Dec 4th, 12:00 AM

Continuous corn response to residue removal, tillage, and nitrogen

Emerson D. Nafziger
University of Illinois

Continuous corn response to residue removal, tillage, and nitrogen

Emerson D. Nafziger, professor and Extension agronomist, Crop Sciences, University of Illinois

There has been a great deal of recent interest in "bioenergy" crops that could be burned to generate electricity or heat or used as a feedstock in the manufacture of liquid fuels. Cornstalks represent one of the major "biomass" sources that currently exist. Because today's healthy, high-yielding hybrids leave behind stalks that present a management challenge, some people are wondering why we don't help solve both problems – the need for biomass and the difficulty of managing residue – by harvesting cornstalks to use as fuel.

Corn residue is organic matter, and we have been taught to value the addition of organic matter to the soil in order to maintain its productivity. Research in Nebraska indicated that maintaining soil organic matter levels requires adding about 2.5 tons of residue with no-till or conservation tillage in continuous corn, and more than 5 tons per acre if a moldboard plow is used in a corn-soybean rotation (Wilhelm et al., 2007). If the moldboard plow is used in continuous corn or no-till in corn rotated with soybean, then about 3.5 tons of corn residue needs to be returned (Figure 1) in order to maintain organic matter levels.

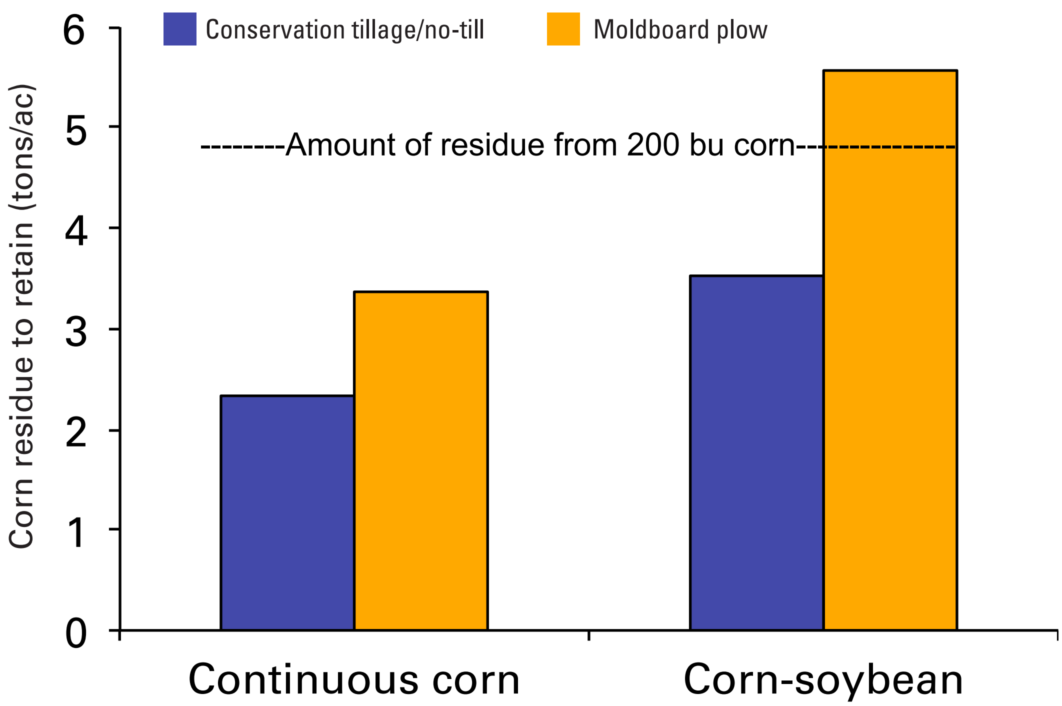

Figure 1. Estimated amounts of corn residue needed to maintain soil organic matter levels in continuous and rotated corn with different tillage treatments. Based on Wilhelm et al., 2007.

