Reprinted from *Agronomy Journal*
Vol. 77, July-August 1985

#145

Hybrid and Irrigation Effects on Conservation Tillage Corn in the Coastal Plain[1]

D. L. Karlen and R. E. Sojka[2]

ABSTRACT

Conservation tillage (CT) can reduce soil erosion loss, but to be voluntarily implemented, corn (*Zea mays* L.) yield must not be reduced when compared with conventional tillage practices such as disking periodically (DP). We compared CT and DP treatments with and without irrigation on Norfolk (fine-loamy, siliceous, thermic Typic Paleudults) sandy loam for 4 yr to determine if hybrid selection, water management, or soil temperature caused CT corn yields to be lower than where DP was used for seedbed preparation. Plant emergence and early season growth were consistently more rapid and uniform with DP than with CT. Water was conserved in CT treatments, but this increased grain yield only under nonirrigated conditions in 1981. Average daily soil temperature for 14 days after planting was 19 °C for both tillage systems and 22 or 24 °C for CT and DP treatments for days 15 to 28. When averaged for 28 days after planting, soil temperatures in CT treatments were 0.5 °C less at 0800 h and 1.1 °C less at 1500 h. Those soil temperature differences do not appear to be sufficient to cause slower, nonuniform emergence, growth, and generally lower corn grain yield when CT practices are used in this region, although maximum yield potential for corn appears to be physiologically initiated very early during the growing season. Therefore, a successful conservation tillage system must promote rapid, uniform germination, and emergence of all plants.

Additional index words: Soil temperature, Irrigation, Nutrient accumulation, *Zea mays* L.

DEVELOPMENT of management systems which reduce soil erosion losses by implementing conservation tillage (CT) has been identified as high priority research (6,11). In the southeastern Atlantic Coastal Plain (ACP), plot- and production-scale research has shown that growing corn (*Zea mays* L.) using CT practices requires a higher level of management to produce yields equivalent to those using conventional tillage practices such as disking periodically (DP) (3). This occurs because of a relatively flat topography and greater rainfall. Also, water conservation associated with reduced tillage is less important than in areas where topography is rolling (8). Physical factors that impede plant root development; lower water and nutrient retention; and higher disease, weed, insect, and nematode pressures associated with a more humid climate may also reduce the competitive advantage for CT in the ACP.

Variations in germplasm can influence many plant growth and development factors, and because our previous CT corn research (3) was limited to two hybrids (Pioneer 3369A and Pioneer 3382), effects of hybrid variation were unknown. Brakke et al. (2) stated that broad hybrid adaptation is one goal for plant breeders, but found this to be very difficult when potential yield levels differed significantly because of water, tillage, or other variables. They concluded that for maximum corn yield in Nebraska, specific cultivars adapted to distinct environments associated with each cropping system should be developed. Wall and Stobbe (13) also suggested a screening program for detecting corn hybrids suitable for zero-tillage in Manitoba, because all eight hybrids that they evaluated responded to the amount of tillage used in seedbed preparation. They found delayed emergence, silking, and maturity; reduced plant dry weight; and lower grain weight per ear when the hybrids were grown without tillage. Reduced soil temperature presumably caused those phenological delays and reduced yield because previous research had shown that soil temperature significantly influenced corn growth and development (1,7,12). In the ACP, however, reduced soil temperatures associated with CT may not be as critical as in more northern latitudes because of the longer growing season. This hypothesis is supported by Allmaras et al. (1) who reported that, in general, corn growth in northern latitudes showed a negative response to lower soil temperature, but in southern latitudes there was either no response or a positive response when soil temperature at the 10-cm depth was lower.

Water shortages frequently limit corn grain yields in the ACP despite an average annual precipitation that exceeds 1100 mm. This occurs because of erratic rainfall distribution and because the coarse, sandy-textured soils have low water holding capacities. Previous ACP conservation tillage research did show water conservation (3), but it was not sufficient to overcome other yield limiting factors. Therefore, our objectives were to evaluate growth, nutrient status, and yield of selected corn hybrids grown with or without supplemental irrigation on a Typic Paleudult soil using either DP or CT practices.

METHODS AND MATERIALS

Conventional (disked [DP]) and conservation (nondisked [CT]) tillage systems for corn production were established on a Norfolk (fine-loamy, siliceous, thermic Typic Paleudult) sandy loam near Florence, SC. Tillage blocks were 23 m wide and 26 m long. Five replicates of each tillage system were evaluated with and without supplemental irrigation in a stripped split-plot experimental design. In 1981 and 1982, five subplots (4.6 m wide) were used to evaluate 'Coker 21,[3] 'DeKalb-Pfizer XL71,' 'Northrup-King PX74,' 'Pioneer 3382,' and 'Ring Around 1502' corn hybrids. Those entries were chosen because of previous good performance in Clemson University variety trials (14). In 1983, Pioneer 3382 and in 1984 McCurdy 84AA hybrids were evaluated in two subplots. The remaining three subplots were used for nematicide, fertilizer, plant population, or row spacing evaluations (D.L. Karlen, 1983 and 1984, unpublished data). Analysis of variance (ANOVA) was computed as outlined in Table 1 with least significant difference (LSD) and coefficient of variation (CV) calculated with appropriate error terms for each parameter (10).

