Paper No. 922572
AN ASAE MEETING PRESENTATION

SUBSURFACE MICROIRRIGATION AND NITROGEN MANAGEMENT FOR COTTON IN THE SOUTHEASTERN COASTAL PLAIN

by

C. R. Camp
Agricultural Engineer

P. G. Hunt
Research Soil Scientist

P. J. Bauer
Research Agronomist

U. S. Department of Agriculture, Agricultural Research Service
Florence, SC

Written for presentation at the
1992 International Winter Meeting
sponsored by
THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Nashville Convention Center
Nashville, Tennessee
15-18 December 1992

SUMMARY:

Two microirrigation tubing placements and three nitrogen sidedress methods were evaluated for cotton production during 1991-1992, and yields were compared to those for rainfall-only treatments. Yields were high in 1991 and were about 150 percent greater than in 1992. Yields of individual treatments were not statistically different in either year, but yields for irrigated treatments were significantly higher than rainfall-only yields in 1992. There was no reduction in yield for one nitrogen treatment where about 30 percent less nitrogen was applied.

KEYWORDS:

Tubing placement trickle irrigation tensiometers GOSSYM/COMAX nitrate

American Society of Agricultural Engineers
2950 Niles Road, St. Joseph, Michigan 49085-9659 USA
Voice: 616.429.0300 FAX: 616.429.3852

INTRODUCTION

Because of poor rainfall distribution and low water storage in coarse-textured soils, irrigation is required about every other year in order to produce optimum yields for most crops in the southeastern Coastal Plain (Sheridan et al., 1979). 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 the delivery system most often used for irragation of agronomic crops, development of economically viable microirrigation systems could result in lower application rates, improve the precision of water placement, and lower water supply pressures. Major disadvantages of microirrigation for agronomic crops are the high initial cost of the system and annual replacement of many system components. Profitability would be improved if systems that reduce the tubing quantity required and/or allow use of components for multiple seasons could be designed. Microirrigation tubing installed 0.2 - 0.3 m below the soil surface has been used for cotton (Tollefson 1985), corn (Camp et al. 1989), and fruits and vegetables (Bucks et al. 1981; Phene et al. 1983).

Profitability of using irrigation in humid areas can also be affected by the manner in which water application is scheduled and how efficiently rainfall is used. Several irrigation scheduling methods, including tensiometers, evaporation pans, and computer models have been available to producers but are not widely used (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 an expert system decision aid, COMAX, that controls simulation parameters (Baker et al. 1983; Lemmon 1986).

Cotton yield is dependent upon the production and retention of bolls, which can be decreased by water stress (Guinn and Mauney, 1984). High-frequency microirrigation can prevent cyclical water stress that is found with low-frequency irrigation, and can minimize root deterioration during fruit filling (Radin et al., 1989). The objectives of this study were (1) to determine if cotton yield is affected by placement of microirrigation tubing under alternate furrows in comparison to under every row, (2) to evaluate three nitrogen sidedress management treatments for cotton-cotton and peanut-cotton cropping sequences, and (3) to determine the affect 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 tubing was 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 tubing placements is included as Figure 1. Three sidedress nitrogen treatments included a standard N application of 112 kg/ha as recommended by the Clemson University Cooperative Extension Service (STD), the same amount as 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. Treatments included all combinations of the two tube placements and three sidedress N methods, and rainfall only (RAIN) for the STD and GOS sidedress N methods, to provide a total of eight.

Additionally, a crop rotation treatment, consisting of either continuous cotton or a peanut-cotton rotation, was included. Cotton and peanut were grown in 1991 and cotton was grown in 1992. A diagram of the experimental layout including the eight blocks, each containing all eight treatments, is shown in Figure 2. The cotton cultivar 'PD3'[1] was planted on May 22 in 1991 and on May 14 in 1992. The experimental design was a randomized complete block in a split-plot arrangement with four replications. Main plots were crop rotation and sub-plots were the irrigation-N combination treatments. Each plot was 15 m long and 8 m wide, which provided eight rows spaced 0.96 m apart.

