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MANAGEMENT OF SOILS
IN SOUTHEASTERN MINNESOTA
A Correspondence Course

Unit 7: Tillage

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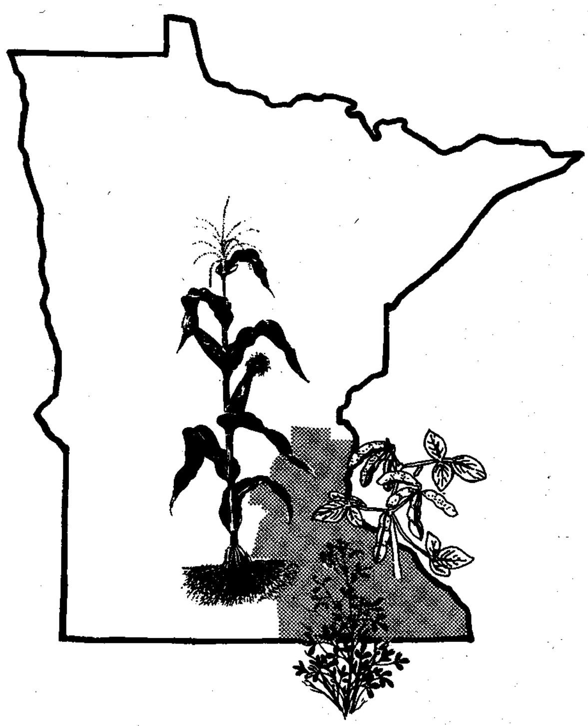
Objectives

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



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TILLAGE: WHY AND HOW

The main reasons for tillage are: (1) to create a favorable seedbed; (2) to incorporate lime, fertilizer, herbicides, and manure; (3) to control weeds; (4) to increase water infiltration and reduce evaporation and runoff; and (5) to loosen compacted soil. Tillage also can reduce soil erosion if done on the contour and if crop residues are managed properly.

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 is known as "ridge-till," "inter-till," "till-plant," or "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. In southeastern Minnesota, conservation tillage is the convention due to the erosive nature of most of the soils, the topography, and the intense rainfall.

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. Corn is the most sensitive common crop, primarily due to its 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 ensure 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

Large reductions in stand due to "no till" (in-row tillage only by fluted coulter) are not frequent in studies on well-drained soils in southeastern Minnesota. However, in two out of four studies no-till corn after corn resulted in higher stand reductions in 1985 than with other tillage systems or where corn followed low residue crops.

Three factors probably were responsible: (1) poor seed-to-soil contact and uneven seed placement because residue was pushed into the seed furrow during planting, followed by very dry weather; (2) possible germination inhibition due to alleopathy; and (3) increased cutworm activity at some sites. In Steele (1985) and Fillmore (1986) counties, lower stands were associated with moldboard plowing. This is due to cloddy conditions resulting in a poor seed bed.

Lancaster, Wisconsin experiment station measurements for 1984 and 1985 show a reduction of about 30 plants per acre for each 1 percent cover in the row. Thus, 60 percent cover in the row would decrease population about 1800 plants per acre. At two of four research sites, no-till corn after corn (for grain) had no stand reduction due to more favorable rains.

To minimize this risk, use clearing discs or sweeps to clean the row area when planting no-till corn in heavy corn residue.

IMPORTANCE OF CROP SEQUENCE

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; inhibition of early growth and development; and insect, weed, and disease problems. If, however, corn is planted after a low-residue crop such as soybeans or alfalfa many of these problems disappear. Tables 1 and 2 illustrate the results of field studies in which, although final stand and grain moisture were affected slightly in some cases, grain yields were not affected by tillage.

Table 1. The effect of tillage on corn grain yields and moisture following sweet clover in 1984 and soybeans in 1985 and 1986 at Wabasha County on a Fayette silt loam soil.[a]

Tillage	Yield			Moisture		
	1984	1985	1986[b]	1984	1985	1986[b]
	bu/A			%		
No-till	154	108	183	24.7	22.7	27.4
Ridge-till	148	102	185	24.9	22.3	26.3
Chisel	146	109	185	25.0	23.1	26.6
Subsoil	154	106	186	24.6	22.6	26.8
Significance[c]	NS	NS	NS	NS	S	S

[a]The ridge till was cultivated twice and chisel was cultivated once. Subsoil and no-till systems were not cultivated. No-till treatments did not have row clearing equipment on the planter.

