Seed Quality Effect on Corn Performance under Conventional and No-Tillage Systems

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In northern regions, no-tillage corn (*Zea mays* L.) planting often results in reduced and/or delayed seedling emergence and growth. The objective of this research was to evaluate the effects of seed quality on the performance of three commercially available corn hybrids grown with conventional-tillage (CT), no-tillage (NT), and no-tillage with in-row residue removed (NT-R). Field studies were conducted under the three tillage systems with seed lots having high (95–99%), medium (89–98%), and low (84–95%) warm and cold germination test values. Hybrids used were FR20A × FR31, LH74 × LH51, and A632 × LH39. The studies were conducted from 1986 to 1988 on Plano silt loam (fine, mixed, mesic Typic Arguidoll) soils near Arlington and Janesville, WI. There were also early (mid- to late April) and late (mid- to late May) planting dates at Arlington. Increased residue cover with NT and NT-R systems resulted in 2 to 4 °F cooler soil temperatures at planting compared to CT, which reduced average percentage corn emergence by 3%, delayed emergence by 2 to 5 d, reduced vegetative dry weight at 45 d after planting by 30 to 60%, delayed silking 5 to 7 d, and increased harvest grain moisture 1 to 5%. Average grain yields were also reduced by 9% under NT compared to CT. Compared to high quality seed, medium and/or low seed quality caused 4 to 6% lower emergence, delayed emergence less than 1 d, reduced vegetative dry weight by 10 to 15%, extended days to silking by 1 to 2 d, increased grain moisture about 1%, and decreased average grain yield by 4% (despite thinning to constant final stands). Seed quality effects were usually smaller than tillage system effects, and tillage system by seed quality interactions were infrequent. Special concern about seed quality under NT is unwarranted, but to optimize probability for high yields growers should plant high quality seed regardless of the tillage system used.

NO-TILLAGE (NT) systems for corn production are promoted for benefits including decreased soil erosion and reduced labor. However, in northern regions, increased surface residue cover at planting with NT slows soil warming, which often reduces and/or delays seedling emergence and slows crop development compared to conventional tillage (CT) (Al-Darby and Lowery, 1986; Carter and Barnett, 1987). Delaying corn planting until soils warm under NT has reduced grain yields (Imholte and Carter, 1986). Since the seed-zone environment is more stressful under NT than CT, there is concern that a higher level of seed quality may be needed to achieve stand establishment and optimum early growth under NT.

Seed quality in corn is measured by the standard germination test (Association of Official Seed Analysts, 1986) which appears on the seed tag, and by cold germination or seedling growth rate tests (Association of Official Seed Analysts, 1983). The standard germination test measures seed viability under favorable conditions, but the cold test is considered a vigor test and relates better to field emergence under a wide range of conditions (Association of Official Seed Analysts, 1983; Burris and Navratil, 1979).

In a CT system, Funk et al. (1962) found that corn plants developing from seed with low cold tests had delayed emergence, were smaller in seedling stages, had lower ear height and had reduced grain yield than seed with high cold test values. Burris (1975) observed a relationship between reduced laboratory-measured seedling vigor and reduced field emergence and/or grain yield at constant stands, but the response was variable across genotypes. Johnson and Wax (1981) reported that seedlings produced by low vigor seed had greater amounts of visible herbicide injury than plants from high vigor seed in some environments, but symptoms were usually outgrown with no adverse effects on grain yield. Reductions in yield due to low seed vigor alone without herbicide injury occurred, but these were associated with decreases in plant density.

TeKrony et al. (1989a, b) evaluated seed vigor effects under CT and NT systems in Kentucky. They found that low- and medium-vigor seed lots had lower emergence than high vigor seed lots in all tillage systems and planting dates, but there was no direct effect of seed vigor on grain yield. Corn producers using NT in the northern Corn Belt need to know whether seed quality of commercially available hybrids influences field performance. Our study was conducted to evaluate the influence of seed quality on the emergence, seasonal development, and grain yield of corn under CT, NT, and NT with in-row residue removal (NT-R) in a northern environment.

MATERIALS AND METHODS

Seed lots of three commonly grown hybrids [LH74 × LH51, 110-d relative maturity (RM); and FR20A × FR31 and A632 × LH39, 100-d RM] were solicited from several seed companies for laboratory analysis prior to beginning field studies in 1986. A minimum of 20 lots per hybrid were obtained and evaluated. Seed lots had been conditioned and treated with captan by the seed firms.

In 1987 and 1988, cold-germination tests were conducted according to the rolled towel procedures described in the *Seed Vigor Testing Handbook*

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Table 1. Cold and warm germination percentage of seed lots used in 1986, 1987, and 1988 field studies.

