COTTON IRRIGATION WITH LEPA AND SUBSURFACE DRIP SYSTEMS ON THE SOUTHERN HIGH PLAINS

James P. Bordovsky and William M. Lyle
Texas Agricultural Experiment Station
Lubbock/Halfway, TX

Abstract

Irrigations were delivered by LEPA and subsurface drip irrigation (SDI) systems to cotton grown in 1995, 1996, and 1997 at the Texas Agricultural Experiment Station at Halfway, TX. The LEPA treatments were irrigated on 1, 2, and 3-day intervals while all SDI treatments were irrigated daily. Irrigation timing and amounts were determined from a protocol which compared calculated field water content to a target soil water content with the target water content providing a controlled decrease in soil water from peak bloom to the end of the growing season. Irrigation quantities were also restricted to maximum irrigation delivery rates of 0.1, 0.2, or 0.3 in./day. Detail profile wetting was monitored during preplant irrigations to evaluate seed germination in SDI and LEPA plots.

Lint yields and water use efficiencies were significantly higher when LEPA irrigations occurred at 2-day rather than 1 or 3-day intervals within the 0.1 in./day irrigation capacity. Differences among interval treatments were smaller as irrigation capacity increased to 0.2 and 0.3 in./day. Within the 0.1, 0.2, and 0.3 in./day capacities, SDI lint yields at 1145, 1225, and 1259 lb/acre resulted in significantly higher 3-year average yields than the best LEPA treatments at 980, 1142, and 1187 lb/acre, respectively ($P<0.05$, Duncan). Water use efficiencies were significantly higher for SDI than LEPA treatments under the management protocol used in this experiment with differences attributed to higher soil surface evaporation of the LEPA system. SDI, with emitter spacing of 24 inches, emitter flow rate of 0.336 gal/hr at 8 psi, and depth of 12 inches in alternate furrows, successfully wetted a dry seedbed for seed germination in an Olton loam soil without rainfall.

Introduction

The low energy precision application (LEPA) irrigation concept was developed by the Texas Agricultural Experiment Station at Halfway, TX between 1976 and 1978. The entire concept was designed to maximize the use of declining ground water and sporadic seasonal rainfall. Subsequent LEPA experiments were designed to determine the best combinations of irrigation quantities and frequencies for optimum cotton lint yield and water use efficiency (Bordovsky, et al., 1992). The results indicated that deficit irrigated cotton (0.4 to 0.6 BI, where BI = ET - effective rainfall) produced greater yields than those obtained with larger irrigation quantities. Irrigation water use efficiencies (IWUE) resulting from 3-day intervals were almost twice those of 9 and 15-day intervals. These results suggested that the optimum interval for alternate furrow LEPA irrigated cotton may be less than 3 days.

Interest in the use of subsurface drip irrigation (SDI) for cotton production has increased in semi-arid West Texas due to its high application efficiency. Systems installed in the Trans-Pecos, TX area in early 1980's continue to be used (Henggler, 1997). The High Plains Underground Water Conservation District No. 1 installed three 10-acre demonstration sites in 1992 to obtain general production information from SDI systems. An estimated 11,000 acres of cotton were irrigated with SDI on the Southern High Plains in 1997 with an additional 5000 acres projected for 1998 (Funck, 1997). However, two major concerns with installing SDI systems have been the potential inability to wet the seedbed for timely seed germination without rainfall and justifying the initial expense compared to other irrigation systems.

As the water supply and availability continues to decline on the High Plains, it will be imperative that producers adopt the most efficient irrigation system possible using management schemes that will maximize the utility and profitability of the system. The focus of an experiment, initiated in 1995 and broadened in 1996 and 1997, was developing optimum irrigation management techniques for the two irrigation systems (LEPA and SDI) which have the potential to sustain our irrigated economy well into the next century and to define the conditions under which each system would be most applicable. An evaluation of these two irrigation methods was begun to determine each system's response to various levels of deficit irrigation and develop a basis for economic comparison.

This paper reports cotton lint yields and water use efficiencies resulting from LEPA irrigation at intervals of 1, 2, and 3 days and SDI on a daily basis using an optimized water management protocol. An additional treatment factor was restricting water availability at three irrigation capacities, 0.1, 0.2, and 0.3 in./day. Changes in profile soil water resulting from preplant irrigation are also reported.

