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On-Farm Comparison of Conservation Tillage Systems for Corn Following Soybeans

Jodi DeJong-Hughes, Regional Extension Educator
Jeffrey Vetsch, Assistant Scientist

Table of Contents

Introduction

The purpose of this publication is to assist producers and crop consultants in selecting a conservation tillage system for corn in a corn-soybean rotation. It presents results of on-farm yield trials conducted across southern Minnesota and provides management tips for conservation tillage.

Selecting a tillage system requires consideration of many factors, including soil and water conservation, economic return, labor availability, and management capability, all of which are specific to the individual farming operation. For a more complete discussion of soil and tillage management in southern Minnesota, see the University of Minnesota Extension Bulletin for South Central or for Southeastern Minnesota:

- "Optimum tillage systems for corn and soybean production and water quality protection in South Central Minnesota—Minnesota River Basin" BU-08315; or
- "Tillage best management practices for water quality protection in Southeastern Minnesota" BU-07694

Both are available in print or on-line at www.extension.umn.edu.

Soil and Water Conservation Considerations

Many agronomic and environmental factors affect the impact of agriculture on soil and water quality in Minnesota. Annual row-crops like corn and soybeans do not protect the soil from direct raindrop impact until the leaf canopy closes, which is usually mid- to late June. Because the period from April through June is generally wet in Minnesota, and soil moisture conditions are at or near field capacity while transpiration rates from row crops are low, this period has the greatest potential for water runoff. When the impact of raindrops detaches soil particles, they can be carried in runoff to surface tile inlets and streams. Excessive soil erosion results in the loss of yield potential over time. It also degrades streams and lakes with phosphorus-induced algal growth and sediment, reducing light penetration and depleting oxygen necessary for fish. Maintaining crop residue cover until canopy closure reduces the impact of raindrops that dislodge soil particles, and can reduce the power of runoff water to move soil to streams. Residue is especially effective if left standing, anchored by roots.

Conservation Tillage and Previous Research

Conservation Tillage is defined as tillage systems that leave at least 30% residue cover on the soil surface after planting. Reduced tillage systems have benefits other than soil conservation, such as increased water infiltration, increased or sustained organic matter content, increased water-holding capacity, and continued long-term productivity of the soil. They also require less capital investment in equipment and fewer field passes, which reduces the amount of labor and fuel used.

So why have producers in Minnesota been hesitant to switch over to a higher residue tillage system for corn? One of the biggest concerns is that increased levels of crop residue will result in cooler and wetter soils in the spring, which may delay planting of corn on poorly drained soils. These are typically the glacial till or lacustrine (lake sediment) soils of the state. Delayed planting can reduce yield potential and result in a higher moisture content in grain at harvest. Leaving a high level of residue on the soil has less effect on soybean emergence and growth, since soybeans are planted later, when soils are warmer and drier.

The University of Minnesota has researched several reduced tillage systems to assist farmers and agricultural advisors in making tillage decisions for corn following soybeans. This research showed that reduced tillage systems can enhance residue cover and soil conservation while maintaining or improving corn yields. Small-plot research performed at the University of Minnesota's Research and Outreach Centers, presented in the two publications cited above, has shown that no-till corn following soybeans on glacial till, heavy clay soils will reduce yields compared with systems that involve some tillage like spring field cultivation, fall strip tillage, or fall chisel plow. However, on the well drained loess soils in southeast Minnesota, research showed no-till corn yields were similar to those of the three reduced tillage systems for corn following soybeans.

On-Farm Research Evaluating Four Tillage Systems

The University of Minnesota and Monsanto Corporation, in cooperation with farmers across the state, compared tillage systems for corn following soybeans on farm fields in 2004 and 2005, using producer-owned commercial tillage equipment. Details of the research methods are presented in the box below.

