No-Till vs. Conventional Tillage for Late-Planted Corn following Hay Harvest

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Farmers who delay corn (*Zea mays* L.) planting into sod until after a hay harvest are interested in no-till to conserve soil and reduce fuel, machinery, time, and labor costs. Growth, yield, and economic returns for corn planted no-till (NT) and with conventional tillage (CT) following hay harvest were compared in a field study conducted from 1985 to 1987. Mixed alfalfa (*Medicago sativa* L.)/grass hay was harvested in late May and corn hybrids of three maturities were planted after either moldboard plowing (CT) or chemically killing (NT) vegetation. Increased residue cover with NT did not consistently influence soil temperature and moisture after planting compared with CT. No-till, however, reduced corn emergence in all years by 8 to 20% and delayed emergence by 1 to 11 d. In addition, NT reduced plant vegetative dry weight at stage V6 by 20 to 60% and delayed silking 5 d in 2 of 3 yr compared with CT. Grain moisture was approximately 4 percentage points higher in 2 of 3 yr when produced under NT. Grain yields were similar for CT and NT in 1986, but yields were reduced 66 bu/acre under NT in 1985 and 25 bu/acre in 1987. Yield reductions probably would have been even greater if plots had not been overplanted and thinned to constant plant densities. Short-season hybrids produced greatest yields for both tillage systems. In all years, NT reduced economic return, from $8 to $156/acre compared with CT. Savings in machinery and labor with NT were offset by increased pesticide costs and lower yields compared with CT. On rolling hillsides in the upper Midwest, reduced tillage may be a better option than NT for late-planted corn following hay harvest.

APPROXIMATELY 1.2 million acres of corn in Wisconsin follow perennial forages each year (USDA, 1988). Farmers usually use CT in the fall or early spring to control perennial forage species before planting corn. If old hay stands are still marginally productive in the spring and forage is needed, some producers harvest hay in late May before rotating to corn. They realize corn yields will be reduced compared to early planted corn, but are willing to trade that yield potential for additional forage.

Growers are interested in NT for late-planted corn following hay for several reasons including (i) soil conservation benefits, (ii) earlier planting, (iii) moisture conservation—which may improve and speed germination, and (iv) labor savings.

Several researchers have compared CT and NT for corn planted into grass sod in the Virginias (Jones et al., 1968; Bennett et al., 1973) and mixed alfalfa/grass sod in Wisconsin (Barnett, 1990; Smith et al., 1992). No-till corn planted into orchardgrass (*Dactylis glomerata* L.) sod produced similar or higher yields than corn grown under CT (Jones et al., 1968; Bennett et al., 1973). With early planting in Wisconsin, Barnett (1990) observed no difference in corn yields due to tillage system. Smith et al. (1992) found that with spring vegetation control and late-April or mid-May planting, corn yields were decreased 10 to 50% with NT in 3 of 4 yr. None of these studies considered corn planting following a hay harvest.

In Georgia, CT and NT were compared for corn planted into sod after grass hay harvest. Adams et al. (1970) found that following coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] or tall fescue (*Festuca arundinacea* Screb.), CT corn always yielded better than corn planted NT into sod with chemically suppressed vegetation. In contrast, Wilkinson et al. (1987), found that, following hay harvest and completely killing tall fescue, NT corn had equal or greater yields than did CT corn.

In the northern Corn Belt, when corn is planted late, grain yields decline more for full-season hybrids than for shorter-season hybrids (Carter, 1984). In addition, slower corn growth under NT for corn following corn can limit yield potential of full-season compared with short-season hybrids by shortening the grain filling period (Carter and Barnett, 1987). Short-season hybrids are likely optimum for late corn planted into sod, but relative full-season and short-season hybrid yields for CT and NT have not been compared under these conditions.

The objective of this study was to determine the influence of tillage system and hybrid maturity on emergence, growth, and grain yields of corn planted into alfalfa/grass sod following May hay harvest.

MATERIALS AND METHODS

Corn was grown following mixed alfalfa/grass in a field study conducted for 3 yr, 1985 to 1987, at the Arlington Agricultural Research Station near Madison, WI on a Plano silt loam (fine, mixed, mesic Typic Argiudoll) soil. Three corn hybrids planted after forage harvest were evaluated under CT and NT. Vegetation was controlled either by moldboard plowing (CT) or with herbicides (NT). Corn was planted 4 June 1985, 30 May 1986, and 1 June 1987. Hybrids were FR23 × CM105, 95-d relative maturity (RM); Pioneer brand 3747, 100-d RM; and Agripro brand 680, 110-d RM. Relative maturities were based on the Minnesota Relative Maturity Rating System (Peterson and Hicks, 1973).

The study was a split-plot arrangement of a ran-

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Abbreviations: CT, conventional tillage; NT, no-till; RM, relative maturity.

domized complete block design with three replicates. Tillage systems were whole plots and hybrids were subplots. Subplots were eight rows (30 in.) wide and 25 ft long.

