Yield Comparisons Between Continuous No-Till and Tillage Rotations

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ABSTRACT

CONTINUOUS use of no-till planting systems may result in reduced yields, especially on finer textured soils that tend to be poorly drained. Soil compaction and poor soil aeration have been identified as possible factors contributing to the lower yields. Research conducted to evaluate tillage rotations on these soils shows that periodic use of the moldboard plow can result in statistically higher yields as compared to continuous no-till. However, use of chisel plow and disk tillage systems following three years of continuous no-till did not result in yield increases. A relationship between cone penetrometer index and yield indicates a trend toward lower yield with higher index values with continuous no-till having the highest index.

INTRODUCTION

No-till farming systems have been used successfully by producers on several different soil types. However, continuous use of no-till has created concerns regarding soil compaction and yield. Bauder et al. (1981) showed that no-till had the greatest soil density and least soil porosity when compared to other tillage systems used for 10 years on a clay loam soil. The same study also indicated that no-till had high soil resistance to penetration of a cone penetrometer. Pope (1982) indicated that soils tend to be more compact with no-till and other reduced tillage systems. According to Voorhees (1982), a no-till system may be undesirable on a fine textured soil or on a soil that has marginal tilth at the outset and that when using conservation tillage, tractors weighing as little as possible are preferred to reduce soil compaction.

Soil compaction is generally viewed as being a cause of reduced plant activity (Gaultney et al., 1980). Taylor (1971) found that an increase in soil compaction as indicated by resistance to penetration can lower crop yields because the depth of root penetration and proliferation is reduced. Trouse (1971) observed that even with relatively low levels of compaction, roots elongate slowly with resulting slower plant development. Voorhees (1979) showed soil compaction induced by wheel traffic can reduce or eliminate root growth in 60% of the upper 30 cm of a clay loam soil. Since most fertilizer is incorporated within this surface layer, plant uptake of immobile fertilizer elements such as phosphorous may be reduced. Phillips and Kirkham (1962) reported corn yield reductions of 10% because of compaction. Gaultney et al. (1980) observed corn yield reductions of about 50% in a compacted soil having excess water, while a 45% reduction occurred in a more normal water regime. Moderate subsoil compaction reduced yields by 25%.

Regardless of tillage or planting system used, the need for timely planting, harvesting or other field operations can result in driving on a field which is too wet. Driving on or tilling a wet soil is a major cause of compaction (Robertson and Erickson, 1978). Moisture conservation and delays in soil drying because of residue cover further complicate the problem of avoiding wet soils when farming with no-till. While systems other than no-till rely on manipulating the soil to reduce compaction problems, no-till relies mainly on annual freeze-thaw cycles. Unfortunately, freezing and thawing broke up only 50% of the compaction in the upper 7 cm of soil and less than 25% in the upper 30 cm in a study by Voorhees (1979). However, fall plowing in conjunction with freezing and thawing eliminated almost 90% of the compaction in the upper 20 cm of soil. Griffith et al. (1973) suggested periodic moldboard plowing be used to reduce some of the compaction problems associated with no-till farming. However, a six-year study by Shear and Moschler (1969) on a loam soil showed no yield advantage in alternating moldboard plow and no-till systems.

The objective of this study was to evaluate the effects on yield of changing from continuous no-till to other tillage systems in both irrigated and non-irrigated conditions on a silty clay loam soil.

PROCEDURE

Continuous corn plots were established in 1977 at the University of Nebraska Field Laboratory near Mead, Nebraska. Soils in the plots were in the Sharpsburg-Fillmore Association with the dominate soil type being Fillmore silty clay loam. The loess soil had less than a 2% slope and was somewhat poorly drained. To obtain relatively equivalent initial conditions, all plot areas were chiseled and disked in 1977. Different tillage treatments were initiated in 1978.

Basic spring tillage systems used were no-till, disk, chisel and moldboard plow. Specific operations, in order within each system, were:

No-till—shred stalks, plant, apply herbicide, fertilize, cultivate twice;

Disk—shred stalks, disk twice, plant, apply herbicide, fertilize, cultivate twice;

Chisel—shred stalks, chisel, disk, plant, apply herbicide, fertilize, cultivate twice; and

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Moldboard plow—shred stalks, plow, disk twice, plant, apply herbicide, fertilize, cultivate twice.

