Corn-Hybrid Performance under Conventional and No-Tillage Systems after Thinning[1]

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ABSTRACT

Corn (*Zea mays* L.) producers question the relative performance of hybrids under different previous-crop residue management systems. The objective of this study was to assess tillage system × corn hybrid interactions for hybrids commonly grown in the northern United States. Field experiments were conducted at four locations in Wisconsin during 1984 and 1985, including sites with Plano and Nickin silt loam (Typic Argiudoll) and Meridian loam (Mollic Hapludalf) soils. Fifteen hybrids with a range of maturities (90–115 days based on the Minnesota Relative Maturity System) were compared under conventional (moldboard plowing and disking) (CT) and no-till (NT) systems, in a corn-following-corn sequence. Stands were thinned after emergence. No-till resulted in cooler soil temperatures (0.8–3.8°C cooler), lower emergence percentage (7–12% lower), delayed vegetative growth [4.4 (NT) vs. 7.9 (CT) g plant^{-1}], later silking (2–5 days later), and increased grain moisture (10–20 g kg^{-1}) compared to CT. For grain yield, differences occurred for all main effects (locations, years, tillage systems, and hybrids), and most interactions were significant. Yields under NT were 92% (cool spring, 1984) and 96% (warm spring, 1985) of CT yields. On silt-loam soils, NT yields were 92 to 95% of CT yields, but tillage systems had similar yields on the loam soil. Superior-yielding hybrids under CT were also good choices with NT, although delayed growth under NT limited the yield potential of later-maturing (100–115 days) hybrids.

Additional index words: Conservation tillage, *Zea mays* L., Grain moisture, Grain yield, Relative maturity.

CONSERVATION -tillage systems for corn (*Zea mays* L.) production are receiving major interest in the Unites States as means of erosion control and improved economy of energy and time. Tillage systems that leave 30% or more of the soil surface residue-cover after planting are defined as "conservation tillage" (Conservation Tillage Information Center [CTIC], 1986).

No-till systems, in which residue and soil are undisturbed except for a narrow seedbed, provide substantial labor savings and erosion-control benefits, and are recommended by the USDA Soil Conservation Service (1983) when corn is produced on steep slopes. However, acceptance of this tillage system in northern corn-growing areas has been relatively slow. In Wisconsin, where rolling, potentially erosive cropland predominates, 30% of corn cropland is produced with conservation tillage, but only 3% of this is no-till (CTIC, 1986).

There are negative factors associated with retaining substantial amounts of residue on the soil surface, which contribute to concerns about adopting no-till systems. Surface residues slow soil warming in the spring (Johnson and Lowery, 1985), which may reduce percent and rate of emergence and retard seedling growth (Allmaras et al., 1964; Griffith et al., 1973; Mock and Erbach, 1977). Lack of tillage may result in increased soil compaction and bulk density (Gantzer and Blake, 1978), factors that may influence nutrient uptake and root growth (Bauder et al., 1981). Herbicide effectiveness and weed populations may change with limited tillage (Triplett, 1985), and harmful insect and disease pressures may also change (Kuhlman and Steffey, 1982; Nyvall, 1982).

These major alterations in the corn-growing environment under conservation-tillage systems have generated questions among corn producers about relative corn hybrid performance under conventional vs. no-tillage. Corn-following-corn cropping sequences generate most concern, due to increased residue cover and pest pressure compared to alfalfa (*Medicago sativa* L.)/corn or soybean [*Glycine max* (L.) Merr.]/corn sequences.

Some studies indicated that relative hybrid performance was similar across a range of tillage systems. In Iowa (Mock and Erbach, 1977; Hallauer and Colvin, 1985; Newhouse, 1985; Newhouse and Crosbie, 1986), South Carolina (Karlen and Sojka, 1985), and Maryland (Anderson, 1986), tillage system × hybrid interactions for grain yield and other traits for corn-following-corn rotations were not important for the commercial and open-pedigree hybrids evaluated. However, Brakke et al. (1983), in Nebraska, found genotype × cropping system interactions for days to flower, grain yield, and harvest moisture when 169 topcrosses were compared under conventional- (fall plowing after corn, irrigated) and ecofallow- [no-tillage into wheat (*Triticum aestivum* L.) stubble, unirrigated] cropping systems. None of the topcrosses yielded within the highest 10% under both conventional and ecofallow systems, and only 5% were within the greatest 25% for both cropping systems. Wall and Stobbe (1983), planting into barley (*Hordeum vulgare* L.) stubble in Manitoba, reported that of eight commercial hybrids tested, grain weight per ear of four hybrids was unaffected by tillage system, while four others had less grain weight per ear under no-tillage than under conventional tillage.

The objective of this study was to assess tillage system × corn hybrid interaction under conventional and no-tillage, with corn following corn, for hybrids commonly grown in the northern United States.