Other researchers have raised concerns about the effect of residue removal on yields of continuous corn. In a no-till continuous corn system in Nebraska, Wilhelm et al. (1986) found that each ton of residue removed per acre after grain harvest reduced grain yield of the following crop by about 3.5 bushels per acre. In a 13-year continuous corn study in comparing different types of tillage in Minnesota, returning crop residue to the soil after grain harvest increased grain yield by an average of 22% when compared to removal of all residue prior to dry years, but had little effect when rainfall was near normal (Linden et al., 2000).

A 200-bushel corn crop produces a total aboveground dry weight of about 10 tons per acre, and the grain and residue each make up about half of this total, or about 5 tons each. So in continuous corn we could presumably remove about half (2.5 tons) of the corn residue with no-till and about one-third (1.5 tons) of the residue if we do tillage. We could remove some corn residue in the corn-soybean rotation, but only if we do little or no tillage. Even then, less can be removed than in continuous corn with tillage, mostly because corn is present only once in two years.

The study

We initiated a study at four locations in Illinois in 2006 to see what effect residue removal, tillage, and N rate have on continuous corn yields. The sites are DeKalb, Monmouth, Urbana, and Perry. All have relatively productive soils, with expected yield at Perry site slightly below that at the other three sites.

After harvest in the fall we remove none, part of (about half), or all of the residue, then we till half of each of the residue removal plots. After spring tillage of the tilled plots, we apply N rates ranging from 60 to 240 lb N/acre to sub-subplots. Each treatment combination stays in the same plot each year.

Findings to date

The study will continue several more years. Here is what we've found, averaged over 30 Illinois site-years from 2006 to 2013:

- Over all of the site-years and N rates, tilled plots yielded 10% (15 bushels per acre) more than no-till. Averaged over tillage, removing part of the residue increased yields by 5 bushels (3%) and removing all of the residue increased yield by 9 bushels (6%) over yields with no residue removed (Figure 2).
- With tillage, yield levels and responses to N rates were almost identical for the different amounts of residue removed. But with no-till, removing residue increased yields and decreased the response to N rate, at least at the higher N rates. Yields of no-till with all residue removed were lower than those of tilled plots at the lowest N rate, but was only slightly lower than yields of tilled plots at the highest (240-lb) N rate. The no-till yield with partial removal of residue was intermediate between that of full removal and no removal, but was equal to that with full removal at the highest N rate. Where no residue was removed, no-till yields were the lowest of all the treatments across the whole range of N rates (Figure 2). It isn't clear that adding even higher rates on N would have brought these yields up to those of tilled plots.
- Averaging across the two higher N rates to duplicate common farming practice, we found that even removing all of the residue did not bring no-till yields up to those of tilled plots. Yields of tilled plots averaged 180 bu/acre and were not affected by residue removal. The highest no-till yield – that following full residue removal – was 6 bushels less than the average for tilled treatments. Removing part of the residue produced yields only 2 bushels less than removing all of the residue, while leaving all of the residue in the field reduced no-till yields by 13 bushels compared to removing all of the residue, and by 19 bushels compared to using tillage.
- Using the quadratic + plateau function to fit the N responses allows us to calculate the changes in agronomic and economic N rates with different combinations of residue removal and tillage. This puts into numbers what we can clearly see in Figure 2 – that with all of the residue present, tillage both decreases (by 21 lb) the amount of N needed to produce the optimum yield, and also increases the yield at the optimum N rate, by 17 bushels per acre (Table 1). Removing all of the residue decreases the differences between tilled and no-till to 13 lb of N and 8 bushels of yield, while removing part of the residue widened the gap between N rates (to 29 lb) but narrowed the difference in yield to only 4 bushels per acre. There were some stress environments included in the averages where residue removal tended to reduce yields and in some cases economic N rates, probably due to effects of residue on soil water retention. This may have influenced the overall yields and N responses.