Procedure

The experiment was conducted at the Texas Agricultural Experiment Station at Halfway, TX on moderately permeable (0.1 in./hour) Olton loam (fine, mixed, thermic Aridic Paleustolls) soil with a slope of less than 0.2%. Five replicates of the 9 LEPA treatments (3 intervals x 3 irrigation capacities) and 3 replicates of 3 SDI treatments (3 irrigation capacities) plus preplant only irrigated checks (used to calculate water use efficiencies) were randomly placed in a 6.2-acre area under a 5-span lateral LEPA

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:409-412 (1998)
National Cotton Council, Memphis TN

irrigation system. Each span was subdivided into two sections with each section delivering water to 16 40-inch rows through a manifold system similar to that described by Bordovsky et al. (1992). In LEPA plots, water was delivered to alternate diked furrows from the manifold system through a drop tube into a wide, flat sock which minimized dike erosion. Drip tubing was buried 12-inches deep on 80-inch centers between adjacent cotton rows in the SDI plots. Emitter spacing along the drip lateral was 24 inches and emitter flow rate was 0.336 gal/hr at an 8 psi operating pressure. The automated LEPA system was programmed to terminate flow over the SDI and check plots. Furrow dikes were maintained in all furrows (both SDI and LEPA) to capture rainfall and retain applied irrigation water. Dikes were removed in non-irrigated furrows in early August to facilitate crop termination and harvest. Crop nutrients were banded on each side of the crop bed based on soil analysis. Preplant irrigations with LEPA and SDI raised profile water content to approximately 85% of field capacity prior to planting based on neutron readings. Paymaster HS26 cotton variety was planted on 13 May 1995, 10 May 1996 and 14 May 1997. Normal cultural practices were used to control weed and insect pests.

Decisions related to irrigation initiation, termination, quantities, and the integration of rainfall were based on the comparison of calculated and target soil water contents as well as irrigation delivery rates (Bordovsky and Lyle, 1996). Calculated soil water content (estimated field content) was determined daily using local irrigation and effective rainfall amounts and regional ET and heat unit (dd_{60}) data obtained from the South Plains PET network . Target soil water content was 85% field capacity from emergence to peak bloom (1480 heat units), declined linearly to 40% field capacity at 2080 cumulative heat units, and was held at 40% field capacity for the remainder of the irrigation season. Irrigations were initiated if calculated soil water (field conditions) were less that target water content. Irrigation delivery rates of 0.1, 0.2, and 0.3 in./day limited application amounts. These quantities correspond to 1/4-mile pivot flow rates of 233, 470, and 700 gpm and represent pumping rates of 1.9, 3.8, and 5.7 gpm/acre. Daily irrigations occurred in the drip plots. LEPA plots were irrigated on 1, 2, and 3-day intervals. Irrigations were terminated with the maturity of upper bolls or a significant change in weather.

A line of four neutron access tubes located 10 inches apart and perpendicular to the crop row were established in selected SDI and LEPA plots prior to preplant irrigations in 1995 and 1996. During preplant irrigation, these sites along with hand excavated soil samples, were used to determine the extent and location of the soil moisture wetting front. Additional neutron attenuation sites in all treatments allowed soil water monitoring throughout the growing season and were used to determine water use efficiencies. Areas (26.2 row-ft) were hand harvested within each replicate of all treatments. Yield samples were ginned with the small TAES gin stand at Lubbock. Lint yield, water use efficiency (WUE), and total irrigation water use efficiency (TIWUE) were determined for each treatment.

Results

Average cotton lint yields resulting from treatment combinations of irrigation interval, delivery system, and irrigation delivery rates are given in Table 1. Within the LEPA treatments, there were no statistically significant ($P<0.05$, Duncan) yield differences due to irrigation interval when irrigation capacity equaled or exceeded 0.2 in./day. However, when capacity is severely limited (Irr. Capacity = 0.1 in./day), the 2-day interval resulted in a significantly higher cotton lint yield than either the 1 or 3-day treatments. With very limited pump delivery rates, decreasing the time between irrigations increases lint yield. However, at the 1-day interval, soil surface evaporation apparently depleted a high portion of the small daily irrigation amount (0.1 in./day) which reduced yields. Lint yields were higher due to water delivery by SDI compared to LEPA at all irrigation capacities. At the 0.1, 0.2, and 0.3 in./day capacities, SDI resulted in 3-year average lint yields of 1145, 1225, and 1259 lb/acre which were significantly higher by 17, 7, and 6 percent over yields of the best LEPA treatments at 980, 1142, and 1187 lb/acre, respectively ($P<0.05$, Duncan). The increase in yield is attributed to less soil surface evaporation and, therefore, more crop water available for SDI than LEPA treatment areas.

