FLUID FERTILIZERS FOR SUSTAINABLE RESIDUE REMOVAL IN HIGH-YIELDING CORN PRODUCTION SYSTEMS: FINAL REPORT

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EXECUTIVE SUMMARY

Stover accumulation has been shown to reduce corn grain yields in continuous corn production systems (Gentry et al. 2013), 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 is a concern and must be considered when growers decide to remove stover from continuous corn fields. In this project, we assessed the effectiveness of stover removal for increasing corn yields in high-yielding and conventional environments as well as nutrient management consequences of stover removal. High yielding environments consisted of higher plant populations, increased nutrient fertilizer application, insect protection traits, and application of fungicides. Conventional 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. Additionally, three residue management treatments (crop rotation, partial stover removal, and tillage) were applied at two levels (9th-year continuous corn vs. long-term corn-soybean rotation, stover retained vs. 50% 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.

This study demonstrated that

- The combined application of commercially available and proven technologies increased yields above the standard treatment by 15% in 2011 (moderate drought), 19% in 2012 (severe drought), and 9% 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 soybean in 2011 and markedly less grain during the drought of 2012 (37% 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.

INTRODUCTION

The Crop Physiology Laboratory at the University of Illinois, Urbana-Champaign has conducted experiments over the last 20 years to identify the principle 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, and 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 soybean generally produce greater yields than 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 (Gentry et al. 2013). 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 (Fronning et al. 2008). Johnson et al. (2007) have also shown that compared to aboveground 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 and 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, and reduced 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.**

MATERIALS AND METHODS (Please see previous year report for further details specific to a site-year)

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 3 whole-plot treatment factors: continuous corn with stover retained (CC), continuous corn with stover removed (CCRM), and corn-soybean rotation with stover retained (CS). The split-plot treatment was Tillage (Conventional Tillage or Strip Tillage). Whole plots and split plots together formed quarter plots within each whole plot (Fig. 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 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 nitrogen fertilizer application was included in the design to assess nitrogen use efficiency.

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 soybean) for the following year. The 2013 study was located at a site previously planted to either 10th-year continuous corn or soybean (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 fall 2010 to establish evenness in fertility levels and to make fertilizer recommendations. A potassium application was made in spring 2011.

Stover removal, tillage, and P fertilizer applications were made in spring 2013. Fifty percent of stover was removed by flail chopping all stover, raking into swaths, collecting and weighing it, and replacing 50%, redistributing it evenly across plots with a manure spreader. Stover was not chopped in the CC treatments 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. MESZ fertilizer was band-applied with a tool bar in conventionally tilled treatments at the same time that tillage occurred. 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 resistance and Cruiser Extreme 250) or GT (refuge hybrid with Cruiser Extreme 250 without rootworm resistance). N was broadcast-applied by hand as SuperU (Treatments 1, 2, 4, 5, 6, and 9) or sprayed in-row as urea ammonium nitrate (Treatments 3, 7, 8, 10, 11, and 12) (Table 1) soon after planting. A side-dress N application of 60 lb N as urea with Agrotain was applied at V4 to Treatments 1, 2, 4, 5, 6, and 9 (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.

Due to the late planting date and poor growing conditions during grain-fill, which made aspects of this study unrepresentative of grower practices, we will present the results of tissue analysis for the 2011 and 2012 growing seasons, which reflect one good (2011) and one drought (2012) growing season.

Root samples were collected during the first week of December. Roots were collected by running a large, custom-designed U-shaped attachment spaced 24 inches apart 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 4 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-Soybean) on soil moisture. Each set of soil moisture sensors contained 4 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.

Results and Discussion

2011 and 2012 Data Summary

2011: Fungicide application and hybrid with corn rootworm 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. This data supports 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 the result of stover accumulation. During poor growing seasons, like 2011, 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 data indicates that stover removal may require additional fertilizer application, especially under high density planting conditions.

2012: Hybrid trait, specifically CRW-resistance traits, played a critical role in protecting corn yields from yield loss during the drought of 2012. This data directly supports previous work from this research group indicating that the yield penalty associated with continuous corn is much greater under drought conditions (Gentry et al. 2013). 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. 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 5 depths in 4 Management Systems in this 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 Data

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, the high-yielding environment did not produce significantly greater corn yields than the conventional environment, despite substantially greater inputs. These results are in contrast to 2011 and 2012, when high yielding environments yielded 15% and 19% greater than conventional 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-soybean. 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 higher 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 that 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% yield reduction relative to the HT treatment, averaged over all systems. A 5.5% 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.

