SUBSURFACE MICROIRRIGATION MANAGEMENT AND LATERAL SPACING FOR COTTON IN THE SOUTHEASTERN USA

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ABSTRACT

Cotton yields for two microirrigation lateral placements (spacings) and three nitrogen sidedress methods were compared with rainfall-only treatments during the 1991-1993 growing seasons. In 1992 and 1993 cotton yield for both in-row and alternate-furrow microirrigation lateral placements was higher than for rainfall-only treatments. Yields were similar for the two lateral spacings. The wider spacing in the alternate-furrow placement should reduce irrigation system cost by about 30 percent. Yields were similar among N application methods despite one having about 30 percent less N applied. The wider lateral spacing and lower N rate could significantly reduce the cost of cotton production with microirrigation, and make this technology more attractive to cotton growers. The ability to apply N as needed via the irrigation system could reduce nitrogen fertilizer rates, thus reducing the potential for ground water contamination.
Keywords. Lateral placement, Trickle irrigation, Tensiometers, Nitrate, Computer simulation

INTRODUCTION

In the southeastern Coastal Plain, irrigation is required about every other year for optimum crop yields because of poor rainfall distribution and low water storage in coarse-textured soils (Sheridan et al., 1979). With boll weevil eradication and improved market price, cotton has again become a competitive crop in the region. In order to produce higher and more consistent yields with better lint quality, many growers are now considering irrigation.

Cotton yield is dependent upon the production and retention of bolls, and both can be decreased by water stress (Guinn and Mauney, 1984). Although sprinkler irrigation is the delivery system most often used for irrigation of agronomic crops, high-frequency microirrigation can prevent cyclical water stress that is found with low-frequency irrigation (Radin et al., 1989). Development of economically viable microirrigation systems could improve the precision of water placement and reduce energy requirements. Two major disadvantages of microirrigation are high initial system cost and annual replacement of many system components. Microirrigation systems with wider spaced laterals buried below the tillage zone use less material initially and use the same material for multiple seasons. Microirrigation laterals installed 0.2-0.3 m below the soil surface have been used for cotton (Tollefson, 1985), corn (Camp et al., 1989), and fruits and vegetables (Bucks et al., 1981; Phene et al., 1983).

Profitable irrigation in humid areas can also be affected by the manner in which water application is scheduled and how efficiently rainfall is used. Although several irrigation scheduling methods (e.g. tensiometers, evaporation pans, and computer models) have been available, they are not widely used in humid areas (Lambert, 1980). Crop growth models, such as GOSSYM/COMAX for cotton, can also be used to manage irrigation and other cultural inputs. GOSSYM is a cotton growth and yield simulation model that has been coupled with COMAX, an expert system decision aid, that controls simulation parameters (Baker et al., 1983; Lemmon, 1986). The potential exists for improved profitability and

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reduced environmental contamination if this model can be modified to manage both water and N fertilizer injected via the irrigation system for buried microirrigation systems.

The objectives of this study were (1) to determine whether cotton yield is affected by placement of microirrigation laterals under alternate furrows in comparison to under every row, (2) to evaluate three nitrogen sidedress management treatments for continuous cotton, and (3) to determine the effect of irrigation on cotton yield.

MATERIALS AND METHODS

The study was conducted on a 1.2-ha site of Eunola loamy sand (Typic Paleudult) near Florence, South Carolina. Microirrigation laterals were installed 0.30 m below the soil surface, either directly under each row (SSER) or under the midpoint of alternate furrows (SSAF). A schematic diagram of the two lateral placements is shown in Fig. 1. Three sidedress nitrogen treatments (all applied via the irrigation system) included a single N application of 112 kg/ha as recommended by the Clemson University Cooperative Extension Service (STD), the same amount of N as in the STD treatment but applied in five equal weekly increments (INC), and weekly applications (11-23 kg/ha N) when the GOSSYM/COMAX cotton growth model (GOS) predicted a N deficiency. Eight treatments included all combinations of the two lateral placements and three sidedress N methods, and rainfall only (RAIN) for the STD and GOS sidedress N methods. There were four replications of each treatment. The cotton cultivar 'PD 3'** was planted on 22 May 1991, 14 May 1992, and 12 May 1993, and all treatments were hand-thinned to a population of 85,000 plants/ha.

