Planting Date and Tillage Effects on Corn Following Corn[1]

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ABSTRACT

Crop residue remaining on the soil surface for erosion control under no-tillage (NT) corn (*Zea mays* L.) production depresses early season soil temperatures compared to conventional tillage (CT). This has resulted in questions concerning planting date recommendations for NT in the northern United States. The objective of this study was to determine the influence of planting date on crop development and grain yield when corn produced under CT and NT follows corn. Conventional and no-till systems were compared during 1983 to 1985 at Arlington, WI, on a Plano silt loam (fine-silty, mixed, mesic Typic Argiudoll). Planting dates were 26 April to 6 May (early), 14 to 19 May (medium), and 27 May to 6 June (late). Plots were overplanted and stands were thinned to constant densities following complete emergence. Daily seed-zone soil temperature and seedling emergence were measured. Colder soil temperatures under NT were associated with reduced corn emergence, delayed emergence and silking, and increased harvest grain moisture compared to CT, for early planting. With medium and late planting dates, differences between tillage systems for emergence and silk date were less pronounced or inconsistent between years, or both. For both tillage systems, highest grain yields were generally obtained when planting was completed by early May, with yield declining as planting was delayed. Decreased grain yields with NT or delayed planting, or both, were related to reduced cumulative air growing degree days between silk and the first 0°C frost. These results suggest that for corn following corn in northern U.S. regions, current recommendations for early planting under CT are applicable to NT. However, increased seeding rates may be required to overcome reduced emergence with NT systems.

Additional index words: ***Zea mays*** **L., No- tillage, Conservation tillage, Soil temperature, Emergence.**

NO-TILLAGE (NT) systems, where all previous crop residue is left on the soil surface at planting, are recommended for soil erosion control on many sloping soils where corn (*Zea mays* L.) production results in severe erosion under conventional tillage (CT) which involves complete residue incorporation. However, unincorporated crop residue depresses early season soil temperatures compared to CT (Griffith et al., 1973; Mock and Erbach, 1977; Johnson, 1983). Cold soil temperatures may lead to slow corn emergence, reduced stands and seedling vigor, and delayed maturity (Willis et al., 1957; Burrows and Larson, 1962; Griffith et al., 1973; Mock and Erbach, 1977). Concern about these problems has slowed adoption of NT in northern corn-growing regions and has led many farmers who do practice NT to delay planting until soils become warmer.

The highest corn grain yields in the northern U.S. Corn Belt under CT are obtained by planting during late April or early May (Hicks, 1977; Andrew and Peek, 1971; Carter, 1984). Yield reductions progressively increase as planting is delayed throughout May and early June. Eckert (1984) found that date of planting had similar effects on yield with NT or CT systems for corn following corn in Ohio. Herbek et al. (1986), in Kentucky on poorly drained soils, reported yield increases under NT with delayed planting from late April to mid-May, but CT yields decreased with the later planting date. They suggested that an optimum planting date under NT should be 2 weeks later than that for CT. No research comparing tillage-system response to planting date has been conducted in the northern United States where cooler, early season soil temperatures under NT could present a serious problem.

The objective of this study was to determine the influence of planting date on emergence, growth and development, and grain yield for corn produced following corn under NT and CT in a northern environment.

MATERIALS AND METHODS

The study was conducted at Arlington, WI, on a Plano silt loam (fine-silty, mixed, mesic Typic Argiudoll) soil in 1983, 1984, and 1985, on a site that had been in corn production previously. Two corn hybrids (FR23 × CM105, 95-day relative maturity [RM]; and FR23 × FR29, 100-day RM) [RM ratings are based on the Minnesota Relative Maturity Rating System (Peterson and Hicks, 1973)] were grown under CT and NT systems. Hybrids were planted at early (5 May 1983, 27 Apr. 1984, 29 Apr. 1985), medium (14 May 1983, 16 May 1984, 19 May 1985), and late (27 May 1983, 1 June 1984, 3 June 1985) dates.