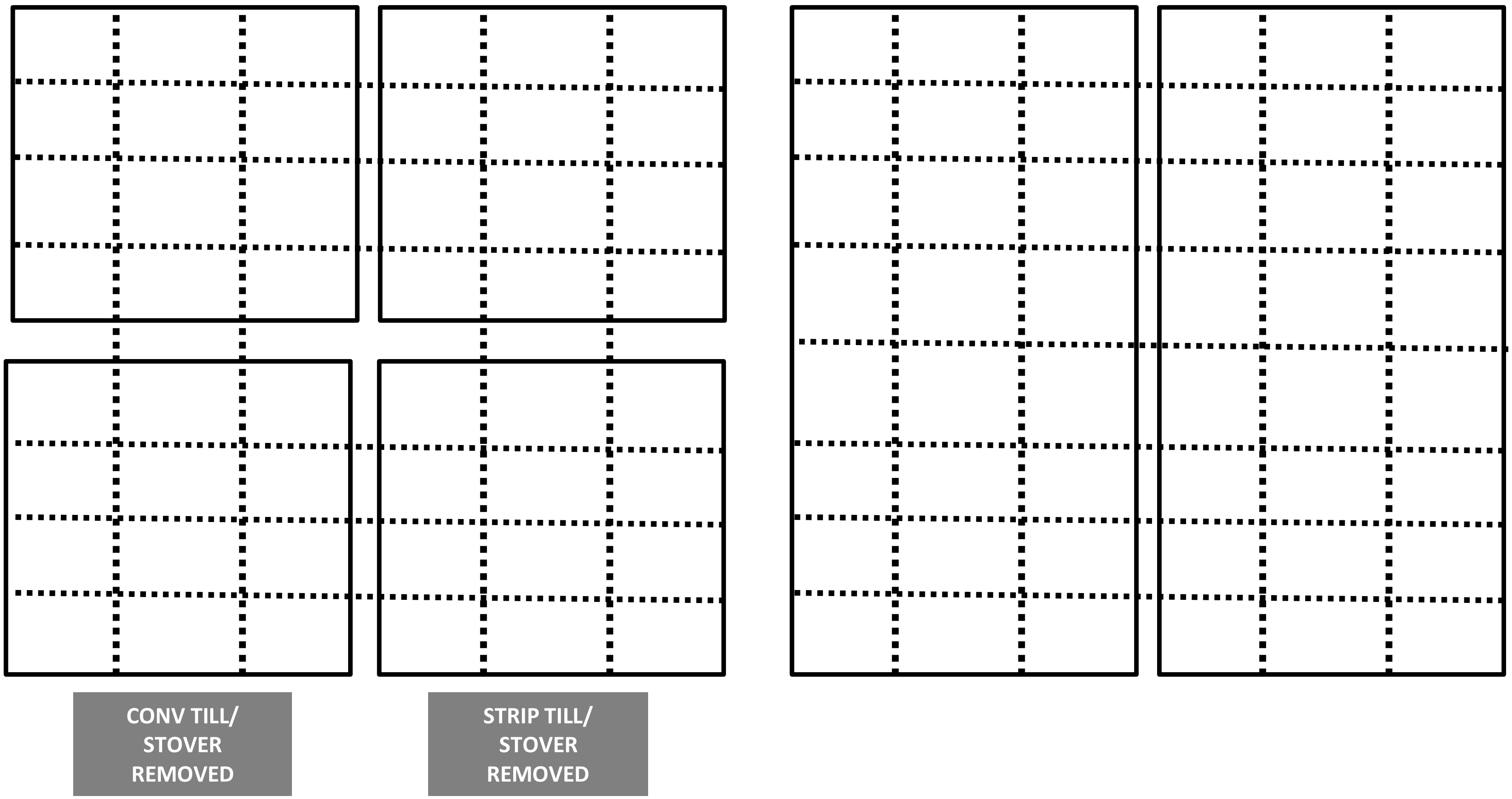

Figure 1. Experimental design of one replication of the study. The 12 treatments are repeated in each quarter-plot of each rotation (corn-corn or corn-soy) plot. The four quarter-plots (conventional tillage+stover, conventional tillage-stover, strip tillage+stover, strip tillage-stover) assess residue 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 nutrients, and crop protection inputs (fungicide).