MATERIALS AND METHODS

Fifteen corn hybrids, with a range in relative maturity (RM) [approximately 90 to 115 days based on the Minnesota Relative Maturity System (Peterson and Hicks, 1973)], were grown under conventional- (CT) and no-till (NT) corn-following-corn systems at (from southernmost to northernmost latitudes) Janesville, Arlington, Sparta, and River Falls, WI, in 1984 and 1985. At Janesville and Arlington, the fields had been under CT before 1984. At River Falls and Sparta, the fields had been under NT production for 1 yr (1983). Conventional tillage was either fall or spring moldboard-plowing, followed by disking or field cultivating before planting. No-tillage consisted of planting directly into unincorporated corn residue. Soil pH was maintained at 6.5 to 6.7, and soil test P and K were above recommended levels at all locations.

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At planting, fertilizer was applied in a band, 50 mm to the side and 25 mm below the seed. The row fertilizer rate was 168 kg ha^{-1}, with an analysis of 6-10.5-20 (N-P-K). For both tillage systems, additional N (196 kg ha^{-1}) was annually applied as NH_4NO_3, either broadcast over the entire plot area before planting (Arlington), or sidedressed after corn emergence (Janesville, Sparta, River Falls). Weed and insect control were accomplished chemically for both tillage systems. Soil classifications, planting and harvest dates, and insecticides and herbicides applied are presented in Table 1. Climatological data for the four locations are shown in Table 2.

Different hybrid seed lots were used each year, and before planting, the standard warm-germination test (Association of Official Seed Analysts, 1983) and a cold-germination test (Wisconsin Crop Improvement Association, 1984; Hoppe, 1955) were conducted. Warm germination was above 95% and cold germination was equal to or greater than 80% for seed of all hybrids each year.

Seed was planted at a rate of 99 000 kernels ha^{-1} using coneseeders on a no-till 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 0.04 and 0.05 m deep under both tillage conditions. Under NT, residue was disturbed only in a 0.025-m-wide slot necessary for seed placement.

The experiment design consisted of randomized complete blocks in split-plot arrangement for each location and year. Tillage systems were whole plots and included 15 four-row subplots (corn hybrids) that were 9.14 m long and 3.04 m wide. Row spacing was 0.76 m. Data were collected from the center two rows of each subplot.

At Arlington and River Falls, midday in-row soil temperatures (0.05-m depth) were recorded daily after planting. Plant stands were thinned to common densities after complete emergence to separate plant-density effects from other growth factors that might influence hybrid performance under different tillage systems. Approximately 45 days after planting, when plants in CT and NT systems were at V6 to V7 and V4 to V5 stages (Ritchie and Hanway, 1982), respectively, plants at all locations were counted and thinned to 58 000 plants ha^{-1}. The exception was Sparta in 1985, where plots were thinned to 50 000 plants ha^{-1}. Thinned plants were selected at random along the entire plot row-length. At thinning, aboveground growth of 10 plants from each subplot was dried and weighed. Days after planting to silk stage (50% of plants with emerged silks) were recorded at Arlington in 1984 and at River Falls both years. After silking, plant height from the soil surface to the flag-leaf node was measured for 10 plants per subplot. Immediately before harvest, final plant-stand and stalk-lodging counts were made. Stalk-lodged plants were those broken at or below the uppermost ear-node. Grain yield was determined by harvest with a plot combine at Janesville and Arlington, while at Sparta and River Falls, ears were hand-harvested and weighed

Table 1. Soil conditions and cultural practices.

		Soil classification			Date		Pesticides† and date applied	
Location	Year	Mapping unit	Family	Subgroup	Planted	Harvested	Herbicide	Insecticide
Janesville	1984	Plano silt-loam, gravelly substratum	fine-silty, mixed, mesic	Typic Argiudoll	7 May	22 Oct.	Profluralin + atrazine (1.7 kg + 1.7 kg) (24 May) Linuron (directed application) (2.2 kg) (2 July)	Terbufos (9 kg)‡ (7 May)
	1985	Same			30 Apr.	10 Oct.	Cyanazine + alachlor (2.2 kg + 2.9 L) (25 Apr.) Linuron (directed application) (2.2 kg) (19 June)	Terbufos (9 kg) (30 Apr.)
Arlington	1984	Plano silt-loam	fine-silty, mixed, mesic	Typic Argiudoll	26 Apr.	26 Oct.	Glyphosate (2 L) (20 Apr.) Atrazine + alachlor (3.4 kg + 2.4 L) (9 May)	Terbufos (9 kg) (26 Apr.)
	1985	Same			29 Apr.	25 Oct.	Atrazine + metolachlor (3.4 kg + 1.4 L) (1 May)	Terbufos (9 kg) (29 Apr.) Fenvalerate (0.25 L) (15 June)
Sparta	1984	Meridian loam	fine-loamy over sandy-skeletal, mixed, mesic	Mollic Hapludalf	4 May	3 Nov.	Cyanazine + alachlor (2.2 kg + 1.9 L) (6 May)	Terbufos (9 kg) (4 May)
	1985	Same			3 May	26 Oct.	Cyanazine + alachlor (2.2 kg + 1.9 L) (8 May)	Terbufos (9 kg) (3 May) Fenvalerate (0.25 L) (14 June)
River Falls	1984	Nickin silt-loam	fine-loamy over sandy-skeletal, mixed, mesic	Typic Argiudoll	23 May	1 Nov.	Atrazine + alachlor (2.2 kg + 2.9 L) (3 June)	Chlorpyrifos (8 kg)
	1985	Same			7 May	4 Nov.	Atrazine + alachlor (2.2 kg + 2.9 L) (3 May)	Chlorpyrifos (8 kg) (7 May)