Conventional tillage was fall moldboard plowing 180 mm deep, followed by one or two diskings 100 mm deep before planting. No-tillage consisted of planting directly into unincorporated corn residue following stalk chopping. Kernels were planted at a rate of 111 000 seeds ha^{-1} using coneseeders on a NT planter equipped with nonpowered rippled coulters, heavy-duty down-pressure springs, double-disk openers, and cast-iron press wheels. Coulters and double-disk openers were adjusted to penetrate 45 mm deep under both tillage systems. Under NT, residue was disturbed only in a 25-mm-wide slot for seed placement.

Initial soil tests indicated a pH of 6.5, 100 kg P ha^{-1}, and 448 kg K ha^{-1}. All plots for both tillage systems received yearly applications of 10-17-33 kg ha^{-1} of N-P-K as a row-applied starter fertilizer, and 224 kg ha^{-1} of N (NH_4NO_3) broadcast over the entire area before the first planting. Terbufos (*S*-{[1,1- dimethylethyl)thio]methyl}-*O,O*-diethyl phosphorodithioate) was applied with the planter for corn rootworm (*Diabrotica longicornis* Say.) control. After each planting, all plots for both tillage systems received a preemergence application of atrazine (2-chloro-4-ethylamino-6-isopropylamino-*S*-triazine) and metolachlor [2-chloro-*N*-(2-ethyl-6—ethylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] for annual weed control. Paraquat (1,1′-dimethyl-4,4′-bipyridiumion) was applied for burndown of green vegetation in NT plots when necessary.

The experimental design was a split split-plot arrangement of a randomized complete block with three replicates. The two tillage systems were whole plots, planting dates were subplots, and hybrids were sub-subplots. Each sub-subplot consisted of four rows 0.76 m apart and 9.2 m in length. Eight border rows surrounded each whole plot.

Midday in-row soil temperatures (50-mm depth) and emerged seedlings were recorded daily for 30 days after planting. Emergence was determined as the number of seedlings emerged, as a percentage of kernels planted. Days-to-emergence was computed as days after planting until 75%

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of final emergence. Following complete emergence, plots were hand-thinned to a uniform density of 55 000 plants ha^{-1} in 1983 and 1984, and 61 000 plants ha^{-1} in 1985. Thinned plants were selected at random along the entire plot length. Days after planting to silk stage were recorded and defined as the date when 75% of plants had emerged silks. At silk stage, aboveground plant dry weight and plant height to the flag-leaf collar were measured for 10 plants from the outside two rows of each sub-subplot. At harvest, final stand (plants per hectare), ear number (ears per hectare), grain moisture (g H_2O kg^{-1}), and grain yield (Mg ha^{-1}) were measured for the interior two rows of each sub-subplot. In October, grain was either hand-harvested and shelled with a portable sheller (1983 and 1984) or combine harvested (1985). Grain moisture was determined from oven-dried samples each year. Grain yields are reported as oven-dry weight per hectare, adjusting for the grain moisture content.

Analyses of variance were computed for data each year and combined over years. In the analysis, all effects were considered fixed, except replicates, which were random. Although subplots (planting dates) and sub-subplots (hybrids) were randomized in 1983 and rerandomized in both 1984 and 1985, whole plots (tillage systems) were randomized only in 1983 and remained in the same position in succeeding years. This resulted in a stripping effect in the split-plot statistical analysis of variance, since whole plots were fixed in time and space (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Early season soil temperatures were affected by tillage system and planting date, as well as yearly weather conditions (Tables 1 and 2). Below-average air temperatures during April and May in 1983 and 1984 produced lower soil temperatures than in 1985. Soil temperatures were always lower under NT compared to CT, within planting date and year, and generally increased with later planting dates for both tillage systems (Table 2).

Hybrid responses to tillage system and planting date were mostly nonsignificant (Table 3), therefore, averages over hybrids will be discussed.

Emergence was generally lower under NT compared to CT at early and medium planting dates, but not with late planting (Table 4). Planting date had little influence on emergence under CT; however, with NT, emergence increased markedly when planting was delayed. Our results showing reduced emergence under NT for early planting dates are similar to previous work (Mock and Erbach, 1977).

