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Cold Tolerance in Corn Hybrids as Affected by Tillage Systems and Planting Dates[1]

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Conservation tillage systems that leave greater crop residue on the soil surface to reduce wind and water erosion are becoming more popular with Iowa farmers. Conservation-tilled soils, however, tend to be wetter and cooler at planting time than conventional fall-plowed soils. Our objective was to compare corn (*Zea mays* L.) hybrids classified as cold or not cold tolerant (based on laboratory germination tests) on soils that were either fall plowed (conventional tillage) or spring disked (conservation tillage). Our results did not show any clear advantage for using conventional instead of conservation tillage. Means for the hybrids classified as cold tolerant and not cold tolerant were similar for both tillage systems. No consistent differences in stand, yield, and grain moisture were found between the two tillage systems which suggested that comparable performance would be expected for the two methods of tillage.

INDEX DESCRIPTORS: *Zea mays* L., conservation tillage, planting dates.

The public is becoming more aware of the problems caused by soil erosion, and farmers are using more effective measures to control it. One method to reduce soil erosion is conservation tillage, which can be defined as any tillage system that tends to leave crop residue on the soil surface. Conservation tillage can include chisel plowing, tillage only within a narrow band over the row at planting time, no tillage in the field, and different combinations of tillage that do not include the moldboard plow.

Because conservation tillage leaves plant residue on the soil surface, soils tend to be cooler and wetter than conventionally moldboard-plowed soils (Amemiya, 1970). Farmers in north-central Iowa have been reluctant to change from conventional moldboard plowing to a conservation tillage system because the heavy, poorly drained soils of the Clarion-Nicollett-Webster (CNW) soil association warm up slower in the spring. Research has shown that corn (*Zea mays* L.) stands and yields are better on fall-moldboard-plowed soils than on conservation tilled soils (Griffith et al., 1973; Mock and Erbach, 1977).

Corn hybrids selected for cold tolerance may improve plant emergence under conservation tillage systems used on CNW soils. Cold-tolerant hybrids may allow farmers to use full-season hybrids on conservation-tilled soils even though the soil temperature was less than optimum. Cold-tolerant lines and hybrids have been identified in corn and have shown improved emergence and seedling vigor in cold soils (Mock and Eberhart, 1972; Mock and Bakri, 1976; Mock and Skrdla, 1978; Burris and Navratil, 1979; Miedema, 1979). Use of cold-tolerant hybrids should permit farmers to switch to conservation tillage systems without a loss in yield. The objective of our study was to compare yield, stand, and maturity of corn hybrids, classified as cold tolerant or not cold tolerant, on conventional and conservation tillage systems on CNW soils.

MATERIALS AND METHODS

Experiments were conducted in 1980 at Algona and Conrad, Iowa, for two tillage systems (conventional and conservation tillage) established in the fall of 1979. At Algona, fall tillage of cornstalk ground included moldboard plowing (conventional) or one pass with a tandem disk (conservation). Spring tillage included one pass with a field cultivator for both tillage types. At Conrad, fall tillage included chisel-plowed soybean stubble (conventional) and disking of cornstalks (conservation). Spring tillage at Conrad included using a field cultivator for both tillage types. Tillage systems were the whole-plot treatments at both locations. Fertilizer was applied in the fall on all plots before the tillage treatments were completed. Rates of fertilizer applications were 176, 133, and 188 kg ha^{-1} of N, P, and K, respectively, at Algona and 168, 134, and 134 kg ha^{-1} of N, P, and K, respectively, at Conrad.

Each whole plot was divided into subplots to permit two dates of planting. Planting dates were April 30 and May 28, 1980, at Algona and April 24 and May 22, 1980, at Conrad. Three replications of each subplot were included in a randomized complete-block design for each planting date within each tillage system.

