Paper No. 982173
An ASAE Meeting Presentation

# SUBSURFACE DRIP IRRIGATION MANAGEMENT FOR NO-TILLAGE PRODUCTION OF COTTON, SOYBEAN, AND WHEAT

by

C. R. Camp
Agricultural Engineer

P. J. Bauer
Research Agronomist

Coastal Plains Soil, Water, and Plant Research Center
USDA-ARS
Florence, SC

Written for Presentation at the
1998 ASAE Annual International Meeting
Sponsored by ASAE

Disney's Coronado Springs Resort
Orlando, Florida
July 12-16, 1998

**Summary:** Subsurface drip irrigation was investigated on a wheat-soybean-cotton crop rotation under no-tillage culture. Irrigated soybean yields were greater than rainfed in one of the two years. There were no yield differences among irrigation lateral spacings or irrigation amounts. Also, neither cotton nor wheat yields were increased by irrigation. Soil compaction at very shallow soil depths restricted root growth and probably limited the efficacy of subsurface drip irrigation, which was located at the 30-cm depth. These results indicate that to obtain optimum no-tillage crop production with subsurface drip irrigation on these soils strategies to reduce soil strength must be developed.

**Keywords:** root growth, cotton, soybean, wheat, trickle irrigation

## INTRODUCTION

Subsurface drip irrigation has been used extensively for cotton production in arid and semi-arid areas, e.g., Arizona and western Texas (Tollefson, 1985a,b; Henngeler, 1995). Because of longer system life and wider lateral spacings, these systems may be profitable for lower-valued crops, but good marginal return with irrigation is required for any crop to be profitable. Interest in subsurface drip irrigation for humid areas such as the southeastern USA has recently increased, especially for cotton on the coarse-textured soils of the southeastern Coastal Plain.

As with many other agronomic crops, irrigation can substantially increase yields of soybean and cotton some years, depending upon rainfall amount and distribution. Double cropping wheat and soybean as a rotation with cotton are economically competitive alternatives to monocropping cotton in the southeastern Coastal Plain. Conservation tillage has been used extensively for soybean in the region, but its use for wheat and cotton has been limited. Conservation tillage should complement subsurface drip irrigation for all three crops because tillage is restricted when laterals are installed at depths of 0.30 m or less.

Subsurface drip irrigation offers several advantages, including installation below tillage zone, system life and amortization of system cost over 10-15 years, frequent fertilization via the irrigation system, potential for less leaching of nutrients and ground water contamination, and water applications more closely matched to crop use. The use of wider lateral spacing (2 m) without yield reduction (Camp et al. 1993, 1997) significantly reduces system cost and makes the technology more affordable. Subsurface drip irrigation has not been evaluated for wheat followed by high population, narrow-row soybean under conservation tillage in the southeastern USA. Consequently, research was initiated in 1996 with the objective of evaluating subsurface drip irrigation for a two-year wheat-soybean-cotton rotation under a no-tillage production system.

## MATERIALS AND METHODS

The study was conducted on a 1.2-ha site of Eunola loamy sand (Aquic Hapludults) near Florence, S.C. Winter wheat, soybean and cotton were grown in a two-year rotation with no tillage. The subsurface drip irrigation system had been used for five years when this study was initiated. Drip irrigation laterals had been installed 0.30 m below the soil surface at spacings of either 1 m or 2 m, which placed them either directly under each cotton row (1 m) or under alternate furrows (midpoint between rows) (2 m). Each plot was 15 m long (irrigation lateral length) and 8 m wide, which provided eight cotton rows spaced 1 m apart. Soybean and wheat were planted with a conservation tillage grain drill in rows spaced 0.19 m apart and perpendicular to the irrigation laterals. Irrigation treatments differed by the depth per application (6 mm, 9 mm, and 12 mm). All combinations of the two lateral spacings and the three irrigation treatments, plus rainfall only (RAIN), comprised the seven treatments. Additionally, all treatments were included in both phases of the crop rotation in both years (1996-97). The experimental design was randomized complete block with four replications. The wheat cultivar Coker 9835 was planted on 25 November 1996 at 345 seeds/m$^2$. The soybean cultivar NK-7555* was planted on 10 June 1996 and 13 June 1997 at 50 seeds/m$^2$. The cotton cultivar Delta Pine and Land 90 (DPL 90) was planted on 2 May 1996 and 7 May 1997 at 14 seeds/m$^2$.

