizer (split plot) was sidedressed as ammonium nitrate (32-0-0) shortly after planting. Rates included 45, 90, 134, 179, and 224 kg N ha^{-1}. Subplots were 6.1 m wide by 7.0 m long. Ammonium poly-phosphate (10-34-0) was also applied to all plots at planting at rate of 46.9 L ha^{-1}. Gypsum ($CaSO_4$) was broadcast applied to all plots prior to spring tillage at a rate of 16.8 kg S ha^{-1}. All other nutrients and soil pH were determined to be non-limiting. Corn was planted at 85,400 seeds ha^{-1} with Dekalb DKC52-59 (102-d relative maturity), which contained transgenic resistance to corn rootworm (*Diabrotica* spp.) and European corn borer [*Ostrinia nubilalis (Hübner*)], in 76 cm rows with planter equipped with row cleaners. In no-tillage and strip-tillage treatments, rows were planted 15 cm to the side of the previous year's rows.

Extended leaf height (LH) and normalized difference vegetative index (an index of crop biomass; NDVI; Raun et al., 2002) were measured at the 8 leaf collar stage (V8; Ritchie et al., 1997). For extended leaf height, ten plants from the harvest rows were randomly selected and the cumulative height of the plant and extended leaves was recorded. For NDVI, a Greenseeker handheld sensor (NuTech Industries, Inc, Ukiah, CA) was positioned approximately 60 cm above the center two rows of the harvest area. Prior to grain harvest, whole-plant samples were collected from each plot at physiological maturity from non-harvest area to determine vegetative biomass (VB) yield. Eight plants were randomly selected from non-border and non-harvest areas, cut 7.5 cm above the soil, partitioned, and dried in a forced-air dryer at 40ºC to constant moisture. Grain yield (GY) was determined after plants reached physiological maturity by machine harvest of four center rows in each plot. Grain yield was standardized to 15.5% moisture. Grain was then analyzed through near-infrared spectroscopy (NIRS) to determine grain protein concentration. Grain N concentration (GNC) was then determined by dividing the grain protein value by 6.25 (Anderson and Peterson, 1973).

Data were analyzed using the MIXED procedure of SAS (SAS Institute, 2003) at $\alpha = 0.10$ to determine the effects of residue removal, N rate, tillage, and their interactions on the response variables. When sources of variation were significant, orthogonal contrasts were constructed in the MIXED procedure to determine the best-fit model (linear vs. quadratic), and coefficients were derived from this procedure.

Results and Discussion

The effects of residue removal, tillage, and N rate were visible in leaf height (LH) and NDVI taken at V8. (Table 1). Regardless of tillage, the removal of residue led to an increase in LH across all N rates (Fig. 1). When residue was not removed, CT produced plants with the greatest LH values at all N rates, while NT produced the lowest. When residue was removed, LH values were the greatest under CT at all N rates up to 90 kg N ha^{-1}, but did not differ from ST and CT beyond that rate. ST produced greater LH compared to NT when residue was present, but did not differ from NT at any N rate when residue was removed. When LH was regressed on spring surface residue coverage after planting, the regression equation predicted a decrease 0.38 cm in LH for every 1% increase in surface residue coverage (Fig. 2). Unlike LH, NDVI was not affected by tillage (Table 1). A significant residue removal by N rate interaction was also observed, but the interaction may have been driven, at least partially, by a possible saturation in the N rates of 134 kg N ha^{-1} and beyond under residue removal. Despite this possibility, the removal of residue greatly increased NDVI, especially at lower N rates (Fig. 3).

Like NDVI, VB was affected by residue removal and N rate, but not tillage (Table 1). In addition, the response of VB to N application rate varied by removal method, as indicated by its significant interaction. As N rate increased, the difference in VB between residue removal methods generally decreased, and did not differ beyond 134 kg N ha^{-1} (Fig. 4). Similar to NDVI, the response of VB to N rate was less pronounced when residue was removed compared to when residue remained.

Similar to NDVI and VB, only N rate and residue removal significantly influenced GY in 2009 (Table 1). Grain yield was not maximized by the N rates used in the study in 2009. Like all in-season measurements and VB, the removal of residue led to an improvement in GY across all N rates (Figure 5). When N was not applied, the removal of residue contributed to a 27% increase in GY, regardless of tillage method. The increase in GY with the lack of N can most likely be contributed to an increase in N availability caused by decreased immobilization potential from the removal of organic C and increased vegetative growth, as illustrated by LH and NDVI. This decreased immobilization of soil nitrogen is probably increased N availability.