[1] Contribution of the Coastal Plains Soil and Water Conserv. Res. Center, USDA-ARS, Florence, SC, in cooperation with the South Carolina Agric. Exp. Stn., Clemson Univ., Clemson, SC.
[2] Soil scientists. Received 29 Nov. 1984.

Published in *Agron. J.* 77:561–567 (1985).

[3] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or the South Carolina Agric. Exp. Stn. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Table 1. Analysis of variance table used to evaluate tillage system, water management, and corn hybrid effects in a stripped split-plot experimental design.

Source of variation	df
Blocks	
Tillage system, factor A	
Error (a)	
Water management, factor B	
Error (b)	
Interaction, AB	
Error (c)	
Corn hybrid, factor C	
Interaction, AC	
Interaction, BC	
Interaction, ABC	
Error (d)	
Total	

Dolomitic lime was applied prior to the 1981 and 1983 corn crops to adjust soil pH to approximately 6.0. In 1981, 1982, and 1983, fertilizer, supplying approximately 66, 30, 170, 40, 3, and 3 kg ha^{-1} of N, P, K, S, B, and Zn, respectively, was broadcast prior to planting. In 1984, 500 kg ha^{-1} of 10–10–10 + 0.5% B was broadcast. Less K and no S or Zn were applied in 1984 because soil test analyses indicated amounts were sufficient for irrigated or nonirrigated corn production (D.L. Karlen, 1984, unpublished data). Corn was planted on 10 Apr. 1981, 9 Apr. 1982, 27 Apr. 1983, and 17 Apr. 1984 using a Brown-Harden Superseeder. This implement disrupts physical restrictions to rooting by subsoiling below each row to a depth of 45 cm. This process disturbs 25 to 30% of the surface residues, but is defined as CT for this physiographic region. Row spacing was 75 cm, seeding depth 4 cm, and seeding rate 10 kernels m^{-2} for irrigated and 7 kernels m^{-2} for nonirrigated treatments. Weeds were controlled with 1.7 kg ha^{-1} glyphosate [isopropylamine salt of *N*-(phosphonomethyl)glycine], 1.7 kg ha^{-1} atrazine [2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine], and 2.1 kg ha^{-1} metolachlor [2-chloro-*N*-(2)ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] in 1981 and with glyphosate, atrazine, and 2.2 kg ha^{-1} alachlor [2-chloro-2′-6′-diethyl-*N*(methyoxymethyl) acetanilide] in 1982, 1983, and 1984. Water was applied to irrigated plots with a traveling gun irrigation system when soil-water tension at 30 cm exceeded 25 kPa as measured using vacuum tensiometers. In 1981, 1982, 1983, and 1984, supplemental water applications totaled 115, 90, 196, and 112 mm, respectively. Seasonal rainfall between planting and physiological maturity for those years totaled 419, 426, 314, and 637 mm, respectively. At growth stage 2.5 (4), anhydrous ammonia was injected between rows at a depth of approximately 20 cm. Sidedress application rates for nonirrigated and irrigated blocks were 135 and 185 kg ha^{-1}. This provided a total N application of approximately 3.5 g plant^{-1} each season.

Soil temperature measurements were made at 0800 and 1500 h three times each week for the first 4 weeks after planting. Thermocouples were installed on wooden stakes at 5-, 15-, and 30-cm depths with several centimeters of lead buried at each junction depth to eliminate heat conduction to that junction. Eight replicates were monitored for each tillage system. Stand counts were made at frequent but irregular intervals for 3 weeks after emergence to evaluate stand establishment. Whole plant samples were collected 7, 17, and 25 days after planting (dap) in 1981; 39 and 52 dap in 1982; 22 dap in 1983; and 29 and 45 dap in 1984 to measure seedling growth and N, P, and K concentrations. Four weeks after emergence, at growth stage 2.0, irrigated and nonirrigated blocks were thinned to approximately 7.8 or 5.7 plants m^{-2}. Corn leaves were collected from opposite and below the primary ear at anthesis to assess N, P, and K concentrations within the crop. At physiological maturity in 1981 and 1983, 2 m of row in the Pioneer 3382 subplots were collected, weighed, and subsampled. An eight-stalk subsample was chopped in a Kemp shredder, mixed, and approximately 2 kg of sample saved for dry matter determination and N, P, K analyses. All plant samples were dried at 70 °C, ground to pass a 0.5-mm screen, and digested using sulfuric and selenous acids in a Technicon block digester. The N and P concentrations were measured colorimetrically while K was measured by flame emission.

