Microirrigation for Reduced Tillage in a Shallow Hardpan Soil

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ABSTRACT

Deep tillage is expensive and time consuming though necessary for proper root development in southeastern Coastal Plain hardpan soils. Maintaining proper water contents within or above the hardpan might maintain yield without deep tillage. Corn (*Zea mays* L.) was grown using microirrigation for three years without subsoil disruption. In three treatments, tubes were placed on the surface either in every row and between every other row or buried within every row. Mean profile soil cone indices were 1.8 to 3.2 MPa for the top 0.6 m. Cone indices were significantly different for treatment interactions by depth and by position by depth. When soil water content was considered as a covariate, cone index treatment differences disappeared. Yields varied from 9.7 to 13.0 Mg/ha. Because soil water was intensively managed, yield levels were maintained over hardpans without deep tillage for three years.

INTRODUCTION

Deep profile disruption is often necessary to provide a suitable medium for plant root growth in Coastal Plain hardpan soils (Doty et al., 1975). Root-restricting cone indices are commonly found in the E horizon of non-tilled coastal Plain subsoils even at field capacity (Campbell et al., 1974).

About 0.075 m of water per meter of soil is typical retention for sandy Coastal Plain Ultisols. Intensive irrigation is needed to provide enough water for profitable plant yield without deep tillage. Wetting the E horizon can also ameliorate its high cone index (Phene and Beale, 1976).

The objective of this paper was to compare water contents and cone indices of hardpan soils for surface and subsurface microirrigation treatments without deep tillage.

METHODS

This study was conducted between 1984 and 1987 on a Norfolk loamy sand soil (fine loamy, siliceous, thermic, Typic Paleudult) in Florence, SC. Plots were 12 by 6 m. Corn (*Zea mays* cv. O's Gold 5509[2]) was planted in twin rows separated by 0.25 m. Centers of the twin rows were 0.75 m apart.

The experimental design was randomized complete block with four replicates. Three treatments were irrigated with microirrigation tubing (Lake Drip-In). In treatment A, tubes were placed between sets of twin rows in alternate mid-rows at 1.5-m spacings; in treatment S, tubes were placed in the middle of each twin-row pair at 0.75-m spacings. The third treatment, B, had tubes buried at 0.25- to 0.30-m depths below the middle of each twin-row pair at 0.75-m spacings.

Because of the buried tube, it was not feasible to in-row subsoil each year, which is the recommended practice for this soil. All plots had been cross subsoiled at 45° angles to the rows in August 1984 prior to installation of the treatments. In early November 1984, tubes were plowed into treatment B using a steel tube attached to a subsoil shank as a guide. No plots were deep tilled thereafter.

Spring land preparation included disking followed by leveling with a tined field cultivator. Corn was planted at 74,000 plants/ha on 27 March 1985, 31 March 1986 and 14 April 1987. The same wheel tracks were maintained throughout the study. Pesticide and fertilizer were applied as recommended by the South Carolina Cooperative Extension Service (265-24-140, 270-24-46 and 260-29-84 kg/ha of N-P-K for 1985, 1986 and 1987, respectively).

If there was no rain, irrigation of 6 mm was applied daily. This was doubled if tensiometers at the 0.3-m depth indicated 25 kPa or drier. Since treatment A had half the number of tubes, irrigation ran twice as long as for treatments S and B. Irrigation was applied either continuously or in 20-min on-off pulses to improve distribution, as suggested by Busscher and Lin (1981).

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Cone indices were taken for two replicates on 23 July 1986 and 23 July 1987. Measurements were taken with a 13-mm diameter, 30° cone tip penetrometer (Carter, 1967) to a depth of 0.6 m at four positions across the row: at the midpoint within the twin-row, at one of the twin-rows, in the quarter row and in the mid-row.

Cone index data were analyzed using the general linear models procedure (GLM) of SAS (1985) with strip sub-plots for depth and position across the row (Radcliffe et al., 1989). Probability levels up to 10% were considered significant.

In 1986, a drought year, plots received a special irrigation of 25 mm before penetrometer readings were taken. In 1987 penetrometer readings were taken after a regularly scheduled 12-mm irrigation. Gravimetric soil-water contents were taken at 0.15-m depth intervals in the mid-row and in-row (midpoint within a twin-row pair) positions on penetrometer sampling dates. Water content data were also analyzed using GLM.

Cone index data were reanalyzed using only the positions where water content had been measured. Data were also reanalyzed with water content as a covariate, as recommended by Asady et al. (1987).