The classic method of calculating water use efficiency (WUE) is dividing lint yield by the total water used within the plant environment. Total water used equaled measured soil water depletion from planting to harvest plus effective rainfall plus seasonal irrigation less drainage. WUE's reported in Table 2 may be in slight error due to the time between plant emergence and the first soil water measurement. Also, a single neutron tube in the crop row irrigated in alternate furrows may not accurately depict true soil water status. Drainage also could not be measured although it was estimated to be low due to the irrigation scheduling technique. WUE's at the 0.1 in./day capacity were significantly higher for SDI than LEPA treatments and significantly higher for 2-day LEPA than 1-day LEPA treatments. WUE's of 1-day LEPA at 0.2 in./day capacity and 3-day LEPA at 0.3 in./day capacity were not significantly different than respective SDI treatments.

Total irrigation water use efficiency (TIWUE) represents the value one receives from the total volume of ground water pumped during the year and is defined as the difference in irrigated and dryland yield divided by the total preplant and seasonal irrigation quantity. The mean 3-year dryland yield was 379 lbs lint/A. Table 3 gives TIWUE for all treatments. The TIWUE of SDI was significantly higher than all LEPA treatments due in part to higher LEPA preplant irrigations. In order to fill the profile to 85% field capacity at planting, a larger quantity of water was require for LEPA than SDI due to lower residual soil water in LEPA plots as well as higher LEPA soil surface evaporation losses during the windy preplant irrigation period. As irrigation capacity increased, differences in TIWUE among treatments decreased. Within the LEPA treatments at the 0.1 in/day capacity, daily irrigation is significantly less efficient than irrigating on a 2 or 3-day interval.

The profile wetting front was determined during preplant irrigation to evaluate seedbed wetting. Changes in soil profile water after 3.0 and 6.8 inches of preplant irrigation in the first year of SDI use are given in Figures 1and 2. Sites where these data were gathered were covered with portable rain-out shelters to prevent rainfall from disturbing the irrigation wetting front. Corresponding LEPA irrigated sites are depicted in Figures 3 and 4. SDI was irrigated daily, LEPA, on a 7-day interval.

Initial SDI irrigations wetted the area immediately below the drip line and moved water below soil water monitoring depth. In the first year of its use, SDI required over 6 inches of preplant water to sufficiently wet the seedbed for germination in this stratified loam soil. In the second year of its use, after profile consolidation around the drip tube, wetting the dry seedbed required only 3 to 3.5 inches of water (data not shown). From Figures 2 and 4, one can see that measuring soil water content with a single neutron access tube can result in misleading information when irrigating with LEPA or SDI systems.

Summary and Conclusions

Both SDI and LEPA irrigation systems can be managed to utilize available water resources while maintaining high yields. As irrigation capacity increases, cotton lint yields are also increased, however, this increase was small relative to the higher pumping capacity. Lint yields and water use efficiencies were significantly higher when LEPA irrigations occurred at 2-day intervals within the 0.1 in./day capacity than at 1 or 3-day intervals. Differences among interval treatments decreased as irrigation capacity increased. Cotton lint yields and water use efficiencies were significantly higher for SDI than LEPA under the management protocol used in this experiment. SDI with emitter spacing of 24 inches, emitter flow rate of 0.336 gal/hr operated at 8 psi, and installed 12 inches deep in alternate furrows, successfully wetted a dry seedbed for seed germination in an Olton loam soil without rainfall.

From observations during this study, the advantages of SDI over the LEPA delivery system in cotton production include increased cotton lint yield and water use efficiencies particularly at very low irrigation capacities. The advantages of LEPA over SDI include lower initial costs, less critical maintenance schedule, known life expectancy and residual value for the system, and the ability to apply foliar materials. The advantage of SDI and LEPA over furrow and spray systems is their ability to efficiently apply very small quantities of water at frequent intervals and be managed to fully utilize our sporadic seasonal rainfall resulting in high cotton yields.