In 1981 and 1982, corn grain yield for each hybrid was measured by hand harvesting eight 5.3-m row segments from each plot. In 1983 and 1984, an Almaco plot combine was used to harvest the center 40 m^2 of each plot. Grain yields were adjusted to a moisture content of 155 g kg^{-1} each year.

RESULTS AND DISCUSSION

In 1981 effects of tillage system and hybrid selection on stand establishment and early season growth were monitored closely in what would become the irrigated half of this experiment (Table 2). Seeding rate for all hybrids was 10 kernels m^{-2}. Within 1 week 64 to 77% of the plants had emerged and were established under conventional tillage (DP), but with conservation tillage (CT) only 27 to 43% of the plants were emerged and established. Seedling weights for all hybrids in CT plots were also lower than for plants in DP plots. Measurements 17 days after planting showed that 80 to 96% of the plants were established for the DP system compared with 78 to 90% for the CT system. A final count 25 days after planting showed an average across hybrids of 3% fewer plants established within CT plots than within DP plots. Seedling weight 17 and 25 days after planting was also lower for CT plants than for DP plants. This reflected later emergence and an apparent slower rate of growth. Except for stand density 7 days after planting, interactions between hybrid and tillage system were nonsignificant.

Sampling intensity was lower in 1982, 1983, and 1984 than in 1981, but early season plant growth response was similar. Plants growing within the CT system were always smaller than plants growing within the DP system (Table 3). Seedling concentrations of N, P, and K were also measured, but showed no consistent trend nor provided any explanation for slower growth by CT plants than by DP plants. Measurements of stand density in 1982, 1983, and 1984 (data not presented) also showed that during the 28 days after planting 5 to 15% fewer plants emerged and became established in CT plots than in DP plots. Those data support current recommendations to overplant by 10 to 15% when using minimum tillage (14). However, in addition to reduced stand establishment, nonuniform emergence may be one reason why CT grain yields are often lower on Atlantic Coastal Plain soils (3) than when conventional seedbed preparation is used. When corn seedlings emerge later than surrounding plants, they are often shaded and presumably perform like weeds by extracting nutrients and water without producing significant grain yield. This emphasizes the need for seedling vigor and uniformity in planting depth, especially when seedbed conditions are suboptimal.

Reduced soil temperature is often cited as a possible cause for slow corn growth and development in CT systems (1,7), because controlled experiments have showed a 20% increase in corn seedling weight for each

Table 2. Tillage system† and hybrid effects on stand density (no. m^{-2}) and seedling weight (mg plant^{-1}) of corn in what would become the irrigated experimental half in 1981.

	Days after planting											
	7		17		25		7		17		25	
	DP	CT	DP	CT	DP	CT	DP	CT	DP	CT	DP	CT
	no. m^{-2}						mg plant^{-1}					
Hybrid by tillage												
Coker 21	7.7	4.3	8.9	8.3	8.7	8.2	19	15	408	359	572	542
DeKalb-Pfizer XL71	7.4	3.7	9.6	9.0	9.8	9.6	15	11	400	347	623	422
Northrup-King PX74	6.6	2.7	8.0	7.8	7.8	7.8	11	8	325	313	353	315
Pioneer 3382	7.7	3.6	9.0	8.3	9.1	8.6	16	12	393	364	596	637
Ring Around 1502	6.4	3.9	8.7	7.9	8.9	8.3	14	10	369	332	632	398
LSD (0.05)	0.7		0.7		0.9		3		28		172	
CV (%)	10.7		6.2		6.2		20.1		5.9		19.5	
Tillage system												
Conventional (DP)	7.2		8.8		8.8		15		379		555	
Conservation (CT)	3.6		8.3		8.5		11		343		463	
LSD (0.10)	1.3		0.3		NS		2		30		74	
CV (%)	32.8		6.0		5.5		23.9		13.8		13.7	
Hybrid selection												
Coker 21	6.0		8.6		8.5		17		384		557	
DeKalb-Pfizer XL71	5.6		9.3		9.7		13		374		523	
Northrup-King PX74	4.7		7.9		7.8		9		319		334	
Pioneer 3382	5.6		8.6		8.9		14		378		616	
Ring Around 1502	5.2		8.3		8.6		12		350		515	
LSD (0.05)	0.5		0.5		0.7		2		20		122	
CV (%)	10.7		6.2		6.2		20.1		5.9		19.5	

† DP = conventional tillage; CT = conservation tillage.

1 °C increase in temperature between 12 and 26 °C (12). Our measurements of soil temperature[4] during the 28 days after planting in 1981, 1982, and 1983 are summarized in Fig. 1, 2, and 3. They show significant differences between tillage treatments at 5 cm for the 1500 hr readings in 3 of 12 periods (Fig. 1), but in each instance, minimum soil temperature at seeding depth was > 26 °C. Minimum soil temperature at 15 cm averaged 22 to 25 °C. Those temperatures were also significantly different for the two tillage systems at 1500 h in 3 of 12 periods (Fig. 2). At the 30-cm depth, both 0800 and 1500 h temperature differences were statistically significant, but minimum temperatures averaged 18 to 20 °C, and differences were only 0.6 to 1.1 °C between DP and CT treatments (Fig. 3).