† Chemical names for pesticides are as follows: profluralin, N-(cyclopropylmethyl)-2,6-dinitro-*N*-propyl-4-(trifluoromethyl)benzeneamine; atrazine, 6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine; linuron, *N'*-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea; cyanazine, 2-{[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino}-2-methylpropanenitrile; alachlor, 2-chloro-*N*-(2,6-diethyphenyl)-*N*-(methoxymethyl)acetamide; glyphosate, *N*-(phosphonomethyl)glycine; metolachlor, 2-chloro-*N*-(2-ethyl-6-methyl phenyl)-*N*-(2-methoxy-1-methyl ethyl) acetamide; chlorpyrifos,*O,O*-diethyl-*O*-(3,5,6-trichloro-2-pyridyl)-phosphorothioate; fenvalerate, cyano(3-phenoxyphenyl)methyl 4-chloro-alpha-(1-methylethyl)benzeneacetate; terbufos, 5-test-butylthiomethyl-*O*-*O*-diethyl phosphorodithioate.

‡ Quantities (kilograms and liters) of pesticides applied per hectare are shown in parentheses.

after shelling with a portable sheller. Harvest grain moisture at each location was determined after oven-drying grain samples from each subplot. Grain yields are reported in dry weight per hectare, adjusting for the grain moisture content of each hybrid.

A split-plot analysis of variance was computed for each trait for each location and year, and combined for the four locations and 2 yr. Tillage systems were randomized within each replicate at each location in 1984, but the same whole-plot randomization was used in 1985. After the position of tillage-system whole plots was determined, these whole plots remained in the same position the second year. Therefore, the whole plots were fixed in time, resulting in a stripping effect in the split-plot statistical analyses of variance (Steel and Torrie, 1960). Hybrids within whole plots were re-randomized each year. All effects, except replicates, were considered fixed in determining the expected mean squares and appropriate *F*-tests in the combined analyses of variance (Table 3).

RESULTS AND DISCUSSION

Adequate precipitation for corn production occurred at all locations in 1984 and 1985, but spring air temperatures were more favorable in 1985 (Table 2). May air temperatures were 1.1 to 2.5°C below average in 1984, and 2.0 to 2.8°C above average in 1985. Air temperatures the remainder of the growing season were near average in 1984, but were cooler than average during June and August in 1985 (Table 2). Growing degree days (GDD) (Aspiazu and Shaw, 1972) accumulated from planting through September were 1468, 1404, 1384, and 1277 (1984) and 1546, 1371, 1358, and 1304 (1985) at Janesville, Arlington, Sparta, and River Falls, respectively.

Soil temperatures at midday the week following planting were lower under NT than CT. Average values were 9.3°C (NT) and 10.1°C (CT) at Arlington

Table 2. Growing-season precipitation and mean air temperature at four locations during 1984 and 1985.

