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Corn Response, Nitrogen Uptake, and Water Use in Strip-Tillage Compared with No-Tillage and Chisel Plow

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ABSTRACT

Tillage systems are among the many factors that affect soil productivity. The challenges associated with different tillage systems have prompted the need to compare corn (*Zea mays* L.) production under strip-tillage (ST), chisel plow (CP), and no-tillage (NT) systems. The study was conducted on two Iowa State University Research and Demonstration Farms in 2001 and 2002. One site was at the Agronomy Research and Demonstration Farm near Ames, IA, where the soils were Nicollet loam (Aquic Hapludolls) and Webster silty clay loam (Typic Haplaquolls). The second site was at the Northeast Research and Demonstration Farm near Nashua, IA, where the soils were Kenyon loam (Typic Hapludolls) and Floyd loam (Aquic Hapludolls). Corn final emergence rate index was slightly higher in ST than either NT or CP. Grain yield, dry matter production, and N uptake were generally similar in the three tillage systems. Soil moisture storage in the 0- to 30- and 0- to 120-cm soil depths and grain water use efficiency show no significant differences between tillage systems. It was apparent that after 2 yr of ST, there were limited advantages for ST when compared with either NT or CP.

Conventional tillage, conservation tillage, and NT each accounted for one-third of Iowa's corn and soybean [*Glycine max* (L.) Merr.] cropland (Iowa Residue Management Partnership Committee, 2000). In the United States, 36% of cropland planted annually is in a conservation tillage system, accounting for approximately 44 million ha (Fawcett and Towery, 2002). Nationwide, the use of NT has increased by 15.5 million ha from 1990 to 2002 while total cropland in conservation tillage remained fairly constant (Fawcett and Towery, 2002).

There are many problems associated with conventional tillage systems in agricultural row crop production. Conservation tillage systems can solve some of these problems by reducing surface runoff and conserving soil moisture due to crop residue cover (Chichester and Richardson, 1992; Fawcett and Towery, 2002; Mickelson et al., 2001). Along with improving soil moisture status, conservation tillage can improve yield productivity (Fortin, 1993) and soil and water quality (Baker and Laflen, 1983; Kettler et al., 2000), lower input costs, and reduce labor needs (Tebrugge and During, 1999). In addition to the advantages conservation tillage systems possess, there are perceptions and factual concerns regarding conservation tillage systems, particularly NT. One of the main concerns is that NT may reduce yields due to poor plant emergence in cold and wet soil conditions early in the spring, especially in poorly drained soils (Uri, 2000). Studies conducted in Iowa, Minnesota, and Canada have documented that NT resulted in slower seed emergence and plant development than conventional tillage systems (Erbach et al., 1992; Fortin, 1993; Gupta et al., 1988; Kaspar et al., 1990). It has also been reported that NT corn yields can be reduced by as much as 35% compared with conventional tillage for moderately well to poorly drained soils (Erbach et al., 1992; Hussain et al., 1999; Vyn and Raimbault, 1992, 1993). On the other hand, a research study conducted in Iowa indicated that yields of NT, reduced tillage, and conventional tillage systems were similar in somewhat poorly to poorly drained soils (Tapela and Colvin, 2002). These results were unexpected because an assumption with NT is that residue cover slows soil warm up, which slows seed germination. However, several studies have examined the effect of NT with in-row residue removal on corn yield (Azooz et al., 1995; Fortin, 1993; Janovicek et al., 1997; Kaspar et al., 1990; Swan et al., 1994). In these studies, in-row residue removal has indeed improved yield response due to the creation of a zone in which unimpeded solar radiation warms up the soil surface and increases soil moisture evaporation.

In the early 1990s, a new tillage system concept, ST, was explored. The system offered a unique opportunity to apply nutrients and prepare a seedbed in one tillage operation. This new system provided a potential solution to the problems associated with NT systems, particularly late emergence of corn due to cool and wet soil conditions, by enhancing soil evaporation and warming of the seedbed while minimizing soil disturbance. Strip-tillage disturbs a narrow zone 15 to 20 cm wide and 15 to 20 cm deep, approximately in the previous crop row, leaving the interrow area undisturbed. Therefore, ST can be identified as a tillage system as well as a nutrient application system in the fall, for which it was initially developed.

