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MANAGEMENT OF SOILS
IN **SOUTHWESTERN** MINNESOTA

A Correspondence Course

Unit 7: Tillage

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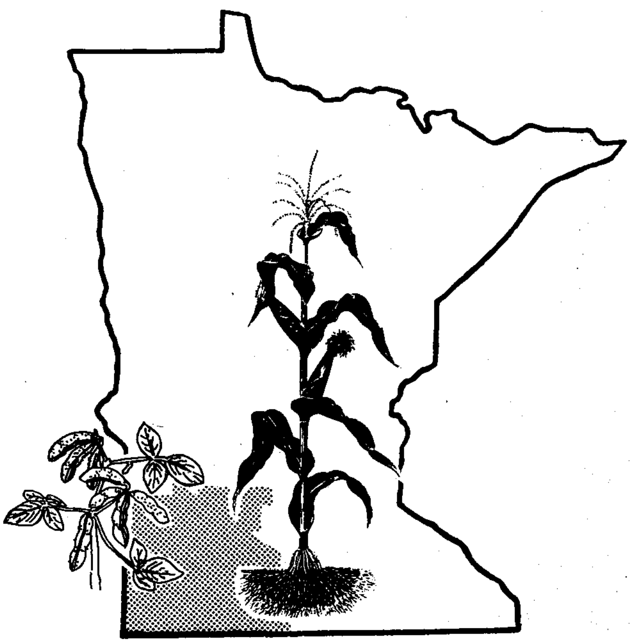
Objectives

- Understand the reasons for tillage.
- Understand the relationships between tillage and crop sequence, soil type, and climate.
- Relate these factors to crop growth and yield, and develop a strategy that allows reducing tillage while maintaining yields.



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TILLAGE: WHY AND HOW

The main reasons for tillage are: (1) to create favorable seedbed conditions; (2) to incorporate lime, fertilizer, herbicides, and manure; (3) to control weeds; (4) to increase water infiltration and storage and reduce runoff; (5) to manage crop residues; and (6) to loosen compacted soil. Contour tillage, surface roughness, and residue management can reduce soil erosion by water.

Tillage can be either full width or strip. Full-width systems include moldboard and chisel plows, discs, and field cultivators. Strip tillage is usually combined with planting and as the name implies tills only a strip. The strategy is to provide a favorable seedbed in a strip. The untilled row middles are a hostile environment for weed growth but are effective at reducing water erosion. The strip width can vary from 2 to 12 inches. Narrow-strip tillage is sometimes referred to as "no-till," "zero-till," or "slot-plant." Wide-strip tillage includes "ridge-till," "inter-till," "till-plant," and "rotary tillage."

CONSERVATION TILLAGE

Conservation tillage, as the name implies, is any tillage practice that protects soil from wind or water erosion. It can complement other erosion control practices such as surface roughness, tilling on the contour, rotations, and strip cropping. Research suggests that 25 to 30 percent of the soil surface should be covered with crop residues after planting to provide adequate erosion control under most conditions.

THE SEEDBED: WHAT'S IMPORTANT?

The soil environment near the seed (seedbed) affects germination, emergence, and early growth. Germination depends on the rate of absorption of soil moisture by the seed and temperature of the seed zone. Inhibitory chemicals leaching out of crop residues can also affect germination (alleopathy). To minimize alleopathy and maximize soil warming, it is important to restrict the amount of crop residue left in the row area, especially when a crop follows itself (the greatest inhibitory effect of leached chemicals is from residue of the same crop).

Soil temperature is directly related to the amount of soil cover in the row area. The degree to which reduced soil temperatures associated with crop residues affects growth depends on the crop and the temperature range encountered. Corn is the most sensitive common crop, primarily due to growth habit. The growing point of corn remains below the soil surface until about the sixth leaf stage of growth (six leaf collars emerged). Up to this time the soil temperature influences both the above and below ground growth. This is one reason why when corn is grown after corn it is usually better to opt for an 8- to 12-inch clean strip for the row area.

Growth delays due to reduced seedbed soil temperature are most noticeable during cold springs, on wet soils, and on north-facing slopes. Research at Lancaster, Wisconsin has shown that during short growing seasons when the growing degree days are marginal and little drought stress occurs, corn with over 30 percent residue cover in the row had increased grain moisture at harvest and decreased yield. Minnesota Experiment Station research has shown that soybeans are much less sensitive to crop residue levels. In a corn-soybean crop sequence less tillage is necessary because the soybeans are less sensitive to soil cover and there is little residue left to affect corn following soybeans.

