ADJUSTING TILLAGE PRACTICES IN A CORN/SOYBEAN ROTATION

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Abstract

Grain crop producers often rotate tillage management to meet soil conservation goals or disrupt yield-limiting soil conditions. A long-term tillage study containing plowed and no-till treatments was modified in 2005 to evaluate the effect of tillage change on soil properties and crop yield on a Plano silt loam soil at the Arlington Agricultural Research Station. Tillage treatments included continuous chisel tillage, the same chisel tillage converted to no-till, continuous no-till, chisel tillage of the same no-till, and strip-tillage. Tillage of the no-till resulted in soil test, penetrometer resistance, and bulk density levels similar to that of continuous chisel and improved early season K uptake by corn. Converting the chisel plowed treatment to no-till increased penetration resistance, bulk density, and decreased K uptake. Yield tended to be highest where the no-till treatment was tilled and lowest where the chiseled treatment was rotated to no-till. These preliminary results showed that tilling continuous no-till may improve soil quality parameters as evidenced by the lower bulk density and penetration resistance, which enhanced nutrient utilization and crop growth and yield. Conversion of plowed ground to no-till reduced these soil quality factors, as well as crop yield and growth possibly due to changes in soil consolidation.

Introduction

Recent erosive rains have amplified the need for reconsideration of the tillage systems used on many Wisconsin soils. Erosion has been evident in many fields, even where considerable residue was left on the surface by chisel plowing and other mulch-tillage systems. Tillage has a profound effect on the soil condition due to changes in residue coverage and soil consolidation. Mulch tillage systems have less runoff initially when compared to no-till because of storage in depressions. However, once secondary tillage is conducted and the crop is planted the soil is more susceptible to erosion. Switching to a no-till cropping system is an accepted way to reduce soil erosion, but it is not without its problems.

Many producers are reluctant to adopt long-term no-till because of a yield penalty that has been associated with this system, especially in northern portion of the Corn Belt. No-till systems, which leave large amounts of residue, protect the soil, but also cause cooler and wetter soil conditions that slow emergence and early growth (Moncrief, 1981; Wolkowski, 2000). Other concerns with no-till systems include higher surface bulk density that reduces porosity (Hill et al., 1985), increased penetration resistance that interferes with root growth (Kaspar et al., 1991), and increased N loss via denitrification (Hilton et al., 1994) and N immobilization (Karlen et al., 1994). Recent research has shown that no-till and strip-till systems are more responsive to P and K fertilization, especially within a corn/soybean rotation (Wolkowski, 2003). For these reasons, the adoption of no-till in Wisconsin lags significantly behind states further south.

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Benefits beyond those related to soil conservation have been observed in no-till systems. Producers that have successfully applied no-till management have touted these for years. These benefits include improvements in aggregate stability (Kladivko et al., 1986), moisture retention during dry periods (Hill, 1990), and C storage (Karlen et al., 1994). Anecdotal suggestions are often made that no-till systems require several years to equilibrate and produce yields equal to those where tillage is performed. There is limited research available to support this claim.

Crop producers are very interested in the influence of tillage on crop growth and the soil condition. The idea of rotational or occasional tillage to loosen the soil has been explored by Pierce et al. (1994), who found that plowing a long-term no-till soil produced soil physical conditions similar to continuously plowed soils. If plowing is ceased the soil returns to the conditions found in continuous no-till in a few years. They indicated that one of the significant benefits of periodic plowing is the redistribution of immobile nutrients, such as P and K, and amelioration of the acidic surface pH which results from the surface application of ammonium-containing fertilizers.

This study is being conducted to evaluate two broad scenarios of tillage management in grain crop rotations. These are the potential benefit of the one-time tillage of a long-term no-till treatment on a site that has shown yield depression in no-till compared to chisel tillage, and the consequence of converting tilled fields to no-till. The latter would determine if in fact there is a period required for no-till yields to equilibrate with those of other systems.

