Economic Evaluation of Texas High Plains Cotton Irrigated by LEPA and Subsurface Drip

James P. Bordovsky
William M. Lyle
Texas Agricultural Experiment Station, Texas A&M University, Lubbock, TX 79403-9757
Eduardo Segarra
Agricultural and Applied Economics, Texas Tech University, Lubbock, TX 79409-2132

ABSTRACT

As water supplies and availability continue to decline in Texas, it is imperative to adopt the most efficient irrigation systems and management techniques. The focus of this study was to optimize irrigation management techniques for low energy precision application (LEPA) irrigation and subsurface drip irrigation (SDI), and compare resulting cotton lint yields and profitability of these irrigation approaches. Four-year average LEPA and SDI cotton lint yields were 1046 lb/ac and 1171 lb/ac, respectively, using only 7.3-in or less of seasonal irrigation water per year. Differences in LEPA and SDI yields are attributed to higher water losses by the LEPA system due to soil surface evaporation. Economic analysis of Texas High Plains cotton production showed that LEPA resulted in higher net returns to management and risk than SDI as irrigation capacity increased above the 0.1 in/d level. However, SDI treatments resulted in net returns of over $80/ac and may be an acceptable alternative where LEPA installation costs are greater than $333/ac, physical constraints prevent the use of LEPA, or SDI installation costs are lower than $800/ac.

KEYWORDS: Drip irrigation, LEPA, Irrigation, Economics, Cotton.

The low energy precision application (LEPA) irrigation concept was developed by the Texas Agricultural Experiment Station at Halfway, TX between 1976 and 1978. The concept was designed to maximize the use of declining ground water supplies and sporadic seasonal rainfall. Subsequent LEPA experiments determined the best combination of irrigation quantities and frequencies for optimum cotton lint yield and water use efficiency (Bordovsky, et al., 1992). Results indicated irrigation water use efficiencies from 72-h irrigation interval treatments were almost twice the levels of those for 216 and 360-h treatments and suggested that the optimal interval for alternate furrow LEPA may be lower than 72-h.

In recent years, interest in the use of subsurface drip irrigation (SDI) for cotton production has increased in West Texas. Systems installed in the Trans-Pecos, TX area in the early 1980's continue to be used today (Henggeler, 1997). The High Plains Underground Water Conservation District No. 1 installed multiple 10-ac demonstration sites to obtain general production information from SDI systems. It is estimated that 30,000 acres of cotton were irrigated with SDI on the Southern High Plains of Texas in 1999 with an addi-

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tional 10,000 acres projected to be irrigated in 2000 (Funck, 1999). However, a major issue concerning SDI is its ability to pay for the system by improving water use efficiency and cotton lint yield over existing, well managed systems.

An experiment was conducted in Halfway, TX from 1995 through 1998 to determine cotton response to high frequency, deficit irrigation using LEPA and SDI. The objective of this experiment was to find the optimum irrigation interval using LEPA at low irrigation capacities and compare its associated cotton lint yields to those resulting from daily SDI irrigation treatments. This paper summarizes the findings of the experiment and compares the net returns to management and risk of cotton irrigated by these systems.