In-row crop residue also can affect seed placement. Accurate seed placement is important: shallow placement may reduce stand and delay emergence under dry conditions, while deep placement delays emergence under cold and wet conditions. Removal of corn residue from the row area with sweeps or clearing discs on conservation tillage planters reduces the variation in depth of seed placement.

Good seed-soil contact, accomplished by firming the soil around the seed during planting, is necessary to assure rapid water uptake. Where soil is not loosened by tillage, the planter must provide whatever loosening is needed. Thus, planter design is more critical with strip tillage systems, since the planter must penetrate dense, residue-covered soils. Research-based recommendations indicate that for optimal seed-soil contact the average aggregate or clod size in the seed zone should be about one-fifth to one-tenth the diameter of the seed.

CONSERVATION TILLAGE AND STAND ESTABLISHMENT

Reductions in stand due to "no-till" (in-row tillage only by fluted coulter) are frequent in studies on somewhat poorly drained soils in southern Minnesota. However, there also are as many instances where stand reductions are attributable to cloddy conditions from moldboard plowing.

Recent results from Meeker County on a clay loam soil following soybeans illustrate the benefit of crop residue under dry conditions (Table 1). The no-till and ridge-till systems resulted in more even emergence and early growth (5/27) because corn was planted into moist soil (notice effect of tillage on the variability of the leaf number). Moist soil conditions at planting in a dry year more than offset the detrimental temperature effects of 20 to 30 percent in-row cover. Later in the season (6/26) the moldboard plow system appeared to have caught up in growth but still showed a lot of variability.

Three factors are generally responsible for variations in stand under different tillage conditions: (1) with plowing, poor seed-to-soil contact due to cloddy conditions; (2) uneven seed placement; and (3) possible germination inhibition due to alleopathy (toxic effects of chemicals leaching out of relatively fresh crop residue, usually from the same crop).

Lancaster, Wisconsin experiment station measurements for 1984 and 1985 showed a reduction of about 30 plants/A for each 1 percent corn residue cover in the row because residue was pushed into the seed furrow during planting. Thus, 60 percent cover in the row decreased population by about 1800 plants/A. In studies on the somewhat poorly drained soils of southern Minnesota, crop residue in the row area reduced stands more than in the Lancaster, Wisconsin example.

Table 2 illustrates the effect of cloddiness (from moldboard plowing) and crop residue (when eliminating primary tillage) on establishment of corn stands. At the Steele County site in 1985 stands were reduced when planting into a fall moldboard plowed seedbed. In 1986 at the Carver County site stands were reduced with systems that left residue on the surface. Although in individual years there are significant tillage effects, on average there is little effect of tillage on stands with well-drained to somewhat poorly drained soils.

To minimize the risk of reduced corn stand due to corn residue when using a system that eliminates primary tillage, it's helpful to use planters equipped with clearing discs or sweeps to clean the row area. It is also essential to closely monitor and adjust operation of planting equipment.

Table 1. The effect of tillage on corn stand, emergence, early growth, and yields at Meeker County on a clay loam soil in 1987.

Tillage	Stand 5/27 (1000 plants/A)	Percent cover[a] in	Percent cover[a] btw	Growth 5/27 (leaves/plant)	Growth 6/26 (g/plant)	Yield (bu/A)
No-till	37.5±2.3	29	24	3.3±0.5	28.3±6.6	190
Ridge-till	37.8±2.8	20	22	3.8±0.4	24.5±3.2	179
Chisel[b]	36.7±2.9	10	10	3.3±1.0	29.5±2.9	188
Moldboard[b]	34.3±3.4	2.5	2.3	3.0±1.4	31.5±8.5	189
significance[c]	S	S	S	S	NS	NS

[a]Soil cover by crop residue after planting is characterized in and between the row. The in-row area is defined as eight inches centered over the crop row and between-row the remainder.
[b]Primary tillage was done in the fall.
[c]If differences between the averages within a column are due to tillage (the result of a statistical test) it is labeled S (statistically significant) and if it is not, NS (not statistically significant).

Table 2. The effect of tillage on corn stands on well-drained to somewhat poorly drained soils.