A further summary of temperature data, computed by averaging all 0800 h and 1500 h measurements collected during the 3 yr at the 5- and 15-cm depth, show CT treatments were 0.5 °C cooler at 0800 h and 1.1 °C cooler at 1500 h. However, during the first 14 days after planting average temperature for both tillage systems was 19 °C, and 15 to 28 days after planting average temperatures were 22 and 24 °C for CT and DP systems, respectively. At those temperatures, germination should occur in 6 to 10 days, while shoot and root growth should proceed at near-optimum rates (9). Therefore, we do not attribute differences in corn growth and development to variation in soil temperature when CT practices are implemented on Coastal Plain soils.

The water management split (irrigated vs. nonirrigated) was imposed each year when soil-water tension within the row exceeded 25 kPa. This generally occurred approximately 30 days after planting when plants were at growth stage 2.0 or 2.5 (4). Nitrogen,

[4] Actual soil temperature data may be made available to selected individuals for use in modeling of temperature upon written request.

Table 3. Corn seedling weight and N, P, and K concentrations as influenced by tillage system.

Tillage system	Year	Hybrid	Days after planting	Shoot weight	Nutrient concentration N	P	K
				g plant^{-1}	g kg^{-1}		
Conventional	1981	Mean of 5†	25	0.56	35.4	2.90	52.5
Conservation	1981	Mean of 5	25	0.46	35.0	3.89	52.2
LSD (0.10)				0.07	NS	0.73	NS
CV (%)				13.7	5.2	20.2	3.2
Conventional	1982	P3382	39	4.44	32.1	2.98	56.8
Conservation	1982	P3382	39	2.62	31.5	2.84	55.5
LSD (0.05)				0.98	NS§	NS	NS
CV (%)				12.4	11.0	8.2	4.3
Conventional	1982	RA1502	52	33.9	25.5	2.80	58.2
Conservation	1982	RA1502	52	20.9	26.0	2.98	58.0
LSD (0.05)				7.2	NS	NS	NS
CV (%)				17.7	10.7	34.3	10.8
Conventional	1983	P3382	22	0.70	32.0	2.52	47.7
Conservation	1983	P3382	22	0.53	28.4	2.62	46.3
LSD (0.05)				0.09	2.6	NS	NS
CV (%)				13.5	7.8	9.3	4.9
Conventional	1984	M84AA‡	29	1.50	30.1	3.24	39.4
Conservation	1984	M84AA	29	1.32	33.5	3.54	42.6
LSD (0.05)				NS	NS	NS	NS
CV (%)				18.0	10.7	8.3	5.0
Conventional	1984	M84AA‡	45	24.3	26.4	3.36	51.1
Conservation	1984	M84AA	45	22.2	25.2	3.60	51.5
LSD (0.05)				2.0	1.0	NS	NS
CV (%)				5.1	2.2	4.9	8.0

† The five hybrids were Coker 21, DeKalb-Pfizer XL71, Northrup-King PX74, Pioneer 3382, and Ring Around 1502.
‡ McCurdy 84AA.
§ NS = not significant.

P, and K concentrations in leaves opposite and below the primary ear were the first parameters measured after the water variable was imposed. However, differences in nutrient concentration were never statistically significant (data not presented). Between tillage systems, the only significant differences in ear leaf nutrient concentration were for N and P in 1982. Plants