Al-Kaisi and Hanna (2002) showed that ST when compared with NT increased soil temperatures 1°C in the top 5-cm soil depth, which resulted in faster soil drying in the spring. Opoku et al. (1997) compared moldboard plow, CP, disking, ST, and NT in a corn–wheat (*Triticum aestivum* L.) rotation in Ontario, Canada. It was found that ST corn yields were significantly higher than NT yields, but they were not significantly different from moldboard plowing or chisel plowing. In southern Indiana, a study showed that ST grain yields were equal or better than conventional tillage in well drained soils, but ST grain yields were depressed on poorly drained soils (Griffith et al., 1973).

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Abbreviations: CP, chisel plow; ERI, emergence rate index; NT, no-tillage; ST, strip-tillage; WUE, water use efficiency.

Other aspects related to tillage systems are moisture availability, water use efficiency (WUE), and N use by the crop. Strip-tillage is not well evaluated in terms of crop N use or WUE. In general, conservation tillage systems are often used to manage residue, which in turn, impacts soil moisture (Christenson et al., 1994; Unger, 1986; Wagger and Cassel, 1993). The impact of a NT system on conserving soil moisture is well documented. In an Iowa study (Karlen et al., 1994), the gravimetric soil moisture in the top 5 cm of soil was 32.4% for NT and between 23.1 and 25.5% for CP and moldboard plow systems. Erbach et al. (1992) had different results and reported that tillage did not influence soil moisture in the surface 20 cm. No-tillage and other conservation practices can increase grain WUE and yields (Wiese et al., 1998; Norwood, 1999, 2000).

Tillage produces conditions where crop residues are rapidly decomposed (McCarthy et al., 1995). Decomposition impacts soil organic N mineralization whereby readily available N for plant use is increased (Dinnes et al., 2002). Therefore, tillage can have a direct effect on N mineralization and plant N uptake (Huntington et al., 1985; McCarthy et al., 1995). However, several studies have concluded that tillage systems do not affect plant or grain N uptake by corn (Mehdi et al., 1999; Sainju and Singh, 2001).

The challenges associated with NT for corn production in a corn–soybean rotation in poorly drained soils in Iowa prompted this research to provide an alternative tillage system that would address corn production concerns. The objective of this study was to compare corn production under ST, NT, and CP systems.

MATERIALS AND METHODS

Site Description

The study was conducted on two Iowa State University research and demonstration farms in 2001 and 2002. One site was located at the Marsden research farm near Ames, IA, where the soils were Nicollet loam (fine-loamy, mixed, mesic Aquic Hapludolls) and Webster silty clay loam (fine-loamy, mixed, mesic Typic Haplaquolls). Tile drainage was not installed at this site. Each tillage main plot was split into two equal halves. The first half was planted to corn, and the second half was planted to soybean. On 10 May 2001, corn (Fontenelle 4741 hybrid[1]) was planted at a seed drop populations of 74 600 plants ha^{-1} with a four-row planter using a 5-cm planting depth and 76-cm row spacing. These plots were moved to the soybean side of the block in 2002 where corn (Fontenelle 4741) was planted on 6 May 2002 at seed drop populations of 79 000 plants ha^{-1}. Seasonal precipitation at Ames (October through September) was 766 and 713 mm in 2001 and 2002, respectively, with a normal precipitation of 813 mm.

The second site was at the Northeast Research and Demonstration Farm near Nashua, Iowa. Soils at this site were Kenyon loam (fine-loamy, mixed, mesic Typic Hapludolls) and Floyd loam (fine-loamy, mixed, mesic Aquic Hapludolls). Tile drainage was not installed at this site. Each tillage main plot was split into two equal halves. The first half was planted to corn, and the second half was planted to soybean. Corn (Dekalb 533-2BT hybrid) was planted with a six-row planter to a 5-cm depth at 76-cm row spacing on 12 May 2001 and 5 May 2002. The target seed drop population was 80 300 plants ha^{-1}. In 2002, corn was planted into soybean residue of 2001. The seasonal precipitation at Nashua was 832 and 711 mm in 2001 and 2002, respectively. The 30-yr average precipitation was 864 mm. Before this study, both locations were in a corn–soybean rotation with soybean planted in 2000. The Ames site had previously been in NT, whereas the Nashua site was previously in a CP tillage system.

[1] Trade names and product lines are used for the benefit of readers and do not imply endorsement by Iowa State University over comparable products.