In 1983 and 1984, emergence was delayed for NT at early and medium planting dates, but not for late planting (Table 4). In 1985, emergence delays with NT occurred at all planting dates. Narrowing of differences between CT and NT in days to emergence in 1983 and 1984 with later planting was associated with warmer soil temperatures following late planting dates, even though soils were still cooler under NT than CT (Table 2). In 1985, soil temperatures after medium and late planting dates were the same (Table 2), but days to emergence still increased with late compared to medium planting for NT (Table 4). Rainfall was below average during the entire planting period in 1985 (Table 1), and by the late planting date, seed-zone soil moisture limited germination rates. Apparently, seed placement under NT magnified dry-soil induced emergence delays compared to CT.

Delays in development of corn grown under NT were present at silk stage for all planting dates (Table 4). Differences between tillage systems in days to silk were most often equal to or greater than for days to emergence. A tillage × planting date × year interaction occurred (Table 3), primarily due to yearly variations in the magnitude of differences between CT and NT in days to silk at early vs. medium planting dates (Table 4). The smallest differences between tillage systems in days to silk tended to occur with late planting. Delayed silking under NT increased the air growing degree days (GDD) (Swan et al., 1977) accumulated from planting to silking, and decreased the GDD accumulated before frost (Table 5). Willis et al (1957) and Mock and Erbach (1977) also found delayed silking when crop residue was left on the soil surface at planting. Eckert (1984) found that in dry years corn grown under NT silked earlier than corn grown under CT.

Delays in development continued to maturity for corn grown under NT, as indicated by higher grain moisture at harvest than under CT (Tables 3 and 4).

Table 1. Precipitation and mean air temperature for 1983 to 1985 growing seasons at Arlington, WI.

Month	1983		1984		1985	
	Precipitation (mm)					
April	45	(−32)†	103	(26)	60	(−17)
May	34	(−46)	82	(2)	63	(−17)
June	45	(−60)	192	(87)	89	(−16)
July	111	(22)	73	(−16)	149	(60)
August	161	(57)	45	(−59)	92	(−12)
September	78	(−14)	93	(1)	174	(82)
Six-month total	474	(−72)	588	(42)	627	(81)
	Mean air temperature (°C)					
April	5.9	(−1.9)	7.7	(−0.1)	10.9	(3.1)
May	11.7	(−2.4)	12.5	(−1.6)	16.9	(2.8)
June	19.2	(0.1)	20.4	(1.3)	17.8	(−1.3)
July	23.6	(1.8)	20.6	(−1.2)	21.3	(−0.5)
August	23.2	(2.6)	22.0	(1.4)	18.7	(−1.9)
September	16.6	(0.5)	15.9	(−0.2)	16.5	(0.4)
Six-month mean	16.7	(0.1)	16.5	(−0.1)	17.0	(0.4)

† Number in parentheses indicates departure from long-term average.

Table 2. Mean mid-afternoon in-row soil temperatures, 50-mm depth, first 7 days after three planting dates for conventional (CT) and no-tillage (NT) systems.

Planting date	1983 NT	1983 CT	1983 Difference†	1984 NT	1984 CT	1984 Difference	1985 NT	1985 CT	1985 Difference
	°C								
Early	13.8	15.3	−1.5*	9.3	10.1	−0.8*	15.6	19.1	−3.5*
Medium	13.8	15.2	−1.4*	17.5	20.6	−3.1*	20.3	24.1	−3.8*
Late	16.9	18.3	−1.4*	20.4	23.4	−3.0*	20.5	24.0	−3.5*
LSD (0.05) = 0.2‡									

* Difference between tillage systems within a planting date and year are significant at $P < 0.05$.
† Difference = NT minus CT.
‡ Least significant difference for comparisons of planting date means within tillage system and year.

Table 3. Summary of statistical significance from analyses of variance for two tillage systems compared at three planting dates, with two corn hybrids, from 1983 to 1985.