	Stand (1000 plants/A)					
	Steele County[a]			Carver County[b]		
Tillage	1985	1987	Mean	1986	1987	Mean
No-till[c]	27.0	27.1	**27.1**	23.2	24.9	**24.1**
Ridge-till	27.2	26.5	**26.9**	—	23.8	—
Chisel[d]	28.8	26.1	**27.5**	23.3	24.4	**23.9**
Moldboard[d]	24.5	26.2	**25.4**	24.9	23.5	**24.2**
Subsoil[e]	27.0	26.3	**26.7**	—	—	—
Significance[f]	S	NS		S	NS	

[a]Corn followed soybeans in 30-inch rows on a moderately well-drained to somewhat poorly drained soil (Le Sueur, clay loam-Aquic Argiudoll).
[b]Corn followed corn in 38-inch rows on a well-drained soil (Lester, loam-Mollic Hapludalf).
[c]In 1987 a planter equipped with row cleaners was used with this system.
[d]Plowing was done in the fall of 1984 for the 1985 growing season and in the spring for 1987.
[e]At the Steele County site the subsoil treatment was done in 1984 and 1985. In 1987 it was planted no-till with a conventional planter.
[f]NS = no statistically significant difference between tillage systems, S = significant difference.

IMPORTANCE OF CROP SEQUENCE AND SOIL TYPE

Corn

Minnesota research has shown that the effect of tillage on corn yields depends on soil type, climate, crop sequence, and proper management of crop residue (Tables 3 through 7).

The data shown in Table 3 show a yield reduction associated with no tillage on an excessively well-drained soil. In this study nitrogen treatments necessitated traffic between all rows, which was partially responsible for the yield reduction with the no-till treatment. Course-textured soils are es-

Table 3. The effect of tillage on corn grain yields in Sherburne County, Minnesota on a loamy sand soil under irrigation.[a]

	Yield (bu/A)				
Tillage	1982	1983	1984	1985	Average
No-till	178	137	167	146	**157**
Ridge-till	197	142	185	168	**173**
Chisel	184	150	178	169	**170**
Moldboard	200	147	179	187	**178**
Significance[b]	S	S	S	S	

[a]Corn was grown after corn on a somewhat excessively drained soil (Hubbard, loamy sand-Udorthentic Haploboroll).
[b]NS = no statistically significant difference between tillage systems, S = significant difference.

Table 4. The effect of tillage and crop sequence on corn grain yields at Lamberton, Minnesota on a well-drained, Ves clay loam soil (Udic Haplustoll).

	Yield (bu/A)				
Tillage	1979	1980	1981	1982	Average
	Continuous Corn				
Moldboard	137	117	122	148	**131**
Chisel	125	109	117	137	**122**
Spring disc	121	119	116	125	**120**
No-till (ridge)[a]	133	124	109	152	**130**
No-till (flat)[a]	124	113	112	125	**119**
	Corn after Soybeans				
Moldboard	128	135	124	146	**133**
Chisel	130	131	135	138	**134**
Spring disc	131	138	126	143	**135**
No-till (ridge)[a]	138	130	121	148	**134**
No-till (flat)[a]	127	135	127	151	**135**

[a]Both no-till treatments were cultivated. Ridges were established on the no-till (ridge) treatment. The planter used was not equipped with row-cleaning tillage tools (sweeps, discs, or fluted coulters). This resulted in differences in soil cover in the row area between these two treatments due to the presence of a ridge. The row area with the "no-till on ridges" system is cleaner than the "no-till-flat" but not as residue-free as it would be with a ridge-till planter equipped with tillage tools to clean the row area.

pecially susceptible to compaction from traffic when all tillage is eliminated. Residue also contributed to yield reduction with corn grown with the no-till system. Other conservation tillage options resulted in similar yields.

No-till corn grown after corn where all residue is left and no clearing discs or sweeps are used has the highest risk of reduced N availability, stand problems associated with poor seed-soil contact, and inhibition of early growth and development. However, if corn is planted after a low-residue crop such as soybeans or alfalfa, or planters equipped with clearing discs or sweeps are used following corn, many of these problems disappear. Over a wide range in yield there is little difference in corn yield due to tillage following soybeans (low residue crop). This is illustrated by data from Redwood and Stevens counties (Tables 4, 5, and 6).