Acknowledgments

This research was funded in part by Cotton Incorporated through the Texas State Support Committee. Their support is gratefully acknowledged.

References

Bordovsky, J.P., W.M. Lyle, R.J. Lascano, D.R. Upchurch. 1992. Cotton irrigation management with LEPA systems. Trans. of the ASAE 35(3):879-884.

Bordovsky, J.P. and W.M. Lyle. 1996. Protocol for planned soil water depletion of irrigated cotton. Proceedings of the International Conference on Evapotranspiration and Irrigation Scheduling. San Antonio, TX, 201-206.

Bordovsky, J.P. and W.M. Lyle. 1997. Planned soil water depletion of irrigated cotton on the Southern High Plains. 1997 Proceedings Beltwide Cotton Conference. 1403-1406.

Funck, J. 1997. Netafim Irrigation, Inc. District Sales Manager. Personal communications.

Henggler J. 1997. Irrigation economics of drip-irrigated cotton under deficit-irrigation. Proceedings of the Irrigation Association Technical Conference. Nashville, TN. 125-132.

Table 1. Cotton lint yield using LEPA and SDI at three irrigation capacities, Halfway, TX, 1995-97.

Irr. Capacity (in./day)	Seasonal Irr. (in.)	Cotton Lint Yield (lb/acre)			
		SDI	LEPA		
		1day	1day	2 day	3 day
0.1	4.6	1145 a[1/]	917 c	980 b	922 c
0.2	6.7	1225 a	1142 b	1120 b	1110 b
0.3	7.1	1259 a	1165 b	1142 b	1187 b
Avg.		1210 A	1075 B	1081 B	1073 B

[1/] Values in a row followed by the same letter are not statistically different (0.05 Duncan)

Table 2. Water use efficiency (WUE) of irrigated cotton, Halfway, TX, 1995-97.

Irr. Capacity (in./day)	Total Water Used (in.)		WUE (lb/acre-in.)[1/]			
			SDI	LEPA		
	SDI	LEPA	1day	1day	2 day	3 day
0.1	18.1	17.8	63.3 a[2/]	51.3 c	55.0 b	52.6 bc
0.2	19.9	19.5	61.6 a	58.7 ab	57.4 b	57.4 b
0.3	20.1	19.8	62.6 a	59.1 b	57.5 b	59.9 ab
Avg.			62.5 A	56.4 B	56.6 B	56.6 B

[1/] WUE = lint yield/(seasonal soil water change + effective rainfall + seasonal irrigation)

[2] Values in a row followed by the same letter are not statistically different (0.05 Duncan)

Table 3. Total irrigation water use efficiency (TIWUE) of irrigated cotton, Halfway, TX, 1995-97.

Irr. Capacity (in./day)	Preplant + Seasonal Irrigation (in./yr.)		TIWUE (lb/acre-in.)[1/]			
			SDILEPA			
	SDI	LEPA	1	1	2	3
0.1	9.6	11.2	78.7 a[2/]	46.5 c	52.8 b	47.5 bc
0.2	11.1	11.6	75.9 a	65.8 b	63.1 b	64.4 b
0.3	11.5	11.5	77.7 a	69.1 b	66.9 b	71.3 b
Avg.			77.4 A	60.5 B	60.9 B	61.1 B

[1/] TIWUE = (irrigated yield - dry yield)/(preplant irrigation + seasonal irrigation), dry yield = 379 lb/A

[2/] Values in a row followed by the same letter are not statistically different (0.05 Duncan)

DRIP WEST

Date of Neutron Reading (doy)	**108**
Total Water Applied at this Time (in.)	**3.02**
Time From Initial Preplant Irrigation (days)	**18**
Time Between Neutron Reading and Last Water Application (days)	**5**

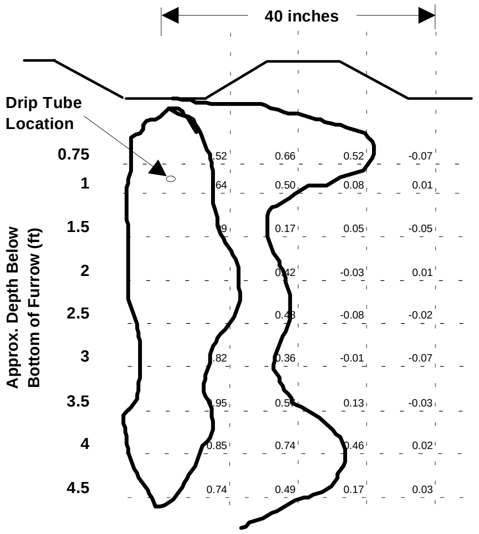

Figure 1. Change in profile soil water due to 3.0 inches of preplant irrigation with SDI in the first year of its use.