Hybrid	Seed quality level	Germination tests Cold 1986	Cold 1987	Cold 1988	Warm 1986	Warm 1987	Warm 1988
		%					
LH74 × LH51	High	–	95.0	95.0	95.0	96.5	98.0
	Medium	–	89.0	87.4	90.5	93.5	95.4
	Low	–	86.5	85.4	84.0	90.0	91.6
FR20A × FR31 (1986)	High	–	98.5	95.5	97.5	98.5	96.4
A632 × LH39	Medium	–	95.0	92.0	92.0	98.0	95.0
(1987 and 1988)	Low	–	92.0	89.5	84.0	94.5	91.9

(Association of Official Seed Analysts, 1983), using Wisconsin Crop Improvement Association facilities and modifications (Hoppe, 1955). In the cold-germination test, four replicates of 50-kernel samples of each seed lot were placed on two paper towels that had been soaked in cold water and covered with saturated, high organic matter peat soil collected from a corn field. A third wet towel was placed over the seeds and soil, and towels were rolled and placed on end in an aluminum box. Boxes were placed in a germination chamber at 50 °F for 7 d and then moved to a chamber at 78 °F for 4 d. Nonviable, abnormal- and normal-germinated seedlings were then counted, using Association of Official Seed Analysts rules for seedling evaluation (Association of Official Seed Analysts, 1986). Warm-germination tests were conducted in 1986 to 1988 according to AOSA rules (Association of Official Seed Analysts, 1986), except that only four replicates of 50-kernel samples of the seed lots were evaluated. For both cold- and warm-germination tests, there was no addition of light, and daily temperatures were constant.

Seed lots of each hybrid were selected for field research on the basis of warm germination in 1986 and warm- and cold-germination test characteristics in 1987 and 1988. These included three lots each of LH74 × LH51 and FR20A × FR31 in 1986 and three different lots of LH74 × LH51 and A632 × LH39 in 1987 with similar seed size/shape (medium-flat) and relatively high, medium, and low warm and/or cold germination (Table 1). Seed lots used in 1986 were not saved; therefore new seed lots were solicited in 1987. Seed not planted in 1987 was stored under controlled temperature and relative humidity (50 °F and 50%), and cold- and warm-germination tests were repeated before planting the same lots in 1988 (Table 1).

Field studies were conducted at Arlington and Janesville, WI on Plano silt loam soils in 1986 through 1988 on sites that had been in corn production the previous several years. Seed quality levels were evaluated under CT, NT, and NT-R systems at Arlington, and under CT and NT at Janesville. There were two dates of planting at Arlington: 24 Apr. 1986, 27 Apr. 1987, and 18 Apr. 1988 (early) and 21 May 1986, 26 May 1987, and 12 May 1988 (late). At Janesville, the planting dates were 26 Apr. 1986, 28 Apr. 1987, and 2 May 1988.

At both locations, CT consisted of fall moldboard plowing to a depth of 7 in., and disking once or twice prior to planting. No-tillage corn was planted 2 in. to the side of the previous year's corn row directly into unincorporated corn residue with only a 1-in band disturbed for seed placement. At Arlington in 1986, the NT-R treatment was accomplished by manually removing a 6-in. band of residue from over the row after planting. In 1987 and 1988 an 8-in. band of residue over the row was cleared with notched, double-disk row furrow openers (Orthman Manufacturing, Inc., Lexington, NE) mounted on the planter. Corn was planted at the rate of 44 500 kernels/acre using cone-seeders on a four-row, no-till corn planter (Kinze Manufacturing Inc., Williamsburg, IA) equipped with rippled coulters, heavy-duty down-pressure springs, double-disk openers, and cast-iron press wheels. For the NT-R treatment at Arlington in 1987 and 1988, rippled coulters were removed and replaced with row-clearing units.

At Arlington, averages of annual soil tests indicated a pH of 6.3, 143 lb/acre P, and 425 lb/acre K. Plots received yearly applications of 9-17-30 lb/acre of N-P-K as row-applied starter fertilizer at planting, and 200 lb/acre of N supplied as ammonium nitrate broadcast over the entire area prior to planting. Terbufos was banded at planting at a rate of 1.05 lb a.i./acre for corn rootworm (*Diabrotica* spp.) control. Pre-emergence applications of atrazine and metolachlor both at 3 lb a.i./acre were applied in 1986 and 1987 for annual weed control and metolachlor and cyanazine at 3 (metolachlor) and 2 (cyanazine) lb a.i./acre were applied in 1988. Fenvalerate was applied at a rate of 0.05 lb a.i./acre at silking in 1988 to prevent silk feeding by corn rootworm beetles. Soil tests at Janesville taken in 1986 indicated a pH of 6.5, 135 lb/acre P, and 405 lb/acre K. All plots received yearly applications of 225 lb/acre of N supplied as urea-ammonium nitrate side-dressed post emergence. Applications of starter fertilizer, herbicides, and insecticides were similar to those at Arlington, except that chemical corn rootworm beetle control was not applied. Also, in 1988 plots were row cultivated, due to lack of adequate chemical weed control.

