SUBSURFACE DRIP IRRIGATION FOR COTTON PRODUCTION IN COASTAL PLAIN SOILS

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Abstract

Replicated tests were conducted for three years at the Edisto Research & Education Center of Clemson University to determine the effects of subsurface drip irrigation on soil compaction and optimum depth of drip irrigation tube placement in coastal plain soils. Three lateral depths (8, 12, and 16 inches), three lateral spacings (under every row, under alternate row middles with and without under the row subsoiling) and a control (non-irrigated) were used.

The rate of water movement in the soil profile for plots with deep tillage was higher than plots without tillage. Soil surface moisture was higher in plots with laterals buried eight inches deep resulting in higher weed infestation than the rest of the treatments. Tillage significantly reduced soil compaction in the top 15 inches of the irrigated plot compared to no subsoiling. Also there was a significant reduction in cone index values in the top 12 inches of dry land plots compared to irrigated lands without tillage. Subsoiled plots with irrigation laterals buried 16 inches deep had the least cone index values at depth of 12-18 inches. Deep tillage significantly increased taproot length in irrigated plots. Taproots in no-till plots were restricted to the depth of the hardpan layer. Keeping this compacted layer wet did not reduced soil strength enough to permit root penetrations into clay.

Drip irrigation significantly increased lint yields compared to non-irrigated plots in all three years. Depth of the irrigation tubes had an effect on cotton yield, increasing with depth in both under every row and using alternate row middles. There were no differences in yield between every vs. alternate row installation at any of the three placement depths. Deep tillage did not increase the cotton yield in 1997 compare to no-till planting because all plots in 1997 had some tillage provided during installation of the irrigation laterals. Although not statistically significant, plots with a deep tillage operation on average yielded 47-lb. and 45-lb. lint/acre more than no-till plots in 1998 and 99 respectively.

Introduction

Subsurface drip irrigation (application of water below the soil surface through emitters) is proving to be an economical method of water application to agronomic row crops such as corn, peanuts and cotton. Research reports for over 30 crops indicated that in most cases subsurface drip irrigation resulted in greater or equal yield than those for other irrigation methods and required less water in many cases (Camp, 1998). In recent years, several investigators have reported on the successful use of subsurface drip irrigation for crop production. Powell and Wright, 1993 reported corn yields of 136-195 bu/acre compared to 49 -149 bu/acre for non-irrigated plots. In a review of subsurface drip irrigation, Camp (1998) found more reports on cotton than any other agronomic crop. Henggeler (1995) reported a cotton yield increase of about 20% for subsurface drip irrigation compared to furrow irrigation in Texas. Irrigated cotton lint yields averaged between 1200 and 1800 lb./acre while non-irrigated cotton yields averaged between 300 and 900 lb./acre (Powell, 1998). Camp et al. (1994 and 1997) reported a significant reduction in system cost by using a wider lateral spacing. Cotton yields were comparable for laterals placed either every row (40-inches) or alternate row middles (80-inches) in the southeastern Coastal Plan.

A subsurface drip irrigation system offers many advantages compared to other irrigation systems: there is less annual labor and an increased life expectancy; a dry soil surface reduces the occurrences of soilborne diseases and helps to control weed infestations; the dry soil in furrow enhances trafficability and reduces soil compaction; there is more efficient use of water and nutrients; and there is a significant improvement in yield and quality components (Phene et al., 1987).

Drip irrigation consists of drip tubes similar to those placed under plastic on beds in high intensity vegetable culture. These tubes are buried 6 to 24 inches below the soil surface under each row or under alternate row middles. By varying the tube types along with the pressure, users can accurately meter out precise amounts of water directly into the root zone. Once installed and with proper management the irrigation system should last longer than ten years. A drip irrigation system installed under each row is estimated to cost $750-$1,000/acre and for alternate row middles about $500-$750/acre. Operating cost for either system is estimated to be between $1.50 and $2.00/acre-inch of water applied (Powell, 1998).