Experimental Design and Management

The study consists of three tillage systems: ST, CP, and NT. The experimental design was a randomized complete block with four replications. Whole-plot dimensions were 36.5 by 18.3 m. Each plot was split into two halves; one-half was planted to corn and the other half to soybean to establish a corn–soybean rotation sequence.

On CP plots, tillage was conducted in the fall followed by field cultivation in the spring at both sites. At Ames, ST treatments were implemented using a four-row rotor tiller with blades of 13 cm in length curved out 5 cm at the end. At Nashua, a four-row anhydrous fertilizer injector consisting of a mole knife between two 51-cm hiller disks was used to perform ST. The mole knife consisting of a shank of 43 cm in length by 1.6 cm in width and a mole of 4.5 cm in width by 9 cm in length. The ST zones at both sites were 20 cm wide, 10 to 15 cm deep, and had a soil mound of 7 to 10 cm in height. As for NT, the only field operations performed were seed planting and N fertilizer application. At both sites, N was fall (mid-November) injected to a 15-cm soil depth at a rate of 170 kg N ha^{-1}. In the CP treatment, N was injected before fall chisel plowing, whereas in the ST treatment, N was applied during the ST operation. At Ames, the liquid urea ammonium nitrate (32–00) was applied using a spoke point injector (Baker et al., 1989) for NT treatment while at Nashua, anhydrous ammonia was applied using a modified toolbar equipped with slot injectors of 1.25-cm-wide shanks with a 2.5-cm-wide shovel and to a depth of 15 cm to minimize soil disturbance for NT. At both locations, the planter was equipped with double-disk openers followed by a set of press wheels. The same planter adjustments were used for all tillage treatments. Weeds were controlled by using pre- and postemergence herbicides. Based on soil test results, P and K fertilizers were not applied. Starter fertilizer was not applied.

Crop Measurements

An emergence rate index (ERI) was calculated by using a method outlined by Erbach (1982) in which two rows 5.3 m long were staked before corn emergence and monitored each day for 10 consecutive days following the first emergence. The ERI was calculated using the equation

$$\mathrm{ERI} = \sum_{n=\mathrm{first}}^{\mathrm{last}} \frac{[\%n - \%(n-1)}{n} \qquad [1]$$

where n is number of days after planting, $\%n$ is percentage of plants emerged on day n, $\%(n-1)$ is percentage of plants emerged on day $n-1$, n = first is the number of days after planting when the first plant emerged, and last is the number of days after planting when emergence was completed. Corn yields were determined by hand-harvesting the center two rows, 5.3 m in length, of each plot. All corn ears were shelled to determine the corn yield. Corn grain yields were adjusted to 155 g kg^{-1} moisture. The grain samples were dried in a forced-air oven at 65°C for 7 d. Plant samples were collected following the protocol outlined by Ritchie et al. (1997) at the sixth-leaf (V6), 12th-leaf (V12), tassel (VT), and physiological maturity (R6) growth stages for the determination of dry matter production and plant N uptake. At the V6, V12, VT, and R6 sampling dates, one plant was cut from each of three 1.53 m of row area. Plant samples were dried in a forced-air oven at 65°C for 4 to 7 d before weighing. Concentration of total N was determined by dry combustion using a LECO CHN-2000 analyzer (LECO Corp., St. Joseph, MI). Plant N uptake at different growth stages was calculated based on the total dry matter mass multiplied by their respective total N concentrations.

Soil Moisture Measurements

Soil moisture was measured to a depth of 1.2 m from corn emergence to R6 for corn plots at both sites. Soil moisture was measured in the 0- to 15-, 15- to 30-, 30- to 60-, 60- to 90-, and 90- to 120-cm soil depth increments using time domain reflectometry (TDR). An Imko TRIME-FM instrument with a TRIME-P3 3-rod probe was used to measure the volumetric water content at the 0- to 15-cm soil depth (MESA Syst. Co., Medfield, MA). Volumetric soil moisture for the 15- to 120-cm soil profile was measured using an Imko TRIME-FM instrument with a TRIME-T3 tube access probe (MESA Syst. Co.). Soil moisture access tubes were installed in the center of the fifth row in each treatment for two replications for a total of 10 access tubes per site in 2001. In 2002, the number of access tubes installed was increased to include three replications or 15 access tubes per site. The access tubes were 44-mm inner diameter clear plastic and 120 cm in length with a 1-mm wall thickness. The access tubes were installed by modifying the instructions developed by Imko to conform to a Giddings model GSRPS hydraulic soil probe (Giddings Machine Co., Fort Collins, CO). A 41-mm slotted soil tube adapted with a quick relief bit was used to remove a 110-cm-long soil core. The soil core removed was 6 mm smaller in diameter and 10 cm shorter than the soil moisture access tubes to ensure good contact between the access tube and the soil. After the soil core was removed, the access tube was installed using a steel guide and ramming head to avoid damaging the access tube. The steel guide was hollow and would fill up with the excess soil from the bottom, allowing the installation of the access tube to a 1.2-m depth. With the tube installed, a rubber stopper assembly was placed in the bottom of the tube to prevent water from entering the tube at the bottom. Between measurements, a plastic cap was placed on the top end of the tube to prevent precipitation, soil, insects, and rodents from occupying the access tubes.