Materials and Methods

A tillage/rotation study that was established in 1997 near Arlington, Wis., USA on a Plano silt loam (Typic Argiudolls) was used for this study. This study utilized three existing rotations [continuous corn (CC), corn following soybean (SbC), and soybean following corn (CSb)], established five tillage treatments (long-term fall chisel/spring field cultivator, fall strip-till, and no-till; long-term chisel that converted to no-till in 2005 and long-term no-till that was converted to chisel plow in 2005; and one-time/one-year tillage conversion with return to the original tillage system), and three P and K fertilizer placement methods (none, fall pre-tillage broadcast, planter-applied 2 x 2 inches – below and to the side of the seed). Row cleaners were not used in the no-till system. Fertilizer was applied at rate of 200 lb 0-23-30/acre. Supplemental N was applied to the corn following University of Wisconsin recommendations. Treatments were replicated four times in a split-split plot treatment arrangement where rotation is the main plot, tillage is the subplot, and fertilization is the sub-subplot. The individual plot size was 10 x 35 feet (four 30-inch rows). All treatments were replicated four times. A full season corn hybrid (DeKalb DKC53-34RR and Renk RK636-RRYGCB) and soybean variety (Kaltenberg KB221RR and Asgrow AG2107RR) were planted in early May 2005 and 2006, respectively using a four row Kinze planter (Kinze Mfg., Williamsburg, IA, USA).

Measurements made included: (1) population; (2) surface crop residue; (3) early growth and nutrient uptake at the V6 growth stage; (4) incremental soil samples, (5) soil bulk density, (6) cone penetrometer resistance, and (7) yield. Population counts were made by counting the number of plants visible along a measured length of row after the majority of plants were emerged. Three crop residue measurements were taken using the line-transect method in each tillage plots. Early season corn plant samples were taken at the V6 growth stage in corn by collecting ten plants per plot. These were dried, weighed, and ground for analysis. Incremental soil samples were collected in mid-June by taking nine cores to 8 inches from each plot, which were then subdivided into 2-inch increments. All samples were analyzed for routine soil test parameters using University of Wisconsin laboratory procedures. Bulk density was measured by collecting intact cores to 9 inches and subdividing these into increments of 3 inches. Penetrometer measurements were made with a constant-rate penetrometer interfaced with a load cell and data logger. Yield was measured by harvesting the middle two rows of the four-row plots with a small plot combine. Wheel traffic was avoided in the middle two rows.

Data were analyzed with an analysis of variance for a split-split plot treatment arrangement using SAS (Statistical Analysis System, Cary, NC). Where significance is found at the $p<0.05$ level a Fisher's LSD was calculated.

Results and Discussion

The 2005 and 2006 crop years were unique with respect to weather conditions. Periods of moderate drought, accompanied by warm temperatures, were experienced in early summer. Adequate mid-season rain arrived at pollination and crop yields in the region were much better than generally anticipated.

Table 1 shows the main effect of tillage treatment on the incremental soil test values collected in 2005. These results show the surface acidification associated with the rotation components which were planted to corn in 2005 (CC and SbC). The pH in the 0- to 2-inch increment was depressed by about a full pH compared to that measured in the CSb treatment. This effect was also observed in the 2- to 4-inch increment. Soil test P was generally not affected by rotation and was in the excessively high category throughout the top 6 inches. Soil test K in the 0- to 2-inch layer was higher in the continuous corn treatment, compared to the treatments that contained soybean. Corn stover will cycle much more K compared to soybean and at normal yields corn grain removes less K compared to soybean. The combination of these effects likely accounted for the higher soil test K in the surface of the continuous corn system. Tillage affected soil test as expected. Soil pH and soil test P and K were higher in the no-till and strip-till treatments in the surface increments. Tillage of the long-term no-till removed the stratification to the extent that soil test levels were similar to those found under chiseling. Fertilization as expected resulted in higher soil test P and K levels in the top 10 cm of soil.