Most of the row crop production in the Southeast is in the Coastal Plains. The sandy soils typical of this region are inherently low in fertility and water holding capacity. The organic matter content of these soils is low (less that 1.0%), which causes poor soil tilth and reduces the rainfall infiltration rate. The result is a lowering of soil productivity and crop yield potential, especially when drought stress

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occurs. Another characteristic of most of the sandy soils of the Southeast Coastal Plains is a hardpan, which restricts root growth and increases the potential for severe yield loss during drought. This hardpan or compaction zone is generic with some soils, and is called an A2 or E-horizon, about 2 to 6 inches thick and 8 to 14 inches deep. This layer must be broken so that root can grow into the subsoil or B-horizon for top crop performance. Deep tillage implements, such as an in-row subsoiler or Paratill, have been shown to improve yields in coastal plain soils and are a requirement for breaking hardpan layers (Garner et al., 1986; Khalilian et al., 1991). Garner, et al. (1989) reported that in-row subsoiling in coastal plain soils increased seed cotton yield by 189 lb./acre compared to non-subsoiled plots. An additional deep tillage operation with Paratill in the fall increased the seed cotton yield about 460 lb./acre. Camp et al. (1999) hypothesized that the need for deep tillage may be reduced if the compacted soil layer is kept moist enough for root growth. They indicated that strategies must be developed to reduce soil strength to obtain optimum no-till crop production with subsurface drip irrigation on coastal plain soils.

Recently interest in subsurface drip irrigation has increased in the southeastern USA. Our farmers are just beginning to recognize the benefits offered by subsurface drip irrigation, benefits southwestern growers have known for years. There is need for research to determine the ideal depth to install the tubes, especially in coastal plain soils, how much water to supply at each application, and whether subsurface drip irrigation can prevent the formation of a hardpan layer in coastal plain soils.

Objectives

The objectives of this study were to determine effects of subsurface drip irrigation on soil compaction (deep tillage vs. no-till) and to determine optimum depth and spacing of drip irrigation tube placement in coastal plain soils.

Materials and Methods

Replicated tests were initiated in 1997 at the Edisto Research and Education Center at Blackville, SC on a Varina loamy sand soil (clayey, kaolinitic, thermic Plinthic Paleudults). Drip irrigation tubes were installed 8, 12, and 16 inches below the soil surface under each cotton row and under alternate row middles (figures 1& 2). These three depths were selected to place the tubes above, within, and below the hardpan layer to determine the optimum depth for installing the irrigation tubes in coastal plain soils. Soil compaction measurements of the test field, before installing the irrigation system, indicated a hardpan in the E-horizon at about 10 to 13-in. depth.

The drip irrigation tubing (T-tape TSX 515, 15 Mil, T-System International, Inc., CA) had in-line, slit-type emitters spaced 24 inches apart delivering about 0.28 gallon of water per 100 ft of tape at eight psi pressure. Laterals were installed using a modified subsoiler shank with a guiding system for the tubing. The drip irrigation system consisted of a 4-in well with a 2-HP electric pump and two canister sand media filtration systems (Yardney Mini-Media, Yardney Water Management Systems, CA). These back washable filters were used for the removal of organic as well as inorganic suspended solids from the water source. Electric control valves and a programmable controller (Rain Bird Model ESP-6LX+, Rain bird Sales Inc., CA) were used for turning the system on and off. Nitrogen was injected into the irrigation system using a venturi injector (MIC Mazzei Injector model 287). Laterals for under every row treatments were connected to one manifold and those for the alternate row middles were connected to another manifold (stations 1 & 2). Within each manifold, a solenoid valve controlled water flow, and pressure was regulated at approximately 20 psi using in-line pressure regulators in the supply manifolds. Flush caps (Ag Products) were installed at the discharge end of each lateral above the soil surface. This allowed partial flushing of every lateral during each irrigation period before pressure buildup in the tubing.

In 1998, test plots were irrigated three times each week. Irrigation applications were usually about 0.75 inches per week (0.25 inch per application day). In 1999, plots were irrigated based on pan evaporation data using water a balance method explained by Harrison and Tyson (1993). The total available water holding capacity in the 24 inch profile for a Varina sandy loam soil is 2.64 inches (SC Agricultural Experiment Station Bulletin 137). Irrigation amount was calculated using local pan evaporation data, crop coefficient values for days after planting, and irrigation efficiency of 90%. Only 50% of the available water holding capacity was replaced. The amount of water applied ranged from 0.3 inches per week at the beginning of season to 1.75 inches per week about four months after planting.