Water Use Efficiency

The WUE was determined as follows:

$$WUE = GY/ET \qquad [2]$$

where WUE is water use efficiency (kg ha^{-1} mm^{-1}), GY is grain yield (Mg ha^{-1}), and ET is seasonal crop water use (mm) that was calculated by multiplying the potential ET (ET_p) times a seasonal Iowa specific crop coefficient. The ET_p was calculated from data collected from a weather station at each site based on the modified Penman equation (Jensen et al., 1971). The ET_p was multiplied by a crop coefficient based on dryland corn water use for Iowa (Roygard et al., 2002; Schwab et al., 1993) at different growth stages to determine the seasonal crop water use (ET). The ET was estimated for corn from emergence to physiological maturity. For the Ames corn site, ET was estimated to be 568 and 614 mm for 2001 and 2002, respectively, while ET for the Nashua corn site was estimated to be 522 mm in 2001 and 527 mm in 2002.

Statistical Analysis

Data were analyzed using the SAS statistical software package (SAS Inst., 2001). The GLM procedure was used to perform the analysis of variance, which was appropriate for a randomized complete block design for ERI, yield, dry matter, soil moisture, WUE, and N uptake. Means were separated using a least significant difference (LSD) when treatment effects were significant. Statistical significance was evaluated at $P \leq 0.05$. The data analysis for each site year was separately performed after the combined analysis across site years of the data was significant.

RESULTS AND DISCUSSION

Emergence Rate Index

Fall ST showed no significant improvement in ERI over the fall CP or NT treatments at Ames in 2001 and 2002 (Fig. 1). Similarly, at Nashua in 2001, there were no significant differences in ERI between the three tillage systems. However, in 2002, the ERI for ST was significantly greater than that of NT and significantly lower

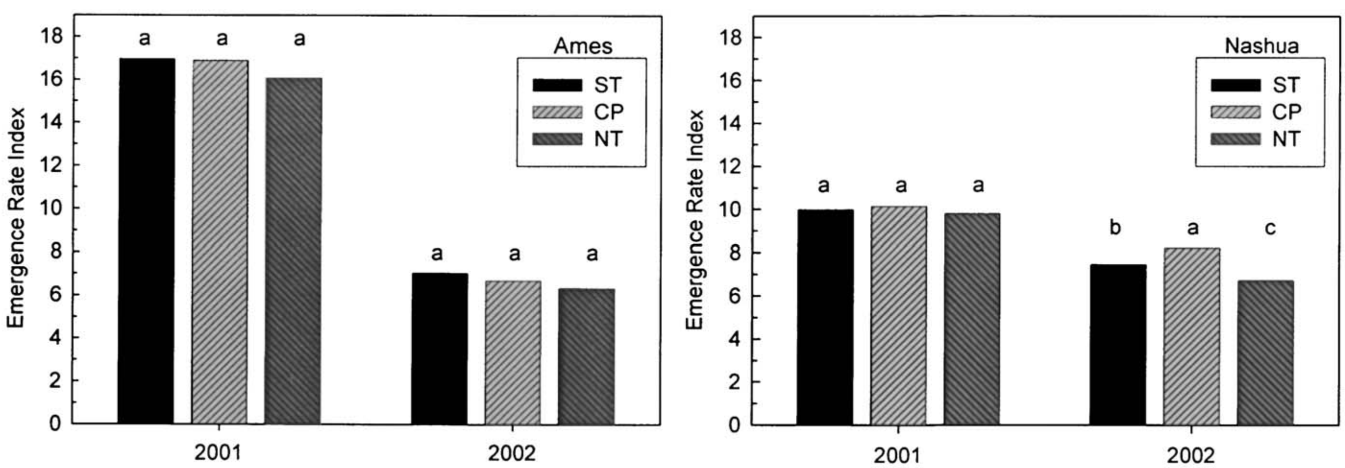

Fig. 1. Emergence rate index for strip-tillage (ST), chisel plow (CP), and no-tillage (NT) treatments in 2001 and 2002 at Ames, IA, and Nashua, IA. The least significant differences are according Fisher's $LSD_{(0.05)}$ test for each location and year.

