Increasing Corn Yields Via Stover Removal Using Fluids

Study shows that using proven technologies increased yields.

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The Fluid Journal • Official Journal of the Fluid Fertilizer Foundation • Fall 2014 • Vol. 22, No. 4, Issue #86

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Summary: *In this project, we assessed the effectiveness of stover removal for increasing corn yields in intensively managed and conventionally managed environments, as well as nutrient management consequences of stover removal. Intensively managed environments consisted of higher plant populations, increased nutrient fertilizer application, insect protection traits, and application of fungicides. Conventionally managed environments consisted of more common planting populations, less intense fertilizer applications, no insect protection traits (a granular soil insecticide was applied at planting in both environments), and no fungicide application.*

Stover accumulation has been shown to reduce corn grain yield in continuous corn production systems, leading to suggestions that high corn prices, which result in more continuous corn production, will also result in widespread implementation of stover removal practices. However, effects of stover removal on soil fertility requirements and soil organic matter levels are a concern and must be considered when growers decide to remove stover from continuous corn fields.

The Crop Physiology Laboratory at the University of Illinois, Urbana-Champaign has conducted experiments over the last 20 years to identify the principal factors that result in increased corn yields. The seven factors found to have the greatest impact on corn grain yields are:

- Weather
- Nitrogen
- Hybrid
- Previous crop
- Plant population
- Tillage
- Growth regulators.

Based on this information, an "omission treatment" experimental design was created to test five of the identified factors (nitrogen, other crop nutrients, genetic traits, population, and growth regulators) for their individual and cumulative effects on yield.

In 2011, we added three more factors (crop rotation, residue management, and reduced tillage) to the omission treatment experimental design in an effort to identify conservation practices that maintain or increase production in high-yielding corn production systems. Compared to corn monoculture, corn-soybean rotations reduce N fertilizer application, reduce pest pressure, and are generally thought to promote a more diverse soil biological community to reduce disease susceptibility and serve as a reservoir for gene conservation.

Research and anecdotal evidence have also shown that corn following soybeans generally produces greater yields than corn following corn. Research by the Crop Physiology Lab indicates that the primary agents of yield reduction in continuous corn systems are nitrogen (N) availability, residue accumulation, and weather. Despite issues associated with corn monoculture, this system is likely to become more prevalent in corn production systems in the foreseeable future as a result of increased demand for corn.

Although frequently considered a poor practice for soil quality considerations, partial stover removal can be performed without degrading soil quality or reducing soil organic matter when used in the appropriate environment and with proper management. Other research has also shown that compared to above-ground corn stover, corn roots are a more long-term stable source of carbon and, thus, better for soil carbon sequestration than stover. In addition to testing the sustainability of removing corn stover in continuous corn systems, we also assess how removing stover affects the continuous corn yield penalty.

Strip tillage is a relatively new reduced tillage system that protects soil from erosion, retains plant-available water later in the growing season, maintains soil structure, retains soil organic matter, and allows banding of fertilizers for more efficient plant uptake. Because strip tillage can incorporate seedbed preparation and fertilizer application into a one-pass field operation, it substantially reduces soil compaction associated with multiple field operations for seedbed preparation, residue incorporation, and fertilizer applications. This also represents cost savings as a result of eliminating fuel use, labor, and equipment wear associated with additional field passes.

These three agricultural management practices

- Crop rotation
- Residue management
- Tillage

were tested for their individual and cumulative effects on agricultural sustainability parameters and corn yields in combination with the omission treatment design previously employed to investigate high yield management factors for corn production.

Each of the aforementioned practices (crop rotation, residue management, and tillage) was applied at two levels (9th year continuous corn versus long-term corn/soybean rotation, stover retained versus 50 percent stover removed, and conventional tillage vs. strip tillage) to assess their individual and combined effects on the input treatments (plant population, nutrients, traits, and fungicide) and corn yields. The three growing seasons during which this study was conducted afforded an opportunity to assess the effects of various management practices on crop yield and stover production.