When corn follows a high residue crop such as corn on moderately well-drained to poorly drained soils, yields vary with different tillage systems. There is about a 10 bu/A yield reduction with corn grown under most conservation tillage systems (Tables 4, 5, and 6). The "no-till on ridges" approach yields equal those under moldboard plowing at the Lamberton site (Table 4). The performance of this system at the Morris site (Table 5) may be due to the fact that the planter used was not equipped with clearing discs to clean the row area. The data shown in Table 6 are also from Morris, Minnesota but refer to a ridge-till system (clearing discs on planter) rather than "no-till on ridges." In this data set all tillage systems result in about equal yields when corn is grown after corn except the no-till, which is about 10 bu/A lower. This illustrates the importance of a clean row area when planting corn after corn with conservation tillage. Over a wide range in intensity of tillage there is no effect on corn yields when following soybeans (Tables 4, 5, and 6).

In summary, corn growth is not affected by tillage over a wide range of soil types if the row area is cleaned of residue at planting and starter fertilizer is used. Corn grown after corn will be less affected by in-row residue on soils that are moderately well-drained or better than on poorly drained sites or sites with north-facing slopes. Corn grown after corn with most conservation tillage systems frequently has shown a yield suppression (10 bu/A or more). The exception appears to be the ridge-till system. When using systems that eliminate primary tillage, traffic must be controlled to avoid soil compaction problems.

When growing corn after soybeans there is no effect of tillage on grain yields. The data base to support this statement includes a range in internal soil drainage from moder-

Table 5. The effect of tillage and crop sequence on corn grain yields at Morris, Minnesota on a poorly drained, Hammerly clay loam soil (Aeric Calciaquoll).

	Yield (bu/A)						
Tillage	1979	1980	1981	1982	1983	1984	Average
	continuous corn						
Moldboard	132	119	139	143	113	131	**130**
Chisel	132	109	121	137	102	133	**122**
Spring disc	126	114	120	133	101	128	**120**
No-till (ridge)[a]	127	108	117	128	111	134	**120**
No-till (flat)[a]	120	108	95	126	98	130	**113**
	corn after soybeans						
Moldboard	137	134	141	148	126	134	**137**
Chisel	138	124	149	155	130	121	**136**
Spring disc	136	127	138	154	124	139	**136**
No-till (ridge)[a]	135	128	143	151	134	134	**138**
No-till (flat)[a]	139	127	136	153	126	136	**136**

[a]Both no-till treatments were cultivated. Ridges were established on the no-till (ridge) treatment. The planter used was not equipped with row-cleaning tillage tools (sweeps, discs, or fluted coulters). This resulted in differences in soil cover in the row area between these two treatments due to the presence of a ridge. The row area with the "no-till on ridges" system is cleaner than the "no-till-flat" but not as residue-free as it would be with a ridge-till planter equipped with tillage tools to clean the row area.

ately well-drained to somewhat poorly drained with a range in tillage from moldboard plowing to systems that eliminate primary tillage.

Soybeans

Research statewide has shown that soybeans are insensitive to tillage over a wide range of soils (with the exception of iron chlorosis on high pH soils, where the soil aeration associated with tillage lessens symptoms). In some years on some soils there are adverse tillage effects but little or no difference in yields in the long term (Tables 8 and 9). These data were collected on somewhat poorly drained soils that are well-tiled. These studies had excellent weed control. Soybean yield differences due to tillage are usually associated with weed control. With few exceptions there is usually a 10 to 15 percent yield advantage to soybeans grown in narrow rows. Data comparing ridge-till tillage and soybeans grown in narrow rows with other tillage systems usually show differences that are due to row spacing and not tillage. Also note that there is no difference in yield between no-till, till plant-flat, and till plant-ridge. It is not as important to keep the row area free of corn residue as it is for corn.

In summary, the effects of tillage system on soybean yields seem to be related to row spacing and weed control rather than to crop sequence or soil type. If weeds are controlled, yields for all tillage systems will be similar.

Table 6. The effect of tillage and crop sequence on corn grain yields at Morris, Minnesota on a well-drained, Barnes loam soil (Udic Haploboroll).

	Yield (bu/A)					
Tillage	1980	1981	1982	1983	1984	Average
	continuous corn					
Moldboard	131	132	146	92	137	**128**
Chisel	115	124	136	94	125	**119**
No-till[a]	121	121	132	90	117	**116**
	corn after soybeans					
Moldboard	129	139	147	103	139	**131**
Chisel	131	134	146	105	141	**131**
No-till[a]	134	130	145	106	147	**132**
	corn-wheat-soybeans					
Moldboard	133	140	157	108	132	**134**
Chisel	137	133	151	103	148	**134**
No-till[a]	140	141	137	113	141	**134**

[a]The no-till treatment was cultivated. The planter used was not equipped with row-cleaning tillage tools (sweeps, discs, or fluted coulters).