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, and indicates the need for additional water or nitrogen. The model was operated three times each week to determine the need for irrigation 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 tubing (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. The tubing was installed at a depth of 0.30 m using a modified subsoiler shank that had a curved tube mounted on the trailing edge of the shank, through which the tubing passed. 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 the SSER-GOS and SSAF-GOS treatments. No tensiometers were installed in the RAIN treatments. Tensiometer readings were recorded three times each week and tensiometers were serviced as required. Rainfall and U. S. Weather Service Class A pan evaporation were measured on site. Seasonal rainfall was computed for the period between planting and two weeks prior to first harvest.

The site was limed to achieve pH 6.0 based on soil testing and subsoiled in two directions prior to installation of the irrigation tubing in 1991. Each year the seedbed was prepared by disking. Each row in the RAIN-STD and RAIN-GOS treatments was subsoiled prior to planting. Granular preplant fertilizer was applied each year at a rate based upon soil test results (Table 1). All sidedress nitrogen was applied via the irrigation system. Sidedress nitrogen for the RAIN-STD and RAIN-GOS treatments was applied via an irrigation system using the same type

---

[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U. S. Dept. of Agr. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

of tubing as used for the irrigated treatments except that the tubing was located on the soil surface immediately adjacent to each row. Preplant and sidedress nutrient application dates and amounts for both years are included in Table 1. Pesticide applications were made at planting for control of thrips (*Frankliniella* spp.) and weeds, and as infestations warranted to control insects in the tobacco budworm-cotton bollworm complex (*Heliothis virescens* and *Helicoverpa Zea*). A 30-m^2 area of two interior rows of each eight-row plot was harvested with a spindle picker on October 17 in 1991 and on November 12 in 1992. Cotton lint yield was calculated from lint percentages determined in the laboratory on a saw gin from subsamples collected from each plot at harvest. Yields were analyzed as a split plot using analysis of variance (ANOVA). Treatment comparisons were made with contrasts (SAS, 1990) using a significance level of $P>.05$.

RESULTS AND DISCUSSION

Seasonal irrigation, rainfall, and total water amounts for all irrigation tubing placement and crop rotation treatments during 1991 and 1992 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 needed in 1992, particularly during the vegetative and early fruiting periods. Most of the irrigation (78 percent) in 1991 was applied during a 2-week period starting on September 10. 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. The small difference in seasonal irrigation amounts for the two crop rotations in 1992 was not planned, but resulted from small differences in individual irrigation applications during the growing season (Table 2).

Tensiometer data for the 0.30-m depth in both tubing placements during 1991 and 1992 are shown in Figure 3. During 1991 soil water potential at the 0.30-m depth was frequently greater than -50 kPa throughout the growing season for both the SSER and the SSAF treatments, and was greater than -25 kPa for much of the latter half of the growing season. As stated above, rainfall amount and distribution during the 1991 growing season were adequate for cotton growth during the first half of the growing season. With two exceptions soil water potential at the 0.30-m depth was greater than -50 kpa throughout the growing season during 1992 for both tubing placement treatments. Major rainfall events occurred during the last half of the growing season in 1992, causing the soil water potential values to be greater than -10 kPa much of the time. In both years, soil water potential was maintained in the range recommended for cotton (>-50 kPa) in the irrigated treatments.

