COMPARISON OF SPRAY, LEPA, AND SUBSURFACE DRIP IRRIGATED COTTON

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Abstract

Preplant irrigations on the Southern High Plains represent an increasingly larger portion of the total irrigation water pumped and can be extremely inefficient, particularly with traditional application systems. One possible method of reducing preplant evaporation losses and increasing water use efficiency is the use of subsurface drip irrigation (SDI). A field experiment was established to compare two preplant irrigation scenarios at two irrigation capacities with water delivered by spray, LEPA, and SDI systems.

High rainfall from March through June of 1999 resulted in few significant differences in lint yield and water use efficiencies (WUE) due to *limited* versus *full* preplant irrigation scenarios. However, abnormally low rainfall in July and August of 2000 resulted in *limited* preplant treatments having significantly lower yields (792 vs. 864 lb lint/acre) and WUE (46 vs. 54 lb lint/acre-in.) than comparable *full* preplant treatments. In both 1999 and 2000, less than 15% of the annual precipitation occurred during the critical cotton development months of July and August. This occurrence highlighted differences in irrigation delivery systems under limited irrigation capacity conditions. SDI treatments resulted in increased lint yields of 42 and 45% over spray and 25 and 22% over LEPA and increased WUE by 40 and 44% over spray and 20 and 18% over LEPA in 1999 and 2000, respectively. Cotton loan prices were significantly affected by irrigation system and preplant scenario treatments in 1999, and by irrigation capacity treatments in 2000.

Introduction

Past research has shown preplant irrigation using furrow application methods provided an economic benefit by filling the soil profile prior to planting cotton on the Southern High Plains of Texas (Newman, 1966). Preplant irrigation amounts can easily exceed seasonal irrigation quantities in areas of low irrigation capacity due to the long opportunity time for irrigation prior to planting (Bordovsky, 1998). However, high wind speeds and low relative humidity are common during the typical preplant period and can cause high evaporative losses in this semi-arid area. Preplant water losses associated with modern irrigation systems were recently measured, as applied irrigation was tracked through neutron attenuation. In a non-replicated experiment at the Halfway research site, of preplant irrigation applications of 5 inches, 81% of spray, 55 % of LEPA, and 23% of SDI applied water was undetected at planting. This would indicate that 23% to 81% of preplant irrigation is lost before planting. Unfortunately, growers continue applying large preplant irrigations without regard to current delivery methods and rapidly declining water supplies.

An experiment was initiated in 1999 to measure water losses from *limited* and *full* preplant irrigation scenarios using spray, LEPA, and subsurface drip irrigation (SDI) systems in treatments limited to irrigation capacities of 0.1 and 0.2 in./day. The second part of this experiment was to determine the effects of these treatments on cotton lint yield, water use efficiency, and fiber quality under the continued seasonal limitations of irrigation capacity and delivery system. The objective of this paper is to summarize the yield, water use efficiency, and the fiber quality effects following the first two years of this study.

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Methods and Materials

This experiment was conducted at the Texas Agricultural Experiment Station at Halfway, TX on moderately permeable (0.1 in./h) Olton loam (fine, mixed, thermic Aridic Paleustolls) soil with a slope of less than 0.2%. The field was 6.2 acres in size, irrigated (except for SDI) by a 5-span linear irrigator. Each span of the irrigator was subdivided into two sections with each section delivering water to 16 40-in. rows through a manifold system similar to that described by Bordovsky et al. (1992). From five of the ten sections, water was delivered by the LEPA method to alternate diked furrows from the manifold system through a drop tube into a wide, flat sock which minimized dike erosion. The remaining five sections delivered water from the manifold system to flat spray applicators located 24 to 30 inches above the soil surface. Drip tubing was buried 1-ft deep on 80-inch centers between adjacent cotton rows in SDI plots. Emitter spacing along the drip lateral was 24 inches with emitter flow rate at 0.33 gph at 8 psi. The automated linear system was programmed to terminate flow over the SDI and check plots. Plot size was 16 rows by 60 feet.