The experimental design was a randomized complete block design in a split-plot arrangement with three replicates at Janesville and a split-split plot with four replicates at Arlington. At Arlington, tillage systems were main plots and planting dates were subplots. Seed-quality levels and hybrids were assigned to sub-sub-plots in a random arrangement. At Janesville, tillage systems were main plots and sub-plots were a random arrangement of seed-quality levels and hybrids. Sub-sub-plots at Arlington were four, 30-in. wide by 25-ft long rows, while at Janesville sub-plots were four, 30-in. wide by 30-ft long rows. Planting dates, hybrids, and seed quality levels were randomized in 1986 and rerandomized in 1987 and 1988. Tillage systems at Arlington were initiated and randomized in 1986 and remained in the same position during succeeding years. At Janesville, tillage sys-

Table 2. Precipitation and mean air temperature for the 1986 to 1988 growing seasons at Arlington and Janesville.

	Arlington			Janesville		
Month	1986	1987	1988	1986	1987	1988
			Temperature			
			°F			
May	59.0(+1.6)†	60.7(+2.9)	62.6(+4.8)	61.5(+1.2)	63.9(+3.6)	61.6(+1.3)
June	66.2(−0.2)	70.7(+4.0)	71.6(+4.9)	68.9(−0.8)	66.3(−3.4)	70.2(+0.5)
July	71.7(+0.5)	74.5(+3.5)	75.0(+4.0)	74.9(+1.0)	73.2(−0.6)	75.4(+1.6)
August	64.1(−5.0)	68.5(−0.4)	74.7(+5.8)	67.0(−4.8)	68.8(−3.1)	74.4(+2.5)
September	61.7(+0.8)	61.7(+0.8)	64.4(+3.5)	63.4(−0.5)	64.7(+0.8)	63.6(−0.3)
Season mean	64.5(−0.5)	67.2(+2.2)	69.7(+4.6)	67.1(−0.8)	67.4(−0.5)	69.0(+1.1)
			Precipitation			
			in.			
May	2.1(−1.1)	4.7(+1.6)	1.0(−2.2)	3.6(+0.4)	3.4(+0.2)	1.0(−2.2)
June	4.2(+0.1)	0.6(−3.5)	1.5(−2.6)	2.9(−1.1)	1.6(−2.4)	1.2(−2.8)
July	4.6(+1.1)	4.0(+0.5)	1.6(−2.0)	3.8(−0.3)	3.4(−0.7)	1.3(−2.8)
August	4.9(+0.9)	4.9(+0.9)	2.9(−1.2)	2.7(−1.1)	5.7(+1.9)	4.2(+0.4)
September	10.7(+7.1)	4.9(+1.3)	3.9(+0.3)	8.4(+5.0)	1.8(−1.6)	3.4(0)
Season total	26.5(+8.1)	19.1(+0.8)	10.9(−7.7)	21.4(+2.9)	15.9(−2.6)	11.1(−14.8)

† Number in parentheses indicates the deviation from the long-term average.

Table 3. Main effects and significance of two-way interactions for tillage systems (T), planting date (D), and hybrid (H) for corn growth and yield for three growing seasons at Arlington. Main effect values are averages of three seed quality levels and the other two main effects.