Research Methods

Ten on-farm trials were completed in 2004 and nine in 2005, with an additional site, Sibley-2, planted but lost to wind in 2005 (See Figure 1 and Appendix: Table A). All sites were on glacial till-derived soils except for those in Fillmore and Wabasha counties, which were on loess-derived soils. Plots were field-length strips ranging in width from 500 to 1,000 ft. and replicated three times in a randomized, complete-block design. The farmer cooperators performed all tillage, planting, spraying and harvesting operations. Generally, experimental sites were chosen that had high to very high levels of soil test phosphorus (P) and potassium (K), and therefore fertilizer P and K was not needed. Nitrogen fertilizer was spring-applied at University of Minnesota recommended rates. Weeds were managed with label rates of herbicides to minimize their impact on corn production. Corn grain yields were measured with a weigh wagon. Percent residue cover, stand counts, grain yield, and grain moisture were measured in each plot at each site. Four tillage treatments were compared at seven sites in 2004 and six sites in 2005. They were no-tillage, spring field cultivate, fall strip tillage, and chisel plow plus spring field cultivate. Two treatments, strip tillage and chisel plow plus spring field cultivate, were compared at an additional three sites each in 2004 and 2005. (See Tables F-I.) The tillage systems are described in the following section.

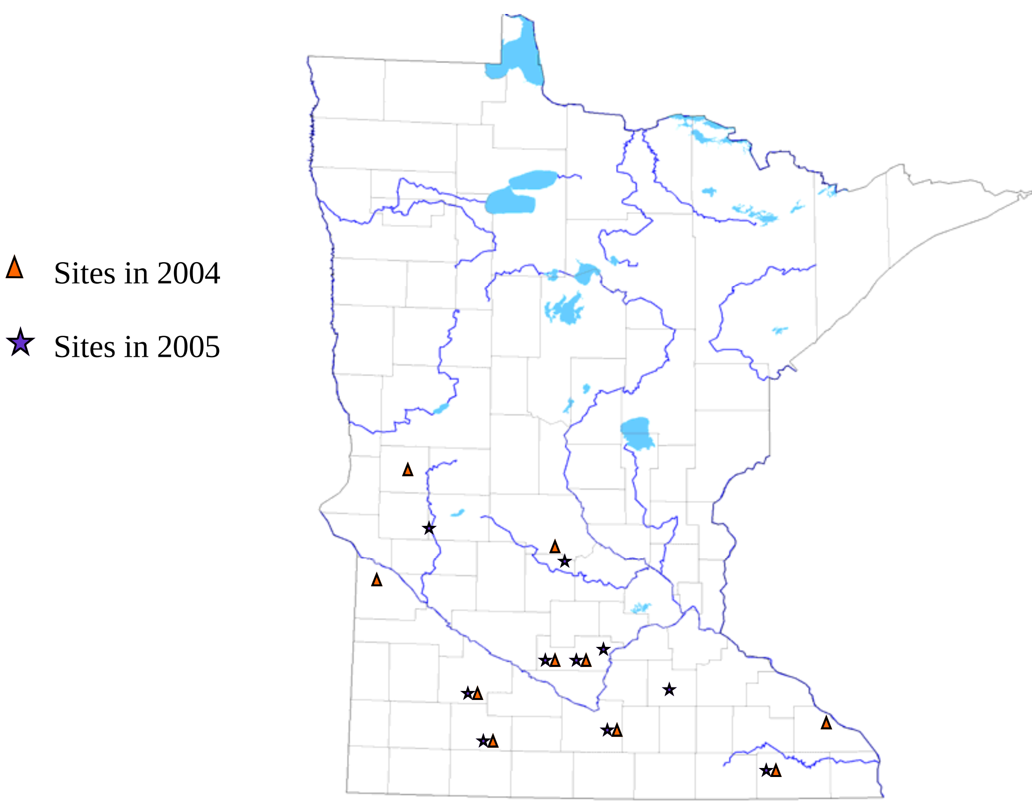


Figure 1. Conservation tillage demonstration sites for the 2004 and 2005 crop-growing seasons.