Conventional tillage consisted of moldboard plowing 7 in. deep followed by two diskings before planting. No-till consisted of planting into undisturbed forage crop residues. Corn was planted 2 in. deep in both tillage systems at a rate of 44 500 kernels/acre using cone seeders on a four-row no-till planter (Kinze Manufacturing, Williamsburg, IA) equipped with nonpowered rippled coulters, heavy-duty down-pressure springs, double-disk openers, and cast-iron press wheels.

Hay stands were in forage production 4 to 6 yr before corn planting and species within stands varied in the different fields each year. Sward composition was estimated visually, with individual species expressed as a percentage of total vegetation. In 1985, the stand contained 40% alfalfa, 40% orchardgrass, and 20% common dandelion (*Taraxacum officinale* Weber). In 1986, the stand was composed of 60% alfalfa, 30% dandelion, and 10% other weedy species. In 1987 the stand included 30% alfalfa, 30% orchardgrass, 20% smooth bromegrass (*Bromus inermis* Leyss), 10% dandelion, and 10% other weedy species.

In 1985 only, Roundup (glyphosate) was applied at a rate of 2 lb a.i./acre on 28 May in both CT and NT for vegetation control. Forage was clipped 3 in. high and removed on 31 May 1985, 28 May 1986, and 30 May 1987. Conventional till plots were then plowed. In all years, both CT and NT plots were sprayed after planting with atrazine and Dual (metolachlor), both at 3 lb a.i./acre, for control of both perennials and annual weeds. In addition, paraquat was applied separately each year at 0.5 lb a.i./acre with surfactant to NT plots to aid in burndown of green vegetation before corn emergence. In 1986, Banvel (dicamba) at 0.5 lb a.e./acre was applied postemergence to NT plots to control both alfalfa and dandelion regrowth.

Soil tests for the 3 yr ranged from: pH 6.4 to 6.5, 58 to 132 lb P/acre, and 156 to 388 lb K/acre. All plots received 9+17+30 lb/acre of N+P+K as row-applied starter fertilizer and 150 lb N/acre as NH_4NO_3 broadcast on all treatments before planting. Counter (terbufos, S-[[(1,1-dimethylethyl) thio] methyl] 0,0-diethyl phosphorodithioate) at a rate of 1 lb a.i./acre was applied with the planter to control soil-borne insects. Pydrin (fenvalerate, [cyano(3-phenoxyphenyl) methyl 4-chloro-α-(1-methyl ethyl) benzeneacetate]) at a rate of 0.15 lb a.i./acre was applied postemergence to NT plots in 1987 to control common stalkborer (*Papaipema nebris* Guenee).

Residue cover after planting was estimated visually in 1985 and 1986 and by the line intersect method (Laflen et al., 1981) in 1987. Midday in-row soil temperatures (2 in. deep) were recorded daily in both tillage systems for 7 d after planting. In 1985 and 1987, soil moisture was determined gravimetrically after planting for a 0- to 3-in. depth, and in 1987 also for a 3- to 6-in. depth. Emerged seedlings were counted daily in both harvest rows until full emergence. Emergence was expressed as the number of seedlings emerged, as a perentage of kernels planted.

Table 1. Mean air temperatures and precipitation for the 1985 and 1987 growing seasons at Arlington, WI. The number of parentheses is the deviation from the 20-yr average.

Month	Year		
	1985	1986	1987
	Air temperature, °F		
April	51.6 (+4.7)	50.4 (+3.4)	50.6 (+4.1)
May	62.4 (+4.0)	59.0 (+0.6)	60.7 (+2.6)
June	64.0 (−2.7)	66.2 (−0.5)	70.6 (+4.1)
July	70.3 (−1.4)	71.8 (0.0)	74.4 (+2.9)
August	65.7 (−3.8)	64.0 (−5.4)	68.4 (−0.8)
September	61.7 (+0.4)	61.7 (+0.4)	61.5 (+0.4)
Six-month mean	62.6 (+0.2)	62.2 (−0.5)	64.4 (+2.2)
	Precipitation, in.		
April	2.4 (−0.7)	2.7 (−0.3)	2.6 (−0.4)
May	2.5 (−0.6)	2.1 (−1.0)	4.7 (+1.5)
June	3.5 (−0.1)	4.2 (+0.6)	0.6 (−3.3)
July	5.9 (+2.3)	4.6 (+1.1)	4.0 (+0.4)
August	3.6 (−0.7)	5.0 (+0.6)	4.9 (+0.6)
September	6.9 (+2.8)	10.7 (+6.7)	4.9 (+0.8)
Six-month total	24.8 (+3.0)	29.3 (+7.6)	21.8 (−0.4)

Days to emergence were calculated as days after planting until 75% of final emergence.