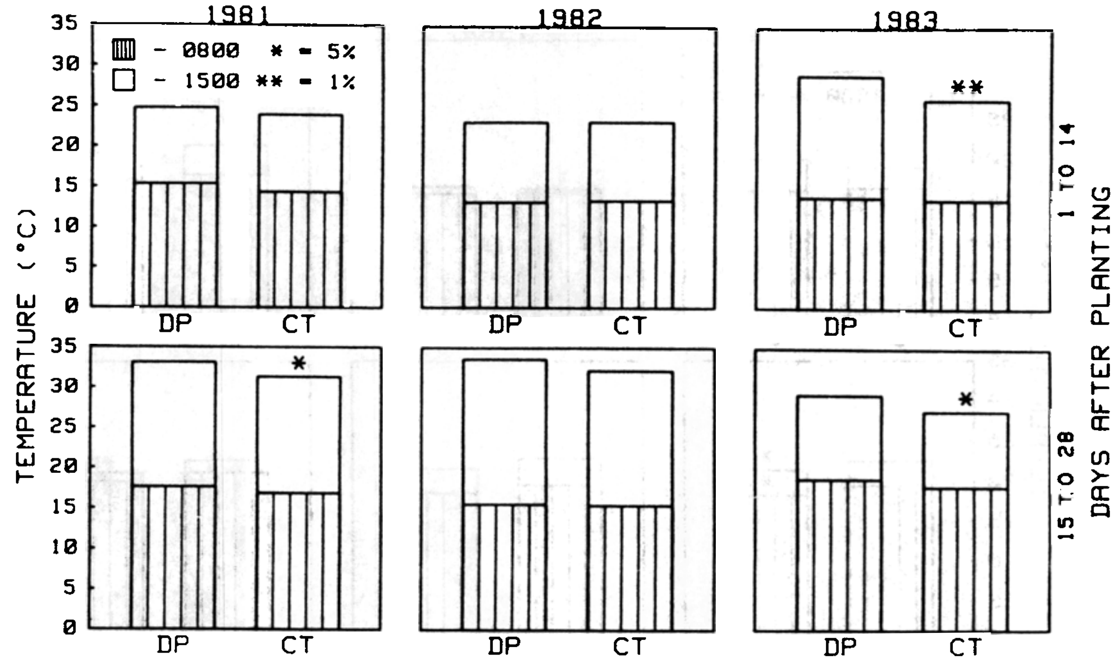

Fig. 1. Influence of conventional disk tillage (DP) or conservation tillage (CT) on 0800 h and 1500 h soil temperatures at 5 cm during the 28 days after planting in 1981, 1982, and 1983.

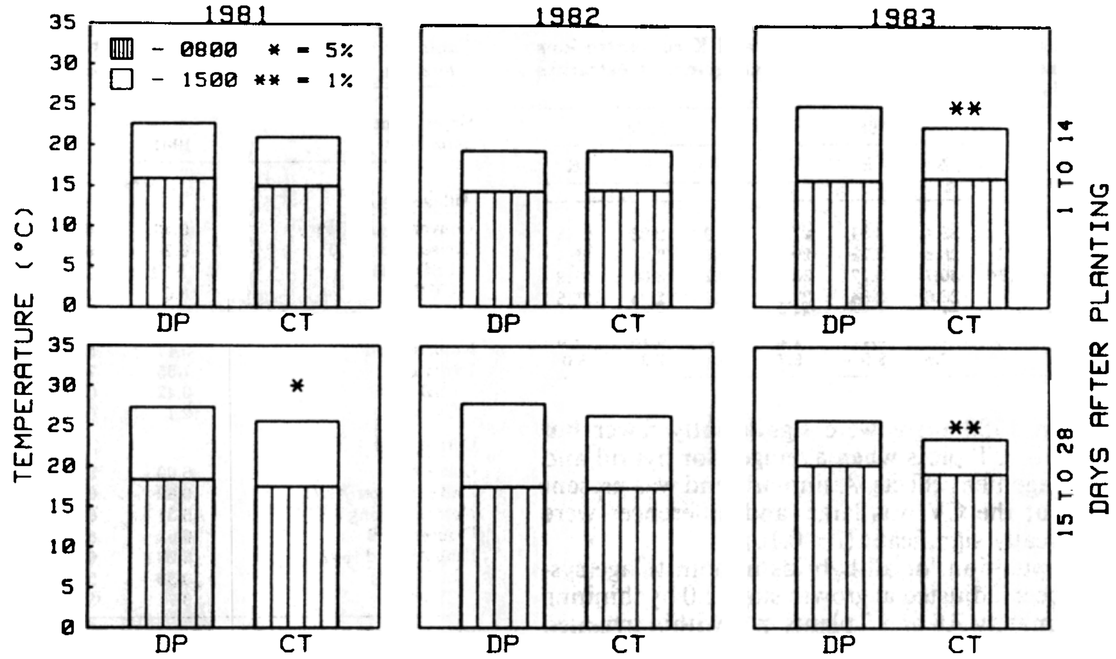

Fig. 2. Influence of conventional disk tillage (DP) or conservation tillage (CT) on 0800 h and 1500 h soil temperatures at 15 cm during the 28 days after planting in 1981, 1982, and 1983.

grown in CT plots had an average across hybrids of 32.3 and 3.09 g kg^{-1} of N and P. This compared to an average of 30.7 and 2.81 g kg^{-1} of N and P for hybrids grown in DP plots. Exact causes for this difference are unknown, although rainfall was better distributed during 1982. This may have increased surface root proliferation, diffusion of P, and mineralization of N. Hybrid by tillage interactions were not significant in either 1981 or 1982. Among hybrids, when averaged for tillage and water management effects, there were significant differences in leaf N, P, and K concentrations (Table 4). The only tillage by water management interactions that were significant for leaf nutrient concentration were for N and K in 1981. Plants grown in CT plots without supplemental irrigation had 0.5 g kg^{-1} more N and 0.8 g kg^{-1} less K than nonirrigated DP plants; with irrigation, CT plants had 1.2 g kg^{-1} less N and 0.5 g kg^{-1} more K than plants grown in DP plots. Those differences were statistically significant, but all concentrations were within normal ranges (5) for corn at anthesis.