DRIP WEST

Date of Neutron Reading (doy)	**125**
Total Water Applied at this Time (in.)	**6.77**
Time From Initial Preplant Irrigation (days)	**35**
Time Between Neutron Reading and Last Water Application (days)	**1**

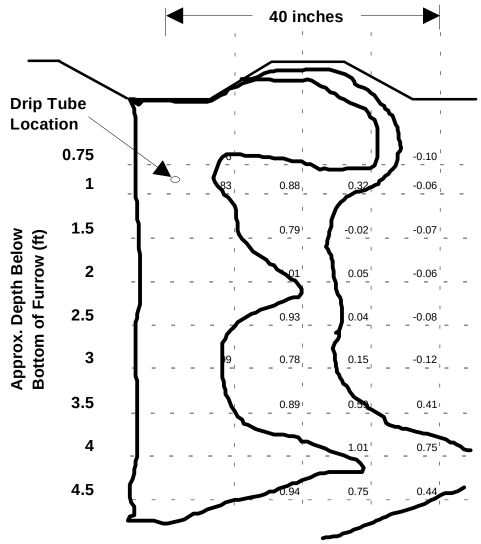

Figure 2. Change in profile soil water due to 6.8 inches of preplant irrigation with SDI in the first year of its use.

LEPA EAST

Date of Neutron Reading (doy)	**108**
Total Water Applied at this Time (in.)	**3**
Time From Initial Preplant Irrigation (days)	**18**
Time Between Neutron Reading and Last Water Application (days)	**5**

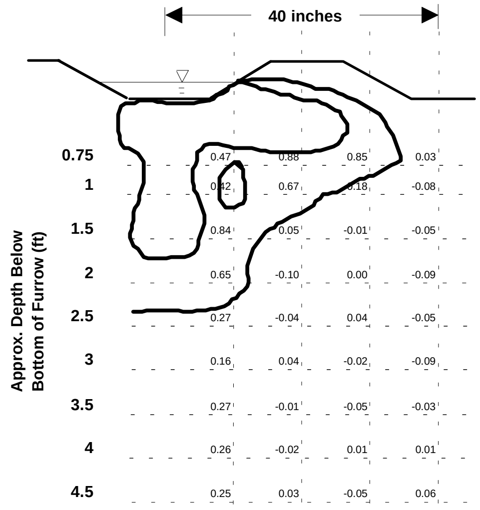

Figure 3. Change in profile soil water due to 3.0 inches of preplant irrigation with LEPA .

	LEPA	EAST
Date of Neutron Reading (doy)	**128**	
Total Water Applied at this Time (in.)	**6.77**	
Time From Initial Preplant Irrigation (days)	**38**	
Time Between Neutron Reading and Last Water Application (days)	**14**	

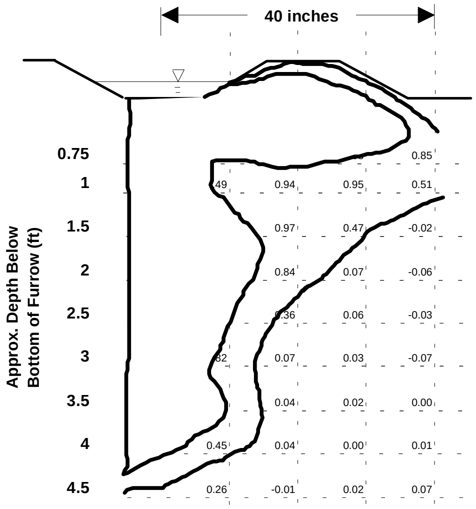

Figure 4. Change in profile soil water due to 6.8 inches of preplant irrigation with LEPA .