METHODS AND MATERIALS

Crop Response to Irrigation

From 1995 through 1998, an experiment was conducted at the Texas Agricultural Experiment Station at Halfway, TX on moderately permeable Olton loam (fine, mixed, thermic Aridic Paleustolls) soil with a slope of less than 0.2 percent. Five replications of the 9 LEPA treatments (3 irrigation capacities x 3 irrigation intervals) and 3 replicates of 3 SDI treatments (3 irrigation capacities x 1 irrigation interval) plus "preplant only" irrigated checks were randomly placed in a 6-ac area under a five-span lateral LEPA irrigation system. Each span was subdivided into two sections with each section delivering water to 16-40-in wide rows through a manifold system. The manifold system consisted of solenoid valves, pressure regulators, and three manifolds, each nozzled at different flow rates and controlled by a programmable controller (Bordovsky et. al., 1992). This irrigator could apply a wide range of irrigation amounts based on the daily needs of respective treatments as well as provide a method to reset valve/manifold combinations as the system moved between treatment plots. Water was delivered by the LEPA method to alternate diked furrows from the manifold system through a drop tube into a wide, flat sock. SDI treatments were randomly placed among the LEPA irrigation plots. Drip tubing was buried in alternate furrows, 12-in deep in the SDI treatment areas. Emitter spacing along the drip lateral was 24-in with emitter flow rate at 0.33 gal/h at 8 lb/in^2 pressure. The automated LEPA system was programmed to terminate flow over the SDI and check plots. Furrow dikes were maintained in all furrows, both LEPA and SDI, to capture rainfall and retain applied irrigation water. Dikes were removed in non-irrigated furrows in early August to facilitate crop termination and harvest. Nutrients were banded on sides of the crop bed based on soil nutrient analysis. Preplant irrigations with LEPA and SDI elevated profile water content to approximately 85 percent of field capacity prior to planting based on neutron moisture measurements with respective plots. Paymaster HS26 cotton variety was planted in early May of each year. Normal cultural practices were used to control weed and insect pests.

Decisions related to irrigation initiation, termination, quantities, and the integration of rainfall during the growing season were based on the comparison of calculated and target soil water contents as well as irrigation delivery rates (Bordovsky and Lyle, 1996 and 1997). Calculated soil water content (estimated field water content) was determined daily using irrigation and effective rainfall amounts, regional ET and heat degree unit data (degree days, base 60°F) obtained from the South Plains PET network (Lyle, et al., 1996), and a locally derived crop curve. Target soil water content was 85 percent field capacity from emergence to peak bloom, declined linearly to 40 percent field capacity at 2080 cumulative heat units, and was held at 40 percent field capacity for the remainder of the irrigation season. Irrigations were initiated if calculated soil water (field conditions) were lower than the target water content. Irrigation amounts equaled the difference between the target and calculated soil water content subject to three delivery rates. Irrigation delivery rates of 0.1, 0.2, and 0.3 in/d limited application amounts in respective quantity treatments. These quantities corresponded to ? -mile pivot flow rates of 233, 470, and 770 gpm and represent pumping rates of 1.9, 3.8, and 5.7 gpm/ac. Due to these irrigation rate limits, the target soil water content (85% of field capacity) could not be maintained during portions of the growing season, particularly in the 0.1 in/d and 0.2 in/d treatments, unless rainfall occurred. A detailed description of this irrigation protocol is presented by Bordovsky and Lyle (1996, 1997). LEPA irrigation interval treatments were 24, 48, and 72-h. SDI treatments were irrigated daily (i.e., 24-h). Irrigations were terminated at maturity of upper bolls or at the beginning of a significant late season cooling trend. Areas (87 ft^2) were hand harvested within all replicates in October of each year. Yield samples were ginned using a small gin stand.

Economics Analysis

The relative profitability of cotton production under LEPA and SDI was evaluated based on the production data generated by this experiment. The approach was to assume the dryland-to-irrigated development of a 120-ac Texas High Plains field and to make economic comparisons using irrigated cotton budgets. These budgets were composed of expected revenues, variable costs, and fixed costs (Segarra, et al., 1999). These components were then used to derive expected levels of net revenues to management and risk above variable and fixed costs. Expected revenue calculations used the corresponding yields for the 12 irrigation treatments (3 SDI and 9 LEPA) over the four-year test period. Constant prices of $0.64/lb cotton lint and $110/ton for cottonseed were used throughout the calculations to derive the levels of expected net revenues. The variable cost estimate took into account all of the variable inputs needed to produce irrigated cotton including herbicide, fertilizer, crop insurance, seed, seed treatment, insecticides, fuel and lube, repairs, labor, harvest-aid chemicals, stripping, module charges, and ginning. These expenses differed across irrigation treatments due to varying pumping costs associated with irrigation capacity treatments and varying harvest and ginning costs associated with cotton lint yield.