Effects of tillage system, water management, and hybrid selection on number and size of corn ears harvested at physiological maturity are summarized in

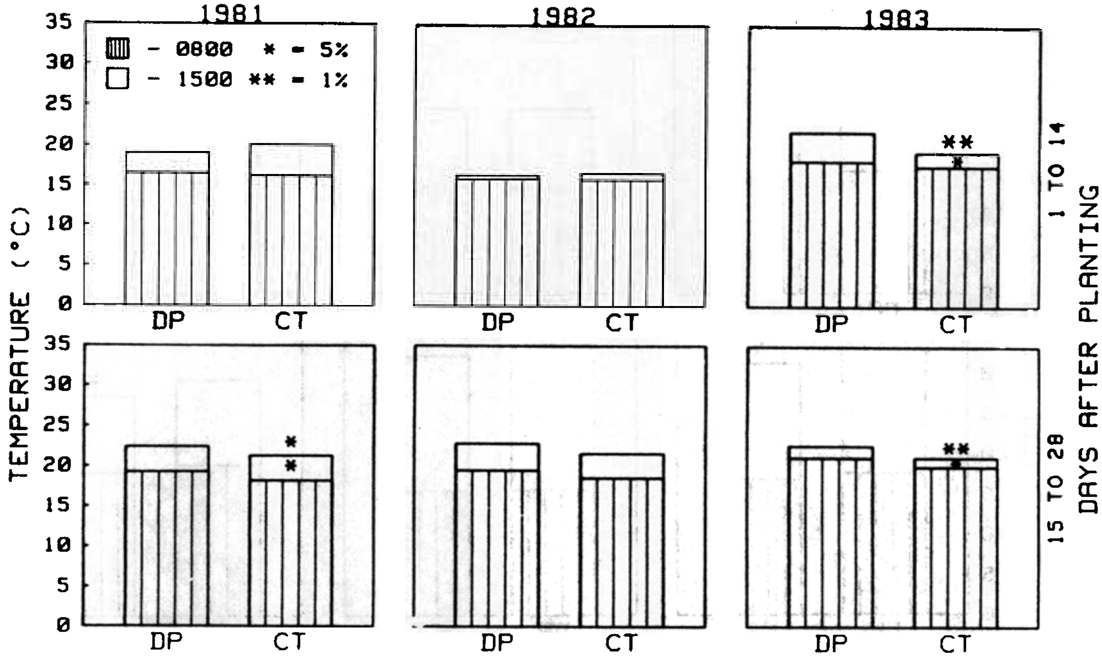

Fig. 3. Influence of conventional disk tillage (DP) or conservation tillage (CT) on 0800 h and 1500 h soil temperatures at 30 cm during the 28 days after planting in 1981, 1982, and 1983.

Table 4. Hybrid variation in leaf N, P, and K concentrations when averaged for tillage and water management treatments at anthesis.

	1981			1982		
Hybrid	N		K	N		K
	— g kg^{-1} —					
Coker 21	29.4	2.84	27.8	31.9	2.83	27.1
DeKalb-Pfizer XL71	28.8	3.23	29.9	30.1	2.96	29.4
Northrup-King PX74	30.7	3.17	30.9	32.1	3.06	28.2
Pioneer 3382	28.6	2.84	27.6	31.7	2.93	26.6
Ring Around 1502	30.4	3.01	27.9	31.9	2.98	26.3
LSD (0.05)	1.3	0.17	1.2	1.0	0.13	1.0
CV (%)	6.8	9.0	6.7	5.1	7.2	6.0

Table 5. In 1982 there were significantly fewer but larger ears in CT plots when averaged for hybrid and water management effects. A similar trend was present in 1981, but the CV was large, and differences were not statistically significant ($P \leq 0.10$).

Plant population for all hybrids in both tillage systems had been adjusted at growth stage 2.0 by thinning to approximately 7.8 or 5.7 plants m^{-2} within irrigated and nonirrigated water management blocks, respectively. This was done because previous research had shown differential plant population to be a major factor causing lower corn yield when CT practices were utilized for corn production in the southeastern ACP (3). In 1981, water stress during anthesis and grain fill was severe and an average of 93 plants per 1000 plants were barren when supplemental irrigation water was not supplied. Ear size (Table 5) further emphasizes the severity of water stress in 1981 because average per grain ear was lower (132 g) at a population of 5.7 plants m^{-2} than at 7.8 plants m^{-2} (141 g). In 1982, when rainfall was well distributed throughout the growing season, ear size inversely reflected plant population, and only 9 plants per 1000 plants were barren in nonirrigated plots.

Table 5. Corn ear number and size† as influenced by tillage system, water management, and hybrid selection.