Source of variation	df	Emergence	Days to emergence	Days to silk	Plant dry wt. (silk)	Final height	Final stand	Ear number	Grain moisture	Grain yield
Blocks (B)	2	NS	NS	NS	NS	NS	NS	NS	NS	(0.06)
Tillage (T)	1	*	**	**	NS	*	NS	*	**	**
Error a	2									
Planting date (D)	2	**	**	**	**	**	NS	**	**	**
T × D	2	**	**	**	**	NS	NS	*	NS	NS
Error b	8									
Hybrid (H)	1	NS	NS	NS	NS	NS	NS	NS	**	NS
T × H	1	NS	NS	NS	NS	*	NS	NS	(0.07)	NS
D × H	2	NS	NS	NS	NS	NS	NS	(0.06)	**	NS
T × D × H	2	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error c	12									
Year (Y)	2	NS	**	**	NS	**	**	**	**	*
Error d	4									
T × Y	2	NS	**	NS	**	NS	NS	NS	NS	NS
Error e	4									
D × Y	4	**	**	**	*	**	*	*	**	**
T × D × Y	4	NS	**	**	NS	NS	NS	NS	NS	(0.07)
Error f	16									
H × Y	2	**	**	*	NS	NS	NS	NS	**	**
T × H × Y	2	NS	NS	NS	NS	NS	NS	NS	NS	NS
D × H × Y	4	*	NS	NS	NS	NS	NS	NS	NS	NS
T × D × H × Y	4	NS	NS	NS	NS	(0.06)	NS	NS	NS	NS
Error g	24									
Total	107									

*,** Significant at the 0.05 and 0.01 probability levels, respectively. NS = not significant.

Table 4. Means for emergence, days to emergence, days to silk, grain moisture, and grain yield for conventional (CT) and no-tillage (NT) systems compared at three planting dates for 1983, 1984, and 1985.

	Emergence†			Days to emergence			Days to silk			Grain moisture			Grain yield		
Planting date	NT	CT	Difference‡	NT	CT	Difference	NT	CT	Difference	NT	CT	Difference	NT	CT	Difference
		%				days					g H_2O kg^{-1}			Mg ha^{-1}	
1983															
5/5	78.0	89.8	−11.8*	20.7	19.0	1.7*	82.7	79.0	3.7*	260	243	17*	6.63	6.99	−0.36
5/14	86.0	91.1	−5.1	17.0	13.5	3.5*	75.7	68.7	7.0*	277	245	32*	6.90	7.44	−0.54*
5/27	81.5	78.2	3.3	14.3	14.0	0.3	67.2	64.0	3.2*	310	292	18*	6.76	6.54	0.22
Avg.	81.8	86.4	−4.6	17.3	15.5	1.8*	75.2	70.6	4.6*	282	260	22*	6.77	6.99	−0.22
1984															
4/27	69.4	88.1	−18.7*	28.0	23.3	4.7*	90.8	86.3	4.5*	252	242	10	7.78	8.92	−1.14*
5/16	83.6	92.0	−8.4	10.5	6.0	4.5*	75.7	71.3	4.4*	265	256	9	7.67	8.44	−0.77*
6/1	92.0	89.8	2.2	6.0	7.0	−1.0	63.8	62.3	1.5*	295	280	15*	6.75	7.02	−0.27
Avg.	81.7	90.0	−8.3	14.8	11.8	3.0*	76.8	73.3	3.5*	271	259	12*	7.40	8.13	−0.73*
1985															
4/29	68.4	81.9	−13.5*	14.8	10.7	4.1*	82.8	76.5	6.3*	249	226	23*	8.78	9.19	−0.41
5/19	72.6	86.0	−13.4*	10.8	7.0	3.8*	71.0	67.0	4.0*	297	270	27*	7.84	8.59	−0.75*
6/3	85.1	85.8	−0.7	12.5	7.5	5.0*	66.8	63.3	3.5*	389	363	26*	5.90	6.92	−1.02*
Avg.	75.4	84.6	−9.2*	12.7	8.4	4.3*	73.6	68.9	4.7*	312	286	26*	7.51	8.23	−0.72*
3-yr avg.	79.6	87.0	−7.4*	15.0	11.9	3.1*	75.2	70.9	4.3*	288	268	20*	7.23	7.78	−0.55*
LSD (0.05)§	8.9			1.0			0.8			11			0.54		
CV (%)	7.0			4.6			0.9			3.5			5.6		

* Difference between tillage systems within a planting date or averages within or over years are significant at $P < 0.05$.
† Emergence before thinning, as a percentage of kernels planted.
‡ Difference = NT minus CT.
§ Least significant differences for comparing planting dates within tillage system and year.