TRT #	TECHNOLOGY	POP	HYBRID[1]	N[2]	FERT.	FUNGICIDE
1	HIGH TECHNOLOGY	45K	MULTI-TRAIT	BASE+SLOW REL	MESZ	STROBILURIN
2	-FERTILITY	45K	MULTI-TRAIT	BASE +SLOW REL	NONE	STROBILURIN
3	-NITROGEN	45K	MULTI-TRAIT	BASE	MESZ	STROBILURIN
4	-HYBRID TRAIT	45K	REFUGE	BASE+SLOW REL	MESZ	STROBILURIN
5	-POPULATION	32K	MULTI-TRAIT	BASE+SLOW REL	MESZ	STROBILURIN
6	-FUNGICIDE	45K	MULTI-TRAIT	BASE +SLOW REL	MESZ	NONE
7	TRADITIONAL	32K	REFUGE	BASE	NONE	NONE
8	+FERTILITY	32K	REFUGE	BASE	MESZ	NONE
9	+NITROGEN	32K	REFUGE	BASE+SLOW REL	NONE	NONE
10	+HYBRID TRAIT	32K	MULTI-TRAIT	BASE	NONE	NONE
11	+POPULATION	45K	REFUGE	BASE	NONE	NONE
12	+FUNGICIDE	32K	REFUGE	BASE	NONE	STROBILURIN

[1] Multi-traits comprised glyphosate tolerance and corn rootworm resistance; refuge hybrid only contained glyphosate tolerance
[2] Nitrogen fertilizer base rate was 180 lb N a^{-1} as either UAN or SuperU

Table 2. **2011** corn grain yields (bu acre^{-1}) among Systems (Rotation/Stover Management), Tillage, and Technologies (omissions treatments)

	2011 Corn Yield (bu acre^{-1}) for System & Tillage Treatments						
Technology	CC/RETAINED/CT[1,2]	CC/REMOVED/CT[1,2]	CS/CT[3,4]	CC/RETAINED/ST[1,2]	CC/REMOVED/ST[1,2]	CS/ST[1,2]	*Average (for Technology across System/Tillage)*[3]
HIGH TECH	**164**	**184**	**179**	**140**	**155**	**184**	***168***
-FERT	162	135	175	139	158	179	*158*
-N	159	160	158	137	146	168	*155*
-HYBRID	158	170	175	149	159	174	*164*
-POP	192	188	183	176	171	182	*182*
-FUNGICIDE	149	163	184	147	161	176	*163*
TRADITIONAL	**146**	**159**	**156**	**133**	**143**	**153**	***148***
+FERT	169	166	163	159	152	162	*162*
+N	164	166	175	157	154	158	*162*
+HYBRID	145	154	156	153	153	159	*153*
+POP	122	121	147	123	123	146	*130*
+FUNGICIDE	125	142	154	141	150	158	*145*
Average (for System/Tillage across Technology)	*155*	*159*	*167*	*146*	*152*	*167*	

[1] LSD ($P<0.10$) for Technology x System <u>within</u> Tillage (compare values within Conventional Tillage OR Strip Tillage treatments) is 15.0 bu a^{-1}
[2] LSD ($P<0.10$) for System x Tillage (compare values from various Technologies within a System x Tillage treatment) is 6.0 bu a^{-1}
[3] LSD ($P<0.10$) for Technology x System x Tillage (compare Technology values averaged across System and Tillage OR between System/Tillage treatments) is 20 bu a^{-1}

Table 3. **2012** corn grain yields (bu acre^{-1}) among Systems (Rotation/Stover Management), Tillage, and Technologies (omissions treatments)

	2012 Corn Yield (bu acre^{-1}) for System & Tillage Treatments						
Technology	CC/RETAINED/CT[1,2]	CC/REMOVED/CT[1,2]	CS/CT[5,6]	CC/RETAINED/ST[1,2]	CC/REMOVED/ST[1,2]	CS/ST[1,2]	*Average (for Technology)*[3]
HIGH TECH	**95**	**113**	**168**	**87**	**90**	**156**	***119***
-FERT	109	107	161	89	99	169	*122*
-N	118	109	165	112	114	160	*130*
-HYBRID	80	88	149	67	65	138	*98*
-POP	126	118	166	124	111	164	*135*
-FUNGICIDE	122	124	158	106	116	168	*132*
0N Check Plot	51		134	47		133	
TRADITIONAL	**85**[4]	**83**	**138**	**73**	**81**	**129**	***99***
+FERT	91	95	147	89	67	137	*104*
+N	87	85	139	77	73	135	*99*
+HYBRID	132	130	149	119	123	149	*134*
+POP	61	62	126	62	46	122	*80*
+FUNGICIDE	72	81	128	72	77	130	*93*
0N Check Plot	43		118	40		99	
Average (for System/Tillage) [1,3]	*99*	*99*	*151*	*91*	*88*	*146*	