The irrigation system included individual polyvinyl chloride (PVC) pipe manifolds (supply and discharge) for each subplot. Each discharge manifold had removable end caps for flushing. Irrigation laterals (GEOFLOW ROOTGUARD®) had in-line, labyrinth emitters spaced 0.6 m apart, each delivering 1.9 L/h at 140-kPa pressure. Pressure was regulated at about 140 kPa using in-line pressure regulators in the supply manifold for individual plots. Water was supplied from a well and filtered via a 100-mesh cartridge filter; see Camp et al. (1997) for additional details regarding the irrigation system. All irrigation applications were monitored and controlled by a programmable microprocessor-based irrigation controller or computer.

The site had been subsoiled in two directions prior to installation of irrigation laterals in 1991, and the site was disked to a depth of about 0.20 m to prepare the seed bed each year until 1995. Thereafter, no tillage was performed except that the RAIN treatment was subsoiled annually to a depth of 0.40 m at a spacing of 1 m. In both years, P, K, lime, and Mn were applied based on soil test results. Sulphur and boron were applied to the cotton each year. Total N fertilizer applied to the cotton was 92 kg/ha each year and the wheat received 102 kg/ha. Weeds were controlled with a combination of herbicides and hand weeding. An in-furrow insecticide application was made to cotton at planting, and foliar insecticides were applied throughout the season as warranted. Wheat was grown in 1996 prior to the soybean crop. Soybean yield in 1996 and wheat yield in 1997 were determined by harvesting 14 m$^2$ in the center of each plot on 14 November 1996 and 12 June 1997, respectively. Soybean yield in 1997 was determined by harvesting 88 m$^2$ on 25 November 1997. Cotton yield was determined by harvesting two interior rows of each plot with a spindle picker on 27 September 1996 and 29 October 1997. Sub-samples of seed cotton were collected from each plot at harvest and cotton lint yield was calculated from lint percentages determined after ginning the samples on a laboratory saw gin.

In 1996, gauge-type tensiometers were installed in the 6-mm soybean treatment at depths of 0.3 m and 0.6 m and at either two or three distances from the irrigation lateral. In 1997, tensiometers were installed at depths of 0.3 m and 0.6 m in all irrigated soybean treatments and at two distances from the lateral, and at one location in the RAIN treatment. Tensiometers were also installed in the cotton row at depths of 0.3 m and 0.6 m in the 6-mm treatments in 1996 and in all irrigated treatments in 1997. For wheat in 1997, tensiometers were installed in the 6-mm irrigated treatments at depths of 0.3 m and 0.6 m and at either two or three distances from the lateral. Tensiometers were serviced as required, and readings were recorded three times each week. Meteorological parameters were measured at a weather station located adjacent to the

---

* Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval of a product to the exclusion of others that may be suitable.

experimental area. Seasonal rainfall for each crop was computed for the period between planting and two weeks prior to first harvest.

Irrigation applications were managed using tensiometer data. Timing of irrigation was determined by mean soil matric potential at the 0.30-m depth in the 6-mm treatment and was initiated at -35 kPa for cotton, -30 kPa for soybean, and -30 kPa for wheat. Equal irrigation depths were applied to the two lateral spacings (1 m and 2 m) at each application; consequently, the 2-m system operated twice as long as the 1-m system.

Seasonal irrigation depths for the three irrigation treatments varied considerably both among crops and growing seasons, and were not closely related to seasonal rainfall amount. While seasonal rainfall for soybean was similar for the two years (493-494 mm), irrigation depths in 1997 were more than double those in 1996 (86 vs. 34 mm for 6-mm treatment). Seasonal rainfall for cotton was slightly greater in 1996 (542 mm) than in 1997 (470 mm), but irrigation depths were 2-3 times greater in 1997 for all irrigation treatments (112 vs. 42 mm for 6-mm treatment). Five irrigation applications (27 mm for 6-mm treatment) were required for wheat in 1997 although significant rainfall (361 mm) occurred.