Thirty corn hybrids that had been identified as either cold tolerant (CT) or not cold tolerant (NCT) were selected for study (Funnemark, 1983). Identification of lines as CT or NCT was based on a laboratory warm germination test, which had shown a good correlation with field performance. Nine of these hybrids were produced by crossing S_2 lines from a Funk breeding population to A635 × A634, which was the male parent tester; three were classified as CT and six as NCT. The Funk breeding population was developed by crossing Funk proprietary lines to three improved synthetic varieties: BS11(FR)C3, BS12(HI)C6, and BSCB1(R)C7. The population was not previosuly selected for cold tolerance. The other 21 hybrids were either single crosses or modified crosses produced from proprietary and public lines. Twelve of the hybrids were CT, and nine NCT. Hybrids were the sub-subplots within each planting date and included two rows of each hybrid spaced 75 cm that were 10 and 9 m long at Algona and Conrad, respectively.

Data were collected on all sub-subplots at both locations for plant stands, days from planting to flower, plant and ear height, root and stalk lodging, yield, and grain moisture at harvest. Stand counts were made after the final cultivaiton. Days to flower were recorded as number of days from planting to when 50% of the plants in a plot had tassels shedding pollen and ear shoots showing visible silks. Plant and ear heights (cm) were measured in August from the soil surface to the top of the tassel and the base of the top ear, respectively. Stalk and root lodging counts (expressed as percentage of erect plants) were made immediately before harvest. All plots were machine harvested, and yields were corrected to 15.5% grain moisture. Harvest dates were October 7, 1980, at Conrad and October 24, 1980 at Algona.

Soil temperature and emergence index data were recorded at the Algona location. Soil temperatures were measured at the 7.6-cm soil depth at 0730 every other day from April 29 to May 30, 1980. Soil temperature readings were not replicated. The number of plants that

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emerged were counted every other day until stands became constant. An emergence index (EI) was used as suggested by Smith and Millet (1964):

$$EI = \frac{\text{Sum (no. of plants emerged on a day) (days after planting)}}{\text{Total no. plants emerged 30 days after planting}}$$

An analysis of variance for each location and combined across both locations was calculated for all traits except EI, which was measured only at Algona. All effects except locations were considered fixed effects in determining the expected mean squares. The form of the analysis of variance was for a design with tillage systems and planting dates in strips. Separate error terms were used to test tillage, dates, and dates by tillage and hybrids, hybrids by tillage, hybrids by dates, and hybrids by tillage by dates. The combined analysis for the two locations had the same form, except that additional sources for locations and interactions with locations were included.

RESULTS AND DISCUSSION

Conservation tillage systems protect the soil from water and wind erosion, but this may be a disadvantage if germination and seedling growth are affected by cooler soil environments. The differences in soil temperatures between the two tillage systems were not greatly different (Fig. 1). Soil temperatures in the conservation tillage plots were slightly lower and tended to change more slowly than in the conventional tillage plots. Although trends in soil temperatures were similar for the two tillage systems, the conservation tillage plots were 1 to 3° cooler.

Emergence index (EI) was similar for both tillage systems when averaged over all hybrids, but the difference between planting dates was significant (Table 1). The average EI was 10.5 units higher for the early planting date (Table 2). Differences among hybrids were significant for EI, but there was no statistically significant relation between hybrids classified as CT and NCT and EI (Funnemark, 1983). When hybrids were reclassified as either CT or NCT on the basis of EI, there also were no significant differences due to cold tolerance ratings.

Few of the sources of variation and their respective interactions were significantly different from zero for most traits except for differences among hybrids (Table 1). There were no consistent trends of significance among traits for tillage systems, dates of planting, and their interactions. The power of the F – tests for some of the main effects and the first-order interactions, however, was poor because only one degree of freedom was available. The first-order interactions that included locations, tillage systems, and dates of planting were significant for three traits for locations by tillage systems, for six traits for locations by dates, and none of the traits for tillage systems by planting dates. The second-order interaction was significant for stalk lodging, yield, and stand.

