Evaluation of fertilizer placement and timing in continuous corn in three long-term tillage systems.

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INTRODUCTION

Economics have shifted to favor a corn on corn rotation versus a corn/soybean rotation for many growers in southern Minnesota. Concern over the high surface residue levels that result from planting corn continuously in a long-term rotation has often led to the use of more aggressive tillage practices, such as the moldboard plow.

Conservation tillage systems, where at least 30% residue cover remains after planting, help minimize soil erosion and runoff potential while potentially leading to reduced fuel use, labor costs, and trips across the field. Although there are many documented benefits of conservation tillage, concern about the effects of higher surface residues in heavy clay soils, particularly in corn on corn, has hindered the adoption of conservation tillage in southern Minnesota.

The University of MN conducted trials across southern Minnesota at four to six locations per year from 2008 to 2011 to evaluate the effect of tillage in a continuous corn system on corn yield and profitability (1). Tillage systems, which included strip-tillage (a conservation tillage system where a strip 6 to 8 inches wide is tilled, typically in the fall, while the area between strips is left undisturbed), a moderately aggressive tillage system such as chisel plow or a disk-rip/in-line rip system, and moldboard plow, were evaluated in long-term replicated trials where corn was planted from year to year. Although yield was not consistently affected by tillage system, the moldboard plow system often resulted in greater yields than the strip-tillage system when differences were found within a given site and year. At the Lamberton site in southwestern Minnesota, corn yields in strip-tillage were consistently lower than in the moldboard plow system. Results have varied for the moderately aggressive system, with this system yielding similarly to the top yielding treatment, the lowest yielding treatment, or to both, depending on the site and year.

Recent research conducted by the University of Illinois in a high yield system found that yields were increased with deep placement of P and K, even though soil test levels were high enough that additional P and K would normally not have been recommended (2). Other research in Iowa and Minnesota has shown that banded K can increase yields in conservation tillage systems due to stratification of K in the upper soil surface limiting K uptake when soils area dry. Previous research has also shown that split applications of nitrogen may result in increased yields compared to a single application of N in the fall or spring.

Although nutrient levels should not have been a limiting factor at any of the sites evaluated in the U of MN long-term tillage trials described above, it is unknown if application of P & K, depending on application method, and/or splitting the application of N could have reduced or eliminated the yield differences observed among the tillage systems evaluated. Information is limited regarding the effects of deep placement of P and K as well information from southwestern Minnesota on the effect of splitting applications of nitrogen, particularly under various long-term tillage systems, in continuous corn. If yield differences among tillage systems could be reduced or eliminated by changes in the placement and/or timing of fertilizer applications, more growers may be willing to practice conservation tillage in a continuous corn system, which could help protect and enhance our soil and water resources.

Through this study, we are evaluating the effect of fertilizer placement and timing on corn yield in continuous corn under three long-term tillage systems in southwestern Minnesota at the Southwest Research and Outreach Center, which contains the Lamberton site of the previously describe long-term tillage trials. Specifically the objectives of this study are to: 1) Evaluate the influence of application method of P and K on corn population and yield in continuous corn under three long-term tillage systems (strip-tillage (ST), in-line rip system (ILR), and moldboard plow(MP)) and 2) Evaluate the effect of nitrogen application timing on corn population and yield in continuous corn under these three long-term tillage systems.

METHODS

The trial was established at the Southwest Research and Outreach Center in Lamberton where a long-term tillage trial was established in the fall of 2007. Corn has been planted on this ground since 2007. The tillage systems evaluated included ST(conducted in the fall), MP (primary tillage conducted in the fall followed by field cultivation in the spring), and ILR (primary tillage conducted in the fall followed by field cultivation in the spring). Tillage treatments were arranged in a randomized complete block design with four replications.

Fertilizer treatments were arranged in a factorial of three P and K treatments (a check of no P and K, broadcast P & K, and banded P & K) and two nitrogen timing treatments (180 pounds of N applied preplant as 28% UAN, and a split application of nitrogen consisting of a preplant application of N as 28% UAN followed by sidedress application of N by the time corn reaches the V6 corn stage, for a total of 180 pound of N), for a total of six treatments. The P and K rates were applied based on soil test level. Individual plots were 100 feet long by ten feet wide.

Initial soil samples (0-6 inch depth) were collected from each plot prior to fertilizer application to determine soil P and K levels.