Table 1. Aboveground dry matter of corn planted in strip-tillage (ST), chisel plow (CP), and no-tillage (NT) in 2001 and 2002.

		2001				2002‡			
Site	Treatment	V6†	V12	VT	R6	V6	V12	VT	R6
		Mg ha^{-1}							
Ames	ST	0.38a§	1.96a	5.83a	21.47a	0.18a	3.78ab	5.92a	–
	CP	0.47a	2.97a	7.96a	20.84a	0.28a	4.57a	6.12a	–
	NT	0.28a	2.24a	6.28a	20.82a	0.16a	3.35b	5.09a	–
Nashua	ST	0.27a	2.94a	5.84a	23.61a	0.08a	2.77a	5.69a	–
	CP	0.29a	3.57a	7.07a	20.99a	0.10a	3.05a	5.90a	–
	NT	0.26a	2.99a	6.53a	22.48a	0.08a	2.56a	5.45a	–

† Growth stages: V6, sixth leaf; V12, 12th leaf; VT, tassel; R6, physiological maturity.
‡ R6 data for both sites in 2002 were omitted due to inconsistency in collecting dry matter samples compared with year 2001.
§ Means within the same column followed by the same letter are not significantly different according to a protected Fisher $LSD_{(0.05)}$.

than that of CP. The greater ERI with ST or CP over NT can be attributed to soil disturbance in the fall and field cultivation early in the spring with CP, which enhanced soil evaporation. The differences in ERI also can be attributed to increased soil temperature for ST and CP, especially during the warmest time of the day (1200–1600 h) when temperature increased by approximately 1 to 2°C at the top 5 cm of soil surface (Licht and Al-Kaisi, 2005).

In 2002, the average ERI for all treatments was 60 and 25% lower than those in 2001 at both the Ames and Nashua sites, respectively (Fig. 1). Weather conditions at Ames in 2002 were much cooler and wetter in the 7 d following planting where the average maximum air temperatures were 15.4°C compared with 28.7°C in 2001 and rainfall increased by 34.5 mm. At Nashua, there was a similar trend in the 7 d following planting in 2002 but to a lesser degree than at Ames where the average maximum air temperatures were 20.7°C in 2002 compared with 26.3°C in 2001 and rainfall was 25.4 mm greater in 2002 than 2001. Additionally, in 2001, germination and seedling emergence occurred within 5 and 4 d of planting at Ames and Nashua, respectively, while in 2002, germination and seedling emergence were prolonged and occurred within 8 d of planting. Cool, wet conditions caused delayed seed germination and emergence across all tillage treatments, minimizing the effect of ST in improving ERI.

Dry Matter Production and Plant Nitrogen Uptake

The ST treatments showed no significant differences in dry matter production compared with CP or NT at the V6, V12, VT, and R6 growth stages in both years and sites except at the V12 growth stage in 2002 at Ames (Table 1). At Ames in 2002, the dry matter weight of V12 growth stage of ST was similar to that of both CP and NT. However, the CP dry matter yield was significantly greater than that of NT. Generally, CP had increased dry matter production during the V6, V12, and VT growth stages compared with ST and NT. However, at the R6 growth stage, ST numerically, but not statistically, produced more dry matter than CP or NT at both sites in 2001.

Dry matter production at the R6 growth stage in 2002 at both locations was much lower than that of 2001. Dry

Table 2. Plant N uptake of corn at different growth stages planted in strip-tillage (ST), chisel plow (CP), and no-tillage (NT) in 2001 and 2002.