In contrast to days to emergence and silk, tillage system interactions with planting date or year, or both, did not occur for grain moisture (Table 3). Previous work has shown inconsistent differences in grain moisture between NT and CT. Higher grain moisture under NT has been reported (Hallauer and Clovin, 1985), but others indicate lower grain moisture for NT or no differences between tillage systems (Mock and Erbach, 1977; Erkert, 1984). Those finding reduced grain moisture under NT attribute it to soil-moisture conservation under NT resulting in more available water during grain fill, and consequently, enhanced kernel development rates (Eckert, 1984). In our study, early season soil temperatures were apparently more important than seasonal soil moisture levels in mediating development rates under different tillage systems.

Grain yield response to planting date varied among years (Table 3), with a small response in 1983 and moderate responses in 1984 and 1985 (table 4). Tillage system had a relatively small influence on grain yield in 1983, but in 1984 and 1985, grain yields averaged over planting dates were lower under NT. In 1984, CT grain yields were greater than NT at early and medium planting dates, but yields were not different with late planting. In contrast, 1985 grain yield differences were not significant between tillage systems with early planting, but NT had lower yields with medium and late planting (Table 4). Averaged over years, greatest grain yields for both tillage systems occurred at the early planting date.

Corn grain yield reductions in the northern United States for NT have been attributed to reduced plant stands or slow early growth caused by cold soil temperatures, or both (Burrows and Larson, 1962; Griffith et al., 1973; Van Doren et al., 1976; Hallauer and Clovin, 1985; Schneider and Gupta, 1985). In our study, the generally lower yields under NT were not due to reduced plant stands since corn was over-planted and thinned to equal densities. However, there was a relationship between cumulative GDD during grain-fill (silk to frost) (Table 5) and grain yield (Fig. 1). In 1984 and 1985, nearly all the variation in grain yields was related to NT- or delayed-planting induced reductions in GDD available before frost (Fig. 1). In 1983, below-average seasonal rainfall and warm air temperatures during July and August (Table 1) limited soil moisture and increased cumulative GDD (Table 5). These factors apparently decreased the significance of the grain yield-GDD relationship (Fig. 1). Swan et al. (1987) also showed that corn growth delay due to in-row residue cover and cool soil temperatures under NT was related to grain yield reductions when cumulative GDD were insufficient to reach maturity before frost and when water stress was minimal. These results indicate that NT grain yields could equal those for CT when the in-row soil temperature difference between systems is minimized. No-till grain yields might be increased relative to those for CT by removing residue from the row area during planting or

Table 5. Growing degree days accumulated from planting to frost, planting to silk, and silk to frost for conventional (CT) and no-tillage (NT) systems at three planting dates for 1983, 1984, and 1985.

	Growing degree days						
		Planting to silk			Silk to frost		
Planting date	Planting to frost†	NT	CT	Difference‡	NT	CT	Difference
	°C						
1983							
5/5	1381	753	704	49	628	677	−49
5/14	1338	742	644	98	596	694	−98
5/27	1279	734	696	38	545	583	−38
1984							
4/27	1373	763	707	56	610	666	−56
5/16	1311	738	692	46	573	619	−46
6/1	1223	692	663	29	531	560	−29
1985							
4/29	1347	749	681	68	598	666	−68
5/19	1188	678	631	47	510	557	−47
6/3	1071	666	617	49	405	454	−49

† Earliest 0 °C frost dates = 23 Sept. 1983, 26 Sept. 1984, and 1 Oct. 1985.
‡ Difference = NT minus CT.