Annual fixed costs were separated into three categories: machinery, land and irrigation system. The machinery and land charges were assumed to be $48/ac and $40/ac, respectively. The irrigation system cost was composed of irrigation well cost and irrigation system cost. The irrigation well cost was assumed to be $33,000 for the 120-ac area (Segarra, et al., 1999). The irrigation system and installation costs were assumed to be $40,000 for LEPA, with SDI costs analyzed at both $600/ac and $800/ac levels (Funck, 1999). Three planning horizons were assumed in the calculations of the annual irrigation system cost, these were 10, 15 and 20 years.

RESULTS

Yield Response

Average cotton lint yields resulting from treatment combinations of irrigation interval, delivery system, and irrigation delivery rates from 1995 through 1998 are presented in Table 1. Within the LEPA treatments, there were no statistically significant ($P<0.05$, Duncan) cotton lint yield differences due to irrigation interval when irrigation capacity equaled 0.2 in/d. However, when capacity is severely limited (0.1 in/d), the 48-h interval resulted in a significantly higher cotton lint yield than either the 24 or 72-h treatments. With very limited pump delivery rates, decreasing the time between irrigations from 72 to

48 hours increases lint yield. However, at the 24-h interval, soil surface evaporation apparently depleted a high portion of the daily irrigation amount significantly reducing yields compared to the 48-h interval.

Cotton lint yields during the 4-year period were higher for treatments watered by SDI than LEPA at all irrigation capacities. At the 0.1, 0.2, and 0.3 in/d capacities, SDI resulted in 4-year average cotton lint yields of 1109, 1190, and 1215 lb/ac, significantly higher by 14, 9, and 5 percent, than yields of the best LEPA treatments at 978, 1091, and 1156 lb/ac, respectively ($P<0.05$, Duncan). The increase in yield from SDI use was attributed to less soil surface evaporation and more available crop water under SDI than under LEPA.

Table 1. Average annual water use and cotton lint yield resulting from irrigation with LEPA and SDI at three irrigation capacities and up to three irrigation intervals.

Irrigation Capacity (in/d)	Average Annual Irrigation (in/y)	Total Water[1] (in/y)	Cotton Lint Yield (lb/ac)				
			Preplant Irr. Only	SDI 24 h	LEPA 24 h	LEPA 48 h	LEPA 72 h
0.0	0.0	12.4	539				
0.1	5.2	17.2		1109 a[2]	897 c	978 b	911 c
0.2	7.1	18.8		1190 a	1091 b	1077 b	1088 b
0.3	7.3	19.0		1215 a	1113 bc	1101 c	1156 b
Avg.				1171 A	1034 B	1052 B	1052 B

[1] Average change in seasonal soil water content (mid June to frost, neutron attenuation to 5 ft depth) + effective seasonal rainfall (planting to frost) + seasonal irrigation.

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

Economic Analysis

Comparisons of the net return to management and risk of LEPA and SDI systems using various economic assumptions and based on average lint yields are depicted in Figures 1 through 3. Figure 1 contrasts the two delivery systems as a function of irrigation capacity with the assumed initial cost of $333/ac for LEPA, and both $600/ac and $800/ac for SDI. Other assumptions include a pumping depth of 300-ft, life expectancy of both LEPA and SDI systems of 20 years, and yield response at 100 percent of the corresponding treatment yields during the 1995-1998 experiment. Figure 1 shows that both LEPA and SDI resulted in positive net returns of at least $80/ac, regardless of initial cost of system or irrigation capacity. Notice, that the net returns of the $800/ac SDI scenario were very close to those of LEPA at the irrigation capacity of 0.1 in/d. However, as irrigation capacity exceeded 0.1 in/d, net return increased much faster for LEPA than SDI. This is due to increased water use efficiency of LEPA with increased irrigation capacity compared to consistently high water use efficiencies of SDI. When the initial cost of SDI was reduced to $600/ac, net returns from the SDI treatments at $120/ac were much higher than LEPA and increased with irrigation capacity. This implies that SDI is a viable irrigation delivery system for cotton production and may be a better alternative than LEPA in situations where LEPA installation costs are higher that $333/ac or irrigation capacity is at or near 0.1 in/d.