This test involved ten treatments (table 1): three lateral depths (8, 12, and 16 inches), three lateral spacings (under every row, under alternate row middles with and without under the row subsoiling) and a control (non-irrigated). Subsoiling in irrigation plots with tubes under alternate row middles and dry land was performed 12-14 inches deep prior to cotton planting to determine the effects of subsurface irrigation on formation of hardpan and the need for tillage with irrigated cotton. The plot size was eight rows, 70-ft long, spaced 38 inches apart and treatments were replicated four times. The cotton variety, DPL NuCOTN 33B, was planted with a John Deere planter at a rate of three seeds/ft on May 15, 1997 and May 18, 1998. In 1999, DP RR 458 cotton variety was planted on May 14. Aldicarb (5 lb./ac) was applied at planting for early season insect/nematode control. Nitrogen was injected at a rate of 8 lb./acre per week for duration of 10 weeks in 1998 and 11 weeks in 1999 (80 and 88 lb./acre total in 1998 and 99 respectively). In 1997, 90 units of nitrogen was applied (30 units at planting and 60 units side dressed). Bollworms, armyworms, and stinkbugs were controlled as needed according to Clemson University thresholds and recommendations. The two middle rows of each plot were machine harvested using a spindle picker.

To determine the effects of subsurface drip irrigation on soil compaction, a tractor-mounted, hydraulically operated, microcomputer-based, digital recording penetrometer system was used to quantify soil resistance to penetration. Soil cone index values were calculated from the measured force required to push a 0.5 in^2 base area, 30^o cone into the soil at a constant velocity. Penetrometer data (four probes per plot) was taken during the growing season and immediately after cotton harvest in 1998 and 1999. Penetrometer readings were taken to a depth of 18 inches from crop rows. Each plot was sampled for soil moisture content to monitor water distribution for different irrigation systems. Two cores 18-inches deep and 2.5-inches in diameter were taken from each plot two and 24 hours after irrigation in 1998. Soil moisture contents were determined at three-inch intervals. In 1999, cotton taproot length was determined after harvest by digging five plants per row from two middle rows of each plot. Crop responses in terms of boll location, plant height, plant population and yield were determined.

Results and Discussion

Soil moisture contents at different depths in the cotton rows for the plot with laterals under alternate row middles are given in tables 2 and 3. These measurements were taken 2 and 24 hours after irrigation on August 3 & 4, 1998. The rate of water movement in the soil profile was higher in the plots with deep tillage than those without tillage. Soil surface moisture was higher in plots with laterals buried eight inches deep. These plots had also significantly higher weed infestations than the rest of the treatments, and required control with herbicides. Water distribution in plots with and without deep tillage, 24 hours after irrigation were similar. Non-irrigated plots were significantly dryer.

Tables 4 and 5 and figures 3 and 4 show effects of irrigation and deep tillage on soil compaction 48 hours after irrigation in 1998 and 99. As indicated by soil cone index values, tillage significantly reduced soil compaction in the top 15 inches of the irrigated plots compared to no subsoiling. Also there was a significant reduction in cone index values in the top 12 inches (tillage depth) of dry land plots compared to irrigated lands without a tillage operation. The biggest difference in soil compaction was found in the E-horizon. Subsoiled plots with irrigation laterals buried 16 inches deep had the least cone index values at depth of 6-18 inches. Cone index values above 150 psi generally reduce crop yield and values above 300 psi stop root growth (Taylor and Gardner, 1963: Carter and Tavernetti, 1968). Cone index values in no-till plots 48 hours after irrigation, were high enough to reduce root penetration into the B-horizon. However, this number could be less than 150 psi during or immediately after irrigation. Taproots in irrigated plots with deep tillage operation were significantly longer than those in no-till irrigated plots (table 7). Most of the taproots in these plots penetrated into the clay layer or B-horizon. Also there was a significant difference in taproot length between deep tilled irrigated and dry land plots. Cotton tap roots in no-till plots were restricted to the depth of the hardpan layer. Keeping this compacted layer wet by irrigation did not reduce soil strength enough to permit root penetrations into clay.