Cotton lint yields for all water management and nitrogen sidedress treatments in 1991 are shown in Table 3. Peanut yields for these same treatments in the peanut crop rotation are not reported here. Cotton lint yields in 1991 were high for all treatments, ranging from 1570 kg/ha to 1910 kg/ha; however, there were no significant treatment differences. Both irrigation tubing placements produced similar yields. Apparently, the small volume of irrigation applied in 1991 did not significantly affect lint yield, possibly because the two-week period in September when most irrigation was needed was not a period critical to lint production. Cotton lint yields for all treatments were much lower in 1992, ranging from 520 kg/ha to 770 kg/ha, but lint yield was significantly greater for irrigated treatments (685 kg/ha) than for rainfall-only treatments (585 kg/ha) (GOS and STD nitrogen treatments). Although yields for the peanut/cotton rotation were higher than yields for the cotton/cotton rotation in 1992, these differences were not statistically significant.

The lower yields measured in 1992 relative to 1991 were most likely caused by the more unfavorable growing conditions in 1992. Temperatures during the spring and early fall were much cooler in 1992 than in 1991, and an early frost (October 20) killed many of the younger leaves and bolls near the top of the plant in 1992. Rainfall patterns were almost opposite in the two years.

The lack of a significant difference in cotton lint yield for the two tubing placements indicates a significant potential for savings (about 30 percent) in irrigation system cost by using the wider tube spacing (SSAF). The SSAF placement supplied both water and nitrogen to cotton plants in sufficient quantities for optimal production both years. Although there were no significant differences in yield among the nitrogen sidedress treatments either year, the GOS treatment received 45 kg/ha less nitrogen than the STD and INC treatments, both of which received the nitrogen amount recommended by the Clemson University Cooperative Extension Service for cotton production on these soils. If this result is found in the remaining 2 years of this experiment, it would indicate the potential for significant savings in nitrogen sidedress applications. This practice should reduce the potential for contamination of surface and ground waters caused by nitrate losses via runoff and drainage out of the crop root zone.

SUMMARY AND CONCLUSIONS

Cotton lint yields for all treatments were 2-3 times greater in 1991, when environmental conditions were more favorable for cotton production. In 1992 the weather was moderately dry during the early growing season and was wet during the latter portion. There was no significant difference in yields among the irrigation tube placement and nitrogen sidedress treatments in either year. In 1992 the mean yield for irrigated treatments was significantly greater than the mean yield for rainfall-only treatments. There were no differences among yields for the three nitrogen sidedress treatments even though the GOS treatment received 45 kg/ha less nitrogen than the other treatments. Based on these preliminary results, it appears that wider microirrigation tube placements (SSAF) supplies adequate water and nitrogen to the cotton crop for optimal production. This result suggests that microirrigation system costs for cotton in this region may be substantially less than expected. If the lower nitrogen rate used in the GOS nitrogen treatment (high-frequency) continues to produce acceptable lint yields for the remaining two years of this experiment, it may indicate the potential for significant savings in nitrogen fertilizer costs and a reduced potential for loss of nitrates to the environment.

REFERENCES

Baker, D. N., J. R. Lambert, and J. M. McKinion. 1983. GOSSYM: A simulator of cotton crop growth and yield. Tech. Bull. No. 1089. S.C. Agr. Exper. Stn., Clemson Univ., Clemson, SC.

Bucks, D. A., L. J. Erie, O. F. French, F. S. Nakayama, and W. D. Pew. 1981. Subsurface micro irrigation management with multiple cropping. Transactions of the ASAE 24(6):1482-1489.

Camp, C. R., E. J. Sadler, and W. J. Busscher. 1989. Subsurface and alternate-middle micro irrigation for the southeastern Coastal Plain. Transactions of the ASAE 32(2):451-456.

Guinn, G. and J. R. Mauney. 1984. Fruiting of cotton. II. Effects of moisture status on flowering. Agron. J. 76:90-94.

Lambert, J. R. 1980. Irrigation management--Humid areas. Proc. 2nd Nat'l. Irrig. Symp., Irrigation Challenge of the 80's. ASAE Pub. No. 6-81, ASAE, St. Joseph, MI 49085. pp. 175-184.

Lemmon, H. 1986. COMAX: An expert system for cotton crop management. Science 233:29-33.

