SCHEDULING IRRIGATION FOR COTTON IN HUMID AREAS

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Irrigated area has increased significantly in the southeastern Coastal Plain during the past 15 years. Because of poor rainfall distribution and low water storage in coarse-textured soils, irrigation is necessary about every other year for optimum yields. With eradication of the boll weevil and improved market price, cotton has again become an attractive crop in the region. In order to produce higher and more consistent yields, with better lint quality, many growers are now considering irrigation.

Although sprinkler irrigation is most often used for agronomic crops, micro irrigation offers several advantages, including low application rates, precise water placement, and low pressure. The major disadvantage for agronomic crops is the high cost when many system components are replaced annually. System designs which reduce tubing quantity or allow use of components for multiple seasons would improve profitability. Micro-irrigation tubing installed 0.2 - 0.3 m deep has been used for cotton, corn, fruits, and vegetables (Tollefson 1985; Bucks et al. 1981; Phene et al. 1983; Camp et al. 1989). Profitability in humid areas is also influenced by the manner in which irrigation is scheduled and the efficient use of rainfall. Several irrigation scheduling methods, including tensiometers, evaporation pans, and computer models are available but are not widely used (Lambert 1980). Computers have been used to compute water balances and to estimate daily evapotranspiration (ET) from weather data and have been compared to other methods for corn in the southeastern Coastal Plain (Camp and Campbell 1988).

The objectives of this study were (1) to evaluate in-row and alternate-middle placements of micro-irrigation tubing and (2) to compare three methods of irrigation scheduling (six treatment combinations) for three cotton cultivars and (3) to compare yields for all irrigated treatments with that for a rainfall-only treatment.

MATERIALS AND METHODS

The study was conducted on a 0.75-ha site of Norfolk loamy sand (Typic paleudults) near Florence, South Carolina. Micro-irrigation tubing was placed on the soil surface, either adjacent to each row (IR) or in alternate middles (AM). Three irrigation scheduling methods were (1) GOSSYM/COMAX, a cotton growth model (GOSY); (2) a Precipitation, Runoff, and Irrigation Scheduling Manager (PRISM); and (3) tensiometers (TENS). Treatments included all combinations of two placements and three scheduling methods and rainfall only (RAIN) to provide a total of seven treatments. The three cotton cultivars were Deltapine Acala 90 (DPL 90), Coker 315, and PD 3. The experimental design was a split-plot with whole plots arranged in a randomized complete block. Each of seven treatments were considered whole-

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plot treatments. Each whole plot was split for random assignment of three cotton cultivars and there were four replications of each treatment. Each plot was 15 m long and 12 m wide, which provided twelve rows spaced 1 m apart, four rows for each cultivar.

GOSSYM/COMAX is a cotton growth and yield simulation model that has been coupled with an expert system decision aid that controls simulation parameters (Baker et al. 1983; Lemmon 1986). While not designed specifically for scheduling irrigation, this model does compute a water stress index and indicates the need for additional water when the value of this index falls below 0.75 bars. For the GOSY treatment the model was operated three times each week to determine the need for irrigation; however, the amount of each irrigation application was determined by the user (6 mm/d). Because GOSSYM/COMAX does not utilize forecast weather data a hot-dry scenario based on weather in 1986 was used for the GOSY treatment.

Irrigation for the PRISM treatment was scheduled using a water balance model developed by Camp et al. (1990). Generally, this model computes the water stored in several soil layers using available soil water, rainfall and irrigation amounts, and ET estimated from weather data. Daily input requirements are irrigation and rainfall amounts, weather data, rooting depth, and allowable depletion of stored soil water. Irrigation was initiated when stored water decreased to the designated allowable depletion level (usually 50%). PRISM was operated twice each week using measured weather data for the days since last model operation and forecast weather data for as many as five days ahead, depending upon data availability. Five-day weather forecasts were obtained from the U. S. Weather Service, Columbia, SC. PRISM was re-initialized periodically during the growing season using measured soil water content by layer, but the GOSY model could not be re-initialized. All other soil and plant data inputs were essentially the same for the two models. Irrigation in the TENS treatment was initiated when the mean reading of tensiometers at the 0.3-m depth in any four plots exceeded 30 kPa or in any two plots exceeded 35 kPa. Normally, daily irrigation application amounts were 6 mm. In the PRISM and TENS treatments, when ET was high enough to cause continued depletion of soil water storage with the 6-mm application, the daily application amount was increased to 12 mm until soil water storage increased to an acceptable level. This flexibility was not available in the GOSY treatment.