Tensiometers were installed in two replicates to aid in irrigation scheduling. They were located at 0.3-, 0.6-, 0.9- and 1.2-m depths at positions next to the tube, one fourth of the way to the next tube and between the tubes. Duplicate sets were located at the emitter and midway between emitters of the microirrigation tube. They were read two to three times a week until irrigation ended, at physiological maturity. Tensiometer data were analyzed using GLM with depth, position between microirrigation tubes and location with respect to the emitter as strip subplots.

After the growing season of 1986, fallow plots of four replicates of treatments S and B received 12 mm of irrigation. Gravimetric samples were taken at 0.15-m depth intervals and at 0.075-m intervals perpendicular to the tube to monitor soil-water content. Samples were taken at positions ranging from adjacent to the microirrigation tube to 0.3 m away from it. For Treatment B, a sample was not taken at the tube since that could have punctured it. Gravimetric samples were taken just before irrigation and at 1 h, 24 h, 48 h and 144 h after irrigation. These data were analyzed using GLM by treatment, position away from the tube and depth to find differences of water content with time.

RESULTS AND DISCUSSION

Average yield over all types of irrigation was 11.6 Mg/ha (Table 1), indicating that Zea mays could be successfully grown for three years without deep disruption of the soil with intensive water management. Average yields were 11.1 Mg/ha and 12.2 Mg/ha for treatments A and S, respectively. These treatments were not subsoiled annually although they could have been since the microirrigation tubes were removed every fall. Treatment B had an average yield of 11.5 Mg/ha. It could not have been subsoiled without destruction of the buried tube. In 1986 South Carolina experienced a severe drought. During periods of excessive heat, maintaining proper soil water was difficult, and yield was reduced on all treatments. A detailed discussion of the irrigation schedule can be found in Camp et al. (1989).

Deep tillage of all plots was necessary in August 1984 to prevent treatment B from having an advantage since the buried tube was installed with a subsoiler. Higher yields for all treatments in 1985 (Table 1) may have been a result of the 1984 subsoiling.

No cone indices were taken until July 1986 to permit reconsolidation of the disrupted subsoil (Busscher et al. 1986). Analysis of cone index data showed statistically significant treatment interactions for 1986 and 1987 by depth and depth by position. In 1987 there was also a position by treatment difference. Cone indices were higher for treatment A than for treatments S and B in both years, although in 1987 the difference over treatment S was marginal (Table 2). When analyzed by depth, treatments that had significantly higher cone indices also had lower soil water contents (Table 3). This trend was also seen for the means but not as rigorously as for the comparisons by depth.

For all treatments, cone index increased with depth from the surface to the 0.20-m depth, which was within the hardpan (Table 2). Cone indices then decreased until the 0.35-m to 0.50-m depth where they began to increase again. Treatment S had the highest mean soil water content both years, though

Table 1. Corn yield.

Tube placement	Yield 1985	1986	1987
	----------mg/ha----------		
A	13.0	09.7	10.7
B	12.6	10.8	11.2
S	12.5	11.6	12.4

Table 2. Mean cone indices for each treatment and depth.

	Cone Index (MPa)					
	1986			1987		
	Treatment					
Depth	A	B	S	A	B	S
--m--	MPa					
0.00	0.31a[1]	0.55a	0.46a	0.27a	0.20a	0.16a
0.05	0.86a	1.43a	1.02a	0.65a	0.53b	0.38b
0.10	1.84a	2.06a	1.57a	1.30a	1.17a	1.04a
0.15	3.09a	2.71a	2.45a	3.02a	2.79a	2.62a
0.20	4.02a	3.05a	2.62a	3.48a	3.65a	3.03a
0.25	3.54a	2.768	2.41a	3.02a	3.34a	2.94a
0.30	3.48a	2.30a	1.95a	2.61a	2.70a	2.44a
0.35	2.81a	1.91ab	1.60b	2.52a	2.24a	2.39a
0.40	2.36a	1.58ab	1.23b	2.40a	1.79a	2.74a
0.45	2.63a	1.53b	1.27c	2.87a	1.93b	3.25a
0.50	4.45a	1.43b	1.47b	4.53a	3.37a	4.66a
0.55	5.46a	1.84b	2.09b	5.15a	4.76a	5.46a
0.60	6.18a	2.26a	2.87a	5.84a	5.08a	6.09a
Mean	3.16a	1.95a	1.77a	2.90a	2.58a	2.86a

[1]Means with the same letter are not significantly different for depth.