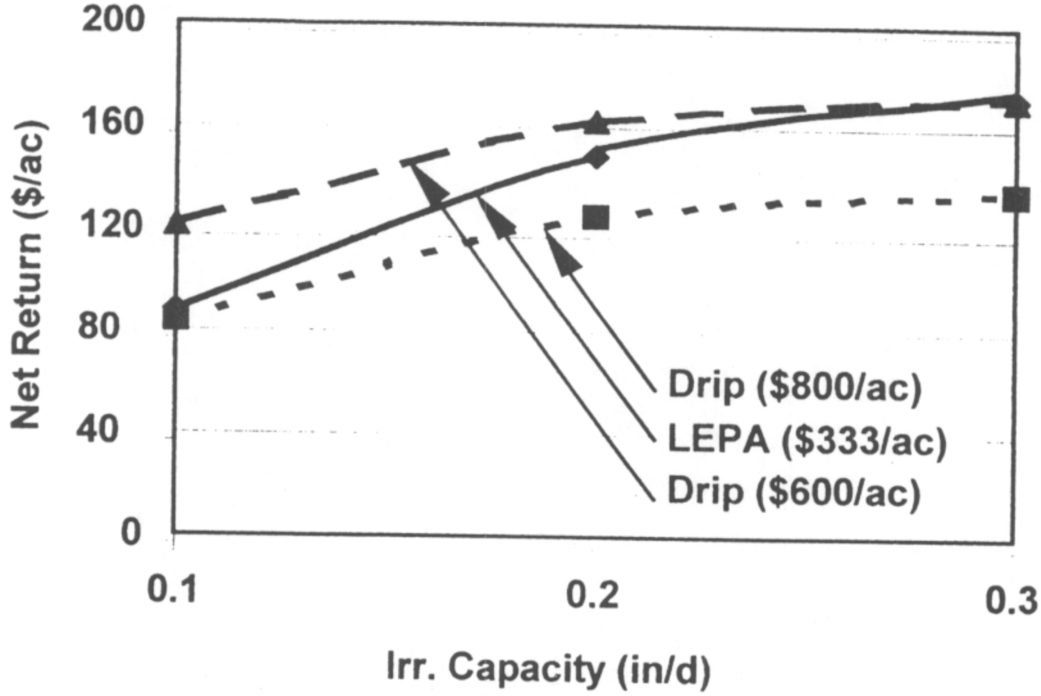

Figure 1. Net return of LEPA and SDI at irrigation capacities of 0.1, 0.2, and 0.3 in/d, with pumping depth of 300 ft and system life expectancy of 20 years.

