NEW HORIZONS IN SOIL SCIENCE

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Using Strip-tillage as an Option for Row Crop Production in Wisconsin

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Introduction

Recent increases crop acres managed by individual producers, rising fuel and equipment costs, the desire to plant crops in a timely manner, and catastrophic erosion events have renewed interest in conservation tillage systems. Historically, no-till management has been a challenge for corn production in Wisconsin because residue has slowed the warming of the soil in the spring. Residue can also physically impair planting by plugging within the planting unit and "hair-pinning" in the seed slot. Therefore most no-till corn planters have been modified to include some type of in-row residue management attachment, either as finger coulters or disks that are designed to move some residue from the row, without substantial contact with the soil. Many producers are now considering more aggressive attachments or separate tillage operations that not only address residue concerns, but till the soil to some degree with the goal of capturing the production advantages of full-width tillage, while offering the soil conservation benefits of no-till. This practice has come to be known as strip-tillage.

What Is Strip-tillage

Strip-tillage can be defined as less than full-width tillage of varying intensity that is conducted parallel to the row direction. Generally no more than 30% of the soil surface is disturbed by this practice leaving most of the previous crop's residue intact. Strip-tillage is generally understood to be a single pass with a separate implement in the fall, although spring strip-tillage is possible on some soils if moisture and residue conditions permit. Some planters are equipped with attachments that conduct tillage in the row just ahead of the planting units. The type of strip-tillage tool used is affected by the stoniness of the soil, the condition of the residue, the potential for soil compaction, power requirements, and other factors specific to individual producers. Table 1 describes the categories of strip-tillage related to tillage intensity and the attachment types and functions of each. Figure 1 shows examples of the three strip-tillage tool types.

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The goal of strip-tillage is to create a seedbed condition in the row that is similar to that achieved by full-width tillage systems such as chisel plowing, while not disturbing the remaining soil. This leaves a relatively high amount of crop residue on the inter-row soil surface to absorb raindrop impact and provide a barrier to runoff. It also maintains open worm channels and other macropores to the surface to enhance infiltration. Combined these factors will reduce runoff and soil erosion. Strip-tillage is also accomplished in a shorter time with lower energy inputs compared to full-width tillage.

Table 1. Summary of strip-tillage tool types.

Strip-tillage category	Attachment types	Function
Residue clearing	Finger coulters, sweeps, brushes	Move residue from the row area. Typically mounted on the planter.
Shallow strip-tillage 2 to 3 inches	Fluted and notched coulters	Cut and move residue, loosen seedbed, apply fertilizer near the seed. Typically mounted on the planter, but can be operated on a separate tool bar. Favored on stony soils.
Moderate strip-tillage 8 to 10 inches	Cutting coulters, mole knives, ridging coulters	Cut and move residue, remove surface compaction, create seedbed, deep-place fertilizer, form a small ridge that will dry and warm quickly.
Deep strip-tillage >10 inches	Straight-shanked knife with limited soil inversion	Remove subsoil compaction

Figure 1. Examples of strip-tillage tool categories. (Left to right: Row cleaner, shallow strip-tillage tool, deep strip-tillage tool).

Often strip-tillage is conducted after soybean, fall-killed legume forage, or other fragile residue crops because of the concern of plugging within the tillage tool and the easy ability to create a residue free strip. Newer, more aggressive strip-tillage tools have been built to handle corn residue in response to the desire of farmers to grow more continuous corn. Some producers also apply fertilizer with their strip-tillage tool, thereby reducing a trip over the field and eliminating the need for planter-applied fertilizer. Fall application of fertilizer would be considered acceptable for P and K materials, but the application of anhydrous ammonia or other N fertilizers in the fall would be discouraged because of the documented N loss and lower N use efficiency of this practice.

