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TILLAGE CONSIDERATIONS FOR FIRST-YEAR CORN AFTER SOYBEAN

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Introduction

Agricultural production systems have changed noticeably in Wisconsin over the past 25 years. As small dairy herds disappear and cow numbers decline, more and more acreage is being planted to grain crops, often in a corn/soybean rotation. While there may be some short-term benefits to the new cropping system it is anticipated that such a shift will have a long-term negative impact on soil quality.

It is well known that medium- and fine-textured soils form aggregates. Aggregation is defined as "*the arrangement of individual soil particles into compound particles of specific shape and size by natural chemical, physical, and biological factors.*" Aggregation is the result of the combined effects of organic matter, biological activity, surface charge sites on clay, and the formation of Fe and Al oxide compounds. Aggregates or peds vary in size from less than a millimeter to several centimeters. They are separated from each other by natural planes of weakness and resist breakdown by physical manipulation. The space between and within peds provides porosity for the soil, which should be approximately 50% in silt loam soils. Sands and loamy sands do not form structure and are considered "single grained." Peds tend to be relatively small and granular in the surface and become larger and blocky in the subsoil. They may become columnar in the deep subsoil. Good soil structure is important for water infiltration and internal drainage, aeration for roots and soil microorganisms, root growth, and nutrient uptake. The maintenance of aggregation is important for these soil functions. Processes that reduce aggregation (i.e., reduce aggregate stability) are detrimental to crop production and soil quality, and can lead to soil degradation and erosion.

Agriculturalists have known for centuries that processes that encourage the formation and maintenance of soil structure are associated with good soil management and productivity. Manuring for example has been considered beneficial for both the nutrient supplied and the effect on the soil condition. More recently UW soil scientists (Chesters et al., 1957) ranked the importance of various factors in aggregation. They suggest the following order of importance as: microbial gums > iron oxide > organic carbon > clay. This clearly shows the importance of biological activity in aggregation.

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Among the factors that influence aggregation is rotation. Rotations such as the soybean-corn system have generally been shown to be more productive than continuous corn, possibly because of N credits, the breaking of pest and disease cycles, and reduced alleopathy. A "mellow" soil condition is often associated with recent soybean production. However, researchers have confirmed anecdotal evidence that suggests soils are more erodible following soybean. Laflen and Moldenhauer (1979) measured the soil loss from a continuous corn and a soybean-corn rotation on a 6% slope in Iowa over seven seasons. They found 60% more soil loss in the soybean-corn compared to the continuous corn. Other Midwestern soils have been shown to have lower aggregate stability following soybean and are therefore more erodible. This is especially apparent for the loess-derived silt loam soils of southern Wisconsin. The silt sized particles that make up the loess are typically comprised of the mineral quartz, which does not have surface charges to aid aggregation. The soybean crop itself appears to reduce aggregate stability. Research conducted in Indiana by Kladivko et al. (1986) have shown lower aggregate stability when soybean is included in the rotation. Their work showed an interaction with tillage, such that plowing further reduced aggregate stability within the rotation.

Another consideration for tillage management following soybean is related to the residue remaining after harvest. It is well known that maintaining surface crop residue is the farmer's best option for reducing soil erosion. Because the soybean crop leaves less and more fragile residue when compared to corn the consequence of even minimal tillage in soybean stubble can be significant. This paper summarizes Wisconsin and regional research that has examined the effect of tillage for first-year corn after soybean on productivity and the potential for soil loss. When one considers the current high cost of fuel and the time demands that many grain farmers now must manage, there needs to be a substantial yield benefit to suggest any tillage of soybean residue.

Wisconsin's Changing Agriculture

Figure 1 shows the change in dairy cattle numbers for the Area Meeting host counties since 1980. Animal reductions in this period range from nearly 50% in Eau Claire Co. to essentially no change in Manitowoc Co. These changes are likely buffered by the fact that herd size has increased dramatically in some regions. Overall most counties have experienced a 30 to 40% drop in dairy cattle numbers in the past 25 years. Without livestock to feed, there will naturally be a change in cropping system—one that has less legume forage and that does not receive manure. Table 1 outlines the change in soybean acreage since 1980 for these eight counties. Several factors control the dramatic increase in soybean acreage, so suggesting a cause and effect relationship between the loss of dairy cattle and an increase in soybean acreage is risky. However further confirmation of this relationship can be found in the fact that considerably fewer acres of alfalfa (data not shown), which would be directly tied to feeding dairy cows, are now harvested in all counties over this 25 year period.