The effect of the rotation and tillage treatments on the soil bulk density measured in 2005 and 2006 is shown in Table 2. Overall bulk density values were typical for a silt loam soil. Those measured in 2005 in the top 6 inches of the no-till and the un-tilled chisel treatment may be considered as high enough to limit porosity or inhibit root growth, although the values moderated somewhat in 2006. Measurements were taken in late June, just prior to canopy closure. Therefore full consolidation of the soil had likely not occurred. Cores were taken from the non-wheel trafficked areas of the plots so that results represent the effect of rotation and tillage. Care was taken to avoid incidental traffic from tillage or spraying activity. The only "traffic" this area would have received was that of the planting unit the previous season as rows were alternated 15 inches each year. Rotation did not appear to have an effect on bulk density. Tillage affected bulk density substantially. Where chisel tillage was converted to no-till the bulk density increased and was found to be close to that in continuous no-till. Similarly, tilling the long-term no-till resulted in bulk density levels equivalent to that found in the long-term chisel system. These effects were most notable in the top 15 cm of soil suggesting that the chisel plow did not substantially disrupt the soil below this depth.

Table 1. Main effect of tillage on the incremental soil test, Arlington, Wis., 2005.

	0 to 2 inches			2 to 4 inches			4 to 6 inches			6 to 8 inches		
Treatment	pH	P	K	pH	P	K	pH	P	K	pH	P	K
		--- ppm ---			--- ppm ---			--- ppm ---			--- ppm ---	
Tillage †												
Chisel	6.0	49	141	6.4	44	104	6.8	35	77	6.9	27	68
CH → NT	5.9	51	142	6.4	42	89	6.8	36	22	6.9	27	68
No-till	5.7	59	150	6.7	42	93	6.9	38	74	6.8	29	68
NT → CH	5.9	46	136	6.3	39	104	6.8	34	80	6.9	28	71
Strip-till	5.9	68	176	6.7	45	99	7.0	40	75	7.0	32	71
Pr>F	0.38	<0.01	<0.01	<0.01	0.74	0.08	0.03	0.81	0.21	0.14	0.70	0.03
LSD	NS ‡	12	19	0.2	NS	NS	0.1	NS	NS	NS	NS	5

† Tillage: Chisel = Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997; CH → NT = Chisel system since 1997 and left un-tilled in 2005; No-till = No-till since 1997; NT → CH = No-till since 1997 and chiseled in the fall of 2004; Strip-till tool consists of residue clearing coulters, knife to 15 cm, and notched closing coulters. Rows alternated 15 inches each year.

[b] NS, not significant.

Table 2. Effect of rotation and tillage on the soil bulk density, Arlington, Wis., 2005 and 2006.

		Tillage system †							
Rotation	Depth	Chisel		CH → NT		No-till		NT → CH	
	inch	g cc $^{-1}$							
		2005	2006	2005	2006	2005	2006	2005	2006
CC	0 - 3	1.17	0.96	1.42	1.22	1.38	1.24	1.13	1.00
	3 - 6	1.24	1.05	1.43	1.25	1.46	1.42	1.29	1.21
	6 - 9	1.35	1.23	1.39	1.17	1.48	1.41	1.45	1.32
CSb	0 - 3	1.21	1.05	1.26	1.24	1.42	1.16	1.20	0.98
	3 - 6	1.23	1.15	1.27	1.30	1.44	1.36	1.23	1.12
	6 - 9	1.43	1.22	1.40	1.37	1.44	1.35	1.42	1.29
SbC	0 - 3	1.24	1.06	1.34	1.14	1.36	1.12	1.14	0.98
	3 - 6	1.32	1.35	1.36	1.30	1.46	1.36	1.23	1.00
	6 - 9	1.40	1.33	1.42	1.34	1.45	1.41	1.44	1.18
Significance (Pr>F)		0 - 3		3 - 6		6 - 9			
		2005	2006	2005	2006	2005	2006		
Rotation		0.95	0.28	0.03	0.75	0.95	0.57		
Tillage		<0.01	<0.01	<0.01	<0.01	0.08	0.01		
T*R		<0.01	0.65	0.10	<0.01	0.55	0.05		

†Tillage: Chisel = Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997; CH → NT = Chisel system since 1997 and left un-tilled in 2005; No-till = No-till since 1997; NT → CH = No-till since 1997 and chiseled in the fall of 2004.