Phene, C. J., M. F. Blume, M. M. S. Hile, D. W. Meek, and J. V. Re. 1983. Management of subsurface micro irrigation systems. ASAE Paper No. 83-2598. Amer. Soc. Agr. Engr., St. Joseph, MI.

Radin, J. W., J. R. Mauney, and P. C. Kerridge. 1989. Water uptake by cotton roots during fruit filling in relation to irrigation frequency. Crop Sci. 29:1000-1005.

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

Sheridan, J. M., W. G. Kneisel, T. K. Woody, and L. E. Asmussen. 1979. Seasonal variation in rainfall and rainfall-deficit periods in the Southern Coastal Plain and Flatwoods Regions of Georgia. Georgia Agric. Exp. Sta. Bull. 243, 73 pages.

Tollefson, S. 1985. The Arizona System: Drip irrigation design for cotton. Drip/Micro Irrigation in Action. Proc. Third International Drip/Micro Irrigation Congress 1:401-405. ASAE, Nov. 1985, Fresno, CA.

Table 1. Preplant and sidedress fertilizer application levels for a cotton experiment on a southeastern Coastal Plain soil during 1991 and 1992.

Year	N-Treatment	Preplant*			Sidedress N						Total N
		N	P	K	1†	2	3	4	5	6	
		kg/ha									
1991	GOS‡	12	15	58	11	11	11	23	11	--	79
1991	INC	12	15	58	22	22	23	22	23	--	124
1991	STD	12	15	58	56	56				--	124
1992	GOS	12	--	--	11	--	23	11	11	11	79
1992	INC	12	--	--	22	--	23	22	22	23	124
1992	STD	12	--	--	56	56	--	--	--	--	124

*Preplant fertilizer also included 11 kg/ha sulphur, 17 kg/ha manganese, and 0.4 kg/ha boron each year.

†Number indicates weeks after first flower bud appearance.

‡Treatment codes for nitrogen sidedress treatments are as follows: GOS = GOSSYM/COMAX, INC = incremental, and STD = standard.

Table 2. Seasonal irrigation and total water amounts for five water management-crop rotation treatments in a cotton experiment on a southeastern Coastal Plain soil in 1991 and 1992.

Tubing Placement/Crop Rotation		1991 Irrig	1991 Total*	1992 Irrig	1992 Total
		mm			
SSAF†	C/C	57(7)‡	475	90(9)	679
SSAF	P/C	---	---	85(9)	672
SSER	C/C	57(7)	475	90(9)	679
SSER	P/C	---	---	85(9)	672
RAIN		---	418	---	589

* Total water amounts include growing season rainfall amounts.

† Treatment codes are defined as follows: SSAF = irrigation tubing below midpoint of alternate furrows, SSER = irrigation tubing below every row, RAIN = rainfall only, no irrigation, C/C = cotton/cotton rotation, and P/C = peanut/cotton rotation.

‡ Numbers in parentheses refer to the number of irrigation events during the growing season.

Table 3. Cotton lint yields for two irrigation tubing placements, two crop rotations, and three nitrogen sidedress treatments in a cotton experiment on a southeastern Coastal Plain soil in 1991 and 1992.

Tubing Placement/ Crop Rotation		1991			1992		
		GOS	INC	STD	GOS	INC	STD
		---------------------------kg/ha---------------------------					
SSAF*	C/C	1725	1755	1595	600	645	550
SSER	C/C	1610	1795	1815	655	535	725
RAIN	C/C	1910	---	1570	520	---	520
SSAF	P/C	---	---	---	750	630	730
SSER	P/C	---	---	---	770	755	710
RAIN	P/C	---	---	---	620	---	690

* Treatment codes are the same as those defined in Table 2.