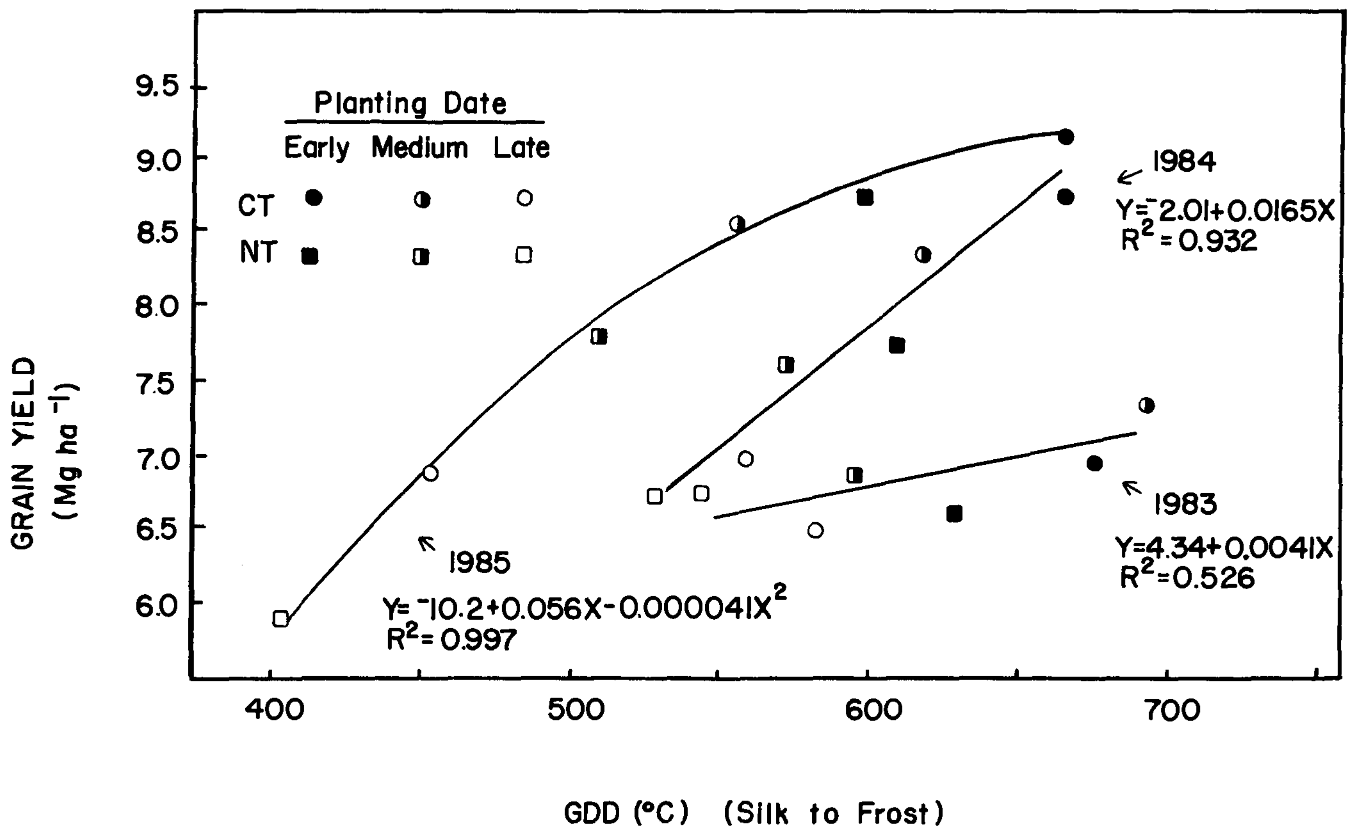

Fig. 1. Corn grain yield vs. air growing degree days (GDD) (summed from silking to frost).

Table 6. Means for plant dry weight (silk), final height, final stand, and ear number for conventional (CT) and no-tillage (NT) systems compared at three planting dates for 1983, 1984, and 1985.