		Growing-season month				
Location	Year	May	June	July	Aug.	Sept.
				Precipitation, mm		
Janesville	1984	128 (47)†	112 (9)	78 (−26)	67 (−30)	80 (−7)
	1985	103 (22)	72 (−30)	113 (9)	77 (−20)	93 (6)
Arlington	1984	82 (26)	193 (88)	74 (−15)	45 (−59)	93 (1)
	1985	63 (−17)	89 (−16)	149 (60)	92 (−12)	174 (82)
Sparta	1984	65 (−29)	162 (58)	135 (42)	77 (−19)	133 (40)
	1985	86 (−8)	52 (−53)	62 (−31)	106 (10)	182 (85)
River Falls	1984	51 (−45)	102 (−27)	102 (0)	99 (−6)	79 (−2)
	1985	87 (−9)	76 (−53)	62 (−40)	109 (5)	147 (67)
				Mean air temperature, °C		
Janesville	1984	13.6 (−2.1)†	21.6 (0.6)	21.8 (−1.4)	22.4 (0.3)	16.5 (−1.2)
	1985	17.7 (2.0)	19.1 (−1.9)	22.9 (−0.3)	20.4 (−1.7)	18.2 (0.4)
Arlington	1984	12.5 (−1.6)	20.4 (1.3)	20.6 (−1.2)	22.0 (1.4)	15.9 (−0.1)
	1985	16.9 (2.8)	17.8 (−1.3)	21.3 (−0.4)	18.9 (−1.9)	16.5 (0.4)
Sparta	1984	12.1 (−2.5)	20.3 (0.9)	20.8 (−1.8)	21.9 (1.3)	15.2 (−0.4)
	1985	16.7 (2.2)	17.9 (−1.5)	21.0 (0.0)	19.2 (−1.4)	15.9 (0.3)
River Falls	1984	13.3 (−1.1)	20.6 (1.2)	21.2 (−0.8)	22.3 (1.6)	14.1 (−1.4)
	1985	16.9 (2.5)	17.6 (−1.8)	21.7 (−0.3)	19.2 (−1.6)	15.7 (0.2)

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

Table 3. Summary of statistical significance of combined analyses of variance for 15 corn hybrids compared under two tillage systems over four locations and 2 yr.

Source of variation	df	Emergence	Vegetative dry wt.	Mature plant ht.	Final stand	Stalk lodging	Grain moisture	Grain yield
Locations (L)	3	NS	**	**	**	*	**	**
Error a	8							
Tillage (T)	1	**	**	NS	**	NS	**	**
L × T	3	**	**	NS	NS	NS	NS	NS
Error b	8							
Hybrids (H)	14	**	**	**	**	**	**	**
T × H	14	NS	NS	NS	NS	NS	**	**
L × H	42	**	*	*	NS	**	**	**
L × T × H	42	*	NS	NS	*	NS	NS	**
Error c	224							
Years (Y)	1	**	*	**	NS	**	**	**
L × Y	3	**	**	**	**	**	**	**
Error d	8							
T × Y	1	**	*	*	**	NS	**	**
L × T × Y	3	NS	NS	**	*	NS	NS	NS
Error e	8							
H × Y	14	**	**	**	**	**	**	**
T × H × Y	14	NS	NS	NS	NS	NS	*	*
L × H × Y	42	**	NS	**	*	**	**	**
L × T × H × Y	42	NS	NS	NS	*	NS	NS	NS
Error f	224							
Total	719							

*,** Significance at the 0.05 and 0.01 probability levels, respectively. NS = nonsignificant.

Table 4. Corn hybrid vegetative dry weights, averaged over tillage systems, locations, and years; and harvest grain moistures for two tillage systems for 2 yr, averaged over four locations.

			Grain moisture								
			Year								
			1984			1985			Average		
Hybrid	RM†	Vegetative dry wt.	Conv.		No-till	Conv.		No-till	Conv.		No-till
	days	g plant⁻¹	g kg⁻¹								
Pioneer 3747	100-105	6.6	235		243	227	*	247	231	*	245
Pioneer 3732	110-115	6.2	247		252	250	*	274	248	*	263
FR20A × FR29	110-115	6.2	259		268	250	*	270	254	*	269
A632 × LH39	100-105	6.1	212	*	224	226		237	219	*	230
CB59G × LH38	110-115	6.4	251		252	266	*	299	259	*	275
FR20A × FR634	110-115	6.4	245	*	262	270	*	300	258	*	281
Mo17 × A634	110-115	5.7	255	*	272	273	*	314	264	*	293
A632 × LH38	110-115	5.5	251	*	265	265	*	303	258	*	284
LH38 × CM105	100-105	6.1	225		235	226	*	240	226	*	238
CM105 × LH38	100-105	6.2	227		238	220	*	240	224	*	239
CM105 × LH39	90-95	6.1	203	*	216	202		209	202	*	212
FR29 × FR23	90-95	6.1	224		224	208	*	220	216		221
Pioneer 3906	90-95	6.5	215		217	207		213	211		215
CB59G × W117	90-95	6.8	207	*	222	199		210	203	*	216
FR23 × CM105	90-95	5.9	199		208	202	*	217	200	*	212
Mean		6.2	230	*	240	233	*	253	232	*	246
LSD (0.05)		0.5				11‡				8§	

* Difference between tillage systems is significant at $P < 0.05$.
† RM = Relative maturity classification.
‡ Least significant difference for comparison of hybrids within tillage system and year over locations.
§ Least significant difference for comparison of hybrids within tillage system, over years and locations.

and 23.7°C (NT) and 26.3°C (CT) at River Falls in 1984. In 1985, soil temperatures were 15.6°C (NT) and 19.1°C (CT) (Arlington) and 20.9°C (NT) and 24.4°C (CT) (River Falls). Warmer soil temperatures at River Falls were due to later planting than at Arlington, especially in 1984 (Table 1).