The corn hybrid DKC 48-12 was planted at a rate of 35,500 seeds per acre on May 14, 2012. All treatments received 2.5 gallons per acre of 10-34-0 and 1 quart per acre of chelated zinc with the planter. Weeds were controlled with a combination of pre- and post-emergence herbicides at labeled rates.

Residue cover was measured in each tillage plot on June 6, 2012 at the V5 stage of corn by using the line transect method. Stand counts were taken the same day by counting the number of plants in 1/1000th of an acre in two adjacent rows within each plot. Ear leaf samples were collected at the R2 stage of corn (50% silking) and analyzed for N, P, and K to assess nutrient availability. Plots were evaluated visually for foliar disease levels during the growing season, and no significant issues were observed. Grain moisture and yield was determined by harvesting the center two rows of each plot at harvest with a plot combine equipped with a weigh cell and moisture sensor. Grain yields were calculated at 15.5% moisture.

Soil samples (0-6 inch depth) were collected from each plot after harvest to determine N, P, K, and Zn levels.

Analysis of variance was used to statistically interpret the data. A 0.10 level of significance was used throughout.

RESULTS AND DISCUSSION

Weather for 2012: Weather data collected from the SWROC weather station at Lamberton in 2012 are shown in Table 1. Although above average rainfall in May resulted in planting delays, drought conditions from the fall of 2011 left soil moisture levels well below normal, and drought conditions were experienced during much of the growing season of 2012. A total of two inches of precipitation was recorded in June and July, a period where 7.76 inches has historically been recorded. Less than an inch of rain fell in July alone (0.74 inches), when historically 3.78 inches of precipitation has been recorded during this month. Temperatures were also warmer than normal during May, June, July and September, and as a result, growing degree unit accumulation was 11% greater than normal for this location during the May1 – September 30th time period. The drought conditions led to reduced yields at this site. Combined with a warm growing season, the crop matured earlier than normal and grain moisture was low at harvest.

Initial Soil Test Results: Results of the initial soil tests taken by tillage treatment in the spring of 2012 are presented in Table 2. After being under a respective tillage system for the previous 4 years (2008 – 2011), differences were observed among the tillage plots in P and K. Bray P levels were 10 ppm in MP (low) while levels were 16 and 17 ppm (high) for ST and ILR, respectively. Soil test K levels were also lowest in MP (104 ppm – medium) compared ST (121 ppm – high) and ILR (134 ppm – high). This is likely due to more stratification of nutrients in the reduced tillage systems, unlike in MP where more mixing of the soil occurred with fall tillage.

Residue Levels After Planting: Residue levels after planting for the tillage treatments were 6% for MP, 22% for ILR, and 55% for ST.

Plant Height at V5, Grain Moisture and Yield: The main treatment effects of tillage, fertilizer placement of P and K, and N application timing on yield, grain moisture, and plant height at V5 are presented in Table 3. No significant differences were observed at this time in plant height across any of the main treatment effects, nor were any significant interactions observed between factors. Although grain moisture was low at harvest, differences were observed among tillage treatments when averaged across P and K treatments and N timing, with ST resulting in a grain moisture content that was 0.9 percentage points greater than the other two tillage systems. Averaged across tillage treatment and N timing, the addition of P &

K resulted in greater grain moisture at harvest compared to where no additional P and K was applied, although placement (band versus broadcast) did not make a difference. Averaged across tillage systems and P and K treatments, timing of nitrogen application did not influence grain moisture content.

Tillage had a significant effect on yield averaged across P and K treatments and N application timing, with ST averaging 26 to 35 bushels per acre less than ILR and MP, respectively. When averaged across tillage treatments and N application timing, banding of P and K resulted in greater yields than applying no P and K or a broadcast application of P and K. Interestingly, there was no yield difference between a broadcast application of P and K and no application of P and K, when averaged across tillage treatments and N application timing. Averaged across tillage treatments and P and K treatments, pre-plant application of N resulted in 6 bushel per acre greater yield than a split application of N. The poor response to the split application of N was likely due to the poor uptake of N since it was likely stratified near the surface in dry soils where the roots were not actively taking it up.

A significant interaction between tillage and N application timing on yield showed that the difference observed between timing of N application was driven by differences observed in strip tillage, where the preplant application of N yielded 16 bushels per acre more than the split application of N when averaged across P and K treatments (Table 4). There was no difference observed between the timing of N application for the other tillage systems, when averaged across P and K treatments. There was also a significant interaction between the effects of tillage and P and K treatment on grain moisture (Table 5). Broadcasting P and K and banding P and K resulted in the greatest grain moisture content for ST and ILR, respectively, while no P and K resulted in the lowest grain moisture content for both tillage systems, when averaged across N application timing. P and K placement did not influence grain moisture content in MP when averaged across N application timing.