Table 3. Mean soil water contents taken at the time of cone index measurement

	Water content					
	1986			1987		
	Treatment					
Depth	A	B	S	A	B	S
--m--	kg/kg					
0.08	0.159	0.157	0.170	0.146	0.182	0.205
0.23	0.131	0.133	0.148	0.127	0.140	0.144
0.38	0.167	0.159	0.193	0.156	0.164	0.178
0.53	0.161	0.174	0.181	0.141	0.164	0.154
Mean	0.154a[1]	0.156a	0.173a	0.142a	0.162b	0.170b

[1]Means with the same letter are not Significantly different.

it was significantly higher than treatment A only in 1987.

Cone index data were reanalyzed using only positions where water content had been measured. Treatment differences with depth in 1986 and with position by depth in 1987 were still significant. When these data were reanalyzed with water content as a covariate, treatment interactions disappeared. The water content effect on cone index was not significant in 1986; however, including it in the analysis prevented the significance of the treatment interactions.

Low matric water tension was maintained throughout the growing season (Fig. 1 and 2). Tensiometer readings varied with depth, generally decreasing with increasing depth early in the growing season and fluctuating later. Interactions of the treatments with depth and positions across and along the row were significantly different for both years. When the data were analyzed by depth and by position across and along the row, the 0.9-m depth in treatment B usually had the lowest overall matric tension in 1986 (Fig. 1). Treatment B does not have the lowest matric tension at the depth of the tube, presumably because increased root growth increases water losses from the zone.

The largest fluctuations of soil water tension were at the soil surface (Fig. 1 and 2). This was

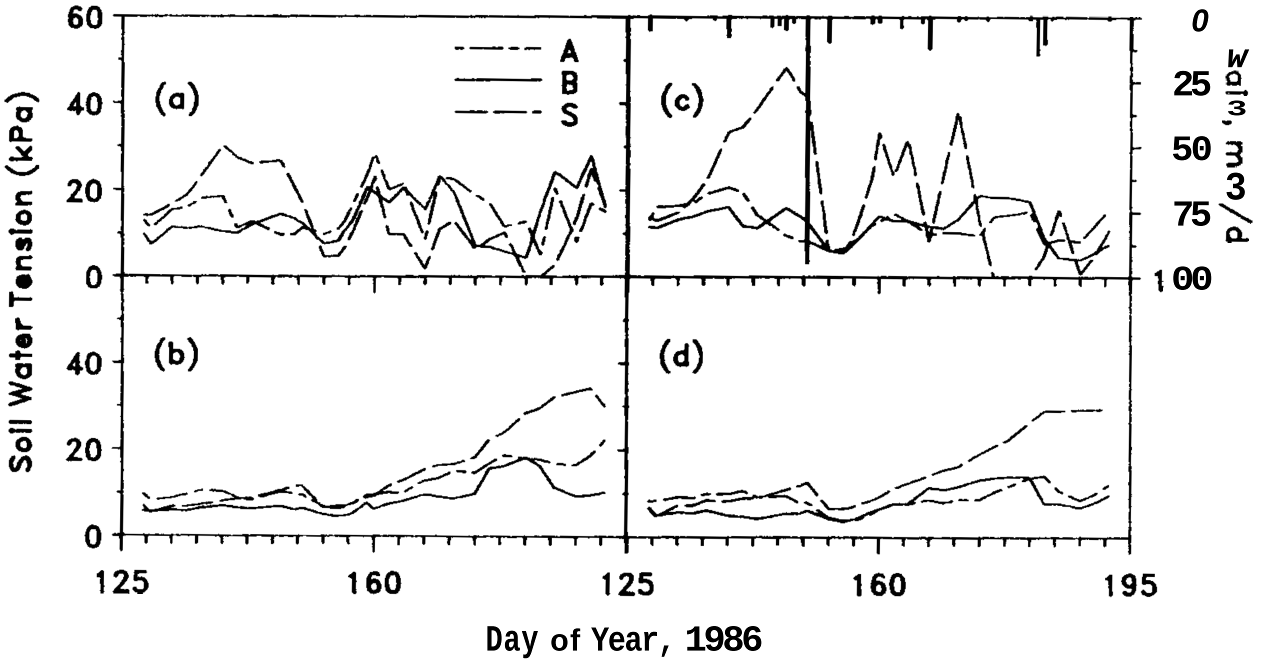

Fig. 1. Soil matric tensions for 0.3-m (a) and 0.9-m (b) depths at the microirrigation tube and for 0.3-m (c) and 0.9-m (d) depths midway between tubes for 1986. The means of readings at the emitter and between emitters were taken before plotting.