The four tillage systems for corn following soybeans compared in this study are described below in order of decreasing residue.

1.) **No tillage (No-till)**: No-till systems leave the greatest amount of residue cover on the soil surface and provide the greatest erosion control. Fertilizers may be broadcast in no-till systems, but band applications at or after planting are preferred. No-till requires complete chemical weed control. Generally, no-till has been successful in regions of Minnesota where there is less precipitation and there are coarse-textured or otherwise well-drained soils.

    The no-till treatment received no fall or preplant tillage prior to planting corn. Planter attachments (row cleaners and/or coulters) were used on the planters at most sites.

Photo 1. Residue remaining in a no-till system after planting.

2.) **Strip tillage (Strip-till):** The strip-till system is relatively new in Minnesota. Strip tillage creates a raised berm by tilling a zone 5 to 9 inches deep and 6 to 10 inches wide, but leaves the soil and residue undisturbed between the tilled zones. Since it leaves more than 30% residue on the soil (averaged across tilled and untilled zones) it is a conservation tillage system. Residue is removed from the tilled zone at the time of strip tillage and corn is planted into the residue-free area. Advantages for fall strip tillage include better warm-up of soils and a mellow seed bed due to freeze-thaw effect. While strip tillage is possible in the spring, the soil has less time to warm up prior to planting and the seedbed may be uneven. Subsurface banding or zone incorporation of P and K fertilizer may be combined in the same pass with fall or spring strip tillage.

    Strip-till implements used in these trials varied across farms, ranging from mole-knife with opening coulter and berm-shaping disks, to combinations of fluted coulters, to a large, toothed disk. All strip tillage was carried out in the fall.

Photo 2. Residue remaining after planting in a strip-till system.

Photo 3.
Typical strip-till unit with cutting coulter, residue managers, mole knife, and berm shapers.

Photo 4.
Coulters-only strip-till unit. Other designs are also on the market.

3.) **Spring field cultivate (One-pass):** The one-pass system of this study had no fall tillage and only a single pass in the spring with a field cultivator before planting. Using this system, fertilizer may be broadcast and incorporated with tillage or applied with the planter. This system typically leaves about 30% residue cover after planting corn in a corn-soybean rotation, and therefore usually qualifies as a conservation tillage system. One-pass, along with strip-till, is also referred to in this publication as “reduced tillage”.

Photo 5. Residue remaining before planting after one-pass with a spring field cultivator.

Chisel plow plus spring field cultivate (Chisel-plow-plus): The chisel-plow-plus system is generally considered conventional tillage for corn following soybean on the poorly drained glacial till soils in Minnesota. Fertilizer may be broadcast and incorporated with tillage or applied with the planter. The soil warms up fast in the spring but is left with less than 30% residue cover.

Photo 6. Residue remaining after planting in a chisel-plow-plus spring field cultivation system.

Rainfall and Growing Degree Units During the Trials

Climatic conditions varied across the state and between years during the study period. In 2004, cumulative growing degree units (GDU) were 5 to 10% below normal at three regional Research and Outreach Centers, and precipitation ranged from 47 to 57% above normal for the months of May through September (Table 1). In contrast, 2005 was an ideal year for crop growth. Precipitation was 28 to 53% above normal and GDUs were 10% above normal (Table 1). Crop producers experienced exceptional corn and soybean yields in 2005.

In addition to the cool and wet conditions in 2004, some Western Minnesota producers experienced a very early frost on August 21. The frost affected maturation, grain moisture, and ultimately crop yields, especially at the Grant County site in West Central Minnesota, where planting and harvest had been delayed.

Table 1. Precipitation (PPT) and growing degree units (GDU) for 2004 and 2005 at three regional Research and Outreach Centers in Minnesota.