[b]In 1986 the paraplow was changed to a spring disc system. The row spacing was changed from 38 inches to 30 inches. Consequently, this is an establishment year for the ridge-till treatments.

[c]NS = no statistically significant difference between tillage systems, S = significant difference.

Table 2. The effect of tillage on corn grain yields, moisture, and population following soybeans at Steele County, 1985 on a LeSueur clay loam soil.[a]

Tillage	Yield (bu/A)	% Moisture	Population (plants/A x 10^3)
No-till	162	25.1	27.0
Ridge-till	167	25.2	27.2
Chisel	167	24.7	28.8
Moldboard	169	25.7	24.5
Subsoil	171	25.7	27.0
Significance[b]	NS	NS	S

[a]All tillage systems received one cultivation (two for ridge-till).

[b]NS = no statistically significant difference between tillage systems, S = significant difference.

Table 3. The effect of tillage on plant population at Fillmore County on a Tama silt loam soil.

Tillage	1985	1986
	(plants/A x 10^3)	
No-till	25.7	27.5
Disc	26.3	27.2
Chisel	26.5	27.4
Moldboard	26.0	24.2
Significance[a]	NS	S

[a]NS = no statistically significant difference between tillage systems, S = statistically significant.

PRIMARY TILLAGE AND CULTIVATION

Research has shown an advantage to cultivation on silt loam soils. Benefits from cultivation on these soils are 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 on a Tama silt loam soil in Fillmore County are shown in Table 4.

Tillage (in both years) and cultivation (in 1985) significantly affected grain yields. There was also an interaction of tillage and cultivation on grain yields in 1985 at this site. In 1985 cultivation resulted in a significant yield increase at moldboard and no-till sites. Cultivation did not affect yields with chisel plowing or discing. Weed pressure generally decreased with less primary tillage (this was not the case in 1986) and with cultivation. The dominant weed at this site was giant foxtail followed by velvetleaf. The response to cultivation in 1985 was likely due to weed control and improved water infiltration under no-till and moldboard conditions.

Table 4. The effect of tillage and cultivation on corn grain yields at Fillmore County on a Tama silt loam soil.[a]

	Cultivation			
	1985		1986	
Tillage	Yes	No	Yes	No
	bu/A			
No-till	168	158	204	199
Disc	175	171	206	207
Chisel	171	174	199	204
Moldboard	177	170	200	202

[a]Corn was preceded by soybeans in 1985 and corn in 1986.

In 1986 tillage significantly affected yields. The spring disc treatment showed a slight advantage. Cultivation effects were not significant. This is due to better weed control and more timely rains this year.

When evaluating cultivation practices, tillage from anhydrous ammonia application should also be considered (e.g., Table 5). Some studies have shown decreased water infiltration under no-till conditions and imply that there will also be increased nitrogen and phosphorus associated with water runoff. This is not likely if secondary tillage such as that associated with anhydrous ammonia application or cultivation has been done.

Table 5. The effect of tillage on water infiltration at Lancaster, Wisconsin in early June.

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

[a]Anhydrous ammonia applied preplant.

SOIL TYPE

The effect of tillage on corn grain yields following soybeans for Steele and Wabasha was similar (Tables 1 and 2). Soils at these sites were a well-tiled LeSueur clay loam and Fayette silt loam, respectively. At Dodge County there was a large difference in grain yield (continuous corn) due to tillage favoring the moldboard plow treatment (Table 6). The soil at this site is a Skyberg silt loam, which formed in a thin mantle of silt loam cap over dense glacial till with poor internal drainage. These three sites illustrate the importance of the interaction of soil texture, drainage, and level of crop residue. It is important to realize that this is an establishment year for Steele and Dodge counties so the ridge-till and no-till treatments are the same with the exception of a ridging operation.

A long-term study at Lancaster, Wisconsin on Palsgrove and Rozetta silt loam soils shows no difference in continuous corn grain yields due to tillage for moldboard and chisel plowing or ridge-till. Yields were lower with a no-till system (Table 7). The site is located on a north-facing contour strip which has 8 to 10 percent slope.

Table 6. The effect of tillage on corn grain yields, moisture, and population following corn on a Skyberg silt loam soil at Dodge County, 1985.

Tillage[a]	Bu/A	% Moisture	Population (plants/A x 10^3)
No-till (cult.once)	118	38.3	30.2
No-till (cult.twice)	123	38.4	30.6
Moldboard	150	33.6	31.3
Significance	.003	.000	NS (.793)

[a]This is an establishment year so the second no-till received a ridging operation.