	Tillage system (T)†			LSD	Planting date (D)‡		Hybrid (H)§					
	CT	NT-R	NT	(0.05)	Early	Late	A	B	T × D	T × H	D × H	CV
										$P > F$¶		%
1986												
Soil temperature (°F)#	66.9	65.3	63.3	0.3	62.8*	67.6			NS			1.2
Emergence (%)	84.7	84.6	83.6	NS	84.5	84.2	83.7	85.0	NS	NS	NS	6.0
Days to 75% emergence	10.8	11.6	13.4	0.6	14.7*	9.2	11.6*	12.3	0.04	NS	NS	5.9
Vegetative dry weight (oz/10 plants)	2.4	1.8	1.4	0.3	1.9	1.8	1.8*	1.9	<0.01	NS	NS	22.4
Days to 50% silking	76.4	77.7	79.2	0.7	86.2*	69.3	79.3*	76.3	<0.01	0.04	NS	1.1
Mature plant height (in.)	90.9	91.7	91.7	NS	88.2*	94.5	93.7*	89.0	NS	NS	0.03	2.8
Final stand (plants/acre × 1000)	20.1	20.0	20.1	NS	20.0	20.2	20.1	20.0	NS	NS	NS	3.4
Grain moisture (%)	23.4	23.9	24.3	0.6	21.5*	26.3	25.4*	22.4	0.05	NS	NS	4.0
Grain yield (bu/acre)	183	172	167	7	186*	162	184*	164	NS	NS	0.01	5.4
1987												
Residue cover (%)	4	75	85	3	54	55			NS			9.7
Soil temperature (°F)	69.8	66.2	66.2	0.5	59.5*	76.5			NS			2.4
Emergence (%)	86.8	85.4	85.0	NS	91.2*	80.2	85.3	86.1	NS	0.02	<0.01	6.3
Days to 75% emergence	10.1	14.6	14.3	0.7	17.5*	8.5	12.9*	13.2	<0.01	NS	NS	6.6
Vegetative dry weight (oz/10 plants)	3.7	2.0	1.9	0.3	2.1*	2.9	2.5	2.6	NS	NS	NS	21.0
Days to 50% sillking	69.3	73.7	74.5	1.5	79.1*	65.9	73.8*	71.2	NS	0.05	NS	2.6
Mature plant height (in.)	72.4	75.2	74.8	NS	72.8*	75.6	76.4*	72.0	NS	NS	NS	3.1
Final stand (plants/acre × 1000)	23.3	23.5	23.5	NS	23.7*	23.2	23.8*	23.1	NS	NS	NS	4.2
Grain moisture (%)	25.5	29.3	30.5	1.4	22.3*	34.4	31.5*	25.3	<0.01	NS	<0.01	7.5
Grain yield (bu/acre)	129	122	116	NS	136*	108	134*	110	0.03	NS	<0.01	10.4
1988												
Residue cover (%)	6	56	81	8	49	46			NS			14.2
Soil temperature (°F)	65.7	65.3	61.9	0.6	54.1*	74.5			NS			2.6
Emergence (%)	88.7	81.9	78.9	10.9	78.6*	87.7	77.8*	88.5	NS	NS	<0.01	7.7
Days to 75% emergence	14.9	18.2	19.9	2.7	25.5*	9.8	17.3*	18.0	<0.01	NS	NS	6.8
Vegetative dry weight (oz/10 plants)	2.4	0.9	0.7	0.7	1.2*	1.5	1.3	1.3	<0.01	<0.01	NS	18.2
Days to 50% silking	80.2	90.5	93.9	3.1	97.3*	79.0	89.6*	86.8	NS	<0.01	NS	2.6
Mature plant height (in.)	76.4	74.0	74.4	NS	72.8*	77.1	76.4*	73.6	<0.01	<0.01	<0.01	5.6
Final stand (plants/acre × 1000)	24.6	23.8	23.6	NS	23.7*	24.4	24.0	24.0	NS	0.03	NS	4.9
Grain moisture (%)	23.3	28.5	32.7	5.3	27.9	28.4	29.5*	26.8	NS	<0.01	<0.01	7.2
Grain yield (bu/acre)	62	64	57	NS	59	63	69 *	53	NS	NS	0.03	18.7

* Differences betwen planting dates or hybrids are significant at $P < 0.05$.

† CT = conventional tillage; NT = no-tillage; and NT-R = no-tillage with in-row residue removed.

‡ Early = 24 Apr. 1986, 27 Apr. 1987, and 18 Apr. 1988; late = 21 May 1986, 26 May 1987, and 13 May 1988.

§ A = LH74 × LH51 (1986–1988); B = FR20A × FR31 (1986) and A632 × LH39 (1987 and 1988).

¶ P values for the two-way interactions of tillage system (T) × planting date (D), tillage system (T) × hybrid (H), or planting date (D) × hybrid (H).

Midday, in-row soil temperature at planting depth (2 in.) averaged over 7 d following planting.

tems were initiated in 1984 as part of a long-term study, and remained in the same position for the duration of the seed-quality study.

Mid-day in-row soil temperatures at a 2-in. depth were recorded daily for each tillage system all 3 yr at Arlington from planting to 30 d after planting and in 1987 and 1988 at planting at Janesville. Residue cover percentage was measured prior to emergence at both sites in 1987 and 1988 using the line intersect method (Dickey et al., 1986). At Arlington, emerged seedlings were recorded daily until plant number stabilized. Days-to-emergence was computed as days after planting until 75% of final emergence. At both locations, percentage emergence was determined as the number of seedlings emerged as a percentage of kernels planted.