	2004[1]		2005[1]		30-Year Normal	
Region	**PPT**	**GDU**	**PPT**	**GDU**	**PPT**	**GDU**
	Inch		Inch		Inch	
WCROC Morris	24.89	2327	24.31	2751	15.85	2348
SWROC Lamberton	24.96	2268	25.72	2668	16.96	2529
SROC Waseca	31.76	2330	26.22	2690	20.42	2419

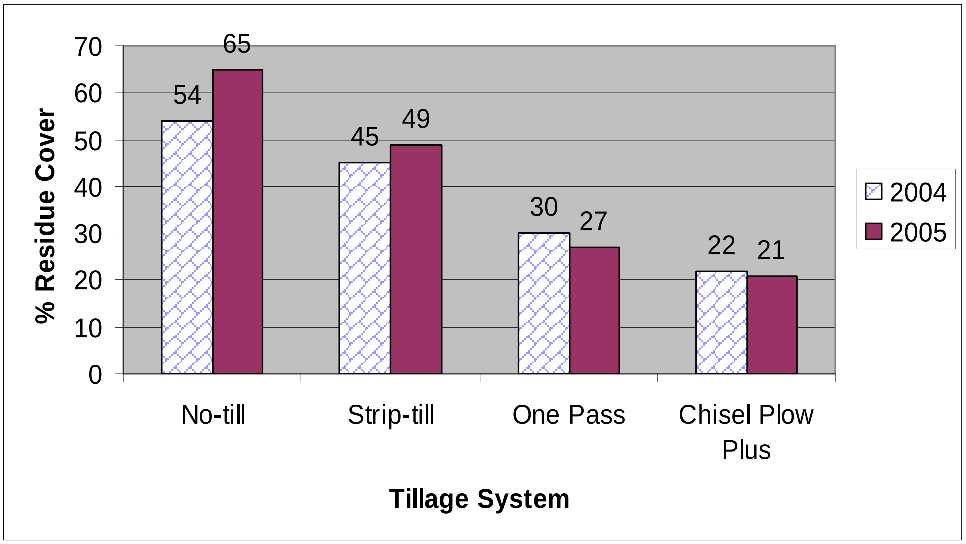
[1] Taken from May 1 to September 30

Tillage Effects on Surface Residue Cover

Residue counts were collected shortly after planting at each site. Average surface residue cover across sites in 2004 for the four tillage treatments was 54, 45, 30, and 22% for no-till, strip-till, one-pass, and chisel-plow-plus, respectively (Fig. 2 and Appendix: Table B). Residue cover in 2005 was 65, 49, 27, and 21% for no-till, strip-till, one-pass, and chisel-plow-plus, respectively (Fig. 2 and Appendix: Table C). On average, chisel-plow-plus left less than 30% residue after planting and, therefore, did not meet the federal standards for conservation tillage. On average, the one-pass tillage treatment just met the requirements in 2004 and was less than 30% in 2005.

An analysis of 13 sites across both years showed that residue cover varied considerably among sites. Residue cover percentages ranged from 30 to 90, 21 to 69, 11 to 54, and 4 to 44% for no-till, strip-till, one-pass, and chisel-plow-plus, respectively (Appendix: Tables B and C). This variation among sites was attributed to the tillage history of the sites and the row spacing and dry matter production of the previous soybean crops.

Figure 2. Percent residue cover after planting across sites for each tillage treatment for 2004 and 2005.



Tillage Effects on Plant Populations

Stand counts were taken shortly after corn emergence at each location. Overall, plant populations were very similar among all tillage systems and the average varied by only 600 plants per acre in 2004 and 1,800 plants per acre in 2005 (Table 2).

In 2004, only one location showed a statistical difference among tillage treatments (Appendix: Table D). At this site, strip-till had the highest plant population while no-till had the lowest. In 2005, only one location had a statistical difference in plant population among treatments (Appendix: Table E). At this site, strip-till had the highest plant population while the one-pass and chisel plow plus had the lowest populations. Plant population for strip tillage was never lower than conventional full-width tillage (one-pass or chisel-plow-plus) at any site.