Data were analyzed by crop and by year using analysis of variance (ANOVA). Treatment sums of squares were partitioned with single degree of freedom contrasts (SAS, 1990). With these contrasts, we compared (1) 1-m and 2-m lateral spacings, averaged over all irrigation treatments; (2) rainfed (RAIN) and irrigated, averaged over lateral spacing and irrigation amount; (3) irrigation amount, averaged over lateral spacing, for linear relationship; (4) irrigation amount, averaged over lateral spacing, for quadratic relationship; (5) interaction between lateral placement and linear irrigation (amount) relationship; and (6) interaction between lateral placement and quadratic irrigation (amount) relationship.

## RESULTS AND DISCUSSION

High rainfall (494 mm) that was fairly well distributed kept the soil very wet throughout the growing season for soybean in 1996 and there were no differences in soil matric potential (SMP) among lateral spacings and position relative to the irrigation lateral. SMP values for cotton reflected similar but slightly drier conditions, with values of -50 MPa on two dates (data not shown). In 1997, SMP values reflected slightly drier soil conditions in the irrigated treatments for both soybean and cotton, but all values were > -40 MPa (fig. 1-2). SMP values were similar for both lateral spacings in both soybean and cotton in 1997 except that soil in the cotton 2-m spacing was slightly drier. This probably occurred because tensiometers in that treatment were located in the cotton row (19 cm away from the lateral), which is normally drier than the soil adjacent to the lateral. In 1997, soil in the RAIN treatment with soybean was much drier than in the irrigated treatments, especially from day of the year (DOY) 230 (August 18) to DOY 265 (September 29) (data not shown).

Crop yields for the three irrigation depths and the two lateral spacings were not different for any crop in either year. Therefore, mean soybean seed, wheat, and cotton lint yields for all irrigation treatments are reported in table 1. Yields in the irrigated treatments were 31 percent greater than in the RAIN treatment for soybean in 1997 but not for other crops, or for any crop in 1996. Except for cotton in 1996, crop yields were less than expected. For a similar soil and culture but without irrigation, Frederick and Bauer (1996, 1998) reported yields of 5800-6550 kg/ha for soybean and 4150-4500 kg/ha for wheat. Previously, on the same site as this experiment, cotton lint yields ranged from 1145 to 1815 kg/ha for three years. In the fourth year, cool temperatures limited lint yields to 535-770 kg/ha. Yields decreased linearly with an increase in the number of days that had minimum temperatures $\leq 15.6°$ C during the first 20 days after planting and with a decrease in accumulated heat units for 50 days after planting (Camp et al., 1997). In a similar manner, cool temperatures during the early growing season in 1997 may have reduced cotton lint yield in this experiment. Also, inadequate rainfall probably caused sufficient water deficits to limit cotton yield in the RAIN treatment although it was subsoiled.

Observations during both years of the study indicated limited rooting depth for all crops. It is likely that crop roots (cotton, soybean, or wheat) were unable to develop in the soil zone near the irrigation laterals and were limited to soil depths of 15 cm or less in the irrigated plots. This soil compaction was probably caused by soil reconsolidation, the absence of deep tillage for seven years, conventional tillage (disking) for the first five years, absence of surface tillage for the last two years, and equipment traffic (combines, cotton pickers, etc.). Vastly different cotton root growth occurred between the irrigated and RAIN treatments. In the irrigated treatment, tap root growth was limited to a depth of about 10 cm with limited horizontal distribution (fig. 3). In the RAIN treatment, which had annual deep tillage, taproot growth extended to a depth of at least 20 cm and had extensive horizontal growth (fig. 4). The limited root development suggests that the high soil strength prevented optimal benefit from the subsurface drip irrigation system. With annual disking, high soil strength near the soil surface normally does not occur. In a no-tillage system, high soil strength near the soil surface may initially limit rooting depth and development, but may be ameliorated later with development of macro pores. It appears that strategies to reduce soil strength at relatively shallow soil depths are needed for conservation tillage culture in these soils before the full benefits of subsurface drip irrigation can be realized.