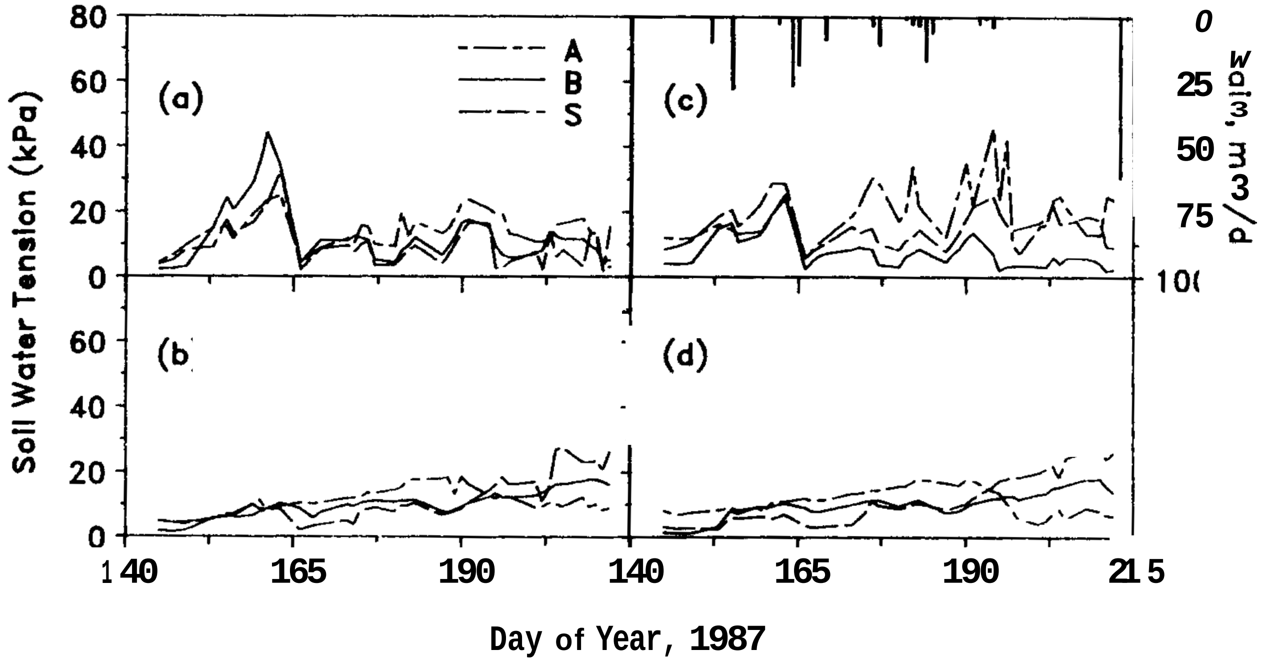

Fig. 2. Soil matric tensions for 0.3-m (a) and 0.9-m (b) depths at the microirrigation tube and for 0.3-m (c) and 0.9-m (d) depths between adjacent tubes for 1987. The means of readings at the emitter and between emitters were taken before plotting.

expected because of root growth and rainfall. Figures 1 and 2 also show a rise of water tension with time at the 0.9-m depth in 1986, a drought year, but not in 1987.

Gravimetric samples taken on bare treatments S and B before and after a 12-mm irrigation in 1986 showed differences in soil wetting patterns, but the water contents for the treatments were not significantly different. However, when data were analyzed by position across the row, treatment wetting patterns did show significant differences (Table 4). During this test, as well as throughout the growing season, water from the tubes of treatment S spread out across the surface before infiltrating. This is seen by the rise in water content at shallow depth 1 hour after initiation of irrigation (Table 4). Occasionally, wet spots were noticed on the surface above the emitters of the buried tubes. However, the wet area was seldom more than 0.1 m in radius. This implies that treatment B would have lower evaporation but may be more susceptible to water losses to deep percolation. Treatment S retained more water in the soil.

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Table 4. Soil water contents for five positions across the rows of bare plots before and after Irrigation.

	Position									
	0		0.076		0.152		0.228		0.304	
Time	S	B	S	B	S	B	S	B	S	B
---h---	kg/kg									
0	0.1%'	--	0.1%	0.13c	0.14b	0.13a	0.14ab	0.13a	0.13b	0.13a
1	0.18a	--	0.17a	0.15a	0.1%	0.14a	0.15a	0.1%	0.14ab	0.14a
24	0.15b	--	0.16ab	0.15ab	0.14b	0.14a	0.14b	0.14a	0.14ab	0.14a
48	0.14bc	--	0.14bc	0.14abc	0.14ab	0.14a	0.15ab	0.14a	0.14ab	0.14a
144	0.14bc	-	0.14c	0.13bc	0.14ab	0.13a	0.15b	0.14a	0.15a	0.14a

'Times with the same letter are not significantly different.