Emergence (percentage of kernels planted that emerged) was reduced under NT compared to CT at all locations, especially during the cool 1984 spring. Values were 74% (NT) and 86% (CT) (1984) and 80% (NT) and 87% (CT) (1985). Hybrid differences in emergence occurred, and hybrids interacted with location, tillage system and location, years, and locations and years (Table 3). Averaged over hybrids and years, the smallest differences between CT and NT occurred at Sparta (6% difference), and the largest differences were at Janesville (15% difference). Thinning to constant stand densities was an attempt to remove the effects of emergence on subsequent grain yield comparisons.

Table 5. Days from planting to silk for hybrids in three relative maturity groups, compared under two tillage systems.

			Year					
			1984			1985		
Location	RM†	No. hybrids	Conv.		No-till	Conv.		No-till
	days		days					
Arlington	90-95	5	86.9		89.6			
	100-105	4	88.6		91.4			
	110-115	6	91.0		95.0			
	Mean		88.8	*	92.0			
River Falls	90-95	5	64.6		66.7	72.0		75.3
	100-105	4	66.8		69.0	73.1		77.9
	110-115	6	69.7		72.5	77.3		81.1
	Mean		67.0	*	69.4	74.1	*	78.1

* Difference between tillage systems is significant at $P < 0.05$.
† RM = Relative maturity classification.

Vegetative dry weight was decreased with NT at all locations and years, averaging 4.4 and 7.9 g plant^{-1} for NT and CT, respectively. Early growth was slower in 1984 than 1985, due to cooler May temperatures (Table 2). At Arlington, where planting and sampling dates were similar both years, vegetative dry weights were 2.8 g plant^{-1} (NT) and 5.1 g plant^{-1} (CT) in 1984, and 3.6 g plant^{-1} (NT) and 7.9 g plant^{-1} (CT) in 1985. Hybrid vegetative dry weights varied, ranging from 5.5 to 6.8 g plant^{-1}, but a tillage system × hybrid interaction did not occur (Tables 3 and 4).

Developmental delays under NT continued to silk stage, with silking occurring about 2 to 5 days later than CT (Table 5). With NT, hybrid silk dates within a particular RM class corresponded to CT silk dates for hybrids 10 RM units later. For example, hybrids in the 100- to 105-day RM group under NT silked approximately the same time as 110- to 115-day hybrids under CT (Table 5). It required about 20 to 50 more GDD to reach silk stage under NT than CT. Swan et al. (1987) found a similar increase in GDD necessary to reach phenological stages from six-leaf to flowering for NT (75–100% in-row residue cover) compared to CT (0% residue cover).

Grain moisture at harvest was generally greater with NT, with a 10 g kg^{-1} difference between tillage systems, averaged over hybrids in 1984, and a 20 g kg^{-1} difference in 1985 (Table 4). Larger differences in 1985 may be attributed to earlier harvest dates than in 1984 at three of four locations (Table 1). Since kernel moisture differences between CT and NT probably narrow during the autumn grain-drying period, earlier harvest may enlarge differences in grain moisture between tillage systems. Hybrid grain moisture responses to tillage system varied, with six (1984) and 11 (1985) hybrids having significantly greater grain moistures under NT (Table 4). Grain moisture difference between NT and CT for hybrids ranged from 0 to 17 g kg^{-1} (1984) and 6 to 41 g kg^{-1} (1985).

Mature plant height of hybrids was similar under CT and NT, and no-tillage system × hybrid interactions occurred (Table 3). Final stands were slightly lower (4% in 1984 and 2% in 1985) under NT than CT, despite early thinning to identical densities. Hybrid stands also varied, with a 7% range (over tillage systems, locations, and years) from highest to lowest. Common stalk borer [*Papaipema nebris* (Guenee)], armyworm [*Pseudaletia unipuncta* (Haworth)], and black cutworm [*Agrostis ipsilon* (Hufnagel)] were observed feeding in NT plots just before thinning and were controlled chemically at Arlington and Sparta in 1985 (Table 1). Some plant mortality due to damage caused by these pests may have reduced stands following thinning. Stalk lodging responses of hybrids varied, but interactions with tillage systems did not occur (Table 3).

For grain yield, all main effects and nearly all interactions were significant (Table 3). Grain yield differences between tillage systems were greater in 1984 than in 1985 (Table 6, Fig. 1A and 1B); averaged over hybrids, NT yields were 92% of CT yields in 1984, and 96% of CT in 1985. Hybrid × tillage system interactions occurred both years, with nine hybrids lower yielding under NT in 1984, and only five hybrids with less NT grain yield in 1985 (Table 6). The improved NT-corn performance with above-average (1985) vs. below-average (1984) May temperatures indicated a relationship between spring temperatures and relative grain yields under NT.