When corn under CT reached the V6 stage (Ritchie et al., 1986), plots were hand-thinned to constant densities ranging from 22 000 to 26 000 plants/acre in different years or locations. In order to minimize bias in selecting plants for thinning, plants were removed along the entire row such that spacing within the row of remaining plants was nearly uniform. Therefore, the decision to remove a particular plant was based on maximizing uniformity of within-row plant spacing, and not on plant appearance or size. At thinning, 10 plants were randomly selected from each plot, harvested at ground level, and dried in a forced-air oven to determine vegetative dry weight. Days from planting to silking, defined as the date when 50% of the plants had emerged silks, were recorded at Arlington.

Final stand (plants/acre), and mature plant height (inches to the flag leaf collar) were determined at harvest. Plots were harvested with a two-row plot combine and grain moisture percentage and grain yield were measured for the two center rows of each plot. Grain yields were converted to bushels/acre at 15.5% moisture. Harvest dates were 3 Nov. 1986, 12 Oct. 1987 and 3 Oct. 1988 at Arlington and 20 Oct. 1986, and 6 Oct. 1987 and 1988 at Janesville.

Analyses of variance were computed for data from each location and year. In the analysis, all effects except replicates were considered fixed.

RESULTS AND DISCUSSION

The range in warm- and cold-germination test values for high, medium, and low-seed quality levels was relatively small (Table 1). In 1987 and 1988, warm- and cold-germination tests were generally correlated, with cold germination 0 to 3% lower than warm germination for high quality seed, and 2.5 to 8% lower for medium and low quality levels. Seed lots of hybrid FR20A × FR31, used only in 1986, had the largest range in warm-germination values, while A632 × LH39 used in 1987 and 1988, had the smallest range (Table 1). The range in warm and cold germination between quality levels was intermediate for seed lots of LH74 × LH51. The range in cold-germination test values of seed evaluated by TeKrony et al. (1989a) and Johnson and Wax (1981) was greater than in our studies, due to much lower cold-test values for their low quality seed lots. Although an industry standard for cold- and warm-germination test levels does not exist and cold-test methods vary, low quality seed lots of both hybrids in 1986 in our studies (Table 1) would probably not have been marketed by seed companies due to low warm-germination tests (E. Amberson, 1989, personal communication). However, all other seed lots used in 1986, 1987, and 1988 (Table 1) would likely have been commercially available.

The combination of near-average air temperatures and adequate to excessive rainfall in 1986 at Arlington and Janesville (Table 2) resulted in high grain yields (Tables 3 and 4). Temperature and precipitation in 1987 at both locations were generally similar to long-term averages except for a low-rainfall period in June (Table 2). In contrast to the 2 preceding years, 1988 was characterized by above-average temperatures and below-normal precipitation. The resulting drought decreased grain yields at both locations, but the reduction was greater at Arlington (Tables 3 and 4).

Tillage, planting date, and hybrid main effects and interactions were similar to results from previous northern Corn Belt studies with continuous corn on silt loam soils (Tables 3 and 4) (Al-Darby and Lowery, 1986; Carter and Barnett, 1987; Hesterman et al., 1988; Imholte and Carter, 1987). In-row residue cover and cool soil temperatures under NT delayed corn growth and often lowered grain yields. Residue cover removal from the row area for NT-R at Arlington increased soil temperature after planting compared to NT in 1986 and 1988, and generally resulted in plant development rates which were intermediate between those for CT and NT (Table 3). Grain yields were not significantly increased for NT-R compared to NT, although NT-R yields were higher each year. Kasper et al. (1985) and Vyn (1986) increased in-row soil temperature, crop growth rates, and grain yield by creating residue-free strips over corn rows.

Late planting at Arlington resulted in warmer soil, and more rapid plant growth than with early planting (Table 3). Yield reductions due to delayed planting occurred in 1986 and 1987. The later-RM hybrid LH74 × LH51 usually yielded more grain than the early maturity hybrid (Tables 3 and 4).

Although tillage system by planting date interactions occurred for several parameters at Arlington (Table 3), planting dates resulting in greatest yields were the same for both tillage systems. Hybrid interactions with tillage system also occurred for several growth factors at Arlington (Table 3), but responses were inconsistent and tillage system by hybrid interactions for grain yield did not occur at either location (Tables 3 and 4). Kaspar et al. (1987) also reported that tillage system by hybrid interactions for early-season growth were not reflected in similar interactions for grain yield.