Table 2. Plant population for each tillage system averaged across all sites in 2004 and 2005.

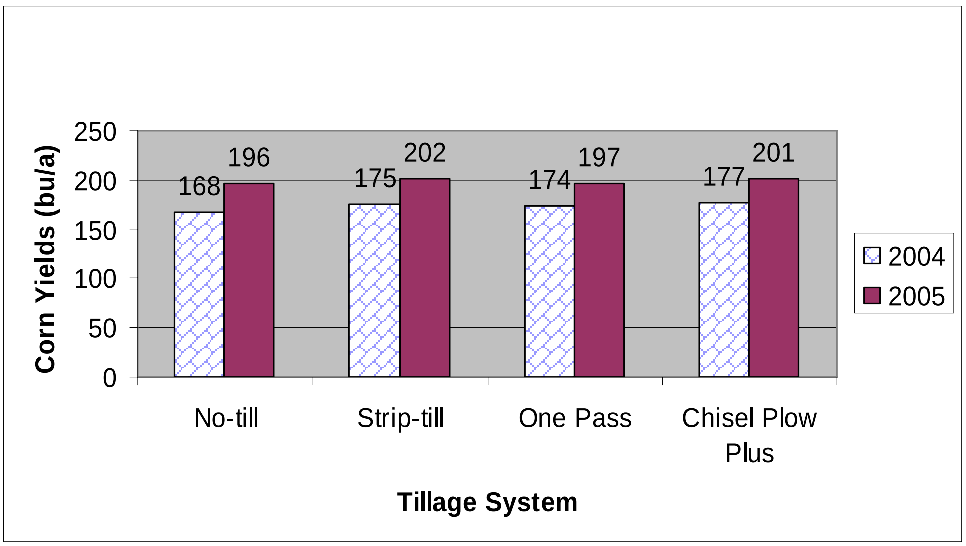
Tillage Treatments	2004	2005
	Plants/acre x 1,000	
No-till	30.5	29.9
Strip-till	31.1	31.2
One-pass	31.0	29.4
Chisel-plow-plus	31.0	29.7

Tillage Effects on Yields

In 2004

Corn grain yields were significantly affected by tillage treatments at six of the ten sites in the record cool growing season of 2004 (Appendix: Tables F and G). Averaged across the sites that used four tillage treatments, corn grain yields, ranked smallest to largest, were: no-till (167.8 bu/acre) < one-pass (174.2) = strip-till (174.6) < chisel-plow-plus (177.4), (Fig. 3 and Appendix: Table F). These data are very similar to results from 31 site-years of small plot research at the University of Minnesota‘s Southern Research and Outreach Center at Waseca (Vetsch and Randall, unpublished). They found chisel-plow-plus yielded 13 bu/acre greater than no-till, but only 3 and 4 bu/acre greater than one-pass and strip-till, respectively. At the three sites where only strip-till and chisel-plow-plus were compared in 2004, the chisel-plow-plus tillage treatment yielded 16 bu/acre greater than strip-till (Table G).

Figure 3. Corn grain yields for each tillage treatment in 2004 and 2005.



The unusually cool growing season of 2004 undoubtedly had an effect on the performance of the three reduced tillage systems in this study. Other research has shown (Randall and Vetsch, 2005) that reduced tillage systems can have significantly lower yields compared with conventional tillage in unusually cool or wet growing seasons, especially when long-term no-till or reduced tillage systems are used. In the six sites in 2004 where chisel-plow-plus increased corn yields compared with strip-till, four of the six sites had a long-term no-till or reduced tillage history.