Grain yield response to tillage systems also varied across locations, ranging from 12% lower yields under NT, averaged over hybrids, at Janesville to similar tillage-system yields at Sparta (Table 7, Fig. 1C–1F). The soil at Sparta was classified as a loam, while the other locations were silt-loam soils (Table 1). Griffith et al. (1973) and Al-Darby and Lowery (1986) also found most favorable NT yield responses on light-textured, well-drained soil types.

Hybrid × location, hybrid × year, and three-way interactions with tillage systems occurred for grain yield (Tables 3, 6, and 7). Generally, however, top-yielding hybrids under CT were also within the group of highest yielders under NT, within locations and years. Averaged over years and locations, hybrids with the five greatest yields under CT also had the top five yields under NT (Table 6).

Although highest-yielding hybrids were similar for both tillage systems, there was a relationship between

Table 6. Grain yields of 15 corn hybrids compared under two tillage systems for 2 yr, averaged over four locations.

		Year					
		1984		1985		Average	
Hybrid	RM†	Conv.	No-till	Conv.	No-till	Conv.	No-till
	days			Mg ha^{-1}			
Pioneer 3747	100-105	8.33 *	7.08	8.67	8.53	8.49 *	7.81
Pioneer 3732	110-115	8.24 *	7.37	8.30	8.38	8.27	7.87
FR20A × FR29	110-115	8.30 *	7.52	8.24	8.44	8.27	7.98
A632 × LH39	100-105	8.15 *	7.47	8.21	8.16	8.18	7.81
CB59G × LH38	110-115	8.11	7.74	8.20	7.76	8.16	7.75
FR20A × FR634	110-115	7.69 *	7.04	8.57 *	7.75	8.13 *	7.39
Mo17 × A634	110-115	7.83 *	6.73	8.19 *	6.85	8.01 *	6.79
A632 × LH38	110-115	7.94 *	7.01	8.06 *	6.88	8.00 *	6.95
LH38 × CM105	100-105	7.45 *	6.83	8.30	8.02	7.87 *	7.43
CM105 × LH38	100-105	7.56 *	6.97	8.01 *	7.35	7.79 *	7.16
CM105 × LH39	90-95	7.69	7.45	7.84 *	7.24	7.76	7.35
FR29 × FR23	90-95	7.56	7.15	7.56	7.85	7.56	7.50
Pioneer 3906	90-95	7.46	7.41	7.62	8.00	7.54	7.70
CB59G × W117	90-95	7.30	6.92	7.71	7.52	7.51	7.22
FR23 × CM105	90-95	7.52	7.08	7.45	7.49	7.49	7.29
Mean		7.81 *	7.19	8.06 *	7.75	7.94 *	7.47
LSD (0.05)			0.49‡			0.34§	

* Difference between tillage systems is significant at $P < 0.05$.
† RM = Relative maturity classification.
‡ Least significant difference for comparison of hybrids within tillage system and year over locations.
§ Least significant difference for comparison of hybrids within tillage system, averaged over locations and years.

Table 7. Grain yields of 15 corn hybrids for two tillage systems at four locations, conducted 2 yr.

		Location											
		Janesville			Arlington			Sparta			River Falls		
Hybrid	RM†	Conv.		No-till	Conv.		No-till	Conv.		No-till	Conv.		No-till
	days						Mg ha^{-1}						
Pioneer 3747	100-105	8.80	*	7.36	9.70		9.35	7.72		7.82	7.76	*	6.70
Pioneer 3732	110-115	8.61	*	7.51	9.54		9.36	7.18		7.94	7.73	*	6.69
FR20A × FR29	110-115	8.44		7.71	9.41		8.92	7.56		7.76	7.67		7.54
A632 × LH39	100-105	8.29	*	7.34	9.30		8.74	7.86		7.64	7.26		7.54
CB59G × LH38	110-115	8.52	*	6.92	9.47		8.97	7.71		7.51	6.92		7.60
FR20A × FR634	110-115	8.62	*	6.94	8.86		8.14	8.39		8.09	6.64		6.40
Mo17 × A634	110-115	8.51	*	6.88	9.08	*	8.25	7.71		7.44	6.74	*	4.89
A632 × LH38	110-115	8.41	*	6.37	9.05	*	8.23	7.25		7.06	7.29	*	6.13
LH38 × CM105	100-105	7.67		7.29	8.96		8.29	7.66		7.16	7.21		6.98
CM105 × LH38	100-105	7.31		7.10	8.96	*	8.06	7.61	*	6.76	7.25		6.73
CM105 × LH39	90-95	7.55		7.11	9.06		8.37	7.30		7.18	7.14		6.71
FR29 × FR23	90-95	7.61		7.22	8.67		8.62	6.72		7.14	7.23		7.03
Pioneer 3906	90-95	7.41		7.55	8.62		8.71	6.86		7.47	7.27		7.08
CB59G × W117	90-95	7.61	*	6.53	8.65		8.26	6.92	*	7.78	6.86		6.31
FR23 × CM105	90-95	7.46		6.65	8.11		8.24	7.24		7.38	7.13		6.87
Mean		8.05	*	7.10	9.03	*	8.57	7.45		7.48	7.21		6.75
LSD (0.05)		0.68‡											