The irrigation system consisted of individual PVC pipe manifolds for each scheduling treatment in each replication, which could be controlled independently by a solenoid valve. Irrigation tubing (Netafim Inline Dripperline)[2] had in-line, labyrinth emitters spaced 0.6 m apart, each delivering 1.9 L/h. Each manifold had removable end caps for flushing and each lateral had self-closing, flushing end caps. Pressure was regulated at about 100 kPa using in-line pressure regulators in the manifold at each plot location. The tubing was recovered each year before harvesting cotton and used the following year. Water was supplied from a well, stored in a pressurized tank, and filtered using a 100-mesh cartridge filter. All irrigation applications were monitored and controlled by a programmable microprocessor-based irrigation controller. Tensiometers were installed at depths of 0.3 m, 0.6 m, and 0.9 m in 1988 and at 0.3 m and 0.6 m in 1989. They were installed in the Coker 315 cultivar for all irrigation treatments in two replications and distributed randomly among the DPL 90 and PD 3 cultivars for all irrigation treatments in the other two replications. No tensiometers were installed in the RAIN treatment. Tensiometer readings were recorded three times each week and tensiometers were serviced as

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required. Rainfall and U. S. Weather Service Class A pan evaporation were measured on site.

The entire site was limed to pH 6.0 and subsoiled in two directions prior to seedbed preparation in 1988. Each year the seedbed was prepared by disking, in-row subsoiling, and bedding. Both preplant fertilizer and sidedress nitrogen were applied in granular form each year. Total nutrient applications were 96 kg/ha N, 15 kg/ha P, and 59 kg/ha K in 1988 and 94 kg/ha N, 29 kg/ha P, and 56 kg/ha K in 1989. Pesticide applications consisted of Temik at planting to control thrips, Treflan and Cotoran for weed control, and weekly applications of Pydrin, Ambush, and Fundal beginning in July each year to control Heliothis spp. Defoliant (DROPP + PREP) was applied on 30 September 1988 but was not applied in 1989 because of defoliation caused by Hurricane Hugo. All cotton cultivars were planted on 4 May 1988 and 17 May 1989. A 27-m^2 area of the center two rows of each four-row plot was harvested by machine on 11 October and 3 November in 1988 and on 10 October 1989. Cotton lint yield was calculated from lint percentages determined in the laboratory from subsamples collected from each plot sample at harvest. Yields were analyzed as a split plot design with four replications using analysis of variance (ANOV), least significant difference (LSD), and contrasts.

RESULTS AND DISCUSSION

Seasonal rainfall and irrigation amounts for all irrigation treatments and the RAIN treatment during 1988 and 1989 are included in Table 1. Rainfall was 59 mm greater in 1988 than in 1989 although there were six more rainfall events in 1989. Seasonal rainfall was computed for the period from planting to two weeks prior to first harvest. Rainfall distribution rather than total rainfall amount was important in determining irrigation requirements in both years. More irrigation was required for all irrigation treatments in 1988, when more rainfall occurred, than in 1989, when more rainfall

Table 1. Seasonal rainfall and irrigation amounts for seven water management treatments in a cotton experiment on a southeastern Coastal Plain soil in 1988 and 1989.

Treatment		1988			1989		
Schedule/Placement		Rainfall	Irrig.	Total	Rainfall	Irrig.	Total
		mm					
GOSY[1]	AM	544(50)[2]	90(9)	634	485(56)	25(3)	510
GOSY	IR	544(50)	95(9)	639	485(56)	30(3)	515
TENS	AM	544(50)	175(18)	719	485(56)	96(10)	581
TENS	IR	544(50)	173(17)	717	485(56)	108(10)	593
PRISM	AM	544(50)	89(8)	633	485(56)	75(6)	560
PRISM	IR	544(50)	89(7)	633	485(56)	77(6)	562
RAIN		544(50)	--	544	485(56)	--	485

[1] Treatment codes are defined as follows: GOSY = COMAX/GOSSYM model, TENS = Tensiometer, PRISM = PRISM model, (AM = Alternate- middle tubing placement, and IR = In-row tubing placement.

[2] Numbers in parentheses refer to the number of irrigation or rainfall events during the growing season.

events occurred. Hurricane Hugo caused substantial damage in the general area on 21 September 1989, although the large rainfall amounts normally associated with hurricanes did not occur.

Cotton lint yields for all treatments in 1988 are included in Table 2. All yields in 1988 were above 890 kg/ha and three irrigation treatments had significantly higher yields than the RAIN treatment. Yields for both TENS treatments and both GOSY treatments were numerically higher than other treatments but only yields for TENS-IR and GOSY-IR were significantly different from the PRISM-AM and RAIN treatments. Operational problems with computer models were experienced in 1988 for both the GOSY and PRISM treatments, but the problems were greater for the PRISM treatment, which required more user input and judgement. Problems with the GOSY treatment were primarily related to lack of user familiarization with the model while those with the PRISM were related more to model development and modification. Consequently, irrigation may not have been managed to the full potential of these methods at some times during this year. Irrigation application amounts were similar in 1988 (89 - 95 mm) for the GOSY and PRISM treatments and were about half that for the TENS treatments. Consequently,

Table 2. Cotton lint yields for seven water management treatments and three cultivars on a southeastern Coastal Plain soil in 1988.