Differences in percentage emergence between seed quality levels occurred in four of the six location-years (Tables 5 and 6). In most cases the lowest emergence

Table 4. Main effects and significance of two-way interactions for tillage system (T) and hybrid (H) for corn growth and yield for three growing seasons at Janesville. Main effect values are averages of three seed quality levels and the other main effect.

	Tillage system (T)†		Hybrid (H)‡			
	CT	NT	A	B	T × H	CV
					$P >$ F§	%
1986						
Emergence (%)	84.8*	78.2	80.6	82.4	NS	7.3
Vegetative dry weight (oz/10 plants)	1.8*	1.0	1.3	1.4	NS	20.6
Mature plant height (in.)	91.3	92.1	94.1*	89.7	NS	2.5
Final stand (plants/acre × 1000)	24.1	23.4	23.8	23.7	NS	3.0
Grain moisture (%)	24.7*	26.5	27.0*	24.2	NS	4.2
Grain yield (bu/acre)	186*	163	183*	166	NS	8.0
1987						
Residue cover (%)	2*	82				11.7
Soil temperature (°F)¶	73.4*	69.9				2.1
Emergence (%)	87.4	87.3	85.5*	89.2	NS	7.4
Vegetative dry weight (oz/10 plants)	1.7	1.6	1.2*	2.0	NS	20.7
Mature plant height (in.)	76.0	75.6	74.0*	77.5	NS	5.2
Final stand (plants/acre × 1000)	23.4*	23.8	23.6*	23.6	NS	3.7
Grain moisture (%)	23.4	23.2	24.3*	22.3	NS	10.3
Grain yield (bu/acre)	130	127	123	136	NS	21.2
1988						
Residue cover (%)	3*	68				21.6
Soil temperature (°F)	65.7*	58.9				7.3
Emergence (%)	88.0	87.4	86.1*	89.2	NS	5.1
Vegetative dry weight (oz/10 plants)	1.9*	0.7	1.3	1.3	NS	19.3
Mature plant height (in.)	73.2*	81.9	81.5*	73.6	NS	4.3
Final stand (plants/acre × 1000)	24.4	26.0	25.2	25.8	NS	5.2
Grain moisture (%)	23.2*	29.4	28.5*	24.1	NS	7.1
Grain yield (bu/acre)	117	112	131*	97	NS	11.2

* Difference between tillage systems or hybrids is significant at $P < 0.05$.

† CT = conventional tillage; and NT = no-tillage.

‡ A = LH74 × LH51 (1986-1988); B = FR20A × FR31 (1986) and A632 × LH39 (1987 and 1988).

§ P value for tillage system (T) × hybrid (H) interaction.

¶ Midday, in-row soil temperature, 2-in. depth, at planting.

occurred for low quality seed, with intermediate values for seed with medium quality. An exception occurred at Arlington in 1988, where medium quality seed had the lowest emergence (Table 5). Averaged over the location-years in which differences occurred, field emergence was 4 and 6% lower for medium and low, respectively, compared to high quality seed. Seed quality by hybrid interactions occurred in 1987 and 1988 at Arlington (Table 5), due to no influence of seed quality on emergence for A632 × LH39, but an average 8% decrease in emergence with LH74 × LH51 for medium and low vs. high quality seed (data not shown). The warm- and cold-germination test range from high to low seed quality was also less for A632 × LH39 than for LH74 × LH51 (Table 2). A seed quality by planting date interaction for percentage emergence also occurred at Arlington in 1988 (Table 5). With early planting, field emergence was decreased with medium and low quality seed, but differences between seed quality levels did not occur at the late planting date (Table 7).

Small growth delays from emergence to maturity often occurred with medium and/or low quality seed. Emergence date at Arlington was generally less than 1 d later with medium and/or low quality seed than for high quality seed (Tables 5 and 7) except for early planting in 1987, when differences did not occur (Table 7). Seed quality-induced differences in vegetative dry weight occurred at Arlington in 1986 and 1987 (Table 5) and Janesville in 1987 (Table 6). For silking date, seed quality had an influence all 3 yr at Arlington (Table 5). Silking averaged 0.5 and 1 d later for plants from medium and low, respectively, compared to high quality seed in 1986 and 1987. In 1988, delays were 1.6 (medium seed quality) and 2.8 (low-seed quality) d with early planting, but seed quality level did not influence silking date with late planting (Table 7). Grain moisture differences between seed quality levels occurred in 1987 and 1988 at Arlington (Table 5) with increased grain moisture for plants from low quality seed.

