Planting Date and Tillage Effects on Corn Following Corn

A. A. Imholte and P.R. Carter

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 Argiaudoll). 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 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). Yields 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 Argiaudoll) 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 cone-seeders 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 (N₂O₃) broadcast over the entire area before the first planting. Terbufos (S-[1-dimethylthethyl]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 pre-emergence application of atrazine (2-chloro-4-ethylamino-6-isopropylamino-S-triazine) and metolachlor [2-chloro-N-(2-ethyl-6-ethylphenyl)-N-(2-methoxy-1-methyl ethyl)acetamide] for annual weed control. Paraquat (1,1'-di-ethyl-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%
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$_2$O 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. Narroing 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 X planting date X 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.

<table>
<thead>
<tr>
<th>Month</th>
<th>1983</th>
<th>1984</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precipitation (mm)</td>
<td></td>
<td>Mean air temperature (°C)</td>
</tr>
<tr>
<td>April</td>
<td>45 (-32)</td>
<td>103 (26)</td>
<td>60 (-17)</td>
</tr>
<tr>
<td>May</td>
<td>34 (-46)</td>
<td>82 (2)</td>
<td>63 (-17)</td>
</tr>
<tr>
<td>June</td>
<td>45 (-60)</td>
<td>192 (87)</td>
<td>89 (-16)</td>
</tr>
<tr>
<td>July</td>
<td>111 (22)</td>
<td>73 (-16)</td>
<td>149 (60)</td>
</tr>
<tr>
<td>August</td>
<td>161 (57)</td>
<td>45 (-50)</td>
<td>92 (-12)</td>
</tr>
<tr>
<td>September</td>
<td>78 (-14)</td>
<td>93 (1)</td>
<td>174 (82)</td>
</tr>
<tr>
<td>Six-month total</td>
<td>474 (-72)</td>
<td>588 (42)</td>
<td>627 (81)</td>
</tr>
</tbody>
</table>

†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.

<table>
<thead>
<tr>
<th>Planting date</th>
<th>1983</th>
<th>1984</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT CT Difference</td>
<td>NT CT Difference</td>
<td>NT CT Difference</td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>13.8</td>
<td>15.3</td>
<td>-1.5*</td>
</tr>
<tr>
<td>Medium</td>
<td>13.8</td>
<td>15.2</td>
<td>-1.4*</td>
</tr>
<tr>
<td>Late</td>
<td>16.9</td>
<td>18.3</td>
<td>-1.4*</td>
</tr>
</tbody>
</table>

* 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.
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 grainfill (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

![Graph of Corn Grain Yield vs. Air Growing Degree Days (GDD)](GDD (°C) (Silk to Frost))

Fig. 1. Corn grain yield vs. air growing degree days (GDD) (summed from silking to frost).
reduced corn emergence, delayed emergence and silk-
ble 6). Final stand was not influenced by planting date
ing dates, was slightly greater under CT than NT (Ta-
but final height was greater with NT than with CT
verages for comparing planting dates within tillage system and year.

Table 6. Means for plant dry weight (silk), final height, final stand, and ear number for conventional (CT) and no-tillage (NT) systems

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Plant dry wt. (silk)</th>
<th>Final height</th>
<th>Final stand</th>
<th>Ear number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NT</td>
<td>CT</td>
<td>Difference</td>
<td>NT</td>
</tr>
<tr>
<td>1983</td>
<td></td>
<td></td>
<td>5/5</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5/14</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6/27</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avg.</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1984</td>
<td>4/27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5/16</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6/1</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avg.</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1985</td>
<td>4/29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5/19</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6/19</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avg.</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-yr avg</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LSD (0.05%)</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CV (%)</td>
<td>9.1</td>
</tr>
</tbody>
</table>

* 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 ob-
tained with NT by increased seeding rates at early
dates. Early planting under NT may partially com-
pensate for the delayed seasonal crop growth and ma-
turation 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 plant-
dates) and 74% (late planting) of those 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 plant-
dates) and 74% (late planting) of those with
CT. In years when grain yields are strongly influenced
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.

REFERENCES

and field environment on consistency of corn yields in northern


Carter, P.R. 1984. Optimum corn planting practices. Univ. of Wis-

Eckert, D.J. 1984. Tillage system × planting date interactions in

Griffith, D.R., J.V. Mannering, H.M. Galloway, S.D. Parsons, and
temperature, percent stand, plant growth and yield of corn on five


and date of planting effects on yield of corn on soils with restricted

Hicks, D.R. (ed.) 1977. Corn management studies in Minnesota:
149.

Johnson, M.D. 1983. Effect of tillage on soil temperature and mois-

rating of corn hybrids. Agronomy no. 27, University of Minne-
sota, Agricultural Extension Service, St. Paul.