Standard production implements were used for all field operations. Depths for the tillage operations were 20 cm for the moldboard plow, 25 cm for the chisel and 15 cm for the initial disking. For final seedbed preparation, disking depth was 10 cm.

Tillage treatments used to evaluate the effect of changing from continuous no-till to other tillage systems included:

1. Continuous no-till
2. Two years no-till followed by
   (a) plow system
   (b) chisel system
   (c) disk system
3. Three years no-till followed by
   (a) plow system
   (b) chisel system
   (c) disk system.

In addition, a continuous disk treatment was included in the study for yield comparisons because the disk system is commonly used in Nebraska (Dickey and Rider, 1980).

The tillage treatments were evaluated in a non-irrigated and three irrigated conditions. Within each of the four water treatments, the tillage plots, 11.0 m wide by 15.2 m long, were replicated three times.

Within years, several cultural practices remained the same. In 1978, a Buffalo Till-Planter equipped with a sweep in front of each planting unit and a runner opener was used in all plots. An Allis-Chalmers 333 No-Til Special, having 7.6 cm wide fluted coulters, double disk furrowers and double disk openers was used to plant all treatments in 1979 and 1980. In 1981, a John Deere Max-Emerge 7000 planter equipped with 7.6 cm wide fluted coulters and double disk openers was used in all plots. No planter adjustments were made among treatments.

The planters were set for 61,880 seeds/ha and a 5 cm planting depth. The corn variety used all four years was B73 x Mo14. Planting was initiated on May 18, 1978; May 16, 1979; April 25, 1980; and May 14, 1981 and was generally completed in less than three days.

Fertilization rates were based on soil tests and University of Nebraska recommendations and were the same for all plots within years. Knives, operating at a depth of 15 to 20 cm, were used to inject liquid fertilizer after planting in all plots except for the 1978 and 1979 irrigated plots where fertigation was used. Herbicide and insecticide application rates and method of application were also the same for all plots within years with the exception of 1981 when herbigation was used on the irrigated plots.

A center pivot sprinkler system, designed by Gilley et al. (1981) to apply three different amounts of water along the pivot length, was used on the irrigated plots. The sprinklers toward the outer end of the machine were sized to supply a discharge (0.90 L/s/ha) to meet the crop evapotranspiration requirements (1.0 ET) for eastern Nebraska. The other two irrigation treatments, 0.75 ET and 0.50 ET, were located adjacent to the 1.0 ET area. To schedule irrigation, ET rates were estimated by using daily weather data, the modified Penman evapotranspiration equation and crop coefficient curves for corn. Soil moisture deficit was measured with a neutron probe. Irrigations were scheduled to maintain a soil moisture depletion of less than 50% in the 1.0 ET plot areas. The total irrigation water and rainfall which occurred in the plot areas from May 1 to September 1 are given in Table 1.

TABLE 1. RAINFALL PLUS IRRIGATION WATER APPLIED TO THE TILLAGE TREATMENTS FROM MAY 1 TO SEPTEMBER 1.

Year	Rainfall plus Irrigation Water			
	Water Treatment			
	Non-irrigated	0.50 ET	0.75 ET	1.0 ET
	mm			
1978	293	377	411	450
1979*	303	400	433	474
1980	348	438	475	520
1981	415	496	529	574

* Irrigated until September 14.

Soil penetration resistance to a cone penetrometer was used to estimate the degree of compaction for the various tillage treatments. Cone index measurements were taken in 1980, three weeks after planting but prior to cultivation and irrigation. A hand-operated soil cone penetrometer having a 30 deg, 3.2 sq cm, 20.27 mm diameter cone was used in accordance with procedures outlined in ASAE Standard S313.1 (ASAE, 1979). Readings were taken in the row at depth increments of 5 cm to a total depth of 20 cm. The cone index measurements for the tillage treatments evaluated consisted of three replications having five subsamples.

Grain yield data were collected by hand picking two 7.7 m row lengths from each plot. Each sample was shelled and weighed. A subsample was taken from the shelled corn and oven dried for moisture content determination. Grain yields are reported on a 15.5% wet basis.