		2001				2002‡			
Site	Treatment	V6†	V12	VT	R6	V6	V12	VT	R6
		kg ha^{-1}							
Ames	ST	16.8a§	59.8a	113.2a	140.3a	8.9b	120.2a	137.1a	–
	CP	20.9a	89.8a	156.6a	149.9a	14.3a	115.9a	136.7a	–
	NT	12.2a	67.1a	141.1a	148.1a	7.9b	84.8a	110.6a	–
Nashua	ST	12.5a	82.8a	119.4a	172.3a	4.1a	91.9a	146.4a	–
	CP	14.1a	99.7a	150.8a	178.9a	5.3a	102.7a	141.5a	–
	NT	11.9a	79.2a	135.3a	152.2a	3.7a	78.9a	124.7a	–

† Growth stages: V6, sixth leaf; V12, 12th leaf; VT, tassel; R6, physiological maturity.
‡ R6 data for both sites in 2002 were omitted due to inconsistency in collecting dry matter samples compared with year 2001.
§ Means within the same column followed by the same letter are not significantly different according to a protected Fisher $LSD_{(0.05)}$.

matter reductions were due to the early cold and wet soil conditions in 2002, which reduced plant population (Fig. 1) compared with 2001. A delay in collecting plant samples of the R6 growth stage caused a significant loss in leaf mass, leading to a lower biomass. Therefore, the data for R6 of both sites in 2002 were not included in the results in Table 1.

Generally, plant N uptake at V6, V12, VT, and R6 was greater with CP than NT and ST treatments in both years and sites (Table 2). The general trend showed that N uptake increased with ST for all growth stages compared with the NT across sites and years. This may be attributed to the effect of N placement within the tilled zone where N becomes more available and the possibility of increased organic N mineralization due to soil disturbance compared with NT treatment.

Corn Grain Yield, Grain Nitrogen Uptake, and Water Use Efficiency

Grain yield associated with CP was greater than that associated with ST and NT by 0.7 and 0.6 Mg ha^{-1}, respectively, in 2001 and 0.6 and 0.7 in 2002 at Ames. At Nashua, yields were not impacted by tillage in 2001. However, in 2002, different results were observed where ST and CP outyielded NT. In general, ST showed a yield increase over both CP and NT of 0.3 to 0.5 Mg ha^{-1} in 2001, and both ST and CP had a yield increase of 1.8 Mg ha^{-1} over NT in 2002 (Table 3). Grain N uptake was not influenced by tillage in 2001 at both sites. Slightly different results were observed in 2002 where NT grain

Table 3. Corn grain yield, grain N uptake, and grain water use efficiency (WUE) of corn planted in strip-tillage (ST), chisel plow (CP), and no-tillage (NT) in 2001 and 2002.

		Corn yield		Grain N uptake		Grain WUE	
Site	Treatment	2001	2002	2001	2002	2001	2002
		— Mg ha^{-1} —		— kg ha^{-1} —		–kg ha^{-1} mm^{-1}–	
Ames	ST	11.4a†	14.2a	130.1a	164.6a	20.0a	23.2a
	CP	12.1a	14.8a	156.4a	159.0a	21.3a	22.5a
	NT	11.5a	14.1a	142.3a	158.2a	20.3a	22.9a
Nashua	ST	13.8a	14.9a	161.6a	174.0a	26.6a	28.3a
	CP	13.3a	14.9a	160.0a	173.5a	25.5a	28.2a
	NT	13.5a	13.1b	147.3a	147.0b	25.8a	24.8b

† Means within the same column with same letter are not significantly different according to a protected Fisher $LSD_{(0.05)}$.

N uptake was lower than that of ST and CP at the Nashua site (Table 3). Strip-tillage showed no significant improvement in the grain WUE when compared with CP and NT at the Ames site in 2001 and 2002 (Table 3). Similarly, at Nashua, tillage did not influence grain WUE in 2001. Different results were observed in 2002 where WUE was lower in NT than ST and CP.

Soil Water Storage

In the postemergence period at Ames in 2001, tillage did not influence soil moisture in the surface 30 cm. Different results were observed in the postemergence period where NT had numerically greater (13 and 23%) soil moisture storage than ST and CP, respectively (Table 4). However, in 2002, stored soil moisture in the 0- to 30-cm soil depth with ST was significantly greater than that of NT at the postemergence period. When comparing soil moisture storage in the top 0- to 30-cm soil depth from postemergence to tasseling in 2001, the moisture storage declined by 29, 25, and 41% for ST, CP, and NT, respectively. In 2002, soil moisture storage in the top 30-cm soil depth from postemergence to tasseling declined by 22, 0, and 8% under ST, CP, and NT, respectively. On the other hand, no considerable changes in soil moisture storage in the top 30-cm soil depth were noticed between tasseling and preharvest for all tillage systems. Similar trends were noticed for the 0- to 120-cm soil profile where soil moisture storage was not different between all three tillage systems during postemergence, tasseling, and preharvest periods. Changes in soil moisture storage in the 0- to 120-cm soil profile from postemergence to tasseling were similar to those of the 0- to 30-cm soil depth.