Experimental parameter	Number 1981	Number 1982	Size 1981	Size 1982
Tillage system				
Conventional (DP)	6.43	6.74	126	166
Conservation (CT)	6.29	6.20	146	172
LSD (0.05)	NS‡	0.08	NS	3
CV (%)	18.6	2.3	36.1	2.9
Water management				
Nonirrigated	5.17	5.65	132	184
Irrigated	7.55	7.29	141	153
LSD (0.05)	0.42	0.22	NS	5
CV (%)	12.1	6.0	20.9	5.0
Corn hybrid				
Coker 21	6.00	5.82	136	191
DeKalb-Pfizer XL71	6.62	6.66	138	163
Northrup-King PX74	6.31	6.24	140	171
Pioneer 3382	6.62	6.99	130	153
Ring Around 1502	6.23	6.64	138	166
LSD (0.05)	0.39	0.23	NS	5
CV (%)	9.7	5.7	10.6	4.6

† Grams of shelled corn at a moisture content of 155 g kg^{-1}
‡ NS = not significant.

With supplemental irrigation, 30 to 60 plants per 1000 plants were barren each year, which suggests that further increases in plant population would not increase grain yield in this system. A water management × tillage system interaction occurred in 1981. Average grain production in nonirrigated DP plots was significantly lower at 114 g ear^{-1} as compared with 138, 144, and 148 g ear^{-1} for irrigated DP, irrigated CT, and nonirrigated CT treatments, respectively. The number of ears produced was significantly different among hybrids in both 1981 and 1982 (Table 5). Grain production per ear was significantly different among hybrids only in 1982, when it was directly proportional

Table 6. Corn grain yield as influenced by tillage system, water management, or hybrid selection.

Tillage system	1981	1982	1983	1984
		Mg ha^{-1}		
Conventional (DP)	8.3	11.0	9.5	9.9
Conservation (CT)	9.2	10.5	8.7	9.2
LSD (0.05)	NS†	0.2	0.7	NS
CV (%)	46.4	4.6	8.2	8.3
Water management				
Nonirrigated	6.8	10.4	7.9	9.2
Irrigated	10.6	11.1	10.3	9.8
LSD (0.05)	0.6	0.5	0.6	NS
CV (%)	12.7	8.3	5.5	9.5
Hybrid selection				
Coker 21	8.3	11.0		
DeKalb-Pfizer XL71	9.1	10.7		
Northrup-King PX74	8.8	10.5		
Pioneer 3382	8.7	10.6	9.1	
Ring Around 1502	8.7	10.9		
McCurdy 84AA	–‡	–		
LSD (0.05)	NS	0.4		
CV (%)	11.5	4.4		

† NS = not significant. ‡ No data.

to ear number. A significant hybrid × tillage system interaction was observed for ear number in 1981. This occurred because PX74 produced an average of only 5.85 ears m^{-2} in CT plots compared with 6.77 ears m^{-2} in DP plots. Presumably, delayed emergence and stand establishment observed for this hybrid in CT plots only 7 days after planting were reflected in ear number (Table 2). Therefore, regardless of tillage system, rapid, uniform germination and emergence are essential for optimum corn production.

Effects of tillage system, water management, and hybrid selection on grain yield are summarized in Table 6. In 1981, severe drought occurred during growth stage 5.0 (anthesis) and caused the irrigation response to be very great (3.8 Mg ha^{-1}). Water was conserved by CT practices, and differences in soil-water content were evident in tensiometer data collected during anthesis and grain fill (not presented). However, when grain yield was averaged for hybrid and water management effects, the yield difference was statistically nonsignificant because of a high CV. The tillage by water management interaction was highly significant. Without supplemental irrigation, grain yield in DP plots averaged 5.9 Mg ha^{-1} compared with 7.7 Mg ha^{-1} for nonirrigated CT plots. With irrigation, grain yields for DP and CT treatments were essentially equal and averaged 10.7 and 10.6 Mg ha^{-1}.

Differences in grain yield because of tillage system were not statistically significant in 1984 (Table 6). However, with or without supplemental irrigation, yield in CT plots was lower than DP plots during 1982, 1983, and 1984. We conclude those differences in grain yield occurred because early season growth differences were never rectified (Tables 2 and 3). By thinning to a constant population, numerical differences in stand were minimized, but physiologically CT plants were less uniform than DP plants. This presumably caused some CT plants to perform like "corn weeds" rather than as productive biological factories and thus accounted for lower ear number in CT plots (Table 5).

The 4-yr average irrigation response was 1.9 Mg ha^{-1}, although seasonal variation ranged from a nonsignificant 0.6 Mg ha^{-1} increase in 1984 to a highly significant 3.8 Mg ha^{-1} increase in 1981 (Table 6). This variation in response to irrigation reflects erratic seasonal rainfall patterns which are encountered in the humid southeastern ACP.

Among hybrids in 1981 and 1982 there were significant differences in grain yield, but those differences were not consistent for the two years (Table 6). The hybrid × tillage system interaction for grain yield was not significant. This is contrary to results of others (2,3), but may have occurred because all hybrids were thinned to constant populations after emergence data were collected. The hybrid × water management interaction was not significant in 1981, but in 1982 it was significant (P=0.01). In 1982, Pioneer 3382 produced the lowest grain yield without irrigation, but the highest grain yield when supplemental water was applied to maintain soil-water tension below 25 kPa.