Like nearly all other previous response variables, GNC was affected only by N rate and tillage (Table 1). Furthermore, regression of GNC on N rate for each residue removal treatment produced a linear trend, emphasizing the strong response of GNC to N rate (Fig. 6). The removal of residue also resulted in an increase of GNC by 5%, when averaged across N rates. Despite the strong difference in GNC, the slope of GNC did not differ between the residue removal methods (Fig. 5). This response is similar to GY.

Summary

Several growth and yield components were affected by residue removal, tillage, N fertilization rate, and their interactions. Of the response variables discussed, only LH was affected by tillage. In all cases, the removal of residue resulted in increased in-season plant productivity in LH and NDVI, greater yields in VB and GY, and elevated GNC. In all cases, increasing N fertilizer rates generally lead to an increase of the variables discussed, regardless of tillage and removal methods. For VB, however, the response to N was greater when residue remained compared to when residue was removed.

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Table 1. ANOVA of fixed effects in select properties affected by residue removal, N fertilization and tillage for 2009 and 2010.

	V8 Leaf Height*	NDVI	Grain Yield	Stover Yield	Grain N Content†
			P > F		
Residue Removal (RR)	0.003	0.003	0.009	0.097	0.009
N Rate (N)	0.002	0.006	<.0001	0.075	0.018
Tillage (T)	0.011	0.171	0.562	0.141	0.135
N × RR	0.657	0.003	0.929	0.008	0.421
RR × T	0.346	0.140	0.859	0.213	0.202
N × T	0.384	0.831	0.150	0.242	0.378
RR × N × T	0.114	0.900	0.137	0.241	0.807

* Extended leaf height at 8 leaf collar stage
† 2009 only

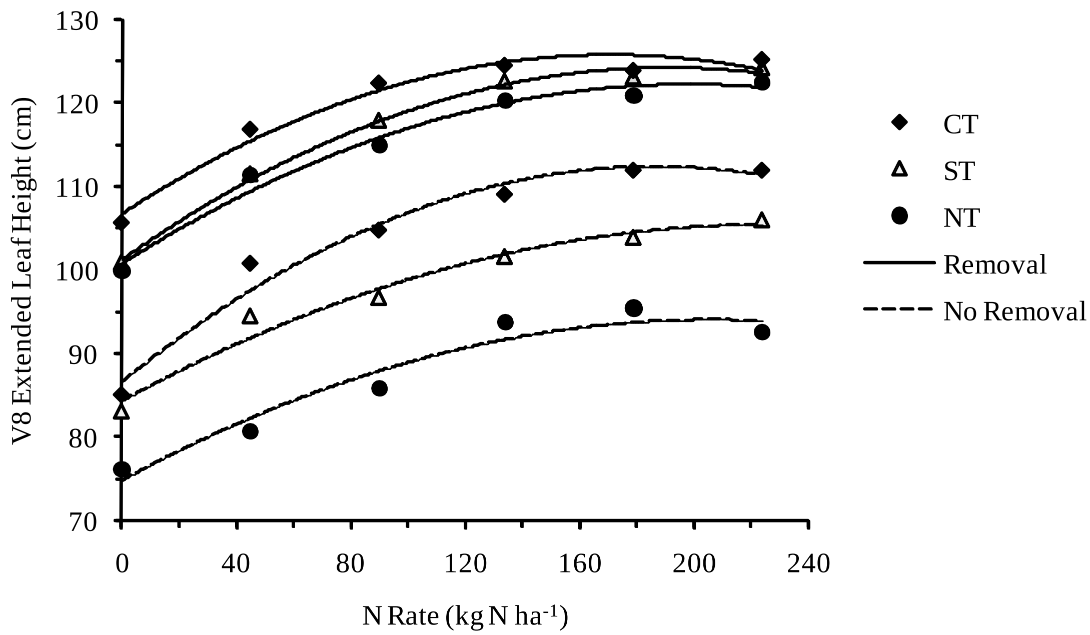

Figure 1. Response of extended leaf height in corn at the eight leaf-collar stage to N rate, residue removal,and tillage at Waseca, MN in 2009 and 2010.