* Difference between tillage systems is significant at $P < 0.05$.
† RM = Relative maturity classification.
‡ Least significant difference for comparison of hybrids within tillage system and location over years.

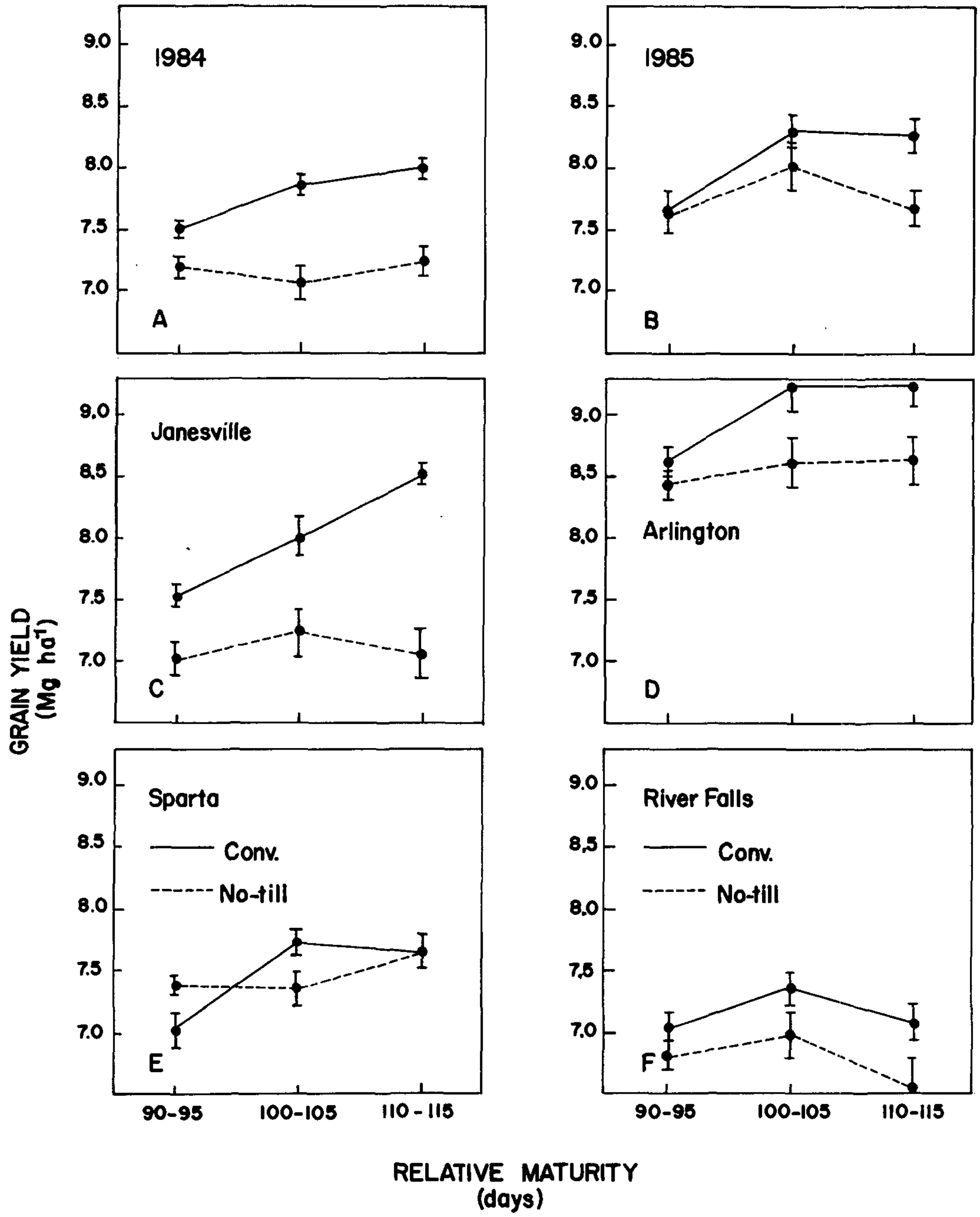

Fig. 1. Grain yields of corn hybrids in three relative maturity groups under conventional and no-tillage for 1984 (A) and 1985 (B), averaged over locations; and for Janesville (C), Arlington (D), Sparta (E), and River Falls (F), averaged over years. Bars indicate the standard error of the mean.