Table 7. The effect of tillage on corn grain yields following corn on a Tara silt loam soil (Pachic Udic Haploboroll) in Stevens County, Minnesota (Sam Evans et al.).[a]

	Yield (bu/A)				
Tillage	1984	1985	1986	1987	Average
Moldboard	131	80	97[b]	150	**115**
Chisel	124	89	127[b]	137	**119**
Ridge-till[c]	131	78	128	137	**118**
No-till[c]	111	77	107	132	**107**

[a]Conducted at the West-Central Agricultural Experiment Station, Morris, Minnesota.
[b]Primary tillage was done in the spring due to wet fall conditions this year.
[c]The ridge-till corn was planted with a planter equipped with clearing disc to clean the row area. The no-till corn was planted with tillage by a fluted coulter which tilled the row area but did not reduce cover by residue very much.

CULTIVATION

Researchers have shown an advantage to cultivation on crusting silt loam soils due to: (1) weed control; (2) improved infiltration and retarded runoff from roughness; and (3) improved aeration (after crusting conditions).

The effects of cultivation and tillage on corn yields (continuous corn) on a Tama silt loam soil in Fillmore County is

Table 8. The effect of tillage on soybean yields following a high residue crop (corn) in Stevens County, Minnesota on a somewhat poorly drained clay loam soil (Evans, unpublished data)[a].

	Yield (bu/A)				
Tillage	1982	1983	1984	1985	Mean
No-till	40	64	47	55	**49**
Till plant[b] ridge	38	63	47	57	**51**
flat	36	63	45	54	**51**
Spring disc	38	61	45	53	**49**
Chisel	37	64	47	57	**51**
Moldboard	35	64	46	57	**50**
Significance[c]	S	S	S	S	

[a]Soybeans grown after corn on a somewhat poorly drained soil (Hammerly, clay loam-Aeric Calciaquoll) at the West-Central Agricultural Experiment Station, Morris, Minnesota.
[b]Corn was planted into a 10-inch residue-free strip with both till plant treatments with a planter equipped with row cleaners. The flat treatment was cultivated but not ridged at cultivation.
[c]NS = no statistically significant difference between tillage systems, S = significant difference.

Table 9. The effect of tillage on soybean yields following a high residue crop (corn) in Waseca and Redwood counties on somewhat poorly drained clay loam soils (Lueschen and Nelson respectively, unpublished data).

	Yield (bu/A)								
Tillage	Waseca County[a]					Redwood County[b]			
	1982	1983	1984	1985	Mean	1982	1983	1984	Mean
No-till	50	47	46	45	**47**	49	50	39	**46**
Till plant[c] ridge	48	45	46	45	**47**	51	53	39	**47**
flat	47	47	46	43	**46**	50	50	38	**46**
Spring disc	52	46	49	47	**49**	53	49	38	**47**
Chisel	51	48	48	44	**48**	53	47	36	**45**
Moldboard	51	50	49	46	**49**	52	47	41	**47**

[a]Soybeans grown after corn on a somewhat poorly drained soil (Webster, clay loam-Typic Haplaquoll) at the South-Central Minnesota Agricultural Experiment Station, Waseca, Minnesota.
[b]Soybeans grown on a somewhat poorly drained soil (Ves-Normania, clay loam-Udic Haplustoll-Aquic Haplustoll) at the Southwestern Minnesota Agricultural Experiment Station, Lamberton, Minnesota.
[c]Corn was planted into a 10-inch residue-free strip with both till-plant treatments with a planter equipped with row cleaners. The flat treatment was cultivated but not ridged at cultivation.

shown in Table 10. Tillage and cultivation significantly affected grain yields. In 1985 cultivation resulted in a significant yield increase with moldboard and no-till grown corn. Cultivation did not affect yields with chisel plowing or discing. The dominant weeds at this site are giant foxtail and velvet leaf. The response to cultivation in 1985 was likely due to weed control and improved water infiltration under no-till and moldboard conditions. In 1986 there was abundant and timely rain. Weeds also were effectively controlled with herbicides. Both factors resulted in no yield response to cultivation. In 1987 preemergence herbicides were less effective and rain was more yield-limiting. In this year there was a response to cultivation in all systems.