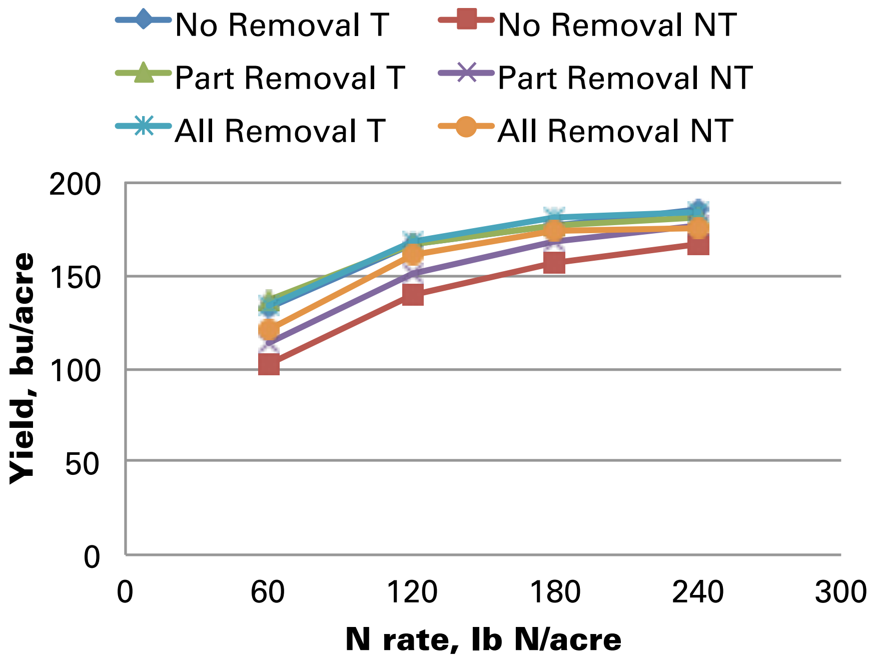

Figure 2. Grain yield of continuous corn as affected by residue removal, tillage, and N rate. Data are averages over 30 Illinois site-years, 2006-2013.

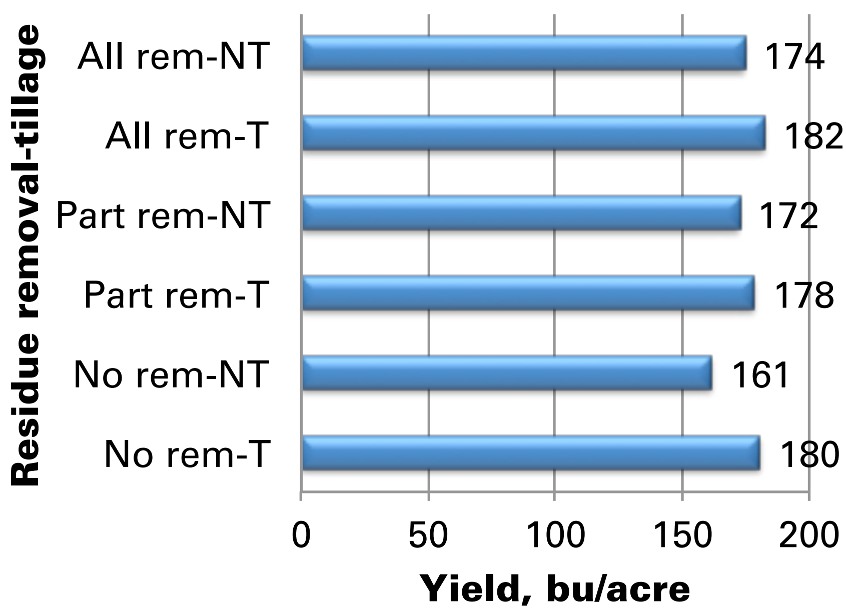

Figure 3. Response to residue removal and tillage, averaged over 180 and 240 lb N per acre. Data are averages over 30 Illinois site-years, 2006-2013.