hybrid RM classification and the magnitude of differences between NT and CT. Hybrid treatment sums of squares for grain yield were partitioned into comparisons of hybrid groupings, based on RM classification (Table 8). Relative maturity groups accounted for 43 and 23% of the tillage system × hybrid and location × tillage system × hybrid sums of squares, respectively (Table 8). Generally, NT yields compared most favorably to CT yields with 90- to 95-day hybrids. Greater differences between tillage systems occurred with increased RM, except at the Sparta location (Fig. 1). Grain yields under CT usually increased between the 90- to 95- and 100- to 105-day classes. No-till yields were relatively unaffected by RM. At Janesville and Arlington, RM effect on tillage system response was increased compared to Sparta and River Falls (Fig. 1C–1F).

Slower growth under NT appeared to limit the yield potential of full-season hybrids by shortening the grain-filling period. At Arlington in 1984, delayed NT silking (Table 5) reduced GDD accumulated between silking and frost (earliest 0°C daily low temperature, 26 Sept.) by 30 to 40 GDD compared to CT for all RM groups. Under NT, 638 GDD accumulated after silking for 90- to 95-day hybrids, but only 619 and 591 GDD accumulated during this period for 100- and 105-day

Table 8. Sum of squares from analysis of variance for grain yield comparisons of 15 hybrids, grouped by relative maturity classification.

Source of variation	df	Sum of squares	
Hybrids (H)†	14	54.80**	
Relative maturity (RM)	2		15.85**
Remainder	12		38.95**
Tillage (T) × H	14	21.38**	
T × RM	2		9.21**
Remainder	12		12.17**
Locations (L) × H	42	40.10**	
L × RM	6		8.45**
Remainder	36		31.65**
L × T × H	42	27.20**	
L × T × RM	6		6.26**
Remainder	36		20.94*
H × Year (Y)	14	16.21**	
RM × Y	2		4.78**
Remainder	12		11.43**
T × H × Y	14	10.17*	
T × RM × Y	2		0.69
Remainder	12		9.48*
L × H × Y	42	32.49**	
L × RM × Y	6		5.72*
Remainder	36		26.77**
L × T × H × Y	42	14.99	
L × T × RM × Y	6		2.87
Remainder	36		11.62

*,** *F* test significant at the 0.05 and 0.01 probability levels, respectively.
† Hybrid relative maturity groups = 90–95 days (5 hybrids), 100–105 days (4 hybrids), and 110–115 days (6 hybrids).

and 110- to 115-day groups, respectively. In another study (Bauer and Carter, 1986) at Arlington, under CT, GDD required from silk to physiological maturity (black layer; Ritchie and Hanway, 1982) with early planting for 90- 100-, and 110-day RM hybrids were 641, 660, and 665, respectively. Nield and Seeley (1977) found that 662 GDD were required from silking to physiological maturity (black layer) for a hybrid (A632 × A619) similar in RM to those in our 110- to 115-day group. Swan et al. (1987) also showed that corn growth delay due to high surface residue cover (NT) was related to decreased grain yield when cumulative GDD were insufficient to reach physiological maturity before frost. At River Falls, less than 600 GDD accumulated between silking and frost for 100- to 115-day hybrids each year for CT and NT, which decreased yields relative to the earlier RM hybrids under both tillage systems (Fig. 1F).

There were two hybrids within both the 90- to 95- and 110- to 115-day RM groups that markedly showed the significant RM × tillage system response. However, these hybrids were not consistently within the group of superior-yielding hybrids under either tillage system. Hybrids Mo17 × A634 and A632 × LH38 (110–115-day RM) were the only hybrids with NT yields significantly lower than CT yields at three of four locations (Table 7). Over locations and years, these hybrids ranked seventh and eighth under CT, but only 15th and 14th, respectively, under NT (Table 6). In contrast, Pioneer 3906 and FR29 × FR23 (90–95-day RM) ranked 13th and 12th under CT, but sixth and seventh, respectively, under NT (Table 6). Pioneer 3906 was the only hybrid with an average yield, over locations, numerically greater for NT than CT.

These results suggest that in northern areas, superior-yielding corn hybrids under CT are likely good choices under NT. Our studies were conducted with thinned stands and adequate weed and insect control, in short-term corn-following-corn rotations. With more variable plant densities, increased pest problems, or long-term continuous NT corn production (resulting in modified soil physical and chemical properties), hybrid responses to tillage system used may be more important. Grain yield under NT was limited by delayed seasonal development, especially with full-season hybrids, and a cool spring. For corn-following-corn NT systems in northern regions, residue removal from the row-zone, to increase soil temperatures, may be required.

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