Ear Leaf N, P, and K at R2 Corn (50 % Silking): N concentration of corn ear leaves collected at R2 (50 % silking) was not influenced by the main effects of tillage, P and K placement, or N application timing (Table 6). The only significant interaction observed among treatment main effects for ear leaf N concentration was between tillage system and N application timing, where ear leaf N concentrations were slightly higher when N was applied preplant versus split applied in ST (data not shown). The ear leaf N concentrations observed fell below the standard expected range of 2.70 to 3.50 % for N (3). Significant drought stress likely impacted N concentrations in the plant at this time.

P concentration of corn ear leaves collected at R2 (50% silking), averaged across P and K placement and N application timing, was higher in ILR tillage system versus ST or MP (Table 6). The main effects of P and K fertilizer placement and N application timing on ear leaf P concentration were not significant, however, and there were no significant interactions among treatments. The ear leaf P concentrations observed fell in the standard expected range of 0.20 to 0.40 %, although levels were on the lower end of this range (3).

K concentration of corn ear leaves collected at R2 (50% silking) were lower in ST than the other two tillage systems when averaged across P and K fertilizer placement and N application timing (Table 6). Ear leaf K concentrations were also lower where no P and K had been applied compared to a band or broadcast application of P, when averaged across tillage system and nitrogen application timing. N application timing did not influence ear leaf K concentrations, when averaged across tillage system and P and K fertilizer placement.

There was a significant interaction between the main effects of tillage system and P and K fertilizer placement for ear leaf K concentrations (Table 7). K concentrations were greatest in the banded application of P and K in ST, while in the ILR system, K concentrations were greatest when P and K were broadcast. In both these systems, K concentrations were lowest where no additional P and K application was made. There was no significant difference in K concentrations across P and K fertilizer placement in MP. Ear leaf K concentrations observed were generally below the standard expected range of 1.70 to 2.50% (3)

Soil Test Values-Fall of 2012: Averaged across P and K treatments and N application timing, soil test N levels were greater in ST than in the ILR or MP tillage systems, while soil test P was lower in MP than ST, and soil test K levels were lowest in MP compared to the other two systems (Table 8). P levels did not change between the spring and fall samples for MP, and changed very little for ST and the ILR system. Soil test K levels were greater for all tillage systems in the fall, testing in very high range, although levels in MP were still lower than in the other two systems. Soil test Zn levels were greater for the ILR system than the other two tillage systems, when averaged across the P and K treatments and N treatments.

Averaged across tillage systems and N application timing, soil test P values were lower where no additional P and K had been applied compared to the banded application of P and K (Table 8). Soil test K levels were also lower where no additional P and K had been applied compared to the treatments where additional P and K had been applied, regardless of timing. There was no difference in soil test N or Zn levels for the P and K application timing main effect.

For the main effect of N application timing, only soil test K levels were influenced, with K levels being greater in the split application of N compared to the preplant application of N.

ACKNOWLEGEMENTS

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Table 1. Precipitation and growing degree units (GDUs) at Lamberton in 2012

	Precipitation		GDUs	
Month	2012	Historic†	2012	Historic†
	------------inches-----------			
May	10.33	3.34	403	346
June	1.26	3.98	612	544
July	0.74	3.78	808	662
August	3.06	3.06	572	594
September	1.11	2.92	412	384
May - Sept. Total	16.50	17.08	2807	2530

†Historic Records are from Lamberton, 1961 - 2012.

Table 2. Initial soil test summary of tillage treatments for samples collected and analyzed for phosphorus (P) and potassium (K) the spring of 2012.

Tillage	Bray P1-P†	Ammonium Acetate K†
	------------ppm-----------	
Strip Till	16a	121b
In-Line Ripper	17a	134a
Moldboard Plow	10b	104c

† Within columns, numbers followed by the same letter are not significantly different at $P \leq 0.10$.

Table 3. Summary of main treatment effects of tillage, P and K fertilizer application method, nitrogen timing means and treatment significances.