For grain yield, differences due to seed quality main effects (1986) or two-way interactions of seed quality with planting date (1987 and 1988) occurred at Arlington (Tables 5 and 7). In 1986 at Arlington, grain yields produced from medium and low quality seed were about 3% less than yields from high quality seed (Table 6). The yield reduction with low quality seed may have been related to slightly decreased final stand, but stands with medium quality seed were not different from those with high quality seed. In 1987 at Arlington, seed quality did not influence grain yield with early planting, but with late-planting yield produced from low quality seed was reduced about 10% compared to high or medium quality seed (Table 7). In 1988, grain yield with early planting and use of medium and low quality seed was about 11% lower than that obtained with high quality seed, but yields were similar among seed quality levels with late planting (Table 7).

At Janesville, grain yield was not influenced by seed quality in 1986 and 1988, but in 1987, there was a seed quality by hybrid interaction for grain yield (Table 8). For LH74 × LH51, yields were 19% lower for plants from low compared to high quality seed, but yields with medium and high quality seed were not different (data not shown). With A632 × LH39, yields were similar with high and low quality seed, but medium quality seed produced 28% lower yields than yields from high quality seed.

The reason for the inconsistent seed quality effect on grain yield at Arlington compared to Janesville is not clear. At Arlington, greatest seed quality effects on grain yield occurred in environments in which unusual stress was present during emergence. These included soil crusting following late planting at Arlington in 1987, and after early planting in 1988 when cold soil temperatures resulted in an average of more than 25 d to emergence (Tables 3, 5, and 7).

The primary objective of this research was to assess whether the increased stress under conservation tillage

Table 5. Seed quality (Q) main effects and significance of two-way interactions with hybrid (H), planting date (D), and tillage systems (T) for corn growth and grain yield for three growing seasons at Arlington. Main effect values are averages of three tillage systems, two planting dates, and two hybrids.

	Seed quality (Q)						
	High	Medium	Low	LSD(0.05)	Q × H	Q × H	Q × T
					P > F†		
1986							
Emergence (%)	87.9	85.9	79.3	2.1	NS	NS	NS
Days to 75% emergence	11.7	11.9	12.1	0.3	NS	NS	<0.01
Vegetative dry weight (oz/10 plants)	2.0	1.8	1.7	0.2	NS	NS	NS
Days to 50% silking	77.3	77.8	78.2	0.3	<0.01	NS	NS
Mature plant height (in.)	91.3	90.9	92.1	NS	0.05	NS	NS
Final stand (plants/acre × 1000)	20.3	20.1	19.9	0.3	NS	NS	NS
Grain moisture (%)	23.9	23.8	24.0	NS	NS	NS	NS
Grain yield (bu/acre)	178	172	172	4	NS	NS	NS
1987							
Emergence (%)	88.2	85.0	83.9	2.2	<0.01	NS	NS
Days to 75% emergence	12.9	13.0	13.2	NS	NS	0.05	NS
Vegetative dry weight (oz/10 plants)	2.7	2.6	2.4	0.2	NS	0.03	NS
Days to 50% silking	72.0	72.5	73.0	0.8	NS	NS	NS
Mature plant height (in.)	74.4	74.4	74.0	NS	NS	NS	0.02
Final stand (plants/acre × 1000)	23.5	23.4	23.4	NS	NS	NS	NS
Grain moisture (%)	28.0	28.0	29.3	0.9	<0.01	NS	NS
Grain yield (bu/acre)	125	122	119	NS	NS	0.01	NS
1988							
Emergence (%)	85.6	80.1	83.7	2.6	<0.01	<0.01	NS
Days to 75% emergence	17.2	18.0	17.8	0.5	NS	NS	NS
Vegetative dry weight (oz/10 plants)	1.4	1.3	1.3	NS	NS	NS	NS
Days to 50% silking	87.6	88.0	89.0	0.9	NS	0.02	NS
Mature plant weight (in.)	74.0	75.6	75.2	NS	NS	NS	NS
Final stand (plants/acre × 1000)	24.1	23.9	24.1	NS	NS	NS	NS
Grain moisture (%)	27.5	27.9	29.1	0.8	<0.01	NS	NS
Grain yield (bu/acre)	62	61	60	NS	NS	0.05	NS

† P values for seed quality (Q) × hybrid (H), seed quality (Q) × planting date (D), and seed quality (Q) × tillage system (T) interactions.

Table 6. Seed quality (Q) main effects and significance of two-way interactions with hybrid (H), and tillage system (T) for corn growth and grain yield for three growing seasons at Janesville. Main effect values are averages of two tillage systems and two hybrids.