Drip irrigation significantly increased cotton lint yields compared to non-irrigated plots in all three years (tables 6 and 7). Depth of the irrigation tubes had an effect on cotton yield, increasing with depth in both under every row and using alternate row middles in 1997. Similar results were obtained in 1998 related to lateral depth. However, differences were not statistically significant. In 1999, irrigated plots with laterals buried 16 inches deep produced significantly higher lint yields. There were no differences in yield between every vs. alternate row installation at any of the three placement depths.

A deep tillage operation did not increase the cotton yield in 1997 compared to no-till planting because all plots in 1997 had some tillage provided during installation of the irrigation laterals. Although not statistically significant, plots with a deep tillage operation on average yielded 47-lb. lint/acre more than no-till plots. In 1999, yield increase due to deep tillage was 45-lb. lint/acre. There was no difference in plant population among the different treatments. Depth of the irrigation laterals had an effect on plant height in 1998, increasing with depth for all irrigated plots. Plants in dry land plots were significantly shorter. In 1999, plants in irrigated plots with laterals buried 16 inches deep were significantly taller than the other irrigation treatments. Again, plants in dry land plots were significantly shorter.

Summary

Replicated tests were conducted at the Edisto research & Education Center to determine the effects of subsurface drip irrigation on soil compaction (deep tillage vs. no-till) and to determine optimum depth of drip irrigation tube placement in coastal plain soils. Three lateral depths (8, 12, and 16 inches), three lateral spacings (under every row, under alternate row middles with and without under the row subsoiling) and a control (non-irrigated) were used.

- The rate of water movement in the soil profile for plots with deep tillage was higher than plots without tillage. Soil surface moisture was higher in plots with laterals buried eight inches deep resulting in higher weed infestation than the rest of the treatments.
- Tillage significantly reduced soil compaction in the top 15 inches of the irrigated plot compared to no-till irrigated plots. Also there was a significant reduction in cone index values in the top 12 inches of dry land plots compared to irrigated lands without a tillage operation. Subsoiled plots with irrigation laterals buried 16 inches deep had the least cone index values at depths of 12-18 inches.
- Drip irrigation significantly increased lint yields compared to non-irrigated plots in all three years.
- Deep tillage significantly increased taproot length in irrigated plots. Taproots in no-till plots were restricted to the depth of the hardpan layer. Keeping this compacted layer wet did not reduced soil strength enough to permit root penetrations into clay.
- Depth of the irrigation tubes had an effect on cotton yield, increasing with depth in both under every row and using alternate row middles.
- There were no differences in yield between every vs. alternate row installation at any of the three placement depths.
- Deep tillage operation did not increase yields in 1997 compared to no-till planting because all plots had some tillage provided during installation of the irrigation laterals.
- Although not statistically significant, plots with a deep tillage operation on average yielded 47 and 45 lb. lint/acre more than no-till plots in 1998 and 99 respectively.

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Table 1. Treatment combinations for subsurface drip irrigation and tillage in cotton, Blackville, SC., 1997-99.

Treatment No.	Treatment ID	Lateral Spacing[1]	Lateral Depth (in.)	Spring Tillage[2]
1	UER-8-N	UER	8	None
2	UER-12-N	UER	12	None
3	UER-16-N	UER	16	None
4	ARM-8-N	ARM	8	None
5	ARM-12-N	ARM	12	None
6	ARM-16-N	ARM	16	None
7	ARM-8-S	ARM	8	Sub
8	ARM-12-S	ARM	12	Sub
9	ARM-16-S	ARM	16	Sub
10	Dry land	----	----	Sub

1. UER = Under every row, 38 inches apart; N = No spring tillage; ARM = Alternate row middles, 76 inches apart; S or Sub = Under the row subsoiler, 13-14 inches deep.
2. In 1997, all plots had some tillage provided during tape installation.

Table 2. Water distribution (percent moisture content) at different depths in the crop row two hours after irrigation, 8/3/98.