Differences among hybrids were highly significant ($P \leq 0.01$) for all traits except stalk lodging and stand. Comparisons between the hybrids classified as CT and NCT were, however, nonsignificant in nearly all instances (Funnemark, 1983). Although there were significant differences among hybrids for most traits, the differences were not due to differences in level of cold tolerance. The range in the classification of the hybrids as either CT or NCT, on the basis of EI at Algona in 1980, was not large, and the EI means for CT (13.8) and NCT (14.5) were not significantly different (Funnemark, 1983). The environmental conditions at the two locations in 1980 did not distinguish any differences between the hybrids classified as CT and NCT.

Mean comparisons for six traits for tillage systems, dates of planting, and CT and NCT hybrids are included in Table 2. Means for the CT and NCT hybrids were similar for each tillage system and for the two dates of planting within each tillage system. None of the differences between CT and NCT hybrids, however, was significant.

Table 1. Summary of the analyses of variance of 30 hybrids evaluated for two planting dates on two tillage systems conducted at two Iowa locations in 1980.

		Days to		Height		Grain	Lodging				
Source	d.f.[a]	Pollen shed	Silk	Plant	Ear	moisture	Stalk	Root	Yield	Stand	EI[b]
Locations (L)	1	**[c]	ns	**	**	**	**	ns	*	**	—[e]
Tillage (T)	1	ns[d]	ns	ns	ns	ns	ns	ns	ns	ns	ns
L×T	1	ns	ns	**	**	ns	ns	ns	ns	**	—
Dates (D)	1	ns	ns	**	**	ns	ns	ns	ns	ns	**
L×D	1	**	**	ns	ns	**	*	**	ns	**	—
T×D	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L×T×D	1	ns	ns	ns	ns	ns	**	ns	**	**	—
Reps/LTD	16	**	**	**	**	**	ns	**	**	**	—
Hybrids (H)	29	**	**	**	**	**	ns	**	**	ns	**
H×L	29	*	**	**	*	**	*	**	**	**	—
H×T	29	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
H×T×L	29	ns	ns	ns	**	ns	ns	*	*	*	—
H×D	29	ns	ns	ns	ns	**	*	ns	**	ns	ns
H×D×L	29	**	**	ns	ns	ns	ns	**	ns	**	—
H×D×T	29	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
H×D×T×L	29	ns	ns	ns	ns	ns	ns	ns	ns	ns	—
Pooled error	464	—	—	—	—	—	—	—	—	—	—
Total	719										

[a]Degrees of freedom for all traits except EI.

[b]Emergence index data recorded at Algona only.

[c]** and * significant at 0.01 and 0.05 probability levels, respectively.

[d]ns indicates nonsignificant F-value.

[e]F-tests were not calculated or available.

