TILLAGE AND NITROGEN RESPONSES TO RESIDUE REMOVAL IN CONTINUOUS CORN

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Abstract

With the growing interest in harvesting corn stalk residue for use as biofuel comes the need to examine how residue removal might affect yield and N needs of the subsequent corn crop. We are conducted an experiment over the past five years (2006 to 2010) at four Illinois locations (three in Mollisols and one in Alfisol) in which all, part, or none of the corn residue is removed, followed by tilled and no-till split within each residue treatment, and with N rates split within each residue-tillage treatment. All treatments stay in place each year. Averaged over 15 site-years, the presence or absence of residue had little effect on yield or N response in tilled plots: optimum N rates were 179, 186, and 195 lb N/ac, and yields at the optimum N rate were 212, 212, and 216 bu/acre with full, partial, and no residue removal, respectively. With no-till, however, optimum N rates fell from 240 to 175 when all residue was removed, and yield increased from 193 to 211 bu/acre. While we do not yet have data to evaluate the long-term sustainability of residue removal, it is clear that in the short run, removing residue both raises yields and lowers N requirements in continuous corn grown without tillage.

Introduction

There has been recent interest in producing ethanol from crop residues to reduce U.S. reliance on imported fossil fuels. In the Midwest, corn residue remaining after grain harvest is one of the most abundant sources of crop residue. If corn residue removal for ethanol production (or combustible fuel) will occur, we believe that it will preferentially occur in fields where corn is grown continuously and not in rotation with soybean, since corn residue is a source of inoculum for many corn diseases. Furthermore, corn residue has a high carbon to nitrogen ratio, thereby favoring immobilization. We therefore hypothesize that when corn is grown continuously, removal of corn residue will reduce the economic optimum nitrogen rate.

While removal of corn residue may reduce the amount of nitrogen fertilizer required for a subsequent corn crop and suppress diseases, we have to consider other roles of crop residue on subsequent crops, and on soils. Residue removal can affect water content, temperature, and strength of soil, thereby affecting corn emergence and growth. Crop residue on the soil surface also reduces water erosion by intercepting raindrops and protecting against soil detachment, hence its removal will tend to reverse these effects.

Maintenance of soil organic matter requires a continuous supply of plant residue to the soil. Previous research with continuous corn in Iowa showed that maintenance of soil organic matter levels required 2 tons/acre of corn residue left on the soil surface prior to plowing each fall (Larson et al., 1972). Similarly, removal of corn residues for 10-12 consecutive years in Indiana and Iowa reduced soil organic matter levels by 10 to 13% under conventional tillage (Barber, 1979; Larson et al., 1972). More recently, differences in soil physical properties and organic matter in the upper four inches of the soil were identified after only two seasons of residue removal in no-tillage continuous corn in Ohio (Blanco-Canqui et al., 2006). The effects of residue management on corn response to nitrogen fertilizer and soil quality, however, will likely be influenced by tillage due to complex associations between residue and soil near the soil surface. Furthermore, different levels of nitrogen fertilization may influence soil response to residue removal. Such information is vital to decisions about future cropping systems.

While there is some published research on the effects of residue removal on continuous corn yield, there is little published research on how residue removal affects continuous corn response to nitrogen fertilizer or other management practices under various tillage systems. Understanding corn response to nitrogen fertilizer rate and tillage in fields will be key to our ability to manage corn for maximum economic and environmental outcomes. We also need to know how residue removal will affect soils and yields before we can confidently remove some of it, and before we can know what price residue should command. Our objective with this research is to answer these questions.

Over the first two years of the present study, responses to residue removal, tillage, and N rate were somewhat different in the lower organic matter soil and under the drier conditions at Perry compared to the other three locations (Coulter and Nafziger, 2008). At Perry, the highest-yielding treatment over those two years was in the treatment with no removal of residue followed by no-till. In contrast, this treatment – retaining all residue and no-tilling – produced the lowest yield in the higher-rainfall, higher-OM locations.

Materials and Methods

This study was initiated following corn harvest in the fall of 2005 at four University of Illinois Crop Sciences Research and Education Centers: DeKalb, on an Elpaso silt loam soil; at Monmouth, on a Muscatune sil; at Perry, on a Clarksdale sil; and at Urbana, on a Drummer sicl. three levels of residue removal—full, partial, and none—were assigned to main plots, with full removal accomplished by chopping stalks and raking them off the plots and partial removal done by raking without chopping stalks. Partial removal thus approximated the effect of baling off some stalks without chopping them: it removes about 50 to 60% of the residue, leaving in the field portions of mostly lower stalk and fine material. Full removal leaves some fine material, but less than 10% of the residue dry weight.

Two tillage systems—chisel plow and none—were assigned to subplots within residue removal main plots, with chiseling done soon after residue removal. No-till plots were undisturbed in the fall, and were planted using a planter equipped with trash movers. Four N fertilizer rates—60, 120, 180, and 240 lb N per acre—were assigned to sub-subplots, and were applied as 28% urea-ammonium nitrate solution, either just before planting or as a sidedress application. Sub-subplots were 6 or 8 rows (15 or 20 ft.) wide by 50 to 60 ft. long. Treatments have remained in the same place each year in each field. Due to wet fall conditions, residue removal and tillage had to be delayed until spring at DeKalb in 2009 and 2010 and at Urbana in 2010.

A plot combine was used to harvest the center two or four rows from each sub-subplot. Yields were adjusted to 15% moisture. In most cases, the quadratic+plateau model was fitted to the data using

SAS PROC NLIN.