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[1] LSD ($P<0.10$) for Technology x System <u>within</u> Tillage (compare values within Conventional Tillage OR Strip Tillage treatments) is 18 bu a^{-1}

[2] LSD ($P<0.10$) for System x Tillage (compare values from various Technologies within a System x Tillage treatment) is 7.0 bu a^{-1}

[3] LSD ($P<0.10$) for Technology x System x Tillage (compare Technology values averaged across System and Tillage OR between System/Tillage treatments) is 24 bu a^{-1}

[4] One outlier removed from dataset

Table 4. **2013** corn grain yields (bu acre^{-1}) among Systems (Rotation/Stover Management), Tillage, and Technologies (omissions treatments)

	2013 Corn Yields (bu/a) for System & Tillage Treatments					
Technology	CC/RETAINED/CT	CC/REMOVED/CT	CS/CT	CC/RETAINED/ST	CS/ST	*Average (for Technology)*[3]
HIGH TECH	**153**	**145**	**154**	**151**	**159**	**152**
-FERT	140	137	144	141	153	143
-N	155	149	151	142	152	150
-HYBRID	137	139	149	135	151	142
-POP	148	155	152	146	157	152
-FUNGICIDE	149	150	148	151	144	148
TRADITIONAL	**136**	**129**	**148**	**134**	**148**	**139**
+FERT	142	158	151	148	155	151
+N	133	139	138	142	144	139
+HYBRID	147	143	150	159	162	152
+POP	132	134	141	130	142	136
+FUNGICIDE	129	130	136	145	138	136
Average (for System/Tillage)[1,3]	*142*	*142*	*147*	*144*	*150*	

[1] LSD ($P<0.10$) for Technology x System <u>within</u> Tillage (compare values within Conventional Tillage OR Strip Tillage treatments) is 17 bu a^{-1}
[2] LSD ($P<0.10$) for System x Tillage (compare values from various Technologies within a System x Tillage treatment) is 7 bu a^{-1}
[3] LSD ($P<0.10$) for Technology x System x Tillage (compare Technology values averaged across System and Tillage OR between System/Tillage treatments) is 25 bu a^{-1}
[4] Four outliers removed from dataset

Table 5. P-values describing sources of variation for corn yield and per-plant root biomass, 2013. Main plot treatment was System (Continuous Corn-Stover Retained, Continuous Corn-50% Stover Removed, and Corn-Soy-Stover Retained). Split-plot treatment was Tillage (conventional tillage vs. strip tillage). Omission split-split plot treatments (Technology) were Fertility, Hybrid, Nitrogen, Population, and Fungicide.

Sources of Variation	**2013 Grain Yield**
SYSTEM	0.0626
TILLAGE	0.8931
TECHNOLOGY	0.0203
SYSTEM*TILLAGE	0.6989
SYSTEM*TECHNOLOGY	0.9178
TILLAGE*TECHNOLOGY	0.9263
SYSTEM*TILLAGE*TECHNOLOGY	0.9497

Table 6. Most influential factors for yield, by year. Values show the treatment value in terms of yield increase when added to the Traditional package (4th column) or yield reduction when removed from the HT package (last column). All averages calculated as differences between average values for technology, stated in the last columns of Tables A, B, and C.

Year	**Primary Factor**	**Secondary Factor**	**Traditional (bu/a increase relative to the TRAD treatment)**	**High Tech (bu/a reduction relative to the HT treatment)**
2011	N & P, S, Zn	Stover removal	N: +15 P, S, Zn: +12 Stover Removal: +3	N: -14 P, S, Zn: -6 Stover Removal:+19
2012	Hybrid	Stover removal (HT only)	Hybrid: +34	Hybrid: -20 Stover Removal: +18
2013	Hybrid	P, S, Zn Fertility	Hybrid: +8 P, S, Zn: +6	Hybrid: -9 P, S, Zn: -8

Table 7. 2011-2012 Nitrogen use efficiency data.