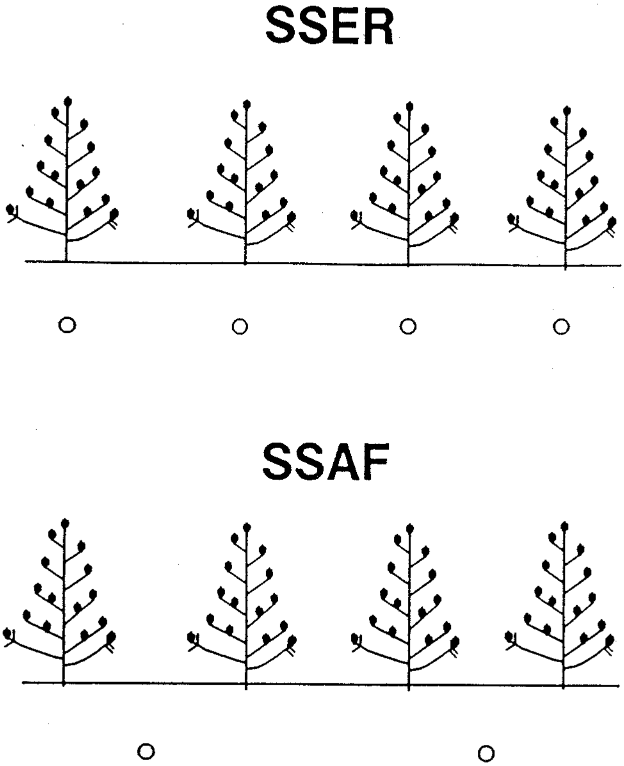

Figure 1. Schematic diagram of two microirrigation tubing placements relative to cotton rows. Open circles indicate tubing location.

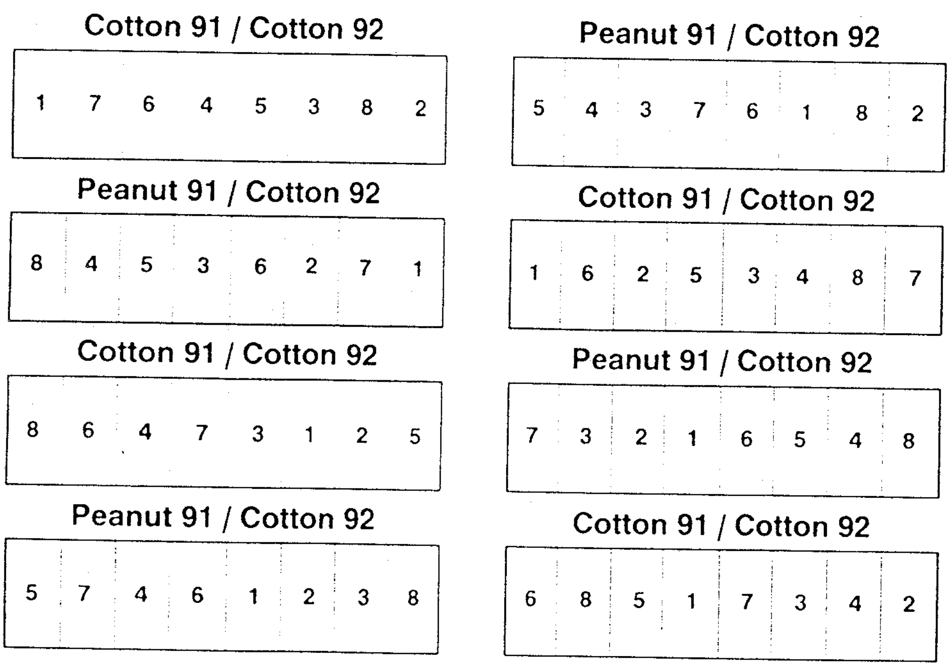

Figure 2. Schematic diagram of experimental layout showing typical locations of the eight treatments for each crop rotation-replication block.