At Nashua, soil moisture storage at the 0- to 30-cm soil depth did not show a significant difference between the three tillage systems in 2001 or 2002 (Table 4) at the three growth stages, except at preharvest in 2001. As the season progressed from postemergence to tasseling, soil moisture storage in the 0- to 30-cm zone decreased by 36, 38, and 21% for ST, CP, and NT, respectively, in 2001, and 28, 26, and 16%, respectively, in 2002. Soil moisture storage in the 0- to 120-cm soil profile was not significantly different for any of the tillage systems, except at tasseling and preharvest, where NT was significantly lower than ST and CP in 2001. Changes in soil moisture storage in the 0- to 120-cm soil depth from postemergence to tasseling were similar to the 0- to 30-cm soil depth.

In summary, tillage did not influence the change in soil moisture storage at both depths. Erbach et al. (1992) had similar findings in Iowa and reported that water content was not affected by tillage in the surface 20 cm. It was also observed that most changes in soil moisture storage occurred between postemergence and tasseling. This may be attributed to lower amounts of precipitation during the postemergence to tasseling periods than during the tasseling to preharvest period where soil recharge takes place and there is slower water uptake by the plant at the later period (Table 4).

CONCLUSIONS

Strip-tillage has the potential to be a competitive tillage system to NT and CP tillage systems. However, results of this study show that ST was comparable to CP and has increased soil temperature by less than 1°C over NT. The advantage ST has over NT is higher ERI in one out of four site-years. In general, ST has no significant effect on increasing corn grain yields, dry matter production, plant and grain N uptake, and WUE compared with the other two tillage systems. The lack of significant advantages of ST over NT may be due to the high variability within the treatments and in part due to a lack of drainage for these soils. Tillage did not influence soil moisture storage in either the 0- to 30- or 0- to 120-cm soil depths. The major change in soil moisture storage occurred between postemergence and tasseling growth stages, with minimal changes in soil moisture between tasseling and preharvest.

Table 4. Tillage effects on soil moisture storage at three growth periods for the Ames and Nashua sites in 2001 and 2002.

			2001			2002		
Site	Depth	Treatment†	Postemergence‡	Tasseling	Preharvest	Postemergence‡	Tasseling	Preharvest
	cm		mm					
Ames	0–30	ST	98.1a§	70.3a	70.7a	99.8a	77.9a	96.2a
		CP	86.9a	65.0a	66.0a	73.8b	74.8a	84.5a
		NT	112.7a	66.3a	71.9a	73.7b	67.5b	86.5a
	0–120	ST	440.7a	314.9a	294.6a	386.0a	364.0a	371.0a
		CP	472.7a	383.5a	285.8a	386.2a	359.8a	376.6a
		NT	545.8a	438.5a	290.2a	358.5a	329.7a	343.1a
		Rainfall	–	44	95	–	113	209
Nashua	0–30	ST	76.6a	48.8a	80.6a	86.3a	62.2a	86.0a
		CP	64.5a	39.7a	72.9a	89.0a	65.6a	95.3a
		NT	55.4a	43.7a	38.3b	86.6a	73.0a	83.8a
	0–120	ST	378.5a	328.3a	325.2a	350.6a	321.5a	377.3a
		CP	391.9a	327.1a	313.3a	351.0a	316.5a	380.3a
		NT	281.9a	241.7b	227.7b	341.6a	314.5a	365.7a
		Rainfall	–	2	124	–	118	283

† ST, fall strip-tillage; CP, chisel plow; NT, no-tillage.

‡ Postemergence, tasseling, and preharvest soil moisture measurements at Ames were taken on 8 June, 10 July, and 28 August 2001 and on 28 May, 9 July, and 19 August 2002, respectively. Postemergence, tasseling, and preharvest soil moisture measurements at Nashua were taken on 28 June, 12 July, and 22 August 2001 and on 30 May, 16 July, and 20 August 2002, respectively.

§ Means within the same column followed by the same letter are not significantly different for each site and depth increment according to a protected Fisher's $LSD_{(0.05)}$.

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