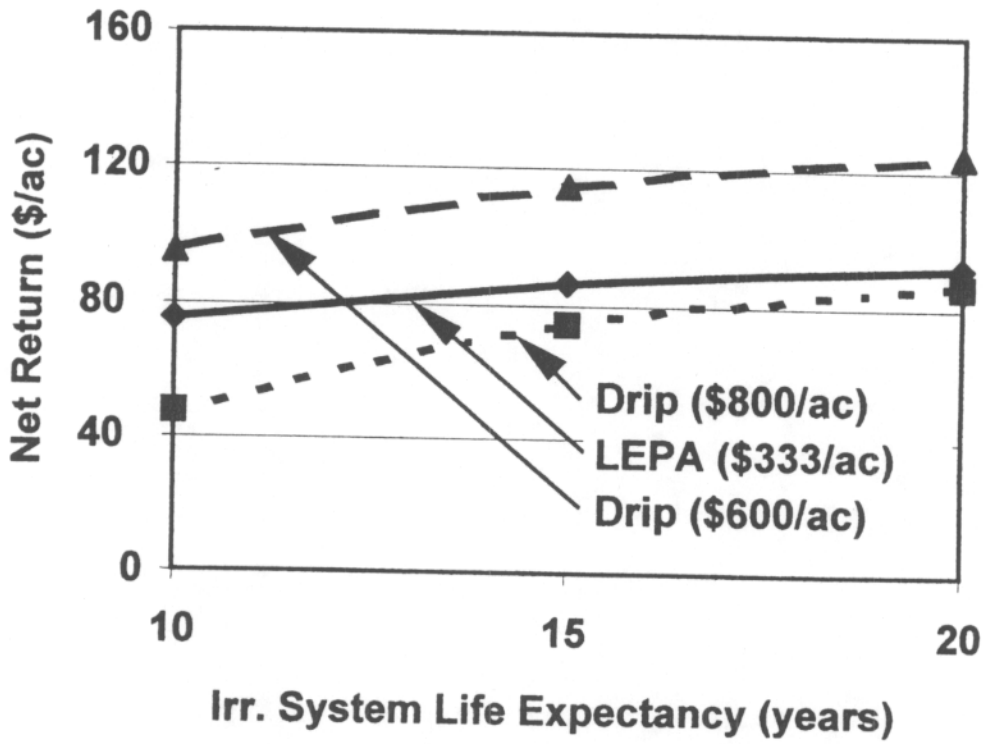

Figure 2. Net returns of LEPA and SDI irrigation systems with life expectancies of 10, 15, and 20 years, with pumping depth of 300-ft and irrigation capacity of 0.1 in/d.

Figure 2 shows the effect on net returns of irrigation system life. Assumptions included pumping depth of 300-ft, irrigation capacity of 0.1 in/d, and yield response at 100 percent of treatment yield. SDI at $800/ac resulted in a net return ranging from $46/ac to $87/ac, almost a 90 percent increase, as system life increased from 10 to 20 years. Net returns of the LEPA system were much less sensitive ranging from $75 to $95/ac over the 10-year period. As one would expect, as initial SDI costs were reduced to $600/ac, net returns became less sensitive to the life expectancy of the system.

The level of yield required to cover fixed and variable expenses is an important benchmark for cotton producers considering installation of a sophisticated irrigation system. Figure 3 displays net returns for LEPA and SDI systems at 80 and 100 percent of the average annual treatment yields assuming 300-ft pumping depth, 0.1 in/d irrigation capacity, system life expectancy of 20 years, and initial SDI installation cost of $800/ac. By assuming a linear relation between yield and net return, the quantity of cotton lint yield required to meet expenses was found to be approximately 812 lb/ac for LEPA and 955 lb/ac for SDI. Additional analysis showed that increases in irrigation capacity would not significantly alter the break even cotton lint yield requirements found.