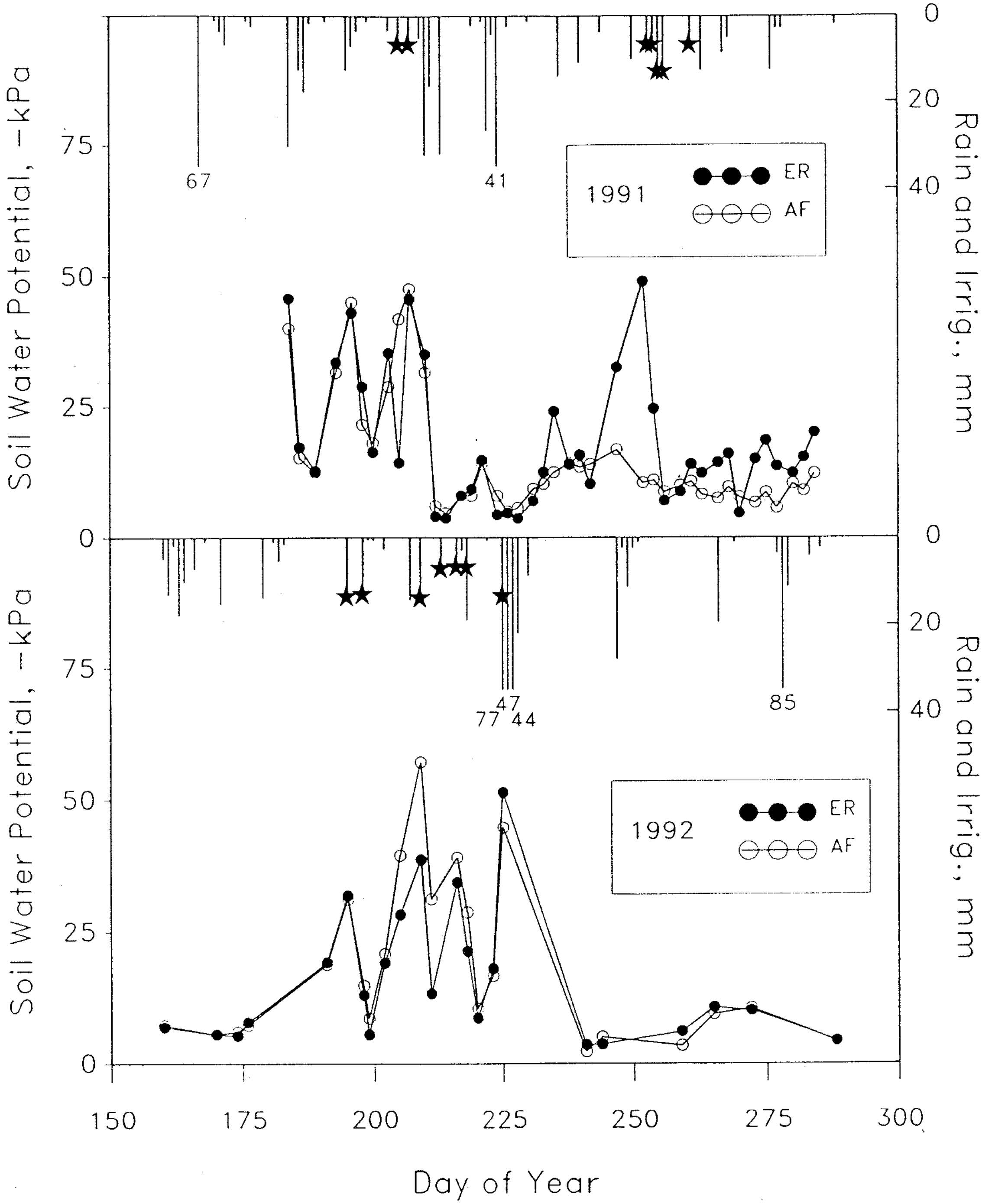

Figure 3. Daily rainfall and irrigation amounts and soil water potential at the 0.30-m depth for two microirrigation tubing placements in a cotton experiment during 1991 and 1992. Stars indicate irrigation events.