Strip-tillage, if coordinated with other field operations, could be considered a method of "controlled traffic farming." This practice confines wheel traffic to specific lanes to limit soil compaction and is much more common in Europe and Australia. If controlled traffic farming were practiced in standard row-crop production, farmers would have to standardize the traffic caused by various field operations to limit the amount of field area that is driven over, especially by heavy equipment such as combines, manure tankers, and large fertilizer spreaders. This may require that some strip-tillage practitioners invest in very accurate GPS and tractor auto-steer systems to ensure that planted rows are placed on the previously strip-tilled ground.

Growth and Yield Response to Strip-tillage

Grain farmers in the northern Corn Belt have been frustrated with the slower growth and lower yields often associated with no-till planting. Strip-tillage has been shown to promote warming within the seed zone because it allows more of the energy of the sun to reach the soil surface. Figure 2 shows the soil temperature measured at 2 inches in the late afternoon at Arlington, Wis. Soil temperature in the fall strip treatment was similar to those where chiseled, and about 5^{o}C warmer than no-till. Emergence and early growth in this study were delayed in no-till compared to the chisel and fall strip-tillage systems at least until silking as is shown in Table 2.

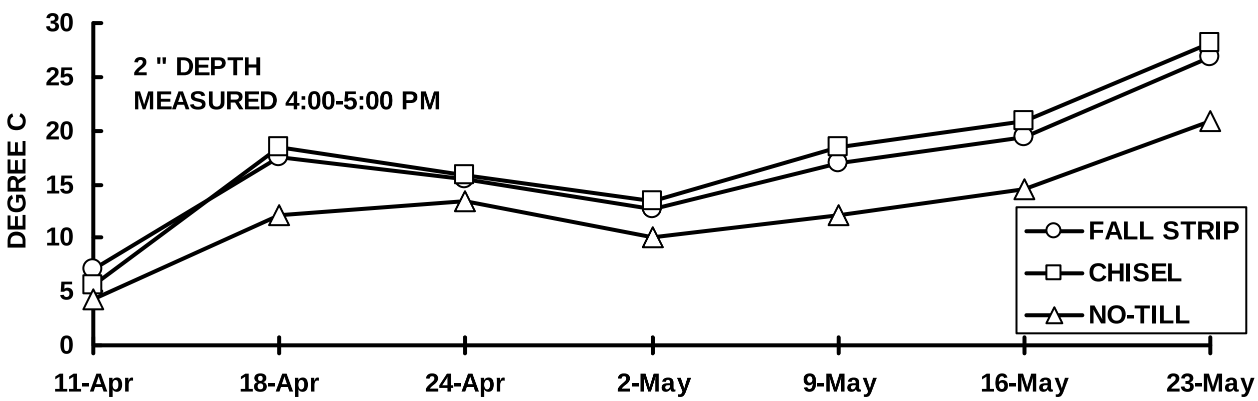

Figure 2. Soil temperature measured in continuous corn under three tillage systems on a silt loam soil, Arlington, Wis.

Table 2. Emergence, early growth, and silking progress as affected by tillage, Arlington, Wis.

Tillage system	Emergence	V6	V12	Silking
	Plants/ft	----------- g/plant	-----------	%
Chisel	1.8	1.1	29	80
Strip-tillage	1.6	1.1	28	62
No-till	0.7	0.7	18	36

Emergence measured 21 days after planting; silking progress measured 80 days after planting. A long-term research study has been conducted at the University of Wisconsin Arlington Agricultural Research Station that compared fall strip-tillage with fall chisel/spring field cultivator and no-till (without row clearing) systems in both a continuous corn and soybean corn rotation. The strip-tillage tool in this study featured a mole knife that was run about 8 inches deep and the tool built a 2–3 inches ridge upon which the subsequent crop was planted. The no-till system (without row cleaners) used in these trials represents the minimal extreme of this tillage practice with associated soil warming and reduced yield issues. Many no-tillers routinely use planter row cleaners to address these issues. Both the strip-tillage and no-till rows were alternated 15 inches between years. The effect of tillage on corn grain yield is shown in Table 3. These data showed equal corn grain yield in first year corn when comparing chisel and strip-tillage. No-till yields were about 5% lower. Yields in continuous corn were highest in the chisel system, being found to be about 4% greater than strip-tillage and 8% greater than no-till.