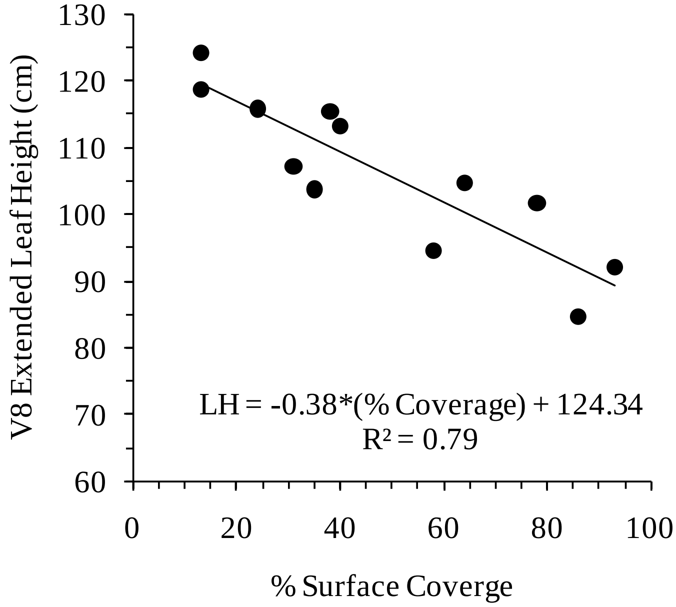

Figure 2. Relationship between % surface residue coverage and extended leaf height in corn at the eight leaf-collar stage, averaged across tillage systems and N rates.

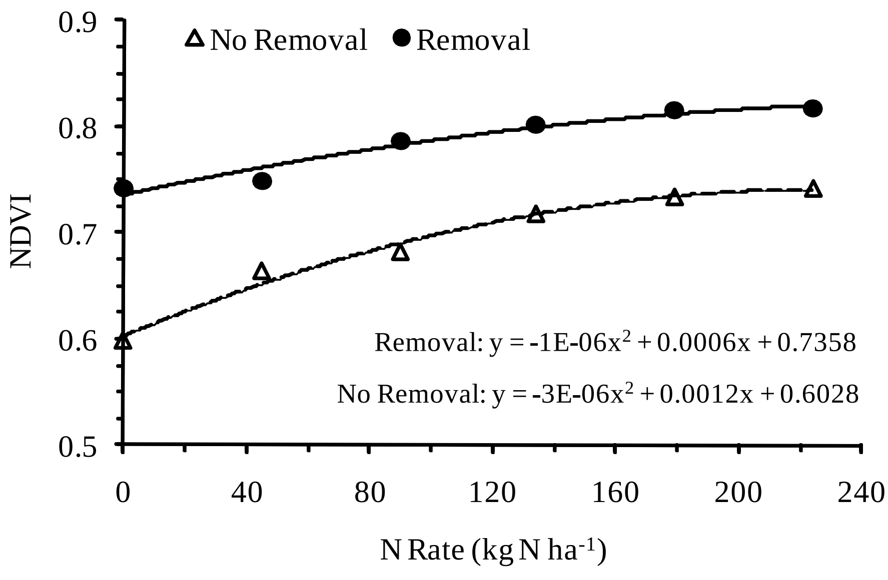

Figure 3. Response of corn NDVI to N rate and residue removal at the eight leaf-collar stage, averaged across tillage systems at Waseca, MN in 2009 and 2010.