Results and Discussion

In the transitional soil (Alfisol) at Perry, where both 2006 and 2007 were dry growing seasons, results were separated from the other three locations with Mollisols by Coulter and Nafziger (2008). In subsequent years, however, responses at this site have been much like the responses at the other three sites, and so have been combined with them. Due to an error at Monmouth in 2006 and low yields and uncharacteristic responses at DeKalb in 2009 and Urbana in 2010, these results were also left out of the combined analysis.

Results averaged over the remaining 15 site-years from the first five years of the study (2006-2010) showed that removal of residue tended to increase yield and to reduce the optimum N rate under no-till, but not when tillage was done (Figure 1.) Based on quadratic+plateau functions fit to the N response data within each residue-tillage treatment, removing all, part, or none of the residue resulted in optimum N rates of 179, 186, and 195 lb N/acre, respectively, in tilled treatments (Table 1). This modest drop in optimum N rate likely reflects to the fact that less residue meant less tie-up of N during residue breakdown. Yields in tilled plots at optimum N rates were relatively unaffected by residue, however, with removal of all, part, and none of the residue resulting in yields of 212, 212, and 216 bu/acre, respectively.

Compared to tilled plots, residue removal under no-till had a much larger effect on both N rate and yield. Removal of all, part, or none of the residue produced optimum N rates of 175, 193, and 240 lb N/acre, respectively, and yields of 211, 206, and 193 bu/acre (Table 1). Under no-till, removing residue lowered the optimum N rate by 65 lb N/acre and increased the yield was increased by 18 bu/acre.

Net return to N, calculated based on optimum yield and N cost minus yield projected at zero N, was higher under no-till than under tillage, only because yields without N were lower under no-till, not because yields at optimum N were higher (Table 1). But without the cost of tillage, it is likely that the most profitable system of the six residue-tillage combination is no-till with full removal of residue, at least in the short run. We do not yet know if constant removal of residue will negatively affect soil or its productivity over the longer run.

This study continues, and will include measurements of soil parameters that might indicate longer-term effects of residue removal and tillage. After five years, it is clear that residue can be left in the field or removed with little effect on yield or N requirements in continuous corn if a chisel-till system is used,. In no-till, removing residue both increases yield, up to that produced with tillage, and decreases the amount of N needed, making this system more or less equivalent to the tilled system in terms of yields, and perhaps more profitable due to cost savings form not tilling. Whether this will be the case after ten or twenty years remains unknown, but if residue can be removed without undue soil compaction and without compromising soil conservation goals, it should be feasible in continuous corn.

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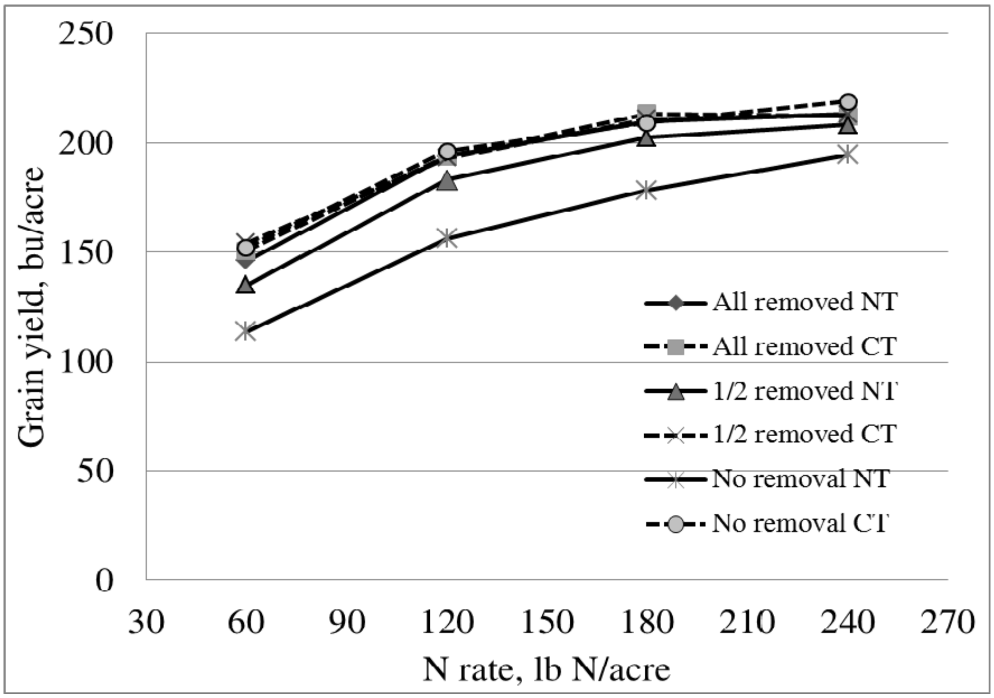

Figure 1. Response of continuous corn yield to residue removal, tillage, and N rate over 15 Illinois site-years between 2006 and 2010.

Table 1. Optimum N rate, yield at optimum, and net return to N at the optimum N rate for different residue removal levels and tillage, averaged over 15 site-years. Optimum N rates and returns to N were calculated taking N at $0.60/lb and corn at $6.00/bu.

Residue-tillage	**Opt N**	**Yield**	**Return to N at opt.**
	lb/ac	bu/ac	$/ac
All removed-NT	175	211	741
All removed-CT	179	212	678
1/2 removed-NT	193	206	729
1/2 removed-CT	186	212	585
No removal-NT	240	193	646
No removal-CT	195	216	616

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