Treatment ID	0-3 in.	3-6 in.	6-9 in.	9-12 in.	12-15 in.	15-18 in.
ARM-8-N	6.8 a	7.5 ab	7.0 b	8.6 ab	10.3 a	13.4 a
ARM-12-N	4.5 b	4.9 cd	5.4 bc	9.5 ab	10.4 a	11.5 b
ARM-16-N	4.3 b	4.8 cd	4.6 cd	4.7 cd	11.8 a	13.6 a
ARM-8-S	6.5 a	8.6 a	10.0 a	10.2 a	11.0 a	13.5 a
ARM-12-S	6.3 a	6.2 bc	5.5 bc	10.4 a	12.2 a	13.5 a
ARM-16-S	5.7 a	5.8 cd	5.4 bc	7.1 bc	12.3 a	14.6 a
Dry land	3.7 b	4.0 d	3.0 d	3.5 d	6.5 b	9.2 b

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 3. Water distribution (percent moisture content) in the crop row 24 hours after irrigation, 8/4/98.

Treatment ID	0-3 in.	3-6 in.	6-9 in.	9-12 in.	12-15 in.	15-18 in.
ARM-8-N	6.4 ab	6.5 a	6.6 ab	8.0 b	10.5 a	13.7 a
ARM-12-N	5.3 bc	6.2 a	6.5 ab	9.7 ab	10.9 a	11.5 ab
ARM-16-N	4.7 bc	5.2 b	5.0 bc	5.1 c	10.5 a	13.0 a
ARM-8-S	6.5 a	6.9 a	8.0 a	10.7 a	11.1 a	13.1 a
ARM-12-S	6.3 ab	6.9 a	7.5 ab	11.2 a	11.5 a	13.7 a
ARM-16-S	6.1 ab	6.3 a	6.4 ab	9.6 ab	12.2 a	13.8 a
Dry land	3.5 d	3.7 c	3.4 c	3.9 c	7.2 b	9.6b

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 4. Effects of tillage and drip irrigation on soil compaction. Penetrometer data were taken 48 hours after irrigation from the crop rows, 1998.

Treatment ID	Cone Index (psi) 0 - 6 in.	6 – 12 in.	12 – 18 in.
ARM-8-N	114.1 a	256.1 a	252.6 a
ARM-12-N	111.7 a	227.7 b	248.2 a
ARM-16-N	119.5 a	241.0 ab	226.1 b
ARM-8-S	64.7 b	110.1 c	193.3 cd
ARM-12-S	63.5 b	101.1 c	173.2 d
ARM-16-S	57.8 b	78.0 d	140.0 e
Dry land	67.4 b	105.0 c	214.0 bc

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 5. Effects of tillage and drip irrigation on soil compaction. Penetrometer data were taken 48 hours after irrigation from the crop rows, 1999.

Treatment ID	Cone Index (psi) 0 - 6 in.	6 – 12 in.	12 – 18 in.
ARM-8-N	108 a	268 b	355 b
ARM-12-N	108 a	285 ab	359 b
ARM-16-N	118 a	311 a	368 b
ARM-8-S	53 b	111 c	205 c
ARM-12-S	66 b	129 c	206 c
ARM-16-S	76 b	134 c	175 c
Dry land	121 a	323 c	411 a

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 6. Plant height (in.), plant population at harvest (plant/ft), and cotton lint yield (lb./acre) for 1997 and 1998 subsurface drip irrigation test, Edisto Research and Education Center, Blackville, SC.

Treatment ID	Plant Height	Plant Population	Yield 1997	Yield 1998
UER-8-N	32.0 c	1.7 a	1164 c	1336 a
UER-12-N	33.4 b	1.8 a	1248 bc	1409 a
UER-16-N	35.6 a	2.0 a	1349 a	1440 a
ARM-8-N	32.0 c	1.8 a	1187 bc	1310 a
ARM-12-N	33.9 b	1.8 a	1332 ab	1402 a
ARM-16-N	34.9 a	1.9 a	1357 a	1434 a
ARM-8-S	32.2 c	1.7 a	1162 c	1380 a
ARM-12-S	33.5 b	1.7 a	1285 ab	1432 a
ARM-16-S	35.0 a	1.9 a	1364 a	1474 a
Dry land	27.9 d	1.8 a	994 d	940 b

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 7. Plant height (in.), plant population at harvest (plant/ft), taproot length (in.) and cotton lint yield (lb./acre) for 1999 subsurface drip irrigation test, Edisto Research and Education Center, Blackville, SC.