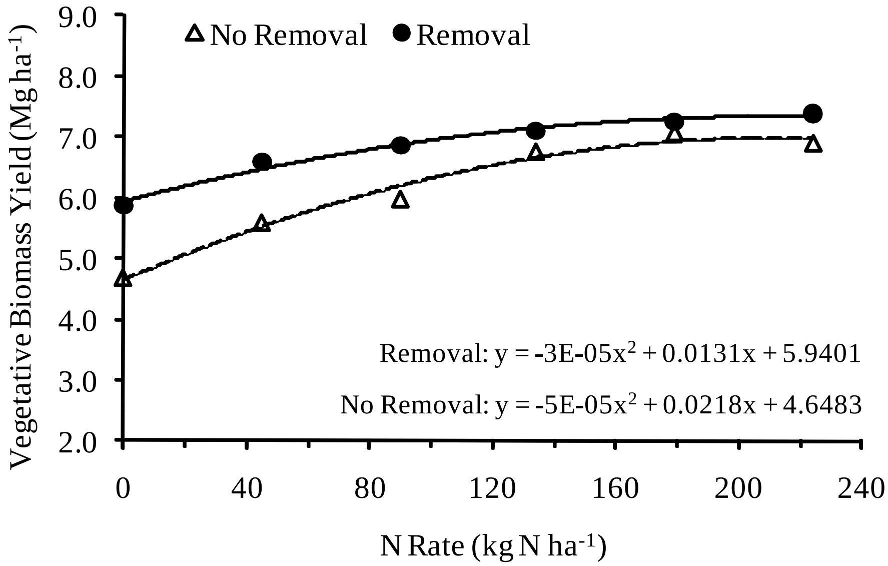

Figure 4. Response of corn vegetative biomass yield to N rate and residue removal, averaged across tillage systems at Waseca, MN in 2009 and 2010.

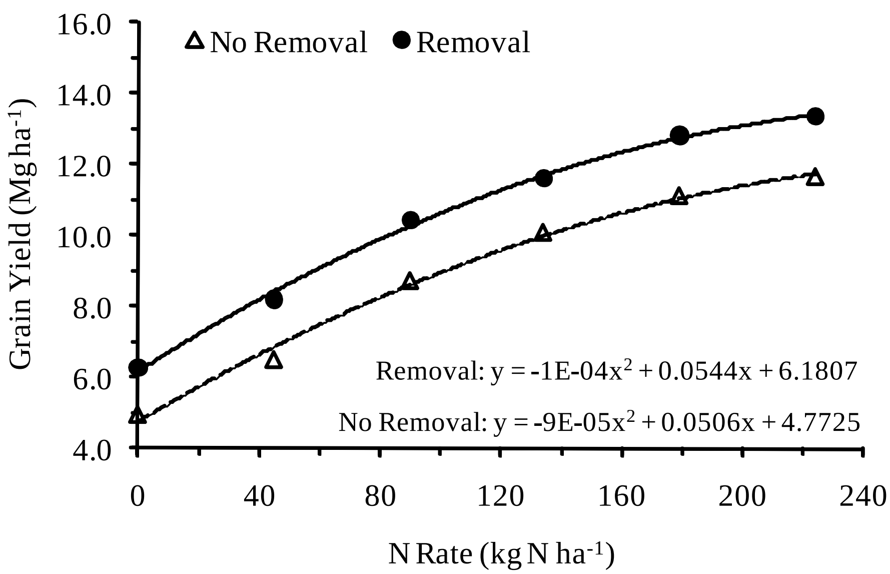

Figure 5. Response of corn grain yield to N rate and residue removal, averaged across tillage systems at Waseca, MN in 2009 and 2010.

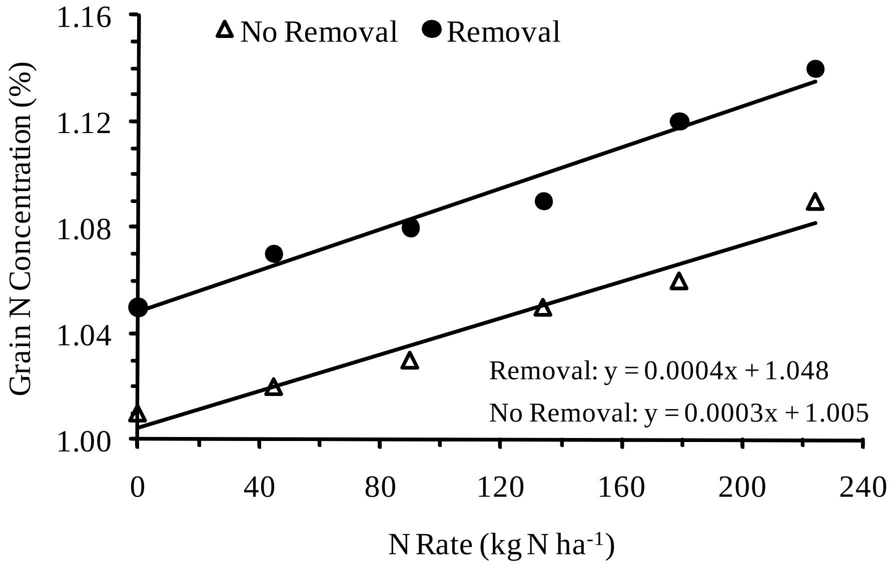

Figure 6. Response of corn grain N rate concentration to N rate and residue removal, averaged across tillage systems at Waseca, MN in 2009.

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