Tillage Effects on Productivity

Lancaster

Several Wisconsin evaluations have been made that examine the effect of tillage type for soybean residue on the subsequent response in corn. One study was established in October 2003 on a Rozetta silt loam soil in a 5-acre contour strip at the Lancaster Agricultural Research Station. The field containing the study was previously in no-till soybean and has an average slope of 8%. The field was split and planted to corn and soybean in 2004 and received all the specific tillage treatments. These crops were rotated for 2005 and 2006. The other half was planted to soybean (no-till drilled) into the corn stubble. Tillage treatments (fall chisel/spring field cultivator, spring field cultivator, fall strip-till, and no-till) were installed on the contour in the soybean residue.

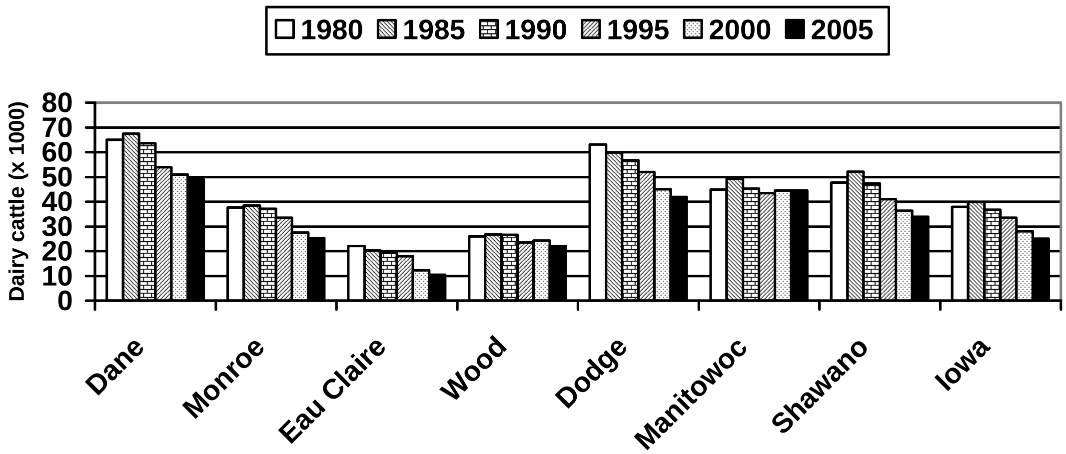

Figure 1. Change in diary cattle numbers for the Area Meeting host counties since 1980 (Source: Wis. Agricultural Statistics).

Table 1. Change in soybean acreage for selected Wisconsin counties since 1980 (Source: Wis. Agricultural Statistics).

Year	Dane	Monroe	Eau Claire	Wood	Dodge	Manitowoc	Shawano	Iowa
	------------------ Acres (x 1000) ------------------							
1980	10.5	2.0	6.0	0.7	2.5	0.6	0.1	1.5
1985	14.9	2.5	5.2	1.4	6.1	1.3	0.7	2.4
1990	20.1	3.7	9.1	2.1	10.3	2.3	1.2	3.1
1995	42.3	5.2	8.4	5.3	30.0	7.4	6.4	9.0
2000	90.5	12.6	15.5	11.3	67.3	22.6	12.0	27.2
2005	80.9	17.5	19.8	12.2	63.3	23.1	19.9	30.9

The chisel system employed a twisted shank plow, followed by a single pass with a combination field cultivator in the spring. The same field cultivator was used for the field cultivator alone treatment. Strip-tillage was conducted with a four-row tool that features finger coulters, a ripple coulter, a mole knife that runs 7 to 8 inches deep, followed by closing disks that form a ridge about 6 inches high. Remlinger, Mfg. of Kalida, OH[2/] has loaned this tool to the Univ. of Wisconsin Department of Soil Science. A Kinze planter equipped with Yetter finger-coulter residue managers was used for the no-till treatment. Two rates of several K fertilization placement treatments were included in the study. The initial K soil test for the field was in the optimum range.