Irrigation applications were managed using the GOSSYM/COMAX model and tensiometers. While not designed specifically for scheduling irrigation and nitrogen applications with subsurface microirrigation, this model does compute a water stress index and a nitrogen stress index. The model was operated three times each week to determine the need for irrigation

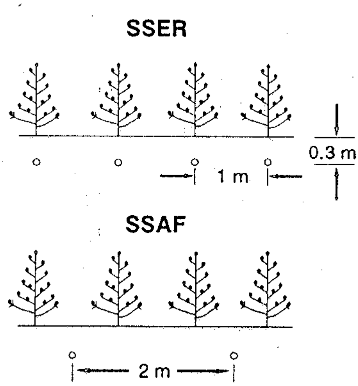

Figure 1. Schematic diagram of two microirrigation lateral placements relative to cotton rows. Closed circles indicate lateral locations.

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and nitrogen. Irrigation applications were normally 6 mm/d and sidedress N applications were normally 11 kg/ha each week, but higher amounts were applied when needed, based on observations and model simulation results. Because GOSSYM/COMAX could not utilize forecast weather data without extensive file editing, three weather scenarios (normal, hot-dry, and cool-wet) were used for future weather inputs. Daily input requirements for the model are irrigation and rainfall amounts, maximum and minimum temperature, solar radiation, and wind run.

The irrigation system consisted of individual polyvinylchloride (PVC) pipe manifolds (supply and discharge) for each plot. Water and nitrogen applications to all plots for each irrigation-N treatment combination in each rotation were controlled by a single solenoid valve. Irrigation laterals (GEOFLOW ROOTGUARD®) had in-line, labyrinth emitters spaced 0.6 m apart, each delivering 1.9 L/h at 140 kPa pressure. Each discharge manifold had removable end caps for flushing. Pressure was regulated at about 140 kPa using in-line pressure regulators in the supply manifold for individual plots. Laterals were installed at a depth of 0.30 m using two modified subsoiler shanks with curved tubes attached to the trailing edges, through which the irrigation line passed. Water was supplied from a well and filtered through a 100-mesh cartridge filter. All irrigation applications were monitored and controlled by a programmable microprocessor-based irrigation controller.

Gauge-type tensiometers were installed at depths of 0.3 m, 0.6 m, and 0.9 m in the SSER-GOS and SSAF-GOS treatments. Tensiometers were serviced as required and readings were recorded three times each week. Meteorological parameters, including U. S. Weather Service Class A pan evaporation, were measured at a weather station located adjacent to the experimental area. Seasonal rainfall was computed for the period between planting and two weeks prior to first harvest.

Lime and preplant nutrients were applied broadcast based on soil testing and Clemson University Extension Service recommendations. The site was subsoiled in two directions prior to installation of irrigation laterals in 1991 and the seed bed was prepared each year by disking to a depth of about 0.20 m. The RAIN-STD and RAIN-GOS treatments were subsoiled each year. Sidedress nitrogen (30% UAN solution) was applied at different intervals via the irrigation system. Sidedress nitrogen for the RAIN-STD and RAIN-GOS treatments was applied via an irrigation system using the same type lateral as used for the irrigated treatments. However, the laterals were located on the soil surface immediately adjacent to each row. Preplant and sidedress nutrient application dates and amounts for all years are included in Table 1. Weeds were controlled with a combination of herbicide, cultivation, and hand-weeding. An in-row insecticide application was made at planting, and foliar applications of insecticides were made as infestations warranted. A 30-m^2 area of two interior rows of each eight-row plot was harvested with a spindle picker on 17 October 1991, 12 November 1992, and 4 October 1993. Cotton lint yield was calculated from lint percentages determined in the laboratory on a saw gin from subsamples collected from each plot at harvest. The experimental design was a randomized complete block. Each plot was 15 m long and 8 m wide, which provided eight rows spaced 0.96 m apart. Yields were analyzed using analysis of variance (ANOVA). Treatment comparisons were made with contrasts (SAS, 1990) using a significance level of $P=0.05$.

RESULTS AND DISCUSSION

Seasonal irrigation, rainfall, and total water amounts for all irrigation lateral placement treatments during the three years of the study are included in Table 2. Rainfall and other weather conditions were more favorable for cotton production in 1991 than in 1992. Although growing-season rainfall was higher in 1992 (589 mm vs 418 mm), distribution was better in 1991 and more supplemental water was applied in 1992, especially during the vegetative and

Table 1. Sidedress fertilizer N application levels for a cotton experiment on a southeastern Coastal Plain soil during three seasons, 1991-1993.