The bulk density measurements were confirmed in the results of the cone penetrometer. These data are presented in Fig. 1 and shows that the long-term chisel and recently tilled no-till had similar penetration resistance. The highest resistance was found in the long-term no-till. Resistance values in chisel converted to no-till were intermediate to those found in chisel and no-till.

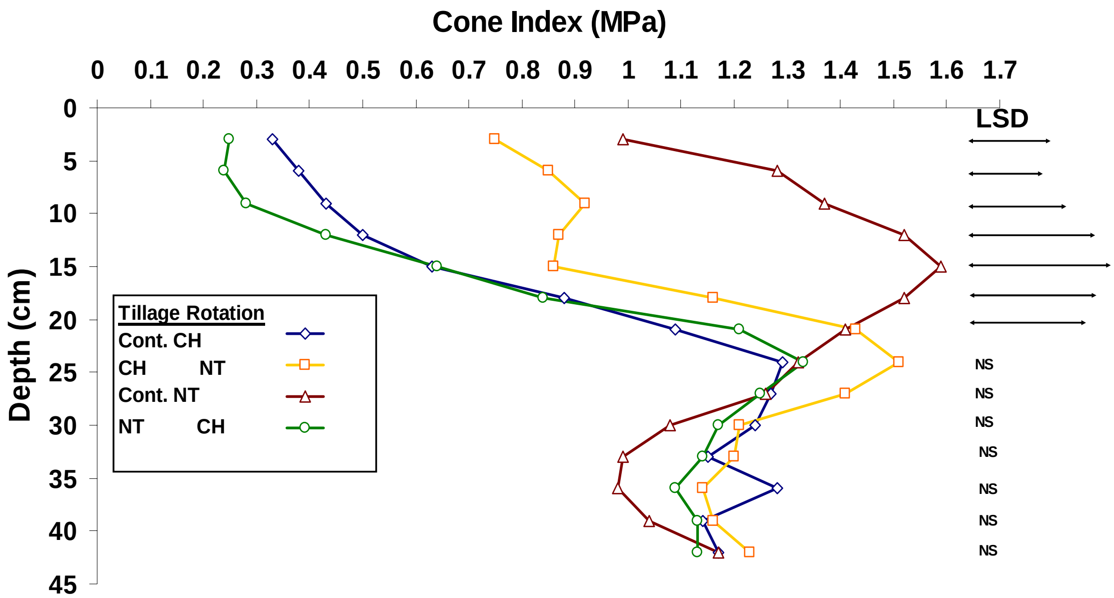

Fig. 1. Cone penetration resistance measured in the tillage rotation study, Arlington, Wis., 2005.

The effect of rotation, tillage, and fertilization on the early season uptake of K by corn in 2005 is shown in Table 3. Uptake is the product of nutrient concentration and dry matter production. Previous studies have demonstrated reduced K uptake in no-till, often inducing visible K deficiency symptoms. Rotation did not affect K uptake. Potassium uptake was lowest in the treatment where long-term chisel was converted to no-till and highest in the long-term no-till converted to chisel. This confirms the effect of the reduction in K uptake in no-till systems is immediate and is probably related to soil properties that control K absorption by the plant. Fertilization with the planter in a 5 x 5 cm placement resulted in higher K uptake compared to broadcast confirming the efficiency of this placement method.