Rotation/Technology	2011 N Fertilizer Recovery Efficiency (%)	2012 N Fertilizer Recovery Efficiency (%)
CC/High Tech	33.5	27.5
CC/Standard	33.3	28.4
C-S/High Tech	39.7	21.7
C-S/Standard	22.4	21.9

Table 8. 2011 Yield, biomass, N, P, K, S, Zn content (on a lb/a basis) of corn stover. Each *Stover Removed* treatment had been subject to one year of 50% stover removal, occurring the previous fall. Only conventionally tilled data displayed. Two systems, continuous corn with stover retained and continuous corn with stover removed (CC/RETAINED and CC/REMOVED) are displayed. Both systems were conventionally tilled. Yield = bu a^{-1}; Biomass = lb stover a^{-1}; N = lb N a^{-1} (whole plant value); P = lb P a^{-1} (stover); K = lb K $^{a-1}$ (stover); S = lb S a^{-1} (stover); Zn = lb Zn a^{-1} (stover). The 4th replicate was omitted from this analysis due to plant tissue testing variability within that data.

	2011 Corn Biomass and Nutrient Content of Corn Stover													
Technology	CC/RETAINED							CC/REMOVED						
	Yield	**Biomass**	**N**	**P**	**K**	**S**	**Zn**	**Yield**	**Biomass**	**N**	**P**	**K**	**S**	**Zn**
HIGH TECH	**164**	**6340**	**142**	**8.34**	**78.89**	**4.66**	**0.08**	**184**	**6831**	**154**	**8.19**	**78.52**	**4.32**	**0.12**
-FERT	162	6020	138	7.82	81.22	3.66	0.07	135	6273	112	7.46	65.77	3.25	0.10
-N	159	7162	131	8.77	82.02	4.27	0.09	160	6573	124	7.89	62.27	3.72	0.06
-HYBRID	158	6462	153	8.42	65.37	4.32	0.08	170	6781	154	8.82	75.79	4.76	0.06
-POP	192	5276	156	6.72	55.55	3.90	0.05	188	6143	151	7.36	70.58	3.86	0.06
-FUNGICIDE	149	6159	143	8.58	67.35	4.91	0.08	163	5874	128	7.32	61.17	3.57	0.06
TRADITIONAL	**146**	**4794**	**109**	**6.37**	**52.21**	**2.86**	**0.06**	**159**	**6711**	**129**	**8.55**	**80.32**	**3.60**	**0.10**
+FERT	169	6313	141	8.12	72.10	4.91	0.07	166	6784	134	8.87	67.98	5.03	0.11
+N	164	5823	135	7.44	71.38	3.33	0.07	166	6286	138	8.01	73.32	3.55	0.10
+HYBRID	145	5996	115	7.38	63.29	3.60	0.08	154	5684	117	6.80	62.66	2.87	0.08
+POP	122	5271	102	6.90	55.59	3.29	0.07	121	6091	106	7.75	57.67	3.72	0.12
+FUNGICIDE	125	5339	101	7.35	63.72	3.28	0.08	142	5098	104	6.68	65.59	2.70	0.06
Average (for System)	***155***	***5688***	***116***	***7.74***	***63.02***	***3.68***	***0.09***	***159***	***6261***	***129***	***7.81***	***68.47***	***3.75***	***0.09***

Table 9. 2012 Yield, stover biomass, and N, P, K, S, Zn content (on a lb/a basis) of corn stover. Each *Stover Removed* treatment had been subject to one year of 50% stover removal, occurring the previous fall. Only conventionally tilled data displayed. Two systems, continuous corn with stover retained and continuous corn with stover removed (CC/RETAINED and CC/REMOVED) are displayed. Both systems were conventionally tilled. Yield = bu a^{-1}; Biomass = lb stover a^{-1}; N = lb N a^{-1} (stover); P = lb P a^{-1}(stover); K = lb K $^{a-1}$(stover); S = lb S a^{-1}(stover); Zn = lb Zn a^{-1}(stover).