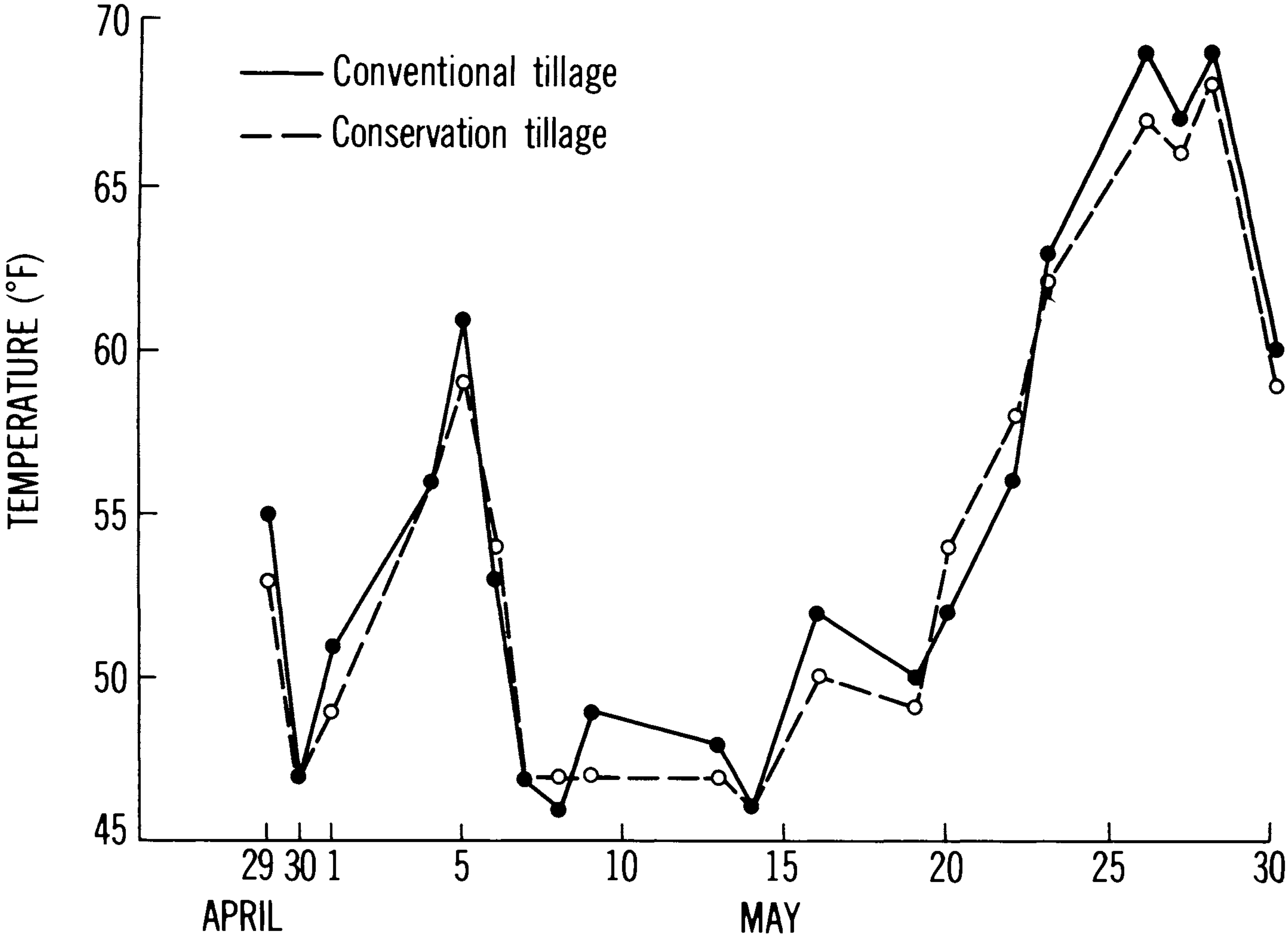

Fig. 1. Summary of soil temperatures at 7.6-cm soil depth for conventional and conservation tillage sytems at Algona, Iowa, 1980.

Differences between planting dates within each tillage system were greater, but they were consistent for each tillage system. The hybrids planted early required about 20 more days to flower, and had better stands, lower ear height and grain moisture, and higher EI and yield than the same hybrids planted later. The greatest difference between tillage systems was for yield of the early planting date on conservation tillage. This was entirely due to one location, however. The conventional tillage plots that were planted early at Conrad sustained water damage. A heavy rain occurred in June, and standing water remained in the lots for about 1 week. Water damage was due to the location of the conventional tillage plot in the field and not due to the method of tillage. Comparative yields at Algona for early planting were 104.1 and 103.6 q ha^{-1} for conventional and conservation tillage, respectively, whereas yields at Conrad were 86.3 and 110.1 q ha^{-1} for conventional and conservation tillage, respectively. Though stands were not reduced, yield was affected by the standing water at Conrad.