Year	N Treatment	Week after first flower appearance						Total N[†]
		1[*]	2	3	4	5	6	
		---------------------------- kg/ha					--------------------------	
1991	GOS[‡]	11	11	11	23	11	--	79
1991	INC	22	22	23	22	23	--	124
1991	STD	56	56	--	--	--	--	124
1992	GOS	11	--	23	11	11	11	79
1992	INC	22	--	23	22	22	23	124
1992	STD	56	56	--	--	--	--	124
1993	GOS	11	--	11	22	11	11	79
1993	INC	22	22	23	22	23	--	124
1993	STD	112	--	--	--	--	--	124

[*] Number indicates week after first flower bud appearance.
[†] All treatments received 12 kg/ha N before planting.
[‡] Treatment codes for N sidedress treatments are as follows: GOS = GOSSYM/COMAX, INC = incremental, and STD = standard.

early fruiting periods. Most of the irrigation (78 percent) in 1991 was applied during a 2-week period starting on 10 September. Much of the rainfall (63 percent) in 1992 occurred late in the growing season (mid-August through October) and all irrigation was applied prior to that period. Rainfall was lower in 1993 (331 mm) than in the other years, and both seasonal irrigation amounts (130-136 mm) and number of applications (19) were higher in 1993. Only 25 percent of the rainfall occurred during the first 75 days (first half) of the 1993 growing season. Most of the seasonal irrigation amount was also applied during this period. The small difference in seasonal irrigation amounts among lateral placements in 1993 resulted from accumulated small differences in individual irrigation applications during the growing season (Table 2).

Tensiometer data for the 0.30-m depth in both lateral placements during 1991, 1992, and 1993 are shown in Fig. 2. Soil water potential at the 0.30-m depth was greater than -50 kPa throughout the 1991 growing season for both the SSER and the SSAF treatments and was greater than -25 kPa for much of the last half of that growing season. With two exceptions, soil water potential at the 0.30-m depth was greater than -50 kpa throughout the 1992 growing season for both lateral placements. Major rainfall events occurred during the last half of the growing season in 1992, causing soil water potential values to be greater than -10 kPa much of the time. In both years, soil water potential was maintained within the range recommended for cotton (>-50 kPa) in the irrigated treatments. In 1993, soil water potential at the 0.30-m depth varied over about the same range as in previous years, but differences between values for the SSER and SSAF treatments were more defined than in previous years. Soil water potential values for the SSER placement were consistently higher than those for the SSAF placement, indicating the placement of water nearer the cotton rows. However, except for one instance, soil water potential values for the SSAF placement remained above -50 kPa for the entire growing season.

Cotton lint yields for all water management and nitrogen sidedress treatments during the 3-year period are shown in Table 3. Cotton lint yields in 1991 were high for all treatments,

Table 2. Seasonal irrigation and total water amounts for five water management treatments in a cotton experiment on a southeastern Coastal Plain soil during 1991-1993.

Lateral Placement	1991		1992		1993	
	Irrig	Total*	Irrig	Total	Irrig	Total
	------------------------- mm -------------------------					
SSAF†	57(7)‡	475	90(9)	679	136(19)	467
SSER	57(7)	475	90(9)	679	130(19)	461
RAIN	---	418	---	589	---	331

* Total water amounts include growing season rainfall amounts.
† Treatment codes are defined as follows: SSAF = irrigation lateral below midpoint of alternate furrows; SSER = irrigation lateral below every row; and RAIN = rainfall only, no irrigation.
‡ Numbers in parentheses refer to number of irrigation events during the growing season.