The effect of tillage and K fertilization treatment on the 3-year study is shown in Table 2. Tillage significantly affected yield in 2006 such that the chisel and strip-till system were superior to the spring field cultivator and no-till treatments. A similar trend was observed in 2004 and 2005. Potassium fertilization did not affect yield in any year.

[2/] Use of product names is for informational purposes only and does not represent an endorsement from the University of Wisconsin).

Table 2. Effect of tillage and K fertilization on corn grain yield from 2004 to 2006, Lancaster, Wisconsin. †

Fert.	K_2O	Chisel 04	Chisel 05	Chisel 06	Field cultivator 04	Field cultivator 05	Field cultivator 06	Strip-till 04	Strip-till 05	Strip-till 06	No-till 04	No-till 05	No-till 06
	lb/a	bu./a											
None	--	193	207	166	194	182	150	195	189	171	196	178	175
2x2	30	207	190	173	211	175	173	198	174	169	186	180	153
2x2	60	197	185	181	207	173	156	190	171	163	197	205	145
Bdct.	30	212	184	168	191	183	172	202	213	181	191	183	172
Bdct.	60	179	202	164	194	190	170	202	198	164	201	170	170
Srf. Str.	30	206	196	180	185	180	167	202	177	171	187	187	167
Srf. Str.	60	219	213	179	200	195	168	203	195	177	203	191	168

Significance (Pr>F)

Effect	2004	2005	2006
Tillage	0.52	0.62	0.05
Placement	0.59	0.23	0.46
Rate	0.85	0.34	0.19
T*P	0.27	0.32	<0.01
T*R	0.22	0.92	0.69
P*R	0.20	0.56	0.11
T*P*R	0.67	0.75	0.36

Main Effects

Tillage	Yield (bu/a) 2004	2005	2006	Place	Yield (bu/a) 2004	2005	2006	Rate (lb K_2O/a)	Yield (bu/a) 2004	2005	2006
Chisel	203	195	175	2 x 2	200	182	164	30	199	185	168
Field cult.	198	183	158	Bdct	197	190	166	60	200	191	165
Strip-till	200	187	171	Surf. strip	201	192	170	LSD	NS‡	NS	NS
No-till	195	186	162	LSD	NS	NS	NS				
LSD	NS	NS	17								

† Control data not included in the ANOVA. ‡ NS, not significant.

Arlington

A tillage/rotation study was established in 1997 on a Plano silt loam soil at the Arlington Agricultural Research Station. The main plot treatment is rotation (continuous corn, soybean/corn, and corn/soybean). These treatments are subdivided into tillage subplot treatments (fall chisel/spring field cultivator, strip-till, and no-till). These treatments were maintained from 1997–2000 and the plots did not receive additional P and K fertilizer until the fall of 2000 when the current fertilizer treatments were installed. The sub-subplot treatment is fertilizer placement. A rate of 200 lb/a of a 9-23-30 material was applied as a fall broadcast prior to primary tillage, in the row on a 2 x 2 placement at planting, and 6 to 8 inches deep in the strip-till treatment only. Similar fertilizer treatments were made in both corn and soybean. The effect of fertilization will not be discussed in this paper. All treatments were replicated four times in a split-split plot treatment arrangement.

The chisel system employed a fall twisted shank coulter chisel plow, followed by a single pass with a combination field cultivator in the spring. Strip-tillage was conducted in the fall with the Remlinger tool. Strips were alternated between rows each year. The succeeding crop was planted on the ridge the next spring. The no-till treatments receive no tillage other than the pass with a four-row Kinze corn planter equipped with a dry row fertilizer attachment and a double-disk opener for the seed unit (the finger coulter residue managers were not employed in this study). The same planter was used in all tillage treatments and was adjusted for changes in soil condition between treatments.

Tillage and rotation management would be expected to have an effect on the surface crop residue. Table 3 shows the surface crop residue measured shortly after planting for 1998–2006. Crop residue was generally 15 to 30% lower in SbC compared to the CC rotation and as expected was lower in the chisel treatment compared to no-till and strip-till. There was often an interaction between rotation and tillage such that chisel tillage in soybean stubble resulted in much less residue than chisel tillage in corn. Although there were differences between years, strip-till generally resulted in 10 to 15% less residue than no-till.

Table 3. Effect of rotation and tillage on surface crop residue measured by the line transect method, Arlington, Wisconsin, 1998 to 2006.