When corn under CT reached the V6 stage (Ritchie and Hanway, 1984), plots were hand-thinned to 24 300 plants/acre. At that time, 10 plants from each sub subplot were randomly selected, harvested at ground level, oven dried, and weighed. Days to silking were calculated as days after planting until 50% of corn plants had emerged silks.

Before harvest, final stand (plants/acre) and mature plant height (soil surface to the flag leaf collar) were measured. Grain moisture (%) and grain yield (bu/acre at 15.5% H_2O) were determined from interior rows of each sub subplot with a two-row plot combine. Harvest dates were 30 Oct. 1985, 25 Oct. 1986, and 12 Oct. 1987.

Analyses of variance were computed for data combined over years and for each year separately. All factors, other than replicates, were considered fixed effects.

Partial budgets were constructed for both tillage systems to evaluate the economic feasibility of NT as an alternative to CT. Only inputs that differed between tillage systems were considered. Pesticide costs were actual market values and machinery costs were estimated from Fuller et al. (1990). Machinery costs included labor costs for operating machinery and both fixed and variable costs for the implement and tractor used. Differences in gross returns for corn were calculated each year assuming a corn price of $2.35/bu.

RESULTS AND DISCUSSION

Seasonal precipitation was near average or greater and season-long air temperatures were nearly average each year (Table 1), although rainfall distribution and temperature patterns were variable. April and May temperatures were 2.6 to 4.7 °F warmer than average each year except for May of 1986. Rainfall in April, May, and June of 1985 was below average and June 1987 rainfall was 3.3 in. below average.

Even though forage was removed, residue cover ranged from 20 to 50% after NT corn planting. This is 40 to 70%

Table 2. Soil and plant measurements following a late-May forage harvest and late-May-to-early-June planting date for corn grown under two tillage systems for 3 yr. Values are averaged over three hybrids.

	1985		1986		1987		CV,
	Conv.	No-till	Conv.	No-till	Conv.	No-till	%
Soil temperature, °F†	77.6*	76.1	73.2	73.3	74.2*	75.8	1.4
Soil moisture, %‡							
0–3 in.	10.2	10.8	--	--	23.3	22.5	3.1
3–6 in.	--	--	--	--	25.3*	21.0	2.9
Emergence, %	98*	78	94*	86	95*	87	7.7
Days to 75% emergence	6*	17	8	10	6	7	15.5
Vegetative dry wt., oz/10 plants at V6	1.6*	1.3	6.1*	3.9	5.1*	2.2	2.1
Days to 50% slik	66*	72	65	65	58*	63	1.2
Mature plant height, in.	87.9	82.0	90.9	86.8	83.6*	72.7	3.4
Final stand, plants/acre × 1000	24.2	22.9	23.9	24.0	23.4	23.6	4.8
Grain moisture, %	36.4*	40.9	31.3	30.4	32.4	36.1	4.7
Grain yield, bu/acre	107*	41	140	137	107*	82	11.8

* Significant difference between tillage systems within years at the 0.05 probability level.
† Midday, in-row temperatures at 2 in. depth, averaged over 7 d following planting.
‡ Gravimetric soil moisture measured after planting.

less residue cover than would be expected with late planting if forage had been chemically killed and not harvested (Smith et al., 1992). Because little leaf area remained after hay harvest, NT vegetation control in 1986 and 1987 was dependent on root-absorbed herbicides rather than those foliarly applied, although paraquat did burn down living material in stubble (alfalfa axillary and crown buds, remaining grass leaf sheaths and stems, and dandelion rosettes). Despite limited rainfall following herbicide application, complete vegetation kill was achieved under NT in all years.

Seed-zone temperature responses to tillage the week following planting were inconsistent, with slightly cooler temperatures for NT in 1985, no difference due to tillage in 1986, and slightly warmer temperatures for NT in 1987 (Table 2). Adams et al. (1970), in Georgia, observed cooler temperatures during June for NT corn under a suppressed grass mulch compared with CT. In our study, there was no difference between tillage systems in seed-zone soil moisture, but soils were drier under NT than CT at the 3- to 6-in. depth in 1987 (Table 2). In contrast, Bennett et al. (1973) measured more available water under NT than CT throughout the growing season after late corn planting into orchardgrass sod.

Emergence in NT was 8% less than in CT in 1986 and 1987, and 20% less in 1985 (Table 2). Days to 75% emergence were increased only slightly by NT in 1986 and 1987. In 1985, corn seedling emergence was delayed 11 d under NT compared with CT (Table 2). Emergence in NT began shortly after the first post-planting rainfall occurred on 15 June. Above average temperatures in April and May 1985 contributed to the greatest alfalfa/grass growth before hay harvest of the 3 yr. This, in conjunction with below-average rainfall, resulted in dry soil at planting and difficulty achieving uniform and adequate seeding depth in NT. Closure of the seed slot was achieved, but even with planter adjustments, corn in NT was planted less than 1 in. deep compared with the desired 2 in. depth in CT.