		Yield	Grain Moisture	Plant Height at V5
		--bu/ac--	---%---	---cm---
Tillage	Strip Till	111b	14.7a	26.2a
	In-Line Ripper	137a	13.8b	26.5a
	Moldboard Plow	146a	13.8b	25.8a
	P>F†	<0.01	<0.001	0.55
Fertilizer	None	130b	13.5b	26.3a
	Banded	136a	14.4a	25.6a
	Broadcast	128b	14.3a	26.7a
	P>F†	0.05	<0.01‡	0.31
Nitrogen	Pre-plant	134a	14.1a	25.9a
	Split	128b	14.0a	26.4a
	P>F†	0.02‡	0.58	0.39

† *P>F*, statistical significance of main treatment effect. Effects are significant at $P \leq 0.10$.

‡ Main effect had a significant interaction with tillage

Table 4. Summary of interaction effects between tillage and nitrogen (N) application timing on corn yield. Statistics determine if the effect of N was significant ($P \leq 0.10$) for each tillage system.

Variable	Tillage	Pre-Plant N	Split Applied N	*P>F*†
		----------bu/ac----------		
Yield	Strip Till	119	103	<0.01
	In-Line Ripper	138	135	0.58
	Moldboard Plow	146	145	0.79

† *P>F*, statistical significance of nitrogen application within each tillage system. Effects are significant at $P \leq 0.10$.

Table 5. Summary of interaction effects between tillage and P and K fertilizer placement on harvested grain moisture. Statistics determined if the effect of placement was significant ($P \leq 0.10$) for each tillage system.

Variable	Tillage	None	Banded	Broadcast	*P>F*†
		----------------------%----------------------			
Grain	Strip Till	13.6	15.0	15.5	<0.001
Moisture	In-Line Ripper	13.4	14.2	13.8	0.03
	Moldboard Plow	13.7	13.6	14.0	0.31

† *P>F*, statistical significance of P and K placement and application within each tillage system. Effects are significant at $P \leq 0.10$.

Table 6. Summary of main treatment effects of tillage, P and K fertilizer application method, nitrogen timing means and treatment significances for ear leaf samples collected at the R2 growth stage (50% silking).

		Ear Leaf N	Ear Leaf P	Ear Leaf K
		----------------------%----------------------		
Tillage	Strip Till	2.47a	0.22b	1.08b
	In-Line Ripper	2.50a	0.26a	1.46a
	Moldboard Plow	2.54a	0.22b	1.60a
	P>F†	0.65	<0.01	<0.01
Fertilizer	None	2.54a	0.22a	1.27b
	Banded	2.48a	0.24a	1.48a
	Broadcast	2.50a	0.23a	1.42a
	P>F†	0.51	0.13	<0.01‡
Nitrogen	Pre-plant	2.53a	0.23a	1.39a
	Split	2.48a	0.23a	1.39a
	P>F†	0.28	0.52	0.98

† *P>F*, statistical significance of main treatment effect. Effects are significant at $P \leq 0.10$.

‡ Main effect had a significant interaction with tillage

Table 7. Summary of interaction effects between tillage and P and K fertilizer placement on ear leaf potassium concentration. Statistics determined if the effect of placement was significant ($P \leq 0.10$) for each tillage system.

Variable	Tillage	None	Banded	Broadcast	*P>F*†
		--------------------%-------------------- -			
Ear Leaf	Strip Till	0.9	1.3	1.1	<0.001
Potassium	In-Line Ripper	1.4	1.5	1.6	0.08
	Moldboard Plow	1.5	1.7	1.6	0.13

† *P>F*, statistical significance of PK fertilizer application within each tillage system. Effects are significant at $P \leq 0.10$.

Table 8. Summary of main treatment effects of tillage, P and K fertilizer application method, nitrogen timing means and treatment significances for soil test values collected the fall of 2012.

		Soil Test N	Soil Test P	Soil Test K	Soil Test Zn
		--------------------ppm--------------------			
Tillage	Strip Till	39a	17a	187a	0.8b
	In-Line Ripper	29b	16ab	189a	1.0a
	Moldboard Plow	28b	10b	167b	0.8b
	P>F†	0.02	0.11	<0.01	0.02
Fertilizer	None	31a	13b	174b	0.8a
	Banded	32a	16a	186a	0.9a
	Broadcast	32a	14ab	183a	0.9a
	P>F†	0.82	0.06	0.02	0.19
Nitrogen	Pre-plant	32a	13a	178b	0.9a
	Split	32a	16a	184a	0.9a
	P>F†	0.89	0.16	0.07	0.95

† *P>F*, statistical significance of main treatment effect. Effects are significant at $P \leq 0.10$.