Conservation tillage systems will be acepted by Iowa farmers if adequate stands can be established to produce high yields with acceptable grain moisture at harvest. Our study showed that, under the conditions of our experiments, this can be realized (Table 3). For the early planting date, which is normal for Iowa, greater yield, with similar plant stands and grain moisture, was obtained on the conservation tillage system that on the conventional tillage system. None of the differences between tillage systems was significant (Table 1). Although yield on the conventional tillage system was reduced because of water damage at Conrad, our results suggest yield was not sacrificed with the use of conservation tillage. If planting is delayed because of weather and field conditions, the differences between the use of conventional and conservation tillage were small for each of the three traits (Table 3). Stand counts were lower for conventional tillage because sand blasting from strong winds caused seedling damage and stand reductions at Algona. The late-planted corn tended to have lower yield and greater grain moisture than the early-planted corn, but the differences were not related to the tillage practices used.

Our results did not show any clear advantage for using conventional tillage instead of conservation tillage. There were no consistent differences in hybrid performance between the two tillage systems, and none of the CT vs. NCT comparisons showed any significant differences for EI, final plant stands, days from planting to flowering, root lodging, and yield. Our results are limited to Algona and Conrad locations in 1980. Additional studies are needed to determine if our results are consistent with different hybrids, environments, and soil associations.

Table 2. Summary of the comparisons between corn hybrids classified as cold tolerant (CT) and not cold tolerant (NCT) compared for conventional and conservation tillage systems and early and late planting dates for two Iowa locations in 1980.

		Tillage[a]					
		Conventional			Conservation		
		Date of planting[b]			Date of planting[b]		
Trait	Hybrid[c]	Early	Late	$\bar{X}$	Early	Late	$\bar{X}$
Days to silk, no.[d]	CT	84.1	64.9	74.5	83.8	64.8	74.3
	NCT	84.2	65.1	74.7	84.4	65.1	74.8
	$\bar{X}$	84.2	65.0	74.6	84.1	65.0	74.6
Ear height, cm	CT	129	140	135	137	145	141
	NCT	132	140	136	138	146	142
	$\bar{X}$	131	140	135	138	145	142
Grain moisture, %	CT	22.3	27.6	25.0	22.8	28.0	25.4
	NCT	22.6	28.1	25.3	23.2	28.4	25.8
	$\bar{X}$	22.4	27.8	25.2	23.0	28.2	25.6
Yield[e], q ha^{-1}	CT	93.2	94.4	93.8	106.3	94.1	100.2
	NCT	96.5	93.4	94.9	107.8	95.6	101.7
	$\bar{X}$	94.8	93.9	94.4	107.0	94.8	100.9
Stand, no. ha^{-1} (x 10^2)[f]	CT	59.7	52.9	56.3	57.0	58.0	57.5
	NCT	58.8	50.7	54.8	56.6	56.7	56.6
	$\bar{X}$	59.2	51.8	55.6	56.8	57.4	57.0
EI[g]	CT	18.6	9.1	13.8	19.0	8.5	13.8
	NCT	19.9	9.3	14.6	20.0	8.7	14.4
	$\bar{X}$	19.3	9.2	14.2	19.5	8.6	14.1

[a]Conventional (T) included fall and spring tillage, and conservation (N) included one pass with field cultivator in the spring.

[b]Early planting was April 24 and 30, and late was May 22 and 28, 1980.

[c]The hybrid means included 15 classified as CT and 15 classified as NCT.

[d]Number of days from planting to 50% silk emergence.

[e]Multiply by 1.6 to obtain bushels per acre.

[f]Divide by 2.471 to obtain number plants per acre.

[g]Emergence index data were included at Algona only.

Table 3. Mean performance of 30 hybrids for plant stand, yield, and grain moisture compared under conventional and conservation tillage that were planted early and late at two Iowa locations in 1980.

	Trait					
Planting	Stand		Yield		Grain moisture	
date	Conventional	Conservation	Conventional	Conservation	Conventional	Conservation
	M ha^{-1}		q ha^{-1}		%	
Early[a]	59.3	56.8	94.9	107.1	22.4	23.0
Late[b]	51.9	57.3	93.9	94.9	27.8	28.2
$\bar{X}$	55.6	57.1	94.4	101.0	25.1	25.6

[a]Planting dates were April 30 at Algona and April 24 at Conrad.

[b]Planting dates were May 28 at Algona and May 22 at Conrad.

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