	2012 Corn Biomass and Nutrient Content of Corn Stover													
Technology	CC/RETAINED							CC/REMOVED						
	Yield	**Biomass**	**N**	**P**	**K**	**S**	**Zn**	**Yield**	**Biomass**	**N**	**P**	**K**	**S**	**Zn**
HIGH TECH	**95**	**7944**	**60**	**4.79**	**70.10**	**6.90**	**0.09**	**113**	**7020**	**58**	**4.06**	**57.83**	**5.28**	**0.11**
-FERT	109	7457	60	4.32	78.25	5.21	0.11	107	7833	67	2.88	56.37	4.21	0.11
-N	118	8867	74	5.06	69.16	6.06	0.11	109	7751	58	3.49	55.28	5.21	0.08
-HYBRID	80	7687	70	7.00	59.13	6.84	0.11	88	7864	64	5.46	50.06	6.53	0.08
-POP	126	7421	56	4.95	71.85	5.48	0.10	118	6001	49	2.72	47.57	4.63	0.07
-FUNGICIDE	122	7777	54	4.33	56.53	5.71	0.06	124	8328	65	4.51	59.48	5.61	0.06
TRADITIONAL	**85**	**6091**	**50**	**4.06**	**47.34**	**4.12**	**0.11**	**83**	**5718**	**45**	**2.58**	**41.44**	**3.55**	**0.08**
+FERT	91	6458	59	4.37	38.42	5.87	0.08	95	6054	48	3.88	43.99	5.12	0.08
+N	87	6096	53	3.37	41.89	4.76	0.09	85	5380	42	2.54	38.77	3.62	0.10
+HYBRID	132	6832	53	3.42	68.51	4.78	0.11	130	6381	45	3.09	52.68	3.42	0.10
+POP	61	6701	51	4.70	53.73	4.91	0.09	62	5931	50	3.50	49.77	4.42	0.12
+FUNGICIDE	72	5749	58	5.29	45.81	4.94	0.12	81	5910	45	2.80	48.88	3.98	0.10
Average (for System)	*99*	*7072*	*58*	*4.63*	*58.14*	*5.44*	*0.10*	*99*	*6681*	*53*	*3.46*	*50.18*	*4.63*	*0.09*

Table 10. All years yield, biomass, and harvest index values.

Technology	CC/RETAINED								CC/REMOVED							
	2011			**2012**			**2013**		**2011**			**2012**			**2013**	
	Yield	**BIO**	**HI**	**Yield**	**BIO**	**HI**	**Yield**	**HI**	**Yield**	**BIO**	**HI**	**Yield**	**BIO**	**HI**	**Yield**	**HI**
HIGH TECH	**164**	**6340**	**0.50**	**95**	**7944**	**0.40**	**153**	0.49	**184**	**6831**	**0.51**	**113**	**7020**	**0.43**	**145**	0.48
-FERT	162	6020	0.51	109	7457	0.40	140	0.52	135	6273	0.49	107	7833	0.38	137	0.48
-N	159	7162	0.48	118	8867	0.40	155	0.49	160	6573	0.49	109	7751	0.36	149	0.49
-HYBRID	158	6462	0.49	80	7687	0.39	137	0.45	170	6781	0.49	88	7864	0.39	140	0.50
-POP	192	5276	0.56	126	7421	0.43	148	0.52	188	6143	0.54	118	6001	0.46	155	0.50
-FUNGICIDE	149	6159	0.49	122	7777	0.43	149	0.50	163	5874	0.49	124	8328	0.41	150	0.50
TRADITIONAL	**146**	**4794**	**0.49**	**85**	**6091**	**0.37**	**136**	**0.48**	**159**	**6711**	**0.49**	**83**	**5718**	**0.40**	**129**	0.48
+FERT	169	6313	0.49	91	6458	0.40	142	0.46	166	6784	0.50	95	6054	0.37	158	0.51
+N	164	5823	0.50	87	6096	0.39	133	0.49	166	6286	0.50	85	5380	0.41	139	0.51
+HYBRID	145	5996	0.48	132	6832	0.44	147	0.50	154	5684	0.49	130	6381	0.43	143	0.50
+POP	122	5271	0.50	61	6701	0.33	132	0.47	121	6091	0.45	62	5931	0.36	134	0.47
+FUNGICIDE	125	5339	0.48	72	5749	0.35	129	0.44	142	5098	0.49	81	5910	0.41	130	0.50
Average (for System)	*155*	*5688*	*0.50*	*99*	*7072*	*0.39*	*142*	*0.48*	*159*	*6261*	*0.50*	*99*	*6681*	*0.40*	*142*	*0.49*