It is interesting to note that the no-till plots were not cultivated in 1987 because crop residues prevented cultivation with a conventional cultivator. The 15 bu/A response in the no-till plots is from the previous year's cultivation. Weed pressure was much reduced. Three-year averages show no advantage to cultivation with a chisel plow. There is a 3 to 4 bu/A yield advantage to cultivation with the moldboard and spring disc systems. The no-till system by far had the biggest yield advantage to cultivation (10 bu/A).

When evaluating the value of cultivation, tillage from anhydrous ammonia application should also be considered (Table 11). Some studies have shown decreased water infiltration under no-till conditions and imply that there also will be increased phosphorus (P) associated with water runoff since broadcast P accumulates at the surface. This not likely if secondary tillage such as that associated with anhydrous ammonia application or cultivation has been done following broadcast P applications. Planter-applied P is even more effective at reducing runoff losses since it is below the soil surface.

EROSION AND YIELDS

There are very little data relating soil erosion and crop yields. The results of one study of the relationship among soil depth, rainfall, and grain yields are shown in Table 12. In 1984 average yields increased 13 bu/A as soil depth increased from 29 to 62 inches. In 1983 under more severe drought conditions soil depth affected yields by 40 bu/A. In 1981 and 1982 when water stress was minimal there was no effect of depth on yields. This study quantifies the relationship between rainfall and soil depth due to erosion and corn yields.

SUMMARY

1. Keep the row area clean of crop residue when planting corn after corn to help ensure uniform and rapid emergence. Conservation tillage corn after corn when row area was not free of residue resulted in lower yields (10 bu/A) than ridge-till or moldboard plowing.

2. Most of the beneficial effects of the ridge-till system on corn growth is due to a residue-free row area rather than a prominent ridge. Ridges may aid in soil and water conservation.

3. Tillage had no effect on yield when corn was grown after soybeans. Starter fertilizer should be used for corn regardless of crop sequence.

4. Soybeans appear to be insensitive to tillage, soil type (with the exception of high pH soils, which cause iron chlorosis), or crop sequence.

5. Research shows generally a 10 to 15 percent yield increase for narrow-row soybeans (10 inches or less vs. 30 inches).

6. Weed control and row spacing, rather than tillage system, usually account for yield differences for soybeans.

7. Cultivation or anhydrous ammonia application improved water infiltration and corn yield when the soil crusted.

8. In a drought year decreased soil depth and the associated reduced soil available water holding capacity decreased yields 1.4 bu/A per inch of total soil depth.

Table 11. The effect of tillage on water infiltration at Lancaster, Wisconsin in early June.

	Infiltration (in/hr)		
Tillage	1981	1982	1983[a]
No-till	1.46	1.10	3.53
Moldboard	0.97	1.52	0.54

[a]Anhydrous ammonia applied preplant.

Table 12. The effect of soil depth (Palsgrove and Rozetta silt loams) to clay residuum and growing season rainfall on corn grain yields at Lancaster, Wisconsin.

	Yield (bu/A)							
	Average depth (inches)				Rainfall (inches)[a]			
Year	29	41	46	62	May	June	July	Aug.
1981	147	147	142	147	0.85	4.28	2.91	11.35
1982	150	143	143	147	5.46	3.45	5.29	4.06
1983	73	85	96	111	5.18	3.28	3.34	3.12
1984	107	110	118	120	3.92	7.77	2.57	1.37

[a]In both 1983 and 1984 long periods of minimal rainfall occurred during the silk and tassel emergence period.

Table 10. The effect of tillage and cultivation on corn grain yields at Fillmore County on a well-drained soil (Tama, silt loam-Typic Argiudoll).[a]

	Yield (bu/A)							
	1985[b]		1986		1987		**Average**	
Tillage	C	NC	C	NC	C	NC	**C**	**NC**
No-till	168	158	204	199	160[c]	145	**177**	**167**
Spring disc	175	171	206	207	164	157	**182**	**178**
Chisel	171	174	199	204	171	161	**180**	**180**
Moldboard	177	170	200	202	167	163	**181**	**178**

[a]Corn was preceded by soybeans in 1985 and corn in 1986 and 1987.
[b]C = cultivated, NC = not cultivated.
[c]No-till corn was not cultivated in 1987. The conventional cultivator at this site was unable to handle the residue that had accumulated. The 15 bu/A response in this year is due to weed (velvet leaf and foxtail) control provide by cultivation from previous years.

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