## SUMMARY AND CONCLUSIONS

After five years of use, a site with drip irrigation laterals at a depth of 0.30 m was converted from conventional tillage to conservation tillage. Both phases of a wheat-soybean-cotton rotation were grown in each of two years under no-tillage culture. The site had not been deep tilled since 1991 when the irrigation system was installed. There were no differences in yield of wheat, soybean, or cotton for two irrigation lateral spacings (1 m and 2 m) or for the three irrigation depths (6 mm, 9 mm, 12 mm). Yield was greater for irrigated treatments than for the rainfed treatment (deep tilled) only for soybean in 1997. Observations indicate that a shallow compacted soil zone limited root growth and reduced the effect of irrigation on these crops. Based on these results, it appears that strategies to reduce soil strength in the surface 15 cm of these soils are required for conservation tillage systems to realize the benefits of subsurface drip irrigation.

## REFERENCES


Camp, C. R., P. J. Bauer, and P. G. Hunt. 1997. Subsurface drip irrigation lateral spacing and management for cotton in the southeastern Coastal Plain. Trans. ASAE 40(4):993-999.

Camp, C. R., W. M. Thomas, and C. C. Green. 1993. Microirrigation scheduling and tube placement for cotton in the Southeastern Coastal Plain. Transactions of the ASAE 36(4):1073-1078.

Frederick, J. R. and P. J. Bauer. 1996. Winter wheat responses to surface and deep tillage on the southeastern Coastal Plain. Agon. J. 88(5):829-833.

Frederick, J. R. and P. J. Bauer. 1998. Tillage management for doublecropped soybean grown in narrow and wide row width culture. Crop Sci. 38: (In press)

Henggeler, J. C. 1995. A history of drip-irrigated cotton in Texas. In Proc. Fifth International Microirrigation Congress, ed. F. R. Lamm, 669-674. St. Joseph, Mich., ASAE.

SAS Institute Inc. 1990. SAS/STAT Users Guide, Version 6. SAS Institute Inc., Cary, NC.

Tollefson, S. 1985a. The Arizona system: Drip irrigation design for cotton. In Proc. Third International Drip/Trickle Irrigation Congress, 1:401-405. St. Joseph, Mich.:ASAE.

Tollefson, S. 1985b. Subsurface drip irrigation of cotton and small grains. In Proc. Third International Drip/Trickle Irrigation Congress, 2:887-895. St. Joseph, Mich.:ASAE.


Table 1. Soybean seed, cotton lint, and wheat seed yields for irrigated and rainfed treatments in a conservation tillage, cotton-wheat-soybean rotation experiment on a southeastern Coastal Plain soil during 1996-1997.

| Year | Crop | Irrigated* | RAIN |
|---|---|---|---|
| | | kg/ha | |
| 1996 | Soybean | 2745 | 2790 |
| | Cotton | 1330 | 1345 |
| 1997 | Wheat | 2360 | 2000 |
| | Soybean | 2765 ** | 2105 |
| | Cotton | 1130 | 1110 |

* Means of two lateral spacings and three irrigation depths.
**Indicates yield for the irrigated and RAIN treatments differed at $P \leq 0.05$.