The treatment factors included preplant scenario, irrigation capacity, and delivery method. Preplant scenario treatments included *limited* preplant which provided sufficient soil water for germination and early plant development followed by early in-season irrigations in excess of evaporative demand to try to fill the soil profile. The *full* preplant treatment elevated soil water to approximately 80% of field capacity. Irrigation capacity treatments limited the maximum irrigation delivery rate to 0.1 and 0.2 in./d. These amounts are well below peak consumptive demand for cotton in this area and equal to 1.8 and 3.6 gpm/acre, respectively. Each of the previously mentioned treatment combinations (2 preplant scenarios x 2 irrigation capacities) were irrigated by spray, LEPA, and SDI systems resulting in 12 primary treatments. Spray and LEPA treatments were replicated 6 times and SDI replicated three times. "Preplant only" and non-irrigated checks plots were also randomly placed among the other treatment plots. Furrow dikes were maintained in all furrows of all plots to capture rainfall and prevent applied irrigation water from moving to adjacent treatment areas. Irrigations were initiated in the *full* preplant treatments on 6 April 1999 and 13 March 2000 with 5.0 to 5.5 inches applied, and in the *limited* treatments approximately 25 days later with amounts of less than 2.6 in. (Table 1). Preplant irrigations were terminated on 28 April 1999 following a rainfall event of 3.38 inches on 29-30 April. In 2000, preplant irrigations were terminated on 25 April.

In-season irrigations were initiated on 7 July 1999 and 13 June 2000 and all seasonal irrigations were terminated by 15 September in both years. Spray, LEPA, and SDI treatments were irrigated once per week, three times per week, and daily, respectively. Soil water content was measured by neutron attenuation at 48 sites on multiple dates during both growing seasons and was used to determine water use.

A controlled traffic tillage system was used to prevent disturbance of the existing buried drip irrigation system. Phosphorus fertilizer was applied with chisels on the sides of existing beds, herbicide applied and incorporated with a rolling cultivator, and furrows were diked. Nitrogen was applied following preplant irrigations. A short season variety, Paymaster 183, was replanted on 2 June 1999 due to earlier hail and Paymaster 2326RR was planted on 8 May 2000. Dikes were removed in non-irrigated furrows in August to facilitate crop termination and harvest. Normal cultural practices were used to control weed and insect pests.

All 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 (Bordovsky and Lyle, 1996). Calculated soil water content, used as an estimate of field water 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 (Lyle, et al., 1996). Target soil water content was 85% field capacity from emergence to peak bloom, 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 than target water content. However, irrigation quantities were limited by irrigation delivery rates (0.1 or 0.2 in./d irrigation capacity treatments). Irrigations were terminated at maturity of upper bolls or at the beginning of a significant late season cooling trend. Areas of 26.2 row-ft within each treatment plot were hand harvested with cotton samples ginned using the TAES gin stand at Lubbock. Lint yield and WUE were determined. Fiber samples from three replicates of each treatment were evaluated at the International Textile Center at Texas Tech University.

Results

Growing Conditions

The weather at the research site was not conducive for cotton growth in the early 1999. Significant hail occurred on 26 May requiring replanting on 2 June. Cool wet weather continued through June with average daily air temperatures at 70.2°F during the two weeks following emergence (compared to long term monthly average of 75.8°F). Total rainfall following preplant irrigation through 20 June and during the period of stand establishment was unusually high at 10.8 inches. However, cotton plants made excellent progress in July and August. Monthly rainfall for July, August, and September 1999 was near average at 1.10, 2.62, and 1.87 inches. Cumulative heat units were 352, 931, 1508 and 1849 DD60 at the end of June, July, August, and September. Weather remained open through cotton harvest.

In 2000, early season weather at Halfway was excellent for cotton growth. Hot temperatures resulted in rapid germination and emergence. Cooler weather and favorable rains occurred in June. However, below normal rainfall in July and August severely stressed plants in treatments where irrigation capacity was limited (0.1 in./d preplant scenario) or where the irrigation delivery system tended to be less efficient. Rainfall in April, May, June, July, August was 1.33, 0.11, 4.32