Methodology

Plot design. The study was created as a split-split plot experimental design. Whole plots combined crop rotation and stover management in a treatment referred to as System. There were three whole-plot treatment factors:

- Continuous corn with stover retained (CC)
- Continuous corn with stover removed (CCRM)
- Corn/soybean rotation with stover retained (CS).

The split plot treatment was Tillage (Conventional Tillage or Strip Tillage). Whole plots and split plots together

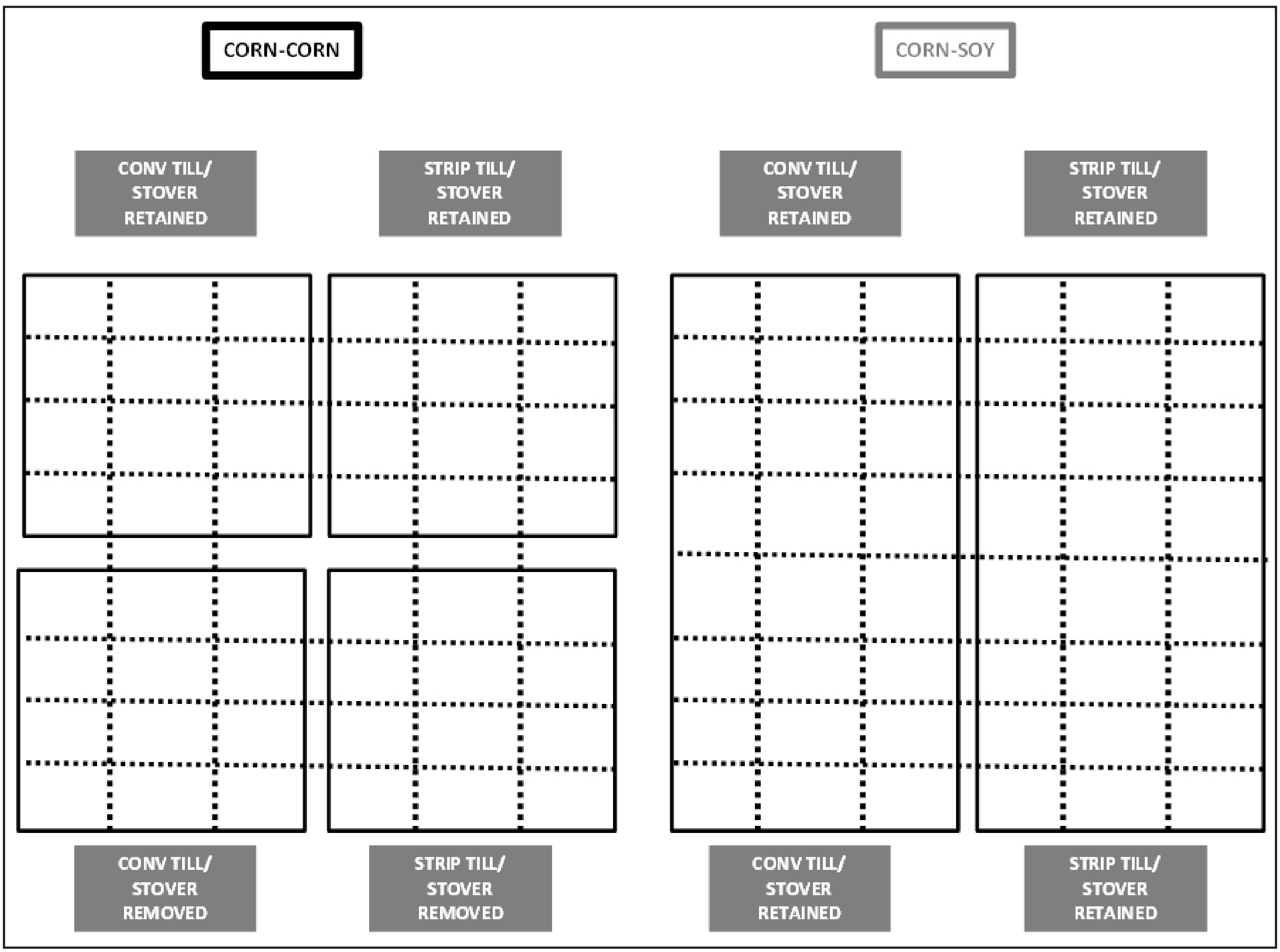

Figure 1. Experimental design of one replication of the 2011/2012 study. The 12 treatments are repeated in each quarter-plot of each rotation (corn-corn or corn-soy) plot. The four quarter-plots (conventional tillage+stover, conventional tillage-stover, strip tillage+stover, strip tillage-stover) assess residue management concerns in high-yielding corn systems. The 12 split-split plot treatments are described in Table 2. A zero-N check plot (not shown) was included to assess nitrogen use efficiency.

Table 1. Subplot treatments evaluated in the Sustainability Omissions Plot Design. The six subplot treatments are plant population, hybrid traits, N rate, other treatments, and crop protection inputs (fungicide).						
Trt. No.	**Trt.**	**Pop**	**Hybrid**	**N**	**Fert.**	**Fungicide**
1	HIGH TECHNOLOGY (HT)	45K	MULTI-TRAIT	BASE+SLOW REL	MESZ	STROBILURIN
2	-POPULATION	32K	MULTI-TRAIT	BASE+SLOW REL	MESZ	STROBILURIN
3	-HYBRID	45K	REFUGE	BASE+SLOW REL	MESZ	STROBILURIN
4	-NITROGEN	45K	MULTI-TRAIT	BASE	MESZ	STROBILURIN
5	-FERT	45K	MULTI-TRAIT	BASE +SLOW REL	NONE	STROBILURIN
6	-FUNGICIDE	45K	MULTI-TRAIT	BASE +SLOW REL	MESZ	NONE