Table 3. Corn yield response to tillage in a continuous corn and soybean/corn rotation, Arlington, Wis., 1997–2007. †

Tillage	1997	1998	1999	2001	2002	2003	2004	2005	2006	2007	Avg.
	------------	------------	------------	------------	------------	bu/acre	------------	------------	------------	------------	------------
						Continuous corn					
Chisel	190	160	147	189	181	161	187	182	211	212	182
Strip-till	178	160	135	182	175	157	178	187	188	204	174
No-till	176	164	147	151	174	149	159	176	166	205	167
						Soybean/corn					
Chisel	172	181	172	192	209	186	206	187	205	231	194
Strip-till	181	175	174	204	206	184	194	191	205	228	194
No-till	180	160	158	194	199	181	180	189	193	220	185

† Yield was not recorded in 2000.

The placement of P and K fertilizer was a component of this long-term tillage rotation study from 2001–2004 to determine whether there was a benefit to placing the material deeper than the standard planter-applied treatment or simply broadcasting the material over the surface. Fertilizer treatments were none; and 200 lb/acre of 9-23-30 fertilizer applied as either a fall broadcast, fall strip using the mole knife to place it at a depth of about 6–7 inches, or planter-applied treatment in a 2 x 2 placement. Soil test P was in the excessively high range for this soil; however soil test K was in the optimum range. Therefore any response to the fertilizer would have been expected to be from the applied K. The average yield response for the different placement treatments in the continuous corn and soybean/corn rotations are shown in Table 4. These results show that there was minimal difference between placement methods; however the corn after soybean was much more responsive to fertilization compared to continuous corn. Early season plant K concentrations were much lower in the no fertilizer control in first year corn compared to continuous corn. It was presumed that the corn stubble from the previous year cycled much more K to the surface in continuous corn compared to the amount supplied by soybean stubble, making the continuous corn less responsive to K fertilization.

Table 4. Corn grain yield as affected by fertilizer placement in strip-tillage, 2001 - 2004, Arlington, Wis.

Placement	Contuous corn	Soybean/corn
	---------------- bu/acre	---------------
No fertilizer	169	184
Broadcast	166	208
2 x 2	170	200
Deep	163	202

Soil Conservation and Strip-tillage

Strip-tillage systems disturb a small portion of the soil surface and therefore most of the previous crop residue is left on the surface to reduce erosion. Crop residue absorbs the impact of raindrops and therefore limits aggregate dispersal and crusting, plus it impedes overland flow and provides more time for runoff to infiltrate through soil pores. Figure 3 shows the crop residue measured using the line-transect method after planting in the soybean/corn rotation of the Arlington study from 1999–2005. These data show that chisel tillage of the fragile soybean residue reduced crop residue to an average of about 15%, whereas strip-tillage and no-till both featured crop residue coverage in the 55–70% range. The amount of crop residue left after strip-tillage was about 15–25% less than that of no-till, substantially more than that left if a full-width tillage system, such as chisel plowing, was used.