Rotation	Tillage	1998	1999	2000	2001	2002	2003	2004	2005	2006
		Surface cover (%)								
CC	CH	34	39	45	36	55	50	34	42	56
	NT	75	83	88	86	71	72	89	99	94
	ST	62	85	70	66	56	72	63	67	81
SBC	CH	9	7	18	17	12	15	15	7	30
	NT	39	67	68	76	74	73	63	79	87
	ST	38	62	58	57	51	59	50	57	74
Pr>F										
Rotation		<0.01	<0.01	<0.01	<0.01	0.05	0.02	<0.01	0.01	<0.01
Tillage		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
R*T		0.05	0.05	0.69	0.09	<0.01	0.20	0.51	<0.01	0.01
Main Effect										
Rotation										
CC		57	69	68	63	61	65	62	69	77
SBC		29	45	48	50	46	49	46	48	64
Sig.		**	**	**	**	*	*	**	*	**
Tillage										
CH		21	23	32	26	34	32	24	25	42
NT		57	75	78	81	72	72	81	89	91
ST		50	73	64	62	54	66	57	62	78
LSD		6	6	19	5	10	20	6	14	7

*,** Significant at the 0.05 and 0.10 levels.

The yield data measured at the Arlington site are shown in Table 4. Yield measurements were not taken in 2000 because no funding was available to support the project in that year and an equipment breakdown would have required that the plot be hand-harvested. The soybean/corn rotation generally produced yields that were greater than those found in continuous corn, with the differences not being significant in 2002, 2003, 2005, and 2006. Interesting tillage did not significantly affect yield except in 2004 and 2006. Some differences were observed in other years, but these were not significant at the p=0.05 level. No-till was always the lowest yielding tillage treatment. The interaction between rotation and tillage was significant in 2001 where no-till resulted in yield substantially lower in CC, but slightly higher in SbC.

Table 4. Effect of rotation and tillage on corn grain yield, Arlington, Wisconsin. 1998 to 2006.

Rotation	Tillage	1998	1999	2000	2001	2002	2003	2004	2005	2006
		---------- Grain yield (bu/a) †----------								
CC	CH	161	147	--	189	181	161	187	181	211
	NT	164	147	--	151	174	149	159	176	166
	ST	160	135	--	182	175	157	178	187	181
SBC	CH	181	172	--	192	209	186	206	187	205
	NT	160	158	--	194	199	181	180	189	193
	ST	175	174	--	204	206	184	194	191	205
Pr>F										
Rotation		0.02	<0.01	--	0.05	0.09	0.12	0.02	0.37	0.28
Tillage		0.25	0.62	--	0.13	0.38	0.70	0.01	0.07	<0.01
R*T		0.06	0.18	--	<0.01	0.81	0.78	0.86	0.31	0.51
Main Effect										
Rotation										
CC		162	143	--	174	205	184	175	181	185
SBC		172	168	--	196	177	156	193	189	199
Sig.		*	**		*	NS	NS	*	NS	NS
Tillage										
CH		171	159	--	190	195	173	197	184	208
NT		162	153	--	172	187	165	169	182	179
ST		167	154	--	193	190	172	186	189	193
LSD		NS	NS	--	NS	NS	NS	16	NS	21

†Yield values are averaged over fertilizer treatments *,** Significant at the 0.05 and 0.10 levels.

Waseca, Minnesota

The final study that will be discussed in this paper was conducted in southern Minnesota by Jeff Vetch and Gyles Randall (Table 5). Their 4-year study was conducted on Nicollet/Webster soils commonly found in southern Minnesota and northern Iowa. Tillage treatments for corn included no-till (with row cleaners), deep strip-till (14 inches), shallow strip-till (8 inches), spring one-pass with a field cultivator, and fall twisted shank chisel with spring field cultivation. Tillage treatments for soybean were either no-till of fall chisel. Plots were further split with treatments of with or without row cultivation. Cultivation did not affect yield and the data presented are the average of the cultivation treatments. Only the corn grain yields for the 4-year average will be discussed in this paper.

Table 5. Effect of tillage following soybean on the yield of corn (4-year average, 2000 to 2003), Waseca, Minnesota.