<u>In 2005</u>
In contrast, corn yields were not significantly affected by tillage treatments at eight of nine sites in the warmer-than-normal growing season of 2005 (Tables H and I). Yields were 195.8, 202.2, 196.5, and 200.5 bu/acre for no-till, strip-till, one-pass, and chisel-plow-plus, respectively, when averaged across the six sites with four tillage treatments (Fig. 3 and Appendix: Table H). These data show strip-till and chisel-plow-plus having significantly greater yields than one-pass or no-till for corn. At the three sites where only strip-till and chisel-plow-plus were compared, there was no significant difference in yield (Appendix: Table I). The trials in 2005 demonstrated how reduced tillage systems, like strip-till, can produce excellent corn yields while maintaining adequate residue cover to protect the soil from erosion.

Average of 2004 and 2005

Corn yield averages across the 13 sites of 2004 and 2005 that compared all four tillage systems are: chisel-plow-plus (190 bu/acre) = strip-till (188) > one-pass (185) > no-till (180). As stated earlier, these data are quite similar to those found in small-plot tillage research averaged across years at Waseca, with little difference among the treatments that include some tillage.

Data Summary and Conclusions

Tillage research for corn following soybean conducted on farmer's fields in 2004 and 2005 has shown:

- Tillage treatments had a greater impact on crop production in the cooler-than-normal growing season (2004) than in the warmer-than-normal growing season (2005).
- Grain moisture was significantly higher with reduced tillage systems in 2004 but not in 2005 (data not shown).
- Residue coverage after planting corn varied considerably among sites and averaged 60, 47, 29, and 21% for no-till, strip-till, one-pass, and chisel-plow-plus, respectively.
- Significant differences in final plant populations among tillage treatments were rare, and when they occurred, were generally small.
- Averaged over years, corn yields were greatest for chisel-plow-plus and strip-till, intermediate for one-pass, and least for no-till. These data showed reduced tillage systems like strip-till can produce yields similar to conventional tillage systems like chisel plow, while maintaining adequate residue cover and reducing the risk of soil erosion.

Conservation tillage can greatly reduce soil erosion, with minimal effect on crop yields and often at lower production costs than conventional tillage. With appropriate adjustments to crop management, conservation tillage offers a low-risk means of achieving substantial reductions in sediment and phosphorus losses from cropland to streams, rivers, and lakes.

Management Tips for Reduced-Till Systems

Tillage systems that leave more than 30% residue after planting corn work for many producers; however, adjustments to management may be required throughout the whole cropping system, in addition to a change in tillage implements. Successful producers have made the following observations and suggestions:

- Well-drained soil, either natural or artificial, is beneficial for enhanced yield performance in a reduced tillage system.
- Chaff spreaders or choppers should be used to evenly distribute chaff leaving the combine, to avoid planting or tilling through piles of residue.
- Residue managers on the planter enhance early growth and promote uniform germination of seed.
- A heavy-duty, reduced tillage planter that is capable of proper depth control and firm seed-to-soil contact for good germination should be used.
- Band application of a starter fertilizer next to the corn row is good insurance against restricted root growth in cold, wet, fine-textured soils.

- Band or inject nitrogen fertilizer, if possible, rather than broadcasting it.

Photo 7.
Residue managers on the planter to clear the row.

Management Tips Specific to Strip Tillage

- Match the width of the strip-till tool bar with that of the planter to ensure row alignment. Corn planted outside the strip is essentially no-till and may suffer in yield.
- Autoguidance systems can be helpful in ensuring alignment of the planter on the strips.
- In strip-till corn after corn, leave corn stubble standing for maximum air movement and less matting of residue, and build the strips between the previous crop rows.
- For the greatest soil warm-up and seed to soil contact, build strips in the fall rather than in the spring.
- In the cooler, fine-textured soils, strip tillage equipment should clear the berm to less than 10% residue for faster soil warm-up in the spring.
- Build a high enough berm in the fall so that it is at least one inch in height by planting. If the tilled area is level or there is a trough in the spring, the berm was not high enough for rapid drying.
- The economic advantages of strip-till are improved when banding P and K fertilizer with the fall strip tillage pass. This reduces trips across the field and allows the lower rates recommended for banded versus broadcast application.