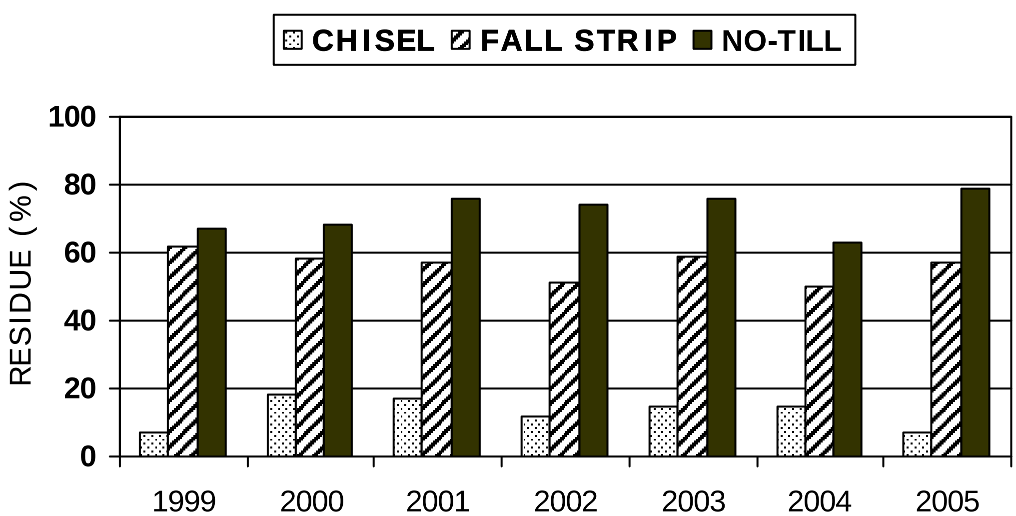

Figure 3. Surface crop residue measured in first-year corn after soybean, Arlington, Wis. 1999–2005.

Strip-tillage is supported as a soil conservation practice by the USDA-NRCS. Conservation planners now use models that help farmers select tillage and other management practices to meet soil conservation goals for individual fields. The "Soil Tillage Intensity Rating" or STIR is one such model that has been developed to integrate tillage type, speed, and depth; traffic management; area of the soil disturbed by tillage; and crop rotation into an index. The STIR model was run for first-year corn after soybean on a Rozetta silt loam soil having an 8% slope in southwest Wisconsin. The STIR indices were 82 for fall chisel, 36 for spring field cultivator, 12 for strip-tillage, and 5 for no-till. Values less than 30 are desired to limit soil erosion.

The direct benefit of strip-tillage was demonstrated in a research study conducted the Lancaster Agricultural Research Station. Passive runoff collectors were installed in a field having site characteristics similar to those used in the STIR scenario shown above. These collectors trapped sediment eroded from a 100 ft^2 area uphill from their placement. The measured soil loss in a year that experienced substantial rainfall during the early part of the growing season prior to crop canopy closure was 4.67 tons soil/acre in chisel and 0.28 tons soil/acre in strip-tillage.

Manure Management and Strip-tillage

Livestock producers and dairymen are often reluctant to adopt no-till or other reduced tillage methods because the manure they spread is often incorporated to reduce odor, increase N credits, and limit interference with planting. Manure with heavy straw or stalk bedding, spread on top of existing corn stalks, presents a challenge for many planters. A study was conducted at four locations that had a wide range of tillage intensity on fields that had received none, 15, or 30 tons straw-bedded dairy manure/acre. Manure was applied in early spring and tillage was conducted shortly before planting as either moldboard plowing, chisel plowing, disking, strip-tillage, and no-till. The moldboard and chisel systems included a secondary tillage pass with a disk to level the soil and create a seedbed. Adding 30 ton manure/acre was found to increase surface crop residue 13% when averaged over all tillage treatments and locations.

The effect of tillage averaged over the manure treatments on corn grain yield for the four locations is shown in Table 5. These data show considerable difference in the yield response to the various tillage systems. Most of the responses can be attributed to the specific characteristics of the soil at the research site or the equipment each research station could provide for the study. For example the low no-till yield at Marshfield was likely due to the poorly drained, silt loam soil that is easily compacted and remains more responsive to tillage. Yield was lower in the no-till at Spooner because the corn planter that was available was light and was not designed to work in high residue conditions. This demonstrates that some of the issues associated with unsuccessful no-till operations are likely due to limitations associated with soil conditions, equipment, and management.

Table 5. Effect of tillage on ground with full corn residue that had received 30 ton straw-bedded dairy manure/acre at four Wisconsin locations (average 2002–2003).