Tillage for corn	Tillage for soybean	Surface residue	Yield
		%	bu/a
No-till	No-till	76 †	151 †
No-till	Chisel plow	59	154
Deep-strip	No-till	44	158
Deep-strip	Chisel plow	40	165
Shallow-strip	No-till	63	156
Shallow-strip	Chisel plow	50	165
One-pass	No-till	49	153
One-pass	Chisel plow	35	156
Chisel plow	Chisel plow	24	161
Main Effect (Pr>F)			
Tillage for Sb/C	No-till	67	152
Residue = <0.01	Deep-strip	161	161
Yield = <0.01	Shallow-strip	160	160
	One-pass	154	154
	LSD	3	4
Tillage for C/Sb	No-till	57	154
Residue = <0.01	Chisel	46	160
Yield = <0.01			
Row cult. or corn	No	53	157
Residue = 0.04	Yes	50	157
Yield = 0.82			

† Average of cultivated and un-cultivated treatments.

This research demonstrated that some tillage was necessary to optimize yield for the conditions found in the regions. These soils commonly have a silty clay loam texture and are somewhat poorly drained. The one-pass tillage in the spring with a field cultivator was marginally better than no-till. Either strip-till treatment was produced yields greater than no-till or the one-pass tillage system. No difference was noted between continuous chisel and the strip-till treatments, both of which maintain substantially more residue than chisel.

Tillage and Erosion Measurements

Dr. Rick Cruse of Iowa State University and staff assisted in the setup and maintenance of “passive” runoff collectors at the Lancaster study in 2004 and 2005. Two collectors were placed in the strip-till and chisel system. The collectors were designed to receive runoff from an upslope area of 5 x 20 feet. Runoff first passed through a sediment basin where much of the sediment was deposited, and then was split by a factor of 1:10 twice, with any remaining runoff being collected in a container and the end of the collector. Sediment was collected following significant runoff events and soil loss was estimated by calculations based on the amount of sediment found at various locations within the collection area.

The early season of 2004 was affected by several intense, high-volume storms prior to canopy closure, whereas storms of this type were non-existent in 2005 until much later in the season. Table 6 shows the rainfall amounts prior to runoff collection and the estimated sediment loss for each event. The reported soil loss is the average of two values. Clearly the soil loss potential was much greater in the chisel system compared to strip-till, especially when intense storms occurred early in the season before the soil reconsolidated and was protected by the crop canopy.

Table 6. Estimated soil loss in first-year corn after soybean in a chisel and strip-tillage system following runoff from significant rainfall events, Lancaster, Wis., 2004 and 2005.

2004				2005			
Date	Rainfall †	Soil loss		Date	Rainfall †	Soil loss	
		Chisel	Strip-till			Chisel	Strip-till
	inch	-------- t/a -------			inch	------- t/a --------	
14 May	0.95	0.12	0.006	6 June	0.96	0.05	0.02
21 May	0.50	0.14	0	27 June	5.00	0.08	0.01
24 May	3.09	2.82	0.23	26 July	3.60	0.001	0
1 June	4.85	0.39	0.39	29 July	1.3	0.10	.12
17 June	2.51	0.71	0	19 Aug	3.28	0.05	0.01
12 July	1.24	0.27	0.009	19 Sep	1.44	0.02	0
4 Aug	1.11	0.22	0				
Total		4.67	0.28			0.30	0.16

† Runoff collected on 24 May 2004, 12 July 2004, and 26 July 2005 were the result of multiple precipitation events.

Summary

Crop production systems are changing in Wisconsin with a trend toward continuous grain crops, which in many cases is the corn/soybean rotation. Researchers have shown that soybean reduces aggregate stability and can increase erosion. No-till and reduced tillage systems have been shown to reduce soil loss, but many producers hesitate to adopt them because of the fear of reduced productivity. Multi-year research conducted at two Wisconsin locations and one in southern Minnesota showed that the yield of first-year corn after soybean was generally higher with fall chisel tillage. Strip-tillage generally produced yields similar to that found with chisel. Yields under no-till were generally lower, but in some years they were equal to or better than chisel. Soil loss at one location was substantially greater under chisel tillage compared to strip-till. Current fuel and equipment costs favor tillage systems that reduce input costs even if yield is somewhat reduced. The consequences of substantial soil loss via erosion when fragile residue such as soybean stubble is tilled are obvious. Reduced tillage systems that maintain residue and soil consolidation should be encouraged when possible for first-year corn after soybean.