Whole plant analyses in 1981 and 1983 showed that aerial N, P, and K accumulation averaged 225, 40, and 280 kg ha^{-1}, respectively. Tillage system did not significantly influence accumulation of those nutrients. Irrigation significantly increased N, P, and K accumulation in 1983 because of a highly significant dry matter response (27.1 Mg ha^{-1} irrigated vs. 22.2 Mg ha^{-1} nonirrigated). Concentrations of N, P, and K were not influenced by water management. There was also no significant water management × tillage interaction for dry matter yield or nutrient accumulation.

SUMMARY AND CONCLUSIONS

Corn hybrid variation was significant for emergence, early season growth, and grain yield, but this variation was not consistent among years. The tillage system × hybrid interaction was generally not significant for grain yield, although that result is probably an artifact of thinning to a uniform plant population.

The water management (irrigation) response ranged from 0.6 Mg ha^{-1} (a non-significant yield increase) in 1984 to 3.8 Mg ha^{-1} (a highly significant yield increase) in 1981, reflecting erratic seasonal rainfall patterns. Water management interacted significantly with tillage in 1981 and with hybrid in 1982 to influence grain yield. The tillage by water management interaction was also significant for leaf N and K at anthesis in 1981, but other water management interactions were generally not significant.

Soil temperature differed significantly in only 3 of 12 time periods during the 28 days after planting in 1981, 1982, and 1983. Average soil temperatures, measured with thermocouples at 5- and 15-cm depths, were 19 °C for both tillage systems during the first 14 days after planting and 22 or 24 °C for CT or DT system during days 15 to 28. Overall, CT plots were 0.5 °C cooler at 0800 h and 1.1 °C cooler at 1500 h than DP plots. We conclude that because mean temperatures were relatively warm, this difference was not enough to sufficiently slow early season corn growth and to explain our growth or yield results when CT practices are utilized. However, yield potential differences between tillage systems appears to be physiologically initiated by those early season differences in corn growth and development. Therefore, for successful conservation tillage corn production in the southeastern ACP, a combination of factors that ensure rapid and uniform plant emergence in suboptimal seedbed conditions must be determined.

REFERENCES

1. Allmaras, R.R., W.C. Burrows, and W.E. Larson. 1964. Early growth of corn as affected by soil temperature. Soil Sci. Soc. Am. Proc. 28:272–275.
2. Brakke, J.P., C.A. Francis, L.A. Nelson, and C.O. Gardner. 1983. Genotype by cropping system interactions in maize grown in a short season environment. Crop Sci. 23:868–870.
3. Campbell, R.B., D.L. Karlen, and R.E. Sojka. 1984. Conservation tillage for maize production in the U.S. Southeastern Coastal Plain. Soil Tillage Res. 4:511–529.
4. Hanway, J.J. 1971. How a corn plant develops. Iowa St. Univ. Coop. Ext. Service Spec. Rep. 48.
5. Jones, J.B., Jr., and H.V. Eck. 1973. Plant analysis as an aid in fertilizing corn and grain sorghum. p. 349–364. *In* L.M. Walsh and J.D. Beaton (ed.) Soil testing and plant analysis. Soil Science Society of America, Madison, WI.
6. Larson, W.E. 1981. Protecting the soil resource base. J. Soil Water Conserv. 36:13–16.
7. Mock, J.J., and D.C. Erbach. 1977. Influence of conservation—tillage environments on growth and productivity of corn. Agron. J. 69:337–340.
8. Phillips, R.E., R.L. Blevins, G.W. Thomas, W.W. Frye, and S.H. Phillips. 1980. No-tillage Agriculture. Science (Washington, D.C.) 208:1108–1113.
9. Shaw, R.H. 1977. Climatic requirement. *In* G.F. Sprague (ed.) Corn and corn improvement. Agronomy 18:591–623.
10. Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. A biometrical approach, 2nd ed. McGraw-Hill Book Co., New York.
11. U.S. Department of Agriculture. 1984. 1984 Soil and water conservation research and education progress and needs. U.S. Department of Agriculture-Soil Conservation Service, Washington, DC.
12. Walker, J.M. 1969. One-degree increments in soil temperatures affect maize seedling behavior. Soil Sci. Soc. Am. Proc. 33:729–736.
13. Wall, D.A., and E.H. Stobbe. 1983. The response of eight corn (*Zea mays* L.) hybrids to zero tillage in Manitoba. Can. J. Plant Sci. 63:753–757.
14. Zublena, J.P., C.L. Parks, E.C. Murdock, J.P. Krausz, R.P. Griffin, G.D. Christenbury, R.A. Spray, L.A. Stanton, and F.J. Wolak. 1983. Corn production guide for South Carolina. Clemson Univ. Coop. Ext. Service Circular 587.