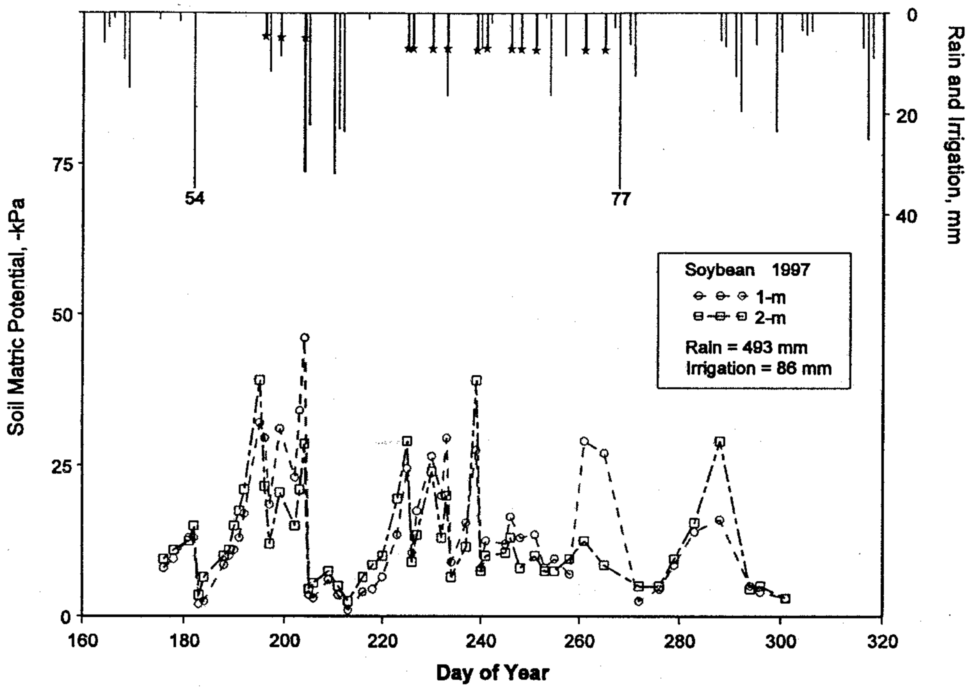


Figure 1. Mean soil matric potential at the 30-cm depth (adjacent to lateral) for two lateral spacings (1 m and 2 m) on soybean in 1997. Each data point is the mean of two values. Daily rainfall and irrigation (stars) are shown as bars at the top.

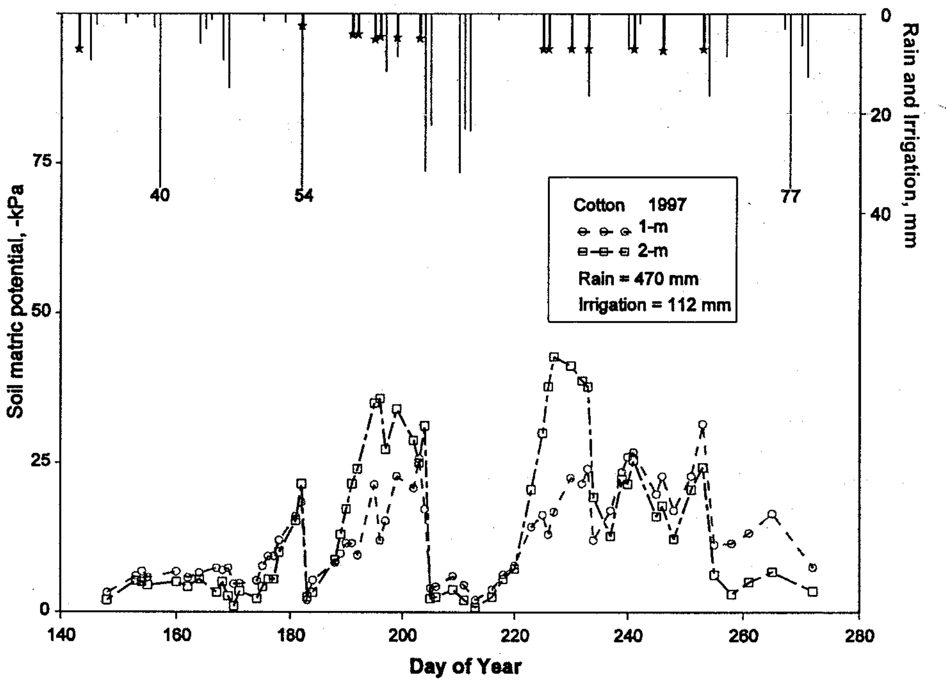


Figure 2. Mean soil matric potential in the cotton row at the 30-cm depth for two lateral spacings in 1997 (adjacent to lateral in the 1-m spacing and 19 cm distance in the 2-m spacing). Each data point is the mean of four values. Daily rainfall and irrigation (stars) are shown as bars at the top.


Figure 3. Photograph of cotton roots in a subsurface drip irrigated treatment (lateral spacing of 1m) followng harvest in 1997.

Figure 4. Photograph of cotton roots in rainfed treatment RAIN (deep tilled) following harvest in 1997.