	Seed quality (Q)					
	High	Medium	Low	LSD(0.05)	Q × H	Q × T
					P > *F*†	
1986						
Emergence (%)	86.2	80.7	77.6	5.2	NS	NS
Vegetative dry weight (oz/10 plants)	1.5	1.4	1.3	NS	0.01	NS
Mature plant height (in.)	92.1	91.7	91.7	NS	NS	NS
Final stand (plants/acre × 1000)	23.8	23.8	23.7	NS	NS	NS
Grain moisture (%)	25.4	26.0	25.5	NS	NS	NS
Grain yield (bu/acre)	170	172	181	NS	NS	NS
1987						
Emergence (%)	89.2	86.5	86.4	NS	NS	NS
Vegetative dry weight (oz/10 plants)	1.9	1.4	1.6	0.3	<0.01	NS
Mature plant height (in.)	76.7	74.8	75.6	NS	0.04	NS
Final stand (plants/acre × 1000)	24.1	23.8	22.8	0.7	NS	NS
Grain moisture (%)	22.8	23.8	23.3	NS	NS	NS
Grain yield (bu/acre)	143	121	122	NS	0.05	NS
1988						
Emergence (%)	89.4	87.2	86.4	NS	NS	NS
Vegetative dry weight (oz/10 plants)	1.3	1.3	1.2	NS	NS	NS
Mature plant height (in.)	78.7	76.8	77.5	NS	NS	NS
Final stand (plants/acre × 1000)	26.1	25.3	25.7	NS	NS	NS
Grain moisture (%)	25.6	26.1	27.2	NS	NS	NS
Grain yield (bu/acre)	116	111	115	NS	NS	NS

† *P* values for seed quality (Q) × hybrid (H), and seed quality (Q) × tillage system (T) interactions.

systems would increase the sensitivity of corn to seed quality. We did observe general delayed growth and reduced grain yield under NT and NT-R compared to CT. There was also an apparent relationship between medium and/or low seed quality and delayed seasonal growth and reduced grain yield. However, seed quality

Table 7. Means for significant seed quality (Q) × planting date (D) interactions at Arlington in 1987 and 1988. Values are averages of three tillage systems and two hybrids.

	Planting date						
	Early planting			Late planting†			
	High‡	Medium	Low	High	Medium	Low	LSD(0.05)§
1987							
Days to 75% emergence	17.3	17.8	17.5	8.4	8.3	8.9	0.5
Vegetative dry weight (oz/10 plants)	2.3	2.0	2.1	3.1	3.1	2.6	0.3
Grain yield (bu/acre)	138	132	137	111	113	101	7
1988							
Emergence (%)	83.8	71.8	80.2	87.5	88.4	87.2	3.6
Days to 50% silking	96.0	97.2	98.8	79.1	78.9	79.1	1.3
Grain yield (bu/acre)	63	56	57	61	65	63	7

† Early = 27 April 1987 and 18 April 1988; late = 26 May 1987 and 13 May 1988.

‡ High, medium, and low seed quality levels based on warm- and cold-germination test values (see Table 1).

§ LSD for comparing seed-quality levels within each planting date.

had less influence on corn performance than tillage systems, and tillage system by seed quality interactions were not important for growth or yield.

Percentage emergence was the only growth factor measured for which the influence of seed quality was equal to or greater than that for tillage systems. Average emergence over locations and years was about 3% lower under NT compared to CT, and emergence averaged nearly 5% lower for low- vs. high-quality seed. At constant final stands due to thinning, grain yields averaged 9% lower under NT than for CT, but average yields were reduced only 4% for low compared to high seed quality.

INTERPRETIVE SUMMARY

Corn producers are encouraged to adopt NT to reduce labor and soil erosion. However, in northern regions NT planting in continuous corn systems results in delayed emergence and growth, due to colder seed-zone soil temperatures compared to CT. This study was conducted to determine whether or not corn performance under NT was influenced by seed quality. We thought that relatively low quality seed might be less productive under increased stress with NT; and if so, corn growers using NT might need a higher level of seed quality than used for CT systems.

Both NT and low seed quality reduced average percentage emergence by 3 to 5% compared to CT and high seed quality. Although the reduction in emergence due to low seed quality was similar under NT and CT, the combined effects of NT and low seed quality reduced emergence by nearly 10% compared to use of CT and high quality seed. This did not influence yields in our studies, due to overplanting and thinning to constant stands. But growers using NT with seed similar to our low-quality seed would need to increase seeding rates to avoid stand reductions.

At constant final stands, corn growth and yield were delayed and reduced both by NT vs. CT and low vs. high quality seed, but NT had a greater negative influence on corn performance than did low-seed quality. For the range in seed quality evaluated, our results suggest that no major need exists for increased concern about seed quality for those using NT. But these studies do indicate that to optimize probability for high yields, growers should plant relatively high-quality seed regardless of the tillage system used.

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