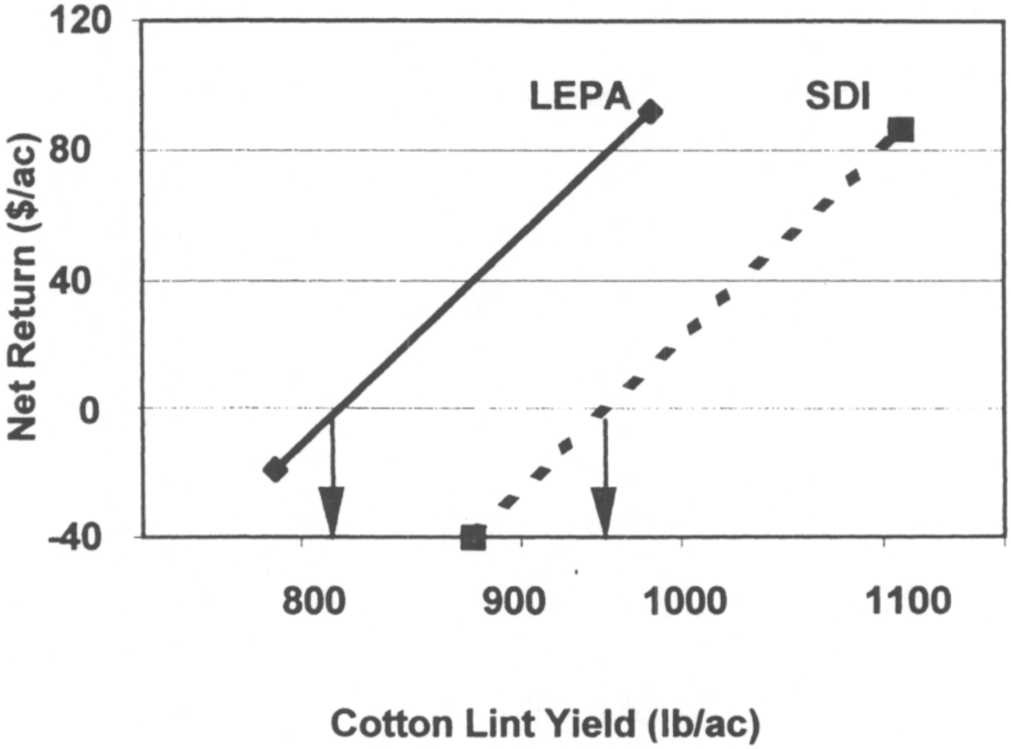

Figure 3. Comparison of net return and break even cost for installation of LEPA and SDI irrigation systems, with pumping depth of 300 ft, irrigation capacity of 0.1 in/d, system life expectancy of 20 years, and SDI cost of $800/ac.

SUMMARY AND CONCLUSIONS

In this study it is shown that both, LEPA and SDI systems can be managed to utilize available water resources while maintaining high cotton lint yields. Four-year average LEPA and SDI cotton lint yields of 1046 and 1171 lb/ac, respectively, resulted from using an average of 7.3-in or less of seasonal irrigation per year. As irrigation capacity increased, cotton lint yields also increased, however, the increase was small relative to the higher level of water applied. Average cotton lint yields ranged from a low of 897 lb/ac at 0.1 in/d (24-h, LEPA) to 1215 lb/ac at 0.3 in/d (24-h, SDI). Forty-eight hour LEPA irrigations increased lint yields compared to 24 and 72-h intervals at the 0.1 in/d capacity, with differences among interval treatments reduced as irrigation capacity increased. Cotton lint yields were higher for SDI than LEPA within all irrigation capacity treatments analyzed. SDI treatments resulted in significantly higher cotton lint yields than 48-h LEPA at the 0.1 in/d capacity (1109 versus 978 lb/ac, respectively) over the four-year period. Differences in cotton lint yields between LEPA and SDI treatments are attributed to higher water losses by the LEPA system due to soil surface evaporation.

The primary advantages of SDI over LEPA in cotton production are increased cotton lint yield and improved water use efficiencies, particularly at very low irrigation capacities. The advantages of LEPA over SDI include lower initial cost, lower management and maintenance requirements, less uncertainty about LEPA life expectancy, and the ability to apply foliar materials. An economic analysis of this data, demonstrated that LEPA would result in higher net returns to management and risk than a $800/ac SDI system, but that it would not be the case for a $600/ac SDI system. Also, LEPA resulted in much higher net returns as irrigation capacity increased above the 0.1 in/d level. However, the SDI system resulted in net returns of over $80/ac and may be an acceptable alternative to LEPA if installation costs are greater than $333/ac, physical constraints prevent the use of LEPA, or SDI installation costs are lower than $800/ac.

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