Photo 8.
Applying banded P and K fertilizer with the strip-till pass.

Photo 9.
Build a high enough berm in the fall so that it is at least one inch in height by planting.

Acknowledgements
The project could not have been accomplished without the site management carried out by the producers and research coordinators listed in Appendix Table A. We wish to thank the staff of USDA-NRCS and Soil and Water Conservation Districts for their contributions to site management in the following counties: Cottonwood, Grant, Pope, Rice, Sibley, Stearns, and Wabasha.

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Appendix

Table A. Individual site information by location for 2004 and 2005.

2004

COUNTY	PRODUCER	SITE COORDINATOR
Blue Earth	Monsanto Farm	Bruce Drager Monsanto Corp.
Cottonwood	Tom Muller	Dave Pfarr And Liz Stahl U of M Extension
Fillmore	Steve Hafner	Bruce Drager Monsanto Corp.
Grant	Mike Flint	Jodi DeJong-Hughes U of M Extension
Lac qui Parle	Jeff Olson	Harmon Wilts Monsanto Corp.
Redwood	Ralph Weber	Randy Gettle Monsanto Corp.
Sibley-1	Todd Mesker	Dave Pfarr U of M Extension
Sibley-2	Dan Pfarr	Dave Pfarr U of M Extension
Stearns	Keith Landwehr	Dave Schwartz U of M Extension
Wabasha	Steve McNallan	Tim Wagar and Brad Carlson U of M Extension

2005

COUNTY	PRODUCER	SITE COORDINATOR
Blue Earth	Monsanto Farm	Bruce Drager Monsanto Corp.
Cottonwood	Tom Muller	Liz Stahl U of M Extension
Fillmore	Steve Hafner	Bruce Drager Monsanto Corp.
Meeker	Keith Landwehr	Dan Martens and Dave Nicolai U of M Extension
Pope	Randy Reese	Jodi DeJong-Hughes U of M Extension
Redwood	Ralph Weber	Randy Gettle Monsanto Corp.
Rice	Mark Bauer	Brad Carlson U of M Extension
Sibley-1	Pete Kramer	Dave Pfarr U of M Extension
Sibley-2	Todd Mesker	Dave Pfarr U of M Extension
Sibley-3	Dan Pfarr	Dave Pfarr U of M Extension

Table B. Residue cover after planting as affected by tillage treatments and previous crop tillage practices at the 2004 sites.

Tillage Treatments	Stearns*	Grant	Wabasha	Sibley-1	Cottonw'd*	Sibley-2	**Average**	**Range**
-----------------------------% Residue/acre-----------------------------								
Previous Tillage	Strip-Till	F-Chisel S-Cult	NT	F-Ripped S-Cult	NT	F-Ripped S-Cult		
No-till	65	56	42	30	90	43	**54**	**30 to 90**
Strip-till	34	68	42	23	60	41	**45**	**23 to 68**
One-pass	21	49	34	16	35	23	**30**	**16 to 49**
Chisel plow+	7	39	22	14	35	14	**22**	**7 to 39**
LSD (0.10)**:	--	7	6	4	--	5		

* Residue counts at these sites were not replicated.

** Least Significant Difference

Table C. Residue cover after planting as affected by tillage treatments and previous crop tillage practices at the 2005 sites.

Tillage Treatments	Sibley-1	Rice	Sibley-2	Cottonw'd	Sibley-3	Meeker	Pope	**Average**	**Range**
-----------------------------% Residue/acre-----------------------------									
Previous Tillage	F-Ripped S-Cult	NT	Ripped Cult	NT	Ripped Cult	Chisel	NT		
No-till	47	68	60	88	69	42	80	**65**	**42 to 88**
Strip-till	36	45	50	69	59	21	65	**49**	**21 to 69**
One-pass	17	32	23	54	20	11	35	**27**	**11 to 54**
Chisel plow+	11	22	22	44	11	4	30	**21**	**4 to 44**
LSD (0.10):	5	6	8	9	4	14	4		

Table D. Plant populations as affected by tillage treatments in 2004.