Table 4 shows the corn grain yield for 2005 and 2006. Surprisingly there was no yield difference between continuous corn and first-year corn after soybean. The effect of tillage was not significant in 2005; however, there was a trend for response (Pr>F = 0.11). The highest yielding treatment was found in the no-till that had been chiseled. The lowest yield was in the long-term chisel converted to no-till. The tillage effect was highly significant in 2006. The highest yield was found in both the long-term chisel and no-till converted to chisel plowed. The lowest yield continued to be the converting long-term chisel plowing to no-till. While these responses cannot be explained at this time it is possible that improved aggregate stability in no-till persisted after tillage and provided an optimal root bed. The early season response to the 2 x 2 placement of fertilizer in 2005 was expressed in yield as this treatment produced a corn yield greater than that where broadcast was used. The response to fertilization was also highly significant in 2006; however there was no difference between broadcast and row placement.

Table 3. Effect of rotation, tillage and fertilization on the K uptake by corn at the V6 growth stage, Arlington, Wis., 2005.

		Tillage system ‡				
Rotation	Fert. †	Chisel	CH → NT	No-till	NT → CH	Strip-till
		lb K a^{-1}				
CC	None	8.9	5.5	8.6	12.4	8.2
	Bdct.	16.6	10.0	10.9	18.6	14.7
	Row	20.3	14.1	16.3	22.1	21.2
SbC	None	8.3	5.5	5.5	6.7	4.7
	Bdct.	11.0	7.1	11.1	16.1	13.0
	Row	20.3	19.3	19.9	25.4	13.4
Significance (Pr>F)						
Rotation	0.31					
Tillage	<0.01					
T*R	0.59					
Fert.	<0.01					
R*F	0.07					
T*F	0.56					
R*T*F	0.13					

† Fertilizer: Broadcast=200 lb 9-23-30/acre in fall 2004 or row=2 x 2 planter placement.

‡ Tillage: Chisel=Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997; CH → NT=Chisel system since 1997 and left un-tilled in 2005; No-till=No-till since 1997; NT → CH=No-till since 1997 and chiseled in the fall of 2004; Strip-till tool consists of residue clearing coulters, knife to 15 cm, and notched closing coulters.

Table 4. Effect of rotation, tillage and fertilization on the corn grain yield, Arlington, Wis., 2005 and 2006.

		Tillage system ‡									
Rotation	Fert. †	Chisel		CH → NT		No-till		NT → CH		Strip-till	
		bu a^{-1}									
		2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
CC	None	172	194	164	131	167	159	198	217	182	177
	Bdct.	182	217	179	168	174	161	194	220	186	178
	Row	191	220	183	169	186	178	186	223	191	188
SbC	None	182	183	171	182	175	166	177	167	175	190
	Bdct.	183	216	169	186	188	204	198	210	202	217
	Row	190	217	204	201	202	209	206	209	196	208
Significance (Pr>F)											
	2005	2006									
Rotation	0.32	0.32									
Tillage	0.11	<0.01									
T*R	0.86	0.03									
Fert.	<0.01	<0.01									
R*F	0.05	0.24									
T*F	0.15	0.96									
R*T*F	0.01	0.32									

[a] Fertilizer: Broadcast = 200 lb 9-23-30/a in fall 2004 or row = 2 x 2 planter placement.

[b] Tillage: Chisel = Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997;

CH → NT = Chisel system since 1997 and left un-tilled in 2005; No-till = No-till since 1997; NT → CH = No-till since 1997 and chiseled in the fall of 2004; Strip-till tool consists of residue clearing coulters, knife to 15 cm, and notched closing coulters.

Conclusions

This paper focuses on the results of a study that examined the effects of tillage rotation on soil properties, crop growth, and yield. Tillage of a continuous no-till system (8 years) reduced bulk density and penetration resistance to that where tillage was continuous, removed much of the soil test stratification in the surface layers, enhanced early-season K uptake, and tended to increase yield. The omission of tillage for one season resulted in higher soil bulk density and penetration resistance approaching those measured in continuous no-till, reduced early season K uptake, and tended to decrease yield. The responses are likely in part due to changes in the soil root zone condition, such as improved aeration and water relationships. This may explain some of the problems growers experience when converting to no-till from aggressive tillage systems. Strip tillage was a reasonable alternative to chisel tillage. Research will be continued to explain these responses.

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