7	TRADITIONAL (TRAD)	32K	REFUGE	BASE	NONE	NONE
8	+POPULATION	45K	REFUGE	BASE	NONE	NONE
9	+HYBRID	32K	MULTI-TRAIT	BASE	NONE	NONE
10	+NITROGEN	32K	REFUGE	BASE+SLOW REL	NONE	NONE
11	+FERT	32K	REFUGE	BASE	MESZ	NONE
12	+FUNGICIDE	32K	REFUGE	BASE	NONE	STROBILURIN

formed quarter plots within each whole plot (Figure 1). The experimental design of the study is unbalanced because stover removal was not conducted in the corn/soybean (CS) system because most research agrees that stover removal in CS rotations is not an acceptable practice due to increased potential for soil erosion and soil organic matter depletion. Figure 1 demonstrates one replication (of four) of the study, illustrating the quarter plot design. Within each quarter plot, twelve split plots comprise the omission treatment study, as illustrated in Figure 1. All treatments were replicated 4 times.

Treatments tested in the omission plot design are described in Table 1. A check strip block with no N fertilizer application was included in the design to assess nitrogen use efficiency (NUE) measures.

Site-years. Due to the rotation treatment, two site-years are required for this study. Each year, one site is used to establish the "previous crops" (corn or soybeans) for the following year. The 2013 study was located at a site previously planted to either 10th year continuous corn or soybeans (in a long-term corn/soybean rotation).

Soils were classified as predominantly Flanagan silt loam with tile drainage and without irrigation. Extensive soil samples were collected in the fall of 2010 to establish evenness in fertility levels and to make fertilizer recommendations. A potassium application was made in the spring of 2011.