Treatment Schedule	Treatment Placement	Coker 315	DPL 90	PD 3	Mean
		kg/ha			
GOSY[1]	AM	985	1115	1170	1090 abcd [2]
GOSY	IR	1125	1260	1275	1220 ab
TENS	AM	1105	1100	1280	1165 abc
TENS	IR	1275	1165	1380	1275 a
PRISM	AM	890	1060	1005	985 cd
PRISM	IR	1055	1045	1050	1050 abcd
RAIN		945	1100	875	975 d
Mean		1055 b	1120 ab	1150 a	1105

1 Treatment codes are the same as those defined in Table 1.
2 Means followed by the same letters within a column or row are not significantly different by ANOV and LSD at $P \leq .05$.

cotton lint yields were somewhat related to irrigation amount, but yields for PRISM were lower than for GOSY, although similar amounts of irrigation water were applied. Distribution of irrigation applications varied slightly between the two methods but were probably not sufficient to cause the yield difference. Statistical evaluation of yields by contrast indicated a significant effect ($P \leq .05$) among scheduling methods and between irrigated and RAIN treatments. The effect of tubing placement was significant at $P \leq .06$.

Cotton lint yields for all treatments in 1989 were lower than those measured in 1988 (Table 3). Although there were numerical differences in yields among treatments, none were statistically significant. Analysis by contrast indicated a trend toward difference among the three scheduling methods, but the difference was not significant at $P \leq .05$. There were no differences in yields for the two tubing placements in 1989. Damage caused by Hurricane Hugo, which occurred when much of the cotton was opening, was a major factor in the lower yields in 1989. Because there did not appear to be a difference in opening among treatments, it is assumed that the yield reduction caused by wind removal of cotton was uniform across all treatments. Observations prior to the storm indicated that two replications appeared to open faster than the others. Although this difference could have influenced losses caused by the storm, it was not evident in the statistical analysis. The relationship between irrigation amount and cotton yield was less evident in 1989. The TENS-IR treatment produced the highest yield, but was not significantly different from other treatments, and received the greatest amount of irrigation. Both GOSY treatments produced high yields but received even less irrigation than in 1988. The PRISM treatments received an intermediate amount of irrigation but had the lowest yields of any irrigation treatment (about equal to yield for the RAIN treatment).

Table 3. Cotton lint yields for seven water management treatments and three cultivars on a southeastern Coastal Plain soil in 1989.

Treatment Schedule/Placement		Cultivar Coker 315	DPL90	PD3	Mean
		kg/ha			
GOSY[1]	AM	880	940	820	880 a[2]
GOSY	IR	900	860	825	860 a
TENS	AM	800	800	885	830 a
TENS	IR	1015	895	980	965 a
PRISM	AM	885	710	910	835 a
PRISM	IR	690	785	775	750 a
RAIN		820	830	785	810 a
Mean		855 a	830 a	855 a	850 a

1 Treatment codes are the same as those defined in Table 1.
2 Means followed by the same letters within a column or row are not significantly different by ANOV and LSD at $P \leq .05$.

The models used to schedule irrigation in the GOSY and PRISM treatments were operating more consistently in 1989 than in 1988 but some operational problems remained. Although it did not affect irrigation scheduling for the GOSY treatment, the memory requirement for the 1989 version of GOSSYM/COMAX was so great that the model would not run without extensive deletion of resident files. The PRISM model was operational but several revisions and improvements were made during the 1989 season. The runoff partitioning module was completed and installed near the end of the 1989 season.

SUMMARY AND CONCLUSIONS

Based upon these preliminary results, it appears that either of the three irrigation scheduling methods used in this study could be used to satisfactorily schedule irrigation for cotton in the humid southeastern Coastal Plain. Clearly, the TENS method requires the greatest amount of irrigation water. The irrigation amount required by the PRISM is not clear at this time because of changes made during this study. There appears to be no consistent yield difference for the two irrigation tubing placements evaluated in this study. Consequently, the AM placement, which requires half as much micro-irrigation tubing, would be the placement method of choice for cotton under these conditions. This study will be continued for another year to further evaluate scheduling methods and tubing placement. The PRISM model will also be used to re-evaluate the 1988 and 1989 seasons and to determine the effect that model changes would have had on scheduling irrigation for those years.

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