Treatment ID	Plant Height	Plant Population	Taproot Length	Yield
UER-8-N	30.5 b	2.7 a	10.7 d	953 bc
UER-12-N	30.8 b	2.8 a	11.8 c	990 bc
UER-16-N	33.6 a	2.8 a	12.3 bc	1122 a
ARM-8-N	30.5 b	2.7 a	10.5 d	907 c
ARM-12-N	30.8 b	2.8 a	11.7 c	980 bc
ARM-16-N	33.3 a	2.8 a	12.1 c	1090 a
ARM-8-S	31.0 b	2.8 a	15.4 a	977 bc
ARM-12-S	31.1 b	2.8 a	15.6 a	1000 b
ARM-16-S	33.7 a	2.8 a	16.1 a	1136 a
Dry land	28.9 c	2.7 a	13.1 b	559 d

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

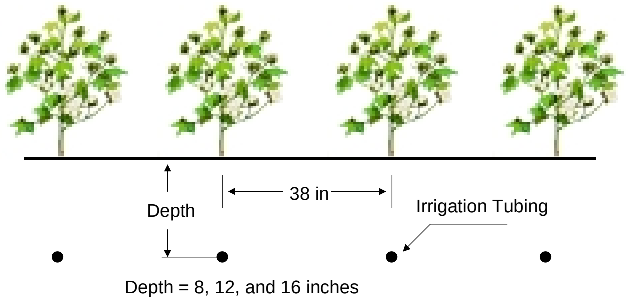

Figure 1. Drip irrigation lateral spacing and depth configuration (subsurface every row).

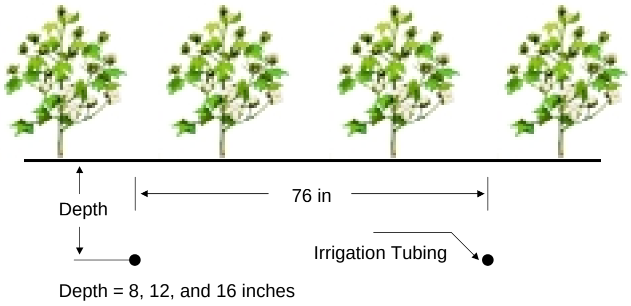

Figure 2. Drip irrigation lateral spacing and depth configuration (subsurface alternate row middles).

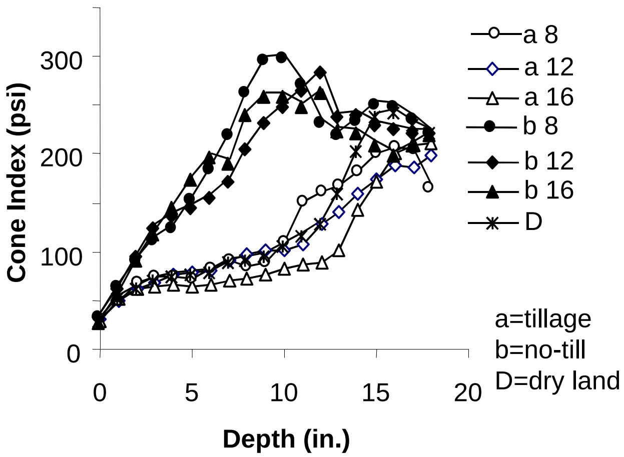

Figure 3. Effects of tillage and irrigation on soil compaction, 1998.

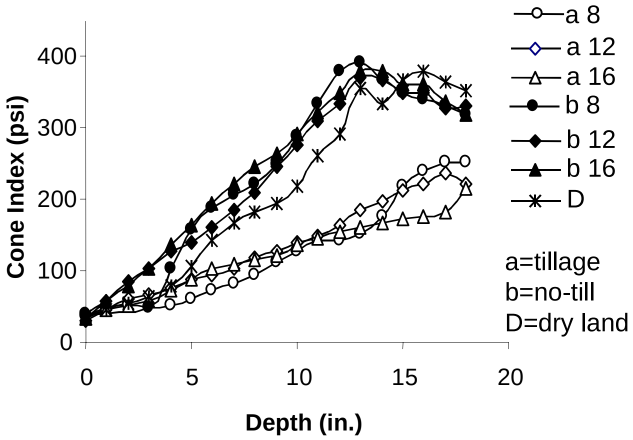

Figure 4. Effects of tillage and irrigation on soil compaction, 1999.