Tillage Treatments	Stearns*	Grant*	Sibley-1	Wabasha	Sibley-2	**Average**
---------------------Plants/acre x 1,000--------------------						
No-till	30.0	34.7	31.1	28.0	28.5	**30.5**
Strip-till	31.2	35.0	31.3	28.1	30.0	**31.1**
One-pass	31.1	34.2	31.1	29.7	28.8	**31.0**
Chisel plow+	30.6	35.4	30.5	28.9	29.6	**31.0**
LSD (0.10):	--	--	NS	NS	0.8	

*Plant population counts were not replicated at these sites.

Table E. Plant populations as affected by tillage treatments in 2005.

Tillage Treatments	Sibley-1	Rice	Sibley-2	Cottonw'd	Sibley-3	Meeker	Pope	**Average**
-----------------------------Plants/acre x 1,000-----------------------------								
No-till	31.2	27.3	32.5	30.1	28.7	33.3	26.5	**29.9**
Strip-till	32.0	31.3	32.7	31.4	30.3	32.8	27.8	**31.2**
One-pass	31.5	26.2	31.0	29.0	26.5	32.5	29.0	**29.4**
Chisel plow+	32.3	29.3	31.7	26.4	27.5	32.8	28.0	**29.7**
LSD (0.10):	NS	NS	NS	NS	2.2	NS	NS	

Table F. Grain yields as affected by tillage treatments at seven sites in 2004.

Tillage Treatments	Stearns	Grant	Wabasha	Sibley-1	Cottonw'd	Sibley-2	Blue Earth	**Average**
--Bu/acre--								
No-till	182.2	115.7	184.7	198.0	128.6	192.2	173.4	**167.8**
Strip-till	187.6	116.3	183.2	196.2	136.9	204.1	198.1	**174.6**
One-pass	186.6	116.7	181.8	199.1	134.3	201.0	200.2	**174.2**
Chisel plow+	183.5	123.8	168.7	201.4	144.7	208.7	211.2	**177.4**
LSD (0.10):	NS	2.9	NS	NS	5.3	5.3	6.3	**2.6**

Table G. Grain yields as affected by tillage treatments at three sites in 2004.

Tillage Treatments	Redwood	Fillmore	Lac que Parle	**Average**
----------------------Bu/acre-------------------				
Strip-till	176.4	190.8	140.4	**169.2**
Chisel plow+	202.0	201.9	153.2	**185.7**
LSD (0.10):	NS	6.1	6.8	**9.3**

Table H. Grain yields as affected by tillage treatments at six sites in 2005.

Tillage Treatments	Sibley-1*	Rice	Cottonw'd	Sibley-3	Meeker	Pope	**Average**
-- Bu/acre --							
No-till	226.0	181.6	179.0	190.3	201.4	196.7	**195.8**
Strip-till	230.5	188.0	186.5	197.6	210.0	200.6	**202.2**
One-pass	225.7	171.0	181.1	184.3	210.8	205.8	**196.5**
Chisel plow +	227.3	189.5	181.4	195.6	205.0	204.4	**200.5**
LSD (0.10):	NS	7.7	NS	NS	NS	NS	**3.8**

* Sibley-2 was lost due to wind damage.

Table I. Grain yields as affected by tillage treatments at three sites in 2005.

Tillage Treatments	Redwood	Faribault	Fillmore	**Average**
------------ Bu/acre ------------				
Strip-till	223.3	224.0	214.2	**220.5**
Chisel plow +	220.7	222.5	215.0	**219.4**
LSD (0.10):	NS	NS	NS	**NS**