Tillage	Arlington	Lancaster	Marshfield	Spooner
	----------------------------------	bu/acre	----------------------------------	
No-till	176	194	105	138
Strip-till	180	191	128	181
Disk	176	195	120	185
Chisel	182	199	131	196
Moldboard	187	174	143	181

Economic Advantage to Strip-tillage

In addition to yield and environmental performance differences across tillage systems, economic costs of production (COPs) must be considered. Reduced tillage systems commonly generate fewer trips across the fields using the same or less horsepower to accomplish more tasks (e.g., tillage and fertilization in one pass). Hence, reduced tillage systems should lower costs of production as well as increase environmental performance (via decreased soil and nutrient losses). Measuring these potential reduced costs on a $/bushel (versus $/acre) basis provides an adjustment for the possibility of lower yields under the reduced tillage systems (see Tables 3 and 5). The economic performance of the reduced tillage systems compared to chisel was conducted on the 10 years of yield data collected in the Arlington Tillage Rotation study using recent cost values.

Table 6 provides a comparison of the cost of production for three tillage systems (CH: fall chisel/spring cultivator, assumed as the BASE or reference tillage; ST: fall strip-tillage; NT: no-till without residue managers) and three crop rotations (CC: continuous corn; SBC, corn following soybeans; and CSB, soybeans following corn) under 2007 WI custom hire rates. Two N fertilizer options were also evaluated: Applied with an applicator or applied with the planter. While the assumed custom hire rates are likely higher than those faced by individual farmers owning older machinery and/or who do not fully account for labor and capital costs, custom hire rates do provide a consistent, market-based estimate of the full economic costs of the alternative tillage systems. These full economic costs include competitive labor rates as well as the depreciation, repairs and the opportunity costs of machinery that are often not included in “back of the envelope” cost calculations. Therefore, these estimates provide somewhat conservative, “upper bounds” to the actual cost of production faced by farmers. Lastly, to remove the year to year yield variations observed in these trials, Table 6 uses the 1997-2007 average yield (excluding 2000 when yield data were not collected) for each trial.

For the CC portion of these field trial 1997-2007 average yields, ST and NT respectively averaged 7.6 and 15.3 bushels/acre less than CH (182 bu/acre). However, the estimated costs/acre were also lower than CH for both reduced tillage system: ST, -$23.20/acre to -$11.20/acre; NT -$25.90/acre. Comparison of these tillage systems on a per bushel basis adjusts for the yield as well as cost differences. For continuous corn, this comparison is not favorable to the reduced tillage systems as their reduced costs/bushel are overshadowed by the associated reduced yields. Hence, only ST with applicator (versus planter) N has marginally lower cost/bu compared to CH.

Table 6. Comparison of 1997-2007 average yields from the Arlington field studies and 2007 costs of production by crop and tillage system.

Crop/ system †	1997-2007 Average	2007 COP/acre		COP/bushel	
CC	YIELD	N w/ App	N w/ Planter	N w/ App	N w/ Planter
CH	182.0	$463.85	$492.35	$2.55	$2.71
ST	174.4	$440.65	$481.15	$2.53	$2.76
NT	166.7	$437.95	$466.45	$2.63	$2.80
		Change from chisel plow average 1997-2007			
ST	-7.6	-$23.20	-$11.20	-$0.02	$0.05
NT	-15.3	-$25.90	-$25.90	$0.08	$0.09
SBC	YIELD	N w/ App	N w/ Planter	N w/ App	N w/ Planter
CH	194.1	$463.85	$492.35	$2.39	$2.54
ST	194.2	$440.65	$481.15	$2.27	$2.48
NT	185.4	$437.95	$466.45	$2.36	$2.52
		Change from chisel plow average 1997-2007			
ST	0.1	-$23.20	-$11.20	-$0.12	-$0.06
NT	-8.7	-$25.90	-$25.90	-$0.03	-$0.02
CSB	YIELD				
CH	52.0	$333.30		$6.41	
ST	51.7	$322.10		$6.23	
NT	50.0	$307.40		$6.15	
		Change from chisel plow average 1997-2007			
ST	-0.3	-$11.20		-$0.18	
NT	-2.0	-$25.90		-$0.26	

† CC = continuous corn; SBC = corn following soybeans; CSB = soybeans following corn. The year 2000 yield data was not collected due to a combine malfunction.