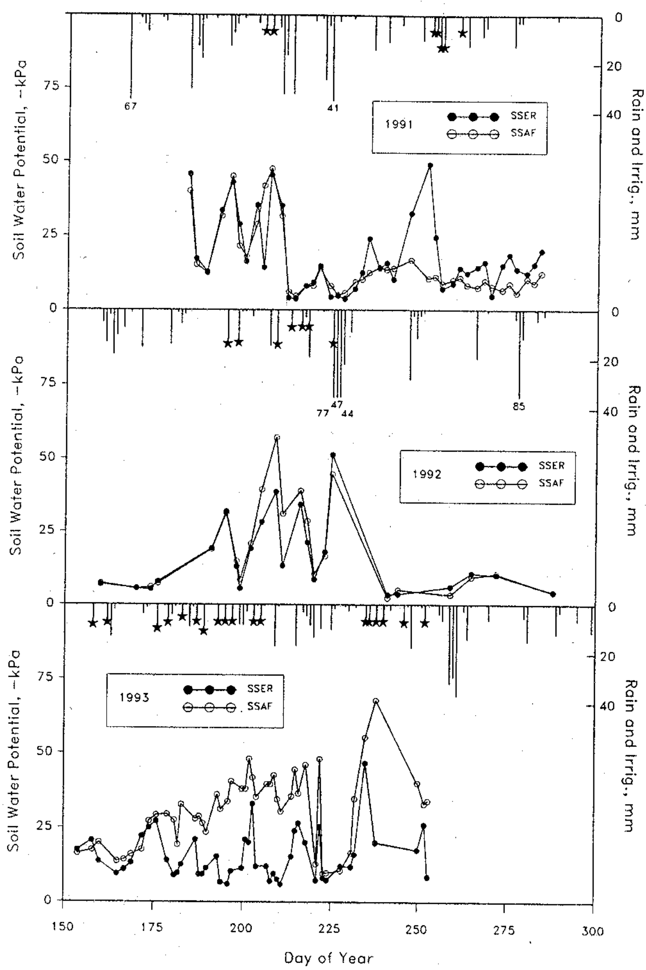

Figure 2. Daily rainfall and irrigation amounts and soil water potential at the 0.30-m depth for two lateral placements in a cotton experiment during 1991-1993. Stars indicate irrigation events.

Table 3. Cotton lint yields for two irrigation lateral placements and three N-sidedress treatments in a cotton experiment on a southeastern Coastal Plain soil during 1991-1993.

Lateral Placement	1991			1992			1993		
	GOS	INC	STD	GOS	INC	STD	GOS	INC	STD
	kg/ha								
SSAF*	1725 a†	1755 a	1595 a	600 a	645 a	550 a	1145 a	1300 a	1155 a
SSER	1610 a	1795 a	1815 a	725 a	535 a	655 a	1145 a	1175 a	1340 a
RAIN	1910 a	---	1570 a	520 b	---	520 b	815 b	--	675 b

* Lateral placement codes are the same as those defined in Table 2.
† Means followed by the same letter within each year are not significantly different according to ANOVA, Duncan's Multiple Range Test, and/or contrasts at P=0.05.

ranging from 1570 kg/ha to 1910 kg/ha. The small volume of irrigation applied in September 1991 did not significantly affect lint yield. Lint yields for the two lateral placements were not different. Cotton lint yields for all treatments were much lower in 1992, ranging from 520 kg/ha to 725 kg/ha. When analyzed by contrasts, lint yield for the irrigated treatments (GOS and STD nitrogen treatments only) (630 kg/ha) was significantly greater than for rainfall-only (520 kg/ha). Again, lint yields for the two lateral placements were not different. Cotton lint yields for irrigated treatments in 1993 were between those for the previous two years, ranging from 1145 kg/ha to 1340 kg/ha. Yields for the rainfall-only treatments (675 kg/ha and 815 kg/ha) in 1993 were similar to those for rainfall-only treatments in 1992 . Yields for the irrigated treatments in 1993 were significantly greater than those for the rainfall-only treatments. As in the two previous years, lint yields for the two lateral placements were not different in 1993. There were no significant differences in lint yields among the N-sidedress treatments in any of the three years.

In 1992, weather conditions were not very favorable for cotton production. Temperatures during the spring and early fall of 1992 were much cooler than in 1991, and a frost (October 20) killed many of the younger leaves and bolls near the top of the plant in 1992. Rainfall patterns for the two years were almost opposite. The lower seasonal rainfall and poor rainfall distribution, which resulted in only 85 mm of rainfall during the first half of the growing season in 1993, contributed to the greater yields for the irrigated treatments.

These results suggest that in the southeastern USA, alternate furrow placement (wider spacing) of microirrigation laterals may be adequate for supplying water to cotton plants on these coarse-textured soils. Significant savings (about 30 percent) in irrigation system cost can be achieved by using the wider lateral spacing (SSAF) instead of under every row (SSER) provided the grower accepts the relatively low risk that irrigation will not be needed for seed germination and plant establishment. Additionally, there were no significant differences in yield among the N-sidedress treatments any year even thought the GOS treatment received 45 kg/ha less fertilizer N than the STD and INC treatments, both of which received the N amount recommended by the Clemson University Cooperative Extension Service for cotton production on these soils.

SUMMARY AND CONCLUSIONS

Cotton lint yields for irrigated treatments were significantly greater than yields for rainfall-only treatments in 1992 and 1993. Yields for the two lateral placements were not significantly different in any of the three years. There were no significant differences among yields for the three N-sidedress treatments even though the GOS treatment received 45 kg/ha less nitrogen than the other treatments. Based on these results, it appears that the wider microirrigation lateral placement (SSAF) is as effective for supplying water and N to cotton as placement under every row (SSER). These results suggest that microirrigation system cost for cotton in this region may be substantially less than expected. The lower N applied with the GOS nitrogen treatment (high application frequency) produced similar lint yields. This suggests a potential for significant savings in N fertilizer cost and for reduced nitrate losses to the environment.

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