Table 7. Continuous corn tillage yields on Palsgrove and Rozetta silt loam soils at Lancaster, Wisconsin, 1979-1983.

Tillage	1979	1980	1981	1982	1983	1984	1979-83	1979-84
	(bu/A)							
Ridge-till[a]	162	157	157	147	100	—	145	—
No-till	163	146	151	141	85	108	137	132
Chisel	160	150	167	154	95	115	145	140
Moldboard	169	159	168	151	89	121	147	143
Subsoil	—	—	—	—	—	106	—	—

[a]Corn was planted flat in 1979 and 1981 and this treatment was not cultivated to form ridges in 1980 and 1983.

SOYBEANS

The effects of tillage on soybean yields at the Wabasha County site is shown in Table 8.

There are significant row spacing effects in two years. There is a sizeable advantage with the narrow rows (10 inches) over the 38-inch rows with the ridge-till treatment in 1984 and 1985. Lambsquarter exerted the most pressure with the chisel plow treatment in 1985. This treatment did not receive a burndown treatment because a field cultivator was used just prior to planting in an unsuccessful attempt to eliminate lambsquarter. The season was extremely dry in 1985, which also favored tillage systems that left residue on the surface. The ridge was also a detriment in the dry year due to increased moisture stress. This is the reason for the lower yield with this tillage system in 1985.

Table 8. The effect of tillage on soybean yield on a Fayette silt loam and LeSueur clay loam soil at Wabasha and Steele counties, respectively.

Tillage	Wabasha[a]			Steele[b]
	1984	1985	1986	1986
	bu/A			
No-till	40	43	43	47
Ridge-till	35	28	46	46
Chisel	44	34	46	46
Subsoil	47	43	43	45
Moldboard	—	—	—	47

[a]The no-till and subsoil treatments at Wabasha County were not cultivated. The subsoiling treatment was changed to a spring disc treatment in 1986. Row spacing for the ridge-till was 38 inches in 1984 and 1985 and 30 inches in 1986 (1984 and 1986 are establishment years for the ridge-till treatment).

[b]30-inch rows.

Table 9. The effect of tillage and row spacing on soybean yield on a Webster clay loam at Waseca, Minnesota, 1982-1985.

Tillage	Row Spacing		
	10-inch	30-inch	Average
	bu/A		
No-till	45	42	44
Till Plant (Ridge)	—	41	41
Till Plant (No Ridge)	—	40	40
Spring Disc	45	42	44
Chisel	45	41	43
Moldboard	45	41	44
Significance[a]	NS	NS	

[a]NS = No statistically significant difference.

The data in Table 8 from Wabasha County are complicated because of the row spacing difference between the ridge-till system and other systems that were planted with narrow row soybeans. The Steele County data do not have the row spacing variable and had excellent weed control. At the same row spacing and with adequate weed control, there has been no effect of tillage on soybean yields in Minnesota. This is also supported by a four-year study at Waseca, Minnesota (Table 9). Essentially, if at a given row spacing weeds are controlled, tillage will not affect soybean yields.

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 10. In 1984 average yields increased 13 bushels per acre as soil depth increased from 29 to 62 inches. In 1983 under more severe drought conditions soil depth affected yields by 40 bushels per acre. 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.

Table 10. The effect of soil depth (Palsgrove and Rozetta silt loams) to clay residuum and growing season rainfall on corn grain yields at Lancaster, Wisconsin.

Year	Average depth (inches)				Rainfall			
	29	41	46	62	May	June	July	Aug.
	(bu/A)				(inches)			
1981	147	147	142	147	.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

SUMMARY

1. Keep the row area clean when planting no-till corn after corn to ensure uniform and rapid emergence.
2. Tillage had no effect on yield when corn was grown after soybeans. No-till corn after corn when row area was not free of residue resulted in lower yields than chisel or moldboard plowing.
3. On soils with poor internal drainage, yield is substantially reduced for corn grown after corn with no tillage.
4. Cultivation or anhydrous ammonia application improved water infiltration and corn yield when the soil crusted.
5. There is a large yield increase for narrow row soybeans (10 inches or less) over 38-inch rows common in southeastern Minnesota.
6. At a given row spacing, soybeans grown with adequate weed control are not affected by tillage.
7. In a drought year shallow soils (less than 30 inches) can cause a 40 bushel per acre yield decline.

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