CH: Fall chisel/spring field cultivator.

ST: fall strip-tillage: aggressive residue mgr. 97-99; mole-knife type unit 01-08.

NT: no-till (w/o residue managers).

The situation changes in the SBC and CSB rotations. In contrast to the CC results, the first-year corn following soybean (SBC) under ST yields are virtually identical to CH (+0.1 bu/acre) while yield under NT is reduced -8.7 bu/acre compared to CH. Given that COP are identical to the CC results above (i.e., planting corn under the alternative tillage systems), these more competitive yield differences generate more competitive cost/bu returns to reduced tillage. Under ST costs/bu range from -$0.06 to -$0.12/bu lower than CH while NT ranges -$0.02 to -$0.03/bu, depending on the N delivery system. This suggests than both cost savings and improved environmental performance are possible with these reduced tillage SBC systems compared to CH, with ST providing stronger economic gains compared to NT.

The soybean (CSB) results are similar to the corn (SBC) results, except that reduced tillage yield differences compared to CH narrow further: ST, -0.3 bu/acre and NT, -2.0 bu/acre. In addition, the estimated COP for NT is almost 2.5 times less than ST, generating substantive COP reductions compared to CH: ST, -$11.20/acre and NT, -$25.90/acre. On a per bushel basis, these yield and COP differences translate to -$0.18/bu (ST) and -$0.26/bu (NT) cost savings over CH.

Economic analysis of this field trial suggests that the economic benefits (defined as reduced costs/bu) to reduced tillage are likely to be stronger in under SBC and CSB rotation than CC. For SBC and CSB rotations, reduced (1997-2007) average trial yields compared to CH under the alternative reduced tillage systems evaluated, are likely to be offset by the reduced costs associated with reduced tillage systems. This suggests that both increase economic ($/bu) as well as environmental performance are likely to be attainable under these rotations with reduced tillage systems.

Selecting a Strip-tillage System

Before changing tillage systems evaluate your current system. Often the modification of existing equipment or management may be all that is required (e.g., adding residue-clearing coulters to a row-crop planter). Ask yourself some simple questions.

- Are you meeting conservation goals?
- Is spring tillage limiting planting timeliness?
- If no-tilling is residue reducing stands and/or slowing emergence?
- Is compaction an issue?

The selection of a strip-tillage system is dependent on the grower's soil, cropping system, and management capabilities. For example, if fields are stony then consider a strip-tillage tool that features coulters rather than one that has knives. Soils with relatively high clay content may offer greater response to systems that provide some shallow in-row tillage with a mole knife to break up surface compaction; and that move residue and form a small ridge to promote drying in the row. This will improve seed to soil contact and permit planting into more favorable conditions. If deep compaction is a concern, then there may be a need to consider deep strip-tillage. It is critical to identify that compaction exists and to locate the depth of the restrictive layer. Tools for this operation should provide minimal soil inversion that would disturb a large portion of the soil volume and bury residue.

Evaluating the economics of tillage systems is very complex. Consideration must be given to the initial and maintenance costs of equipment, the size of tractor needed to pull the tool, equipment depreciation, labor and opportunity costs, conservation program incentives, and increased management costs related to fertilizer and pest management. Producers will have to determine if it is cost effective to strip-till all row crops, as opposed only strip-tilling first-year corn into soybean stubble or fall-killed alfalfa, no-till planting soybean into corn or small grain stubble, and using chisel plowing or similar full-width systems for growing continuous corn. Growers are encouraged to set up simple side-by-side comparisons of different tillage systems to evaluate response on their own soils.