Stover removal, tillage, and P fertilizer applications were made in the spring of 2013. Fifty percent of the stover was removed by flail chopping all stover, raking into swaths, collecting and weighing it and replacing 50 percent, redistributing it evenly across plots with a manure spreader. Stover was not chopped in the CC treatments in order to better represent growers' field conditions and eliminate unnecessary equipment traffic and related compaction. This created a discrepancy between the CC and CCRM treatments, since the chopped stover replaced in the stover removed (CCRM) treatments was subject to being blown about by wind and was also likely to decompose faster than in the CC plots where stover was not chopped. Micro-essentials SZ (a fertilizer with N-P-K-S—Zn formulation 12-40—0-10-1 from the Mosaic Company) was band-applied with a tool bar in conventionally tilled treatments at the same time that tillage occurred.

Planting. The 2013 planting season was wet and resulted in late planting dates throughout Illinois. The study was planted on June 19th with Syngenta hybrid N63R (109 days) 3000GT (with corn rootworm and corn borer resistance and Cruiser Extreme 250) or GT (refuge hybrid with Cruiser Extreme 250 without insect protection).

Applications. N was broadcast-applied by hand as SuperU (Treatments 1, 2, 3, 5, 6, and 10) or sprayed in-row as urea ammonium nitrate (Treatments 3, 7, 8, 9, 11, and 12 [Table 1]) soon after planting. A sidedress N application of 60 lbs N as urea with Agrotain was applied at V4 to Treatments 1, 2, 3, 5, 6, and 10 (Table 1). Strobilurin fungicide was applied to select treatments at VT. Aboveground plant biomass samples were taken at R6 October 14-16 and grain was harvested a few weeks later.

Root samples were collected during the first week of December. Roots were collected by running a large, custom-built U-shaped attachment approximately 16 inches deep over the center two rows in each plot to loosen soil around the root balls. Four roots were collected from each row. Roots were stored in a covered area outdoors at freezing or colder temperatures in onion sacks for up to four weeks until they could be washed, weighed, and ground.

Soil moisture was monitored continuously all season using John Deere soil moisture sensors operating on the principle of heat capacitance. Four sets of soil moisture sensors were placed in the TRAD technology treatments of a single replication (Rep 4) in the CC/Stover Retained/ Conventional Tillage, CC/Stover Retained/Strip Tillage, CS/Conventional Tillage, and CS/Strip Tillage treatments in order to test the effect of Tillage (Conventional vs. Strip Till) and Rotation (Continuous corn vs. Corn Soybeans) on soil moisture. Each set of soil moisture sensors contained four individual sensors measuring soil moisture at 4, 8, 12, 20, and 40 inches below the soil surface. Sensors were carefully placed within the crop row and between corn plants to better indicate soil moisture conditions experienced by corn roots.

2011

Fungicide application and hybrid with insect resistance traits were less effective than fertility (N, P, S, and Zn applications) for increasing yields in 2011. Strip tillage performed as well as conventional tillage in corn-soybean rotations, but did not produce corn yields equivalent to conventional tillage in continuous corn production systems. Yield results support previous work, indicating that continuous corn systems result in lower yields than corn–soybean rotations and that the yield penalty associated with continuous corn is partly the result of stover accumulation. During average and poor growing seasons, corn/soybean rotations are more likely to support high plant populations than continuous corn. Partial stover removal did not overcome the continuous corn yield penalty in strip-tillage systems, but it did overcome the yield penalty in conventionally tilled systems and was especially beneficial in High Technology treatments in 2011. We believe stover removal will be even more effective under favorable growing conditions. This datum indicates that stover removal may require additional fertilizer application, especially under high density planting conditions.