Table 3. Annual costs of crop production for inputs which differed for two tillage systems, 1985 to 1987.

Tillage system	Input	Cost/acre
Conventional tillage	Plow†	13.50
	Disk	5.71
	Conv. planter	10.55
	Total	$29.76
No-till	No-till planter	15.18
	Paraquat	6.94
	Surfactant	0.83
	Sprayer	1.94
	Fenvalerate‡	2.55
	Sprayer	0.38
	Dicamba	2.17
	Sprayer	0.38
	Total	$30.37
	Difference	−$0.61

† Equipment operating costs (including labor) obtained from Fuller et al. (1990).
‡ Fenvalerate, dicamba, and spraying costs occurred only once in 3 yr. Values represent 1/3 of an application cost (variable costs only for sprayer).

Corn dry weight at V6 was lower under NT than CT all 3 yr (Table 2). In 1986, days to 50% silk were not delayed by NT compared with CT, but delays were 6 and 5 d in 1985 and 1987, respectively (Table 2). Mature plant height was reduced under NT only in 1987 (Table 2). Because plots were hand-thinned, final stands did not differ in any of the 3 yr. Delayed season-long development with NT in 1985 and 1987 resulted in grain with 4.5% (1985) and 3.7% (1987) ($P < 0.10$) more moisture than for CT.

In 1985 and 1987, grain yields were lower under NT than CT (Table 2). Yield reductions may have been even greater if plots had not been overplanted and thinned to constant plant densities. Possible reasons for the lower NT yields are below-normal late-spring rainfall and delayed silking under NT. In 1986, when June rainfall was above average (Table 1), silking dates and grain yields (Table 2) were not affected by tillage. But in 1985, when May and June rainfall was below average, and in 1987, when June rainfall was below average (Table 1), NT silking was delayed (Table 2) and NT yields were only 40% (1985) and 77% (1987) of those for CT (Table 2). Different responses to tillage in 1985 and 1987 compared with 1986 also may be related to different mixtures of species in the vegetation which preceded corn. Grass species composed 40 to 50% of the perennial vegetation in 1985 and 1987, but there was less than 5% grass in the 1986 hay stand. In 1985, corn rootworm beetles (*Diabrotica* spp.), attracted to NT corn because of delayed emergence and late silking, severely clipped silks. The consequent poor pollination contributed to reduced grain yields.

Hybrid maturity affected grain production, with average full-season hybrid yields 5 and 12% lower than those for the mid- and short-season hybrids (data not shown). But tillage × hybrid interactions occurred only for vegetative plant dry weight and plant height.

Production costs for CT and NT differed for only a few inputs (Table 3). Machinery costs were greater for CT, whereas pesticide costs were greater for NT. There was a net increase in input costs of $0.61/acre for NT compared with CT (Table 3). In addition, yield reductions of 66, 3, and 25 bu/acre for NT compared with CT in 1985, 1986, and 1987, respectively, resulted in gross income reductions per acre of $155.10, $7.05, and $58.75. Reductions in economic return per acre using NT, calculated by adding cost increases and losses (Table 3), were $155.71, $7.66, and $59.36 in 1985, 1986, and 1987, respectively.

INTERPRETIVE SUMMARY

In the upper Midwest, corn is often planted in late May after an early hay crop has been harvested. Field experiments were conducted in 1985, 1986, and 1987 to compare CT and NT with corn hybrids of three maturities planted following a late May cutting of alfalfa/grass hay.

Vegetation control (achieved with herbicides) for NT was adequate in all years. Even though more residue remained after corn planting with NT than CT, soil temperature and moisture differences were not consistent for all environments. No-till reduced corn emergence every year and increased days to emergence in 1985 when conditions before and just after planting were warm and dry. No-till also resulted in reduced vegetative plant dry weights and plant heights all 3 yr, and increased grain moisture at harvest in 1985 and 1987. With nearly ideal growing conditions in 1986, NT and CT produced similar yields. But grain yields were reduced under NT 66 bu/acre in 1985 and 25 bu/acre in 1987. For both tillage systems, short-season maturity hybrids were a better choice than mid- or full-season maturity hybrids. Economic returns per acre for NT were reduced approximately $8 (1986) to $156/acre (1985) compared with CT. Savings in machinery and labor with NT were counter balanced by increased pesticide costs and lower yields compared with CT.

For farmers who are willing to delay corn planting to obtain a spring hay harvest, CT affords less yield risk than does NT. On steep slopes, however, CT may not be an option due to soil erosion potential. On rolling hillsides in the upper Midwest, some type of reduced or conservation tillage may be the best compromise for late-planted corn following a hay harvest.

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