RESULTS AND DISCUSSION

GRAIN YIELD

Yields from each tillage and water treatment for the four year study are shown in Table 2. Highest and lowest yields were obtained in 1978 and 1980, respectively. Even though more than 330 mm of rainfall occurred between May 1 and September 1, 1980, there was no measurable precipitation from mid-June through mid-August causing plant stress and subsequent yield reductions on the non-irrigated and partial irrigation treatments.

TABLE 2. GRAIN YIELD FROM THE TILLAGE AND WATER TREATMENT COMBINATIONS FOR THE FOUR YEAR STUDY.

Year	Tillage treatment*	Yield			
		Water treatment			
		Non-irrigated	0.50 ET	0.75 ET	1.0 ET
		kg/ha			
1978	N	9,270	10,700 ^{a}†	9,450 ^{a}	11,000 ^{a}
	D	8,360	9,740 ^{b}	10,400 ^{a}	10,200 ^{a}
1979	NN	4,810 ^{a}	7,910 ^{a}	8,750 ^{a}	9,070 ^{a}
	DD	4,890 ^{a}	7,770 ^{a}	9,420 ^{a}	8,780 ^{a}
1980	NNN	327 ^{b}	5,840 ^{ab}	6,910 ^{b}	8,260 ^{a}
	DDD	505 ^{b}	5,300 ^{b}	7,460 ^{b}	8,360 ^{a}
	NND	704 ^{b}	5,370 ^{ab}	7,080 ^{b}	8,170 ^{a}
	NNC	1,290 ^{b}	6,140 ^{ab}	7,370 ^{b}	8,760 ^{a}
	NNP	2,900 ^{a}	6,640 ^{a}	8,550 ^{a}	8,770 ^{a}
1981	NNNN	7,350 ^{b}	8,980 ^{bc}	8,710 ^{ab}	9,030 ^{ab}
	DDDD	8,310 ^{ab}	8,360 ^{c}	8,040 ^{b}	8,350 ^{b}
	NNND	—	9,160 ^{abc}	8,510 ^{ab}	8,710 ^{ab}
	NNNC	—	9,170 ^{abc}	8,720 ^{ab}	8,750 ^{ab}
	NNNP	8,650 ^{a}	9,700 ^{a}	8,950 ^{ab}	8,990 ^{ab}
	NNPN	—	9,230 ^{ab}	9,440 ^{a}	9,890 ^{a}

* N is no-till system, D is disk system, C is chisel system and P is moldboard plow system.

† Numbers with same superscript are not significantly different (Duncan's multiple range test, 5% level) within each water treatment and each year.

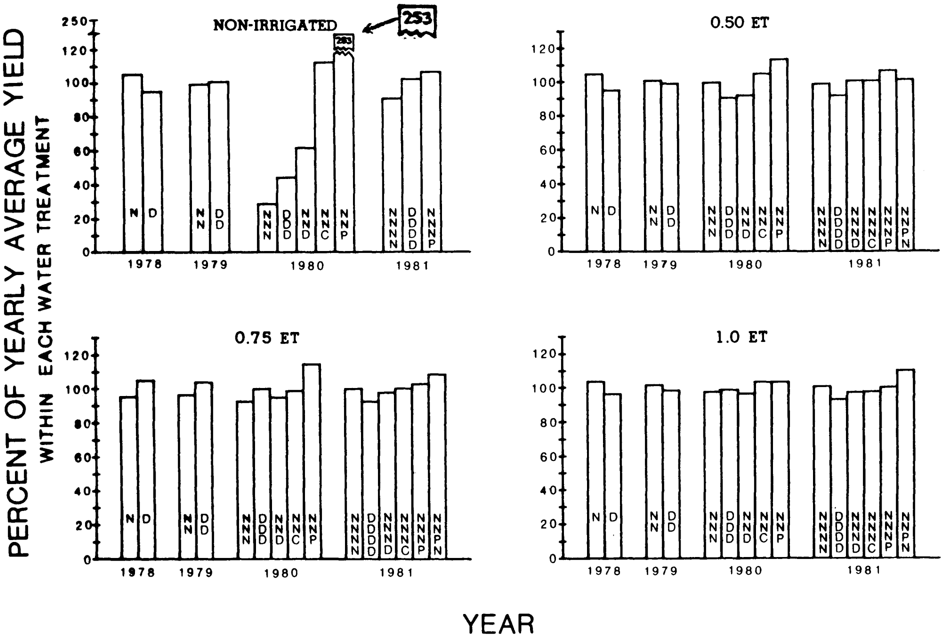

Fig. 1—Grain yield as a percent of yearly average for the different tillage systems within each water treatment. N is no-till, D is disk, C is chisel, and P is the moldboard plow system.