2012

Hybrid trait, specifically insect resistance traits, played a critical role in protecting corn yields from yield loss during the drought of 2012. Yield data directly support previous work from this research group, indicating that the yield penalty associated with continuous corn is much greater under drought conditions. Reduced plant populations and omission of fungicide also improved crop yields during the severe drought of 2012. P, S, and Zn fertilizers had generally positive results when applied to the TRAD package, increasing yields by an average of 6 bu/A-1, but N, P, S, and Zn applications actually reduced grain yields when applied to the high-population, high-input HT package. During poor growing seasons like 2012, corn/soybean rotations are more likely to support high plant populations than continuous corn. Stover removal was effective for high-population, conventionally-tilled continuous corn systems, but did not provide a yield advantage to other systems under the poor growth conditions of 2012. Surprisingly, reduced surface residues in corn/soybean rotations appear to have made soil moisture penetrate the residue/soil interface and move deeper in the soil profile, as evidenced by soil moisture readings at five depths in four Management Systems in the study. During a severe drought, such as 2012, accumulation of residue on the soil surface appears to have made rainfall less root-available by sequestering the moisture in the residue where it was more vulnerable to rapid evaporation.

2013

A late planting date, late-season drought, and extensive plant lodging resulted in lower yields and a muted effect of technology and stover management treatments. Averaged over other treatments, intensively-managed treatments did not produce significantly greater corn yields than the conventionally-managed environment, despite substantially greater inputs. These results are in contrast to 2011 and 2012 when intensively-managed environments yielded 15 and 19 percent greater than conventionally-managed environments. Yield data from 2013 were unique in a number of respects, owing to weather, late planting date, and late-season drought. There was no significant continuous corn yield penalty observed in 2013, meaning that yields were essentially the same between continuous corn and corn following soybeans. When stover was removed in 2013, treatments consisting of lower plant populations and higher levels of P, S, and Zn inputs (i.e., +FERT) resulted in greater yields than other treatments, whereas treatments consisting of high plant populations and/or lower levels of P, S, and Zn inputs (i.e. TRAD, HT, -FERT) demonstrated reduced yields. These data suggest that the drought during pollination, coupled with fertility lost from stover removal, proved detrimental to crop yields. Full retention of stover may have proved beneficial by reducing evaporative soil moisture losses during the drought in August.

There was essentially no stover removal effect in 2013, with one notable exception. It appears that higher plant populations and lower levels of P, S, and Zn resulted in reduced yields when stover was removed.

One entire system, CC/Stover Removed/Strip Tillage, had to be omitted from the study as a result of severe lodging in two replicates, which was the result of the location of the split plots along wind-affected field edges that were impacted by a strong wind event. We do not believe that the lodging was the result of a treatment effect due to strip tillage, since other plots were similarly impacted but fortunately did not result in loss of entire reps.

As in 2012, Hybrid was the most influential technology factor in 2013, followed closely by P-S-Zn application. Replacing the triple-stack, insect-protected hybrid with the same hybrid without the Bt traits and keeping other Technology factors at the advanced level (-HYBRID) resulted in a 6 percent yield reduction relative to the HT treatment, averaged over all systems. A 5.5 percent yield increase was demonstrated when the triple-stack hybrid replaced the non-Bt hybrid when other Technology factors were applied at the standard level (+HYBRID) relative to the TRAD treatment.

Summing up

This study demonstrated that:

- The combined application of commercially available and proven technologies increased yields above the standard treatment by 15 percent in 2011 (moderate drought), 19 percent in 2012 (severe drought) and 9 percent in 2013 (late planting with dry mid-season conditions)
- The effects of various management factors are highly dependent on growing season and no single factor is consistently the most beneficial to crop growth. The most influential factors were nutrient applications in 2011, crop hybrid in 2012, and crop hybrid and nutrient applications in 2013.
- Continuous corn production yielded significantly less grain than corn following soybeans in 2011 and markedly less grain during the drought of 2012 (37 percent reduction). In 2013 no yield penalty was observed for continuous corn
- As demonstrated in 2012 and 2013, application of strobilurin-containing fungicides can be beneficial even during dry growing seasons when most fungal pressure is low. However, if late-season conditions during grain fill and afterwards are poor, fungicide can actually reduce grain yield.

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