Table 1. N rates and yields at the N rate needed to maximize yield and the N rate at the economically optimum point, after fitting the data of Figure 2 to quadratic+plateau curves. The economic optimum is that point of the curve where one bushel of yield “buys” 10 lb of N.

		At yield plateau		At optimum N	
Residue	**Tillage**	**N rate**	**Yield**	**N rate**	**Yield**
No Removal	Tilled	222	183	196	182
No Removal	No-till	240	166	217	165
Part Removal	Tilled	205	179	180	178
Part Removal	No-till	233	175	209	174
All Removal	Tilled	198	183	179	182
All Removal	No-till	179	175	166	174

These results indicate that removing some or all of the residue caused no loss in yield or change in N requirement over eight years and among sites with different soils, and that removing residue can increase yields and improve N use efficiency under no-till. Residue removal appears to have minimal effect on yields or N responses when tillage is used in continuous corn. These are relatively flat soils not subject to much water erosion, so removing residue or tilling in the fall would not be expected to have much effect on soil loss.

Can we safely remove corn crop residue?

Soil organic matter formation is a process that takes place over years, decades, and centuries. Organic materials in the form of plant residue provide the raw material for soil organic matter, so it makes sense that removing crop residue might eventually slow the production of soil organic matter. Two factors suggest, however, that this effect might not be large. First, studies show that much soil organic matter forms from root, not top, material. As an example, prairies were often burned (naturally or set by humans) every year, thus removing most topgrowth, yet organic matter levels in prairie soils reached 5% or higher in many cases. Secondly, corn yields have been very high in recent years, and it’s likely that at least some residue can be removed without a penalty in soil matter.

Even if residue removal has a small effect on soil organic matter over time, such changes will be so small that they are unlikely to measurable within a decade or two. Each percentage of organic matter represents 20,000 lb of organic matter in the top 7 inches of topsoil. So a topsoil with 3% OM that’s about a foot deep would contain more than 50 tons of organic matter per acre. Only about 1 percent of organic carbon in crop residue is expected to eventually end up as stable organic matter; the rest is respired away by microbes during the breakdown process. That means that adding back the full amount of 5 tons per year would add about 100 lb of organic matter, and removing half of it for use as biofuel will add back only 50 lb per acre per year. Against a background of 50 tons, such a tiny amount will not quickly be missed. It is thought that roots, with their higher lignin content and slower breakdown, might contribute more to soil organic matter than does the stover. In that case residue removal might have even less effect on soil organic matter.

So if residue removal can be done without excessive compaction and without increasing loss of soil to erosion, then partial removal might make sense for those who can market the residue. We estimate that each ton of residue harvested leaving a foot or so of lower stalk in the field contains about 15-5-20 lb of N-P_2O_5-K_2O, which at current prices would cost about $20 per ton to replace, or about $50 per acre if we remove half the residue from 200-bushel corn.

While removing some of the residue might make economic sense, will it affect how we manage the crop? If we are committed to no-tilling, then removing some residue might help increase yields while reducing the amount of N required. With tillage, such differences are much less likely, though in cases where heavy residue interferes with planting of other field operations, removal of some of the residue might be helpful, especially in years with difficult spring conditions.

References

Linden, D.R., C.E. Clapp, and R.H. Dowdy. 2000. Long-term corn grain and stover yields as a function of tillage and residue removal in east central Minnesota. Soil Tillage Res. 56:167-174.

Wilhelm, W.W., J.W. Doran, and J.F. Power. 1986. Corn and soybean yield response to crop residue management under no-tillage production systems. Agron. J. 78:184-189.

Wilhelm, W.W., Jane M. F. Johnson, Douglas L. Karlen and David T. Lightle. 2007. Corn stover to sustain soil organic carbon further constrains biomass supply. Agron. J. 99:1665-1667.