While not an integral part of this study, a yield response from irrigation occurred. To make comparisons between the tillage and irrigation treatment combinations, corn yields are shown relative to the yearly mean yield for all tillage treatments within each water treatment in Fig. 1.

Non-Irrigated: The mean yield for non-irrigated plots was 5,730 kg/ha for the four year study and ranged from a yearly mean of 1,140 to 8,790. In both 1980 and 1981, yields tended to increase as the amount of tillage increased with the moldboard plow treatment having the highest yield (Fig. 1). Although the disk and chisel treatments had higher yields than the continuous no-till treatment in 1980, there were no statistical differences among these treatments. Moldboard plowing after no-till was statistically higher than continuous no-till in both 1980 and 1981. The difference in yield between these treatments was 2,570 and 1,300 kg/ha in 1980 and 1981, respectively.

0.50 ET: The mean yield for the 0.50 ET treatment was 8,250 kg/ha, ranging from a yearly mean of 5,730 to 10,240. Following two years of no-till, there was a trend of increased yields as the tillage went from the disk treatment to moldboard plow treatment. However, only the yields from moldboard plowing were higher than those of the continuous disk treatment at the 5% significance level. In 1981, moldboard plowing following three years of no-till produced a significantly higher yield than either continuous disk or continuous no-till, 1,340 and 722 kg/ha higher, respectively. The no-till treatment yield following the 1980 plow treatment was also significantly higher than the continuous disk treatment indicating that the benefits derived from moldboard plowing were extended into the following season.

0.75 ET: The mean yield for the 0.75 ET treatment for the four year study was 8,810 kg/ha, a 54 percent increase above the non-irrigated plots. The annual mean yield ranged from 7,480 to 9,930 kg/ha. In 1980, the moldboard plow treatment was statistically higher than all other tillage treatments. The yield difference between the plow and no-till treatments was 1,640 kg/ha. Although not statistically higher, the 1981 moldboard plow treatment yield was higher than all treatments except no-till following plowing. As with the 0.50 ET treatment, the yields from no-till following plowing were statistically higher than continuous disk, again indicating that it may not be necessary to plow every year.

1.0 ET: The average yield for all treatments receiving 1.0 ET was 9,250 kg/ha with a range of 8,470 to 10,630 in the yearly mean. The average yield was 61% greater than the yield of the non-irrigated plots. In 1980, no statistical yield benefits were derived from any tillage treatment used following two years of continuous no-till. However, in 1981, no-till yields following the plow treatment were higher than all other treatments. As seen in the 0.50 and 0.75 ET treatments, no-till yields following the plow treatment were statistically higher than the continuous disk treatment.

Yield Summary: Corn yields from the non-irrigated plots tended to increase as the amount of tillage increased with the moldboard plow having the highest yield and no-till having the lowest yield in both 1980 and 1981. This trend was also observed in 1980 for the irrigated plots. However, the trend toward increased yields with more tillage was not as pronounced as the amount of water applied increased. In 1981, plowing following no-till also increased yields, but the highest yields for the 0.75 and 1.0 ET treatments occurred when no-till was used following the 1980 plow treatment. This indicates for the soil studied, that plowing has a definite yield advantage over continuous no-till farming but the soil does not need to be plowed every year. Based on the results presented, as a maximum, the soil would need to be plowed only in alternate years. Although the chisel and disk treatments used following two and three years of no-till tended to increase yields when compared to either the continuous disk or no-till treatments, the yield increase was not statistically significant at the 5% level. For the soil studied and yield trends observed, chiseling periodically would be more advisable than periodic