Planting date	Plant dry wt. (silk)			Final height			Final stand			Ear number		
	NT	CT	Difference†	NT	CT	Difference	NT	CT	Difference	NT	CT	Difference
	g plant^{-1}			m			M ha^{-1}					
1983												
5/5	124	116	8	1.92	1.96	−0.04	51.9	53.0	−1.1	51.3	53.5	−2.2*
5/14	133	121	12	2.05	1.97	0.08	53.3	53.8	−0.5	54.4	53.9	0.5
5/27	131	138	−7	2.16	2.11	0.04	52.5	52.2	0.3	54.2	52.1	2.1
Avg.	129	125	4	2.04	2.01	0.03	52.6	53.0	−0.4	53.3	53.2	0.1
1984												
4/27	115	122	−7	2.16	2.13	0.03	55.1	56.2	−1.1	54.8	56.5	−1.7
5/16	126	117	9	2.25	2.25	0.00	55.0	56.3	−1.3	54.2	56.9	−2.7*
6/1	124	137	−13	2.25	2.25	0.00	53.8	42.7	1.1	52.0	51.6	0.4
Avg.	122	126	−4	2.22	2.21	0.01	54.6	55.0	−0.4	53.6	55.0	−1.4
1985												
4/29	97	116	−19	2.13	1.99	0.14*	58.5	60.1	−1.6	59.8	61.9	−2.1
5/19	124	132	−8	2.14	2.08	0.06	58.0	58.6	−0.6	59.2	60.5	−1.3
6/13	111	135	−24*	2.33	2.27	0.06	60.0	60.3	−0.3	60.0	60.4	−0.4
Avg.	111	128	−17*	2.20	2.11	0.09*	58.8	59.7	−0.9	59.7	60.9	−1.2
3-yr avg.	121	126	−5	2.15	2.11	0.04*	55.3	55.9	−0.6	55.5	56.4	−0.9*
LSD (0.05)‡	13			0.10			3.3			2.8		
CV (%)	9.1			3.1			3.5			4.6		

* Difference between tillage systems within a planting date or averages within or over years are significant at $P < 0.05$.
† Difference = NT minus CT.
‡ Least significant differences for comparing planting dates within tillage system and year.

by using NT following crops leaving less residue than corn, or both.

No yield advantage for delayed planting under NT was present in our study at the equal plant densities utilized. Actually, these results indicate the necessity of early planting with NT in the northern United States, provided that acceptable plant densities can be obtained with NT by increased seeding rates at early dates. Early planting under NT may partially compensate for the delayed seasonal crop growth and maturation with this tillage system. In the year with greatest negative grain yield response to delayed planting (1985), yields decreased at a greater rate with NT than with CT. Grain yields for medium and late planting dates were 89 and 67%, respectively, of those with early planting under NT, but were 93 (medium planting) and 75% (late planting) of early planting with CT. In years when grain yields are strongly influenced by planting date, early planting may be especially important with NT systems.

Plant dry weight at silk stage and final height generally increased as planting was delayed for both tillage systems (Table 6). A tillage × planting date interaction occurred for plant dry weight at silk (Table 3) because, averaged over years, dry weights were similar between tillage systems at early and medium planting dates, but averaged 15 g/plant greater under CT than under NT with late planting. In 1985, averaged over planting dates, plant dry weight at silk was lower under NT, but final height was greater with NT than with CT (Table 6). Ear number, averaged over years and planting dates, was slightly greater under CT than NT (Table 6). Final stand was not influenced by planting date or tillage system (Table 3 and 6).

Cooler soil temperatures under NT were related to reduced corn emergence, delayed emergence and silking, and increased harvest grain moisture compared to CT for early planting. With medium and late planting dates, differences between tillage systems for emergence and silking date were less pronounced or inconsistent between years, or both. For both tillage systems, highest grain yields were generally obtained when planting was completed by early May, with yield decreasing as planting was delayed. These results suggest that for corn following corn in northern regions, current recommendations for early planting under CT are applicable with NT. However, increased seeding rates may be required to overcome reduced emergence with NT systems.

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