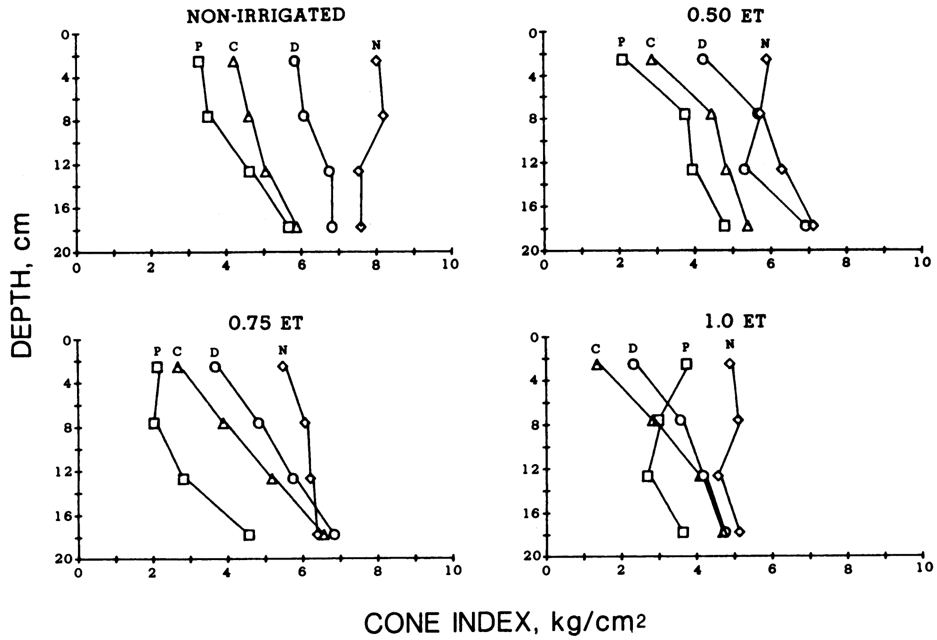

Fig. 2—Cone index measurements with depth for the different tillage and water treatments. Two years of consecutive no-till preceded the 1980 treatments of no-till (N), disk (D), chisel (C) and moldboard plow (P).

disking.

SOIL PENETRATION RESISTANCE

The cone index generally decreased as the amount of tillage increased (Fig. 2). With the exception of the 1.0 ET water treatment, the moldboard plow system had the least soil resistance to penetration while no-till had the greatest amount of resistance. At 1.0 ET, the plow treatment, though lower than no-till, had a higher cone index than either the chisel or disk treatments in the upper 5 cm of soil. Generally, the cone index and thus compaction increased with depth for the plow, chisel and disk treatments. However, no-till tended to have about the same cone index throughout the soil profile measured.

The moldboard plow treatment had a significantly lower cone index at the 5% level than did no-till at all depths measured and for all water treatments (Table 3). With the exception of 1.0 ET, the plow treatment generally had a statistically lower cone index than the disk treatment. Except for 0.50 ET, the no-till treatment always had a statistically higher cone index in the upper 10 cm of soil. Below 10 cm, the no-till cone index was generally not statistically different than either the disk or chisel treatments.

RELATING CONE INDEX AND YIELD

The cone index, being largest for the no-till treatment, never exceeded 8.4 kg/cm². Threadgill (1982) indicates that cone index values greater than 21.1 kg/cm² frequently reduce crop yields and values above 14.1 kg/cm² reduce root growth. For this study, grain yield was consistently lower for the continuous no-till treatment, even though the maximum cone index values were less than half those reported by Threadgill. However, cone index values reported by Voorhees (1979) for the northern corn belt are comparable to those obtained in this study. As with Voorhees' results, the cone index values reported were obtained early in the growing season when the soil was relatively moist. Differences in cone index values among tillage treatments would have probably been greater, if taken later in the growing season because of lower soil moisture contents.

Cone index values were lower as the amount of tillage increased with the moldboard plow treatment having the lowest cone index value. Conversely, yields tended to increase as the amount of tillage increased, except yield differences became less as the amount of water applied increased. In 1980, at the 1.0 ET water treatment, statistical differences were measured in cone index values, but there were no statistical differences in yield. These results indicate that given adequate rainfall or

TABLE 3. CONE INDEX VALUES BY TILLAGE AND WATER TREATMENT FOR DIFFERENT DEPTHS.

Water Treatment	Tillage Treatment*	Cone Index			
		Soil Depth (cm)			
		0-5	5-10	10-15	15-20
		kg/cm²			
Non-irrigated	P	3.28 a†	3.52 a	4.62 a	5.66 a
	C	4.21 a	4.61 a	5.05 a	5.88 ab
	D	5.84 b	6.08 b	6.75 b	6.82 ab
	N	8.02 c	8.20 c	7.53 b	7.59 b
0.50 ET	P	2.10 a	3.75 a	3.94 a	4.78 a
	C	2.88 ab	4.45 ab	4.83 ab	5.39 a
	D	4.24 bc	5.60 b	5.31 bc	6.91 b
	N	5.92 c	5.73 b	6.29 c	7.12 b
0.75 ET	P	2.13 a	2.03 a	2.81 a	4.56 a
	C	2.68 a	3.88 b	5.17 b	6.55 b
	D	3.68 a	4.82 b	5.73 b	6.83 b
	N	5.48 b	6.06 c	6.20 b	6.38 b
1.0 ET	P	3.74 b	2.99 a	2.69 a	3.63 a
	C	1.36 a	2.83 a	4.08 b	4.69 b
	D	2.33 a	3.57 a	4.17 b	4.75 b
	N	4.88 c	5.10 b	4.56 b	5.13 b

* P is moldboard plow system, C is chisel system, D is disk system and N is no-till system.

† Numbers with same superscript are not significantly different (Duncan's multiple range, 5% level) within each depth and water treatment.

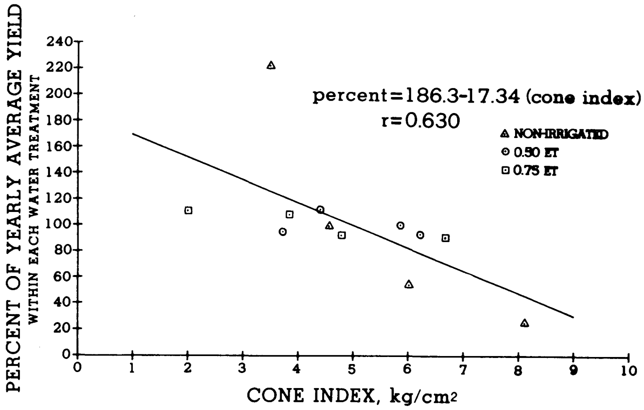

Fig. 3—Relationship between cone index for the 5 to 10 cm depth and yield as a percent of the yearly water treatment average yield.

irrigation, compaction may not influence yield, at least within the range of cone index values measured in this study.

Yields from the tillage treatments in the non-irrigated, 0.50 ET and 0.75 ET water treatments were used to develop potential relationships with cone index values. In order to make comparisons among the water treatments, yields were expressed as a ratio of tillage treatment yield to the mean yield for the water treatment. Though not conclusive, Fig. 3 indicates a definite trend ($r = 0.63$) toward reduced yields as the cone index increases. Cone index values measured in the 5 to 10 cm depth were used in the relationship because that was the location of plant roots when the cone penetrometer measurements were taken.

CONCLUSIONS

Moldboard plowing after two or more years of continuous no-till farming may offer yield increases on somewhat poorly drained soils. However, plowing may not be needed every year since the yield from no-till following plowing was similar to that of plowing. The yield advantage resulting from plowing the continuous no-till area tended to decrease as the amount of water applied increased with no statistical yield difference being measured at 1.0 ET. Although rotating from continuous no-till farming to either the chisel or disk systems tended to increase yield, the increases were not statistically significant at the 5% level at any level of water application.

As indicated by the cone index values, the continuous no-till treatment was the most compact soil, while plowing was the least compact. Chiseling and disking also had lower cone index values than continuous no-till in the upper 10 cm of soil. However, no statistical difference in cone index value among these three tillage treatments existed below 10 cm. A relationship was developed showing yield decreases as cone index values increase. Even though the cone indexes were different at the 1.0 ET water treatment, yields were not statistically different indicating that, given adequate rainfall or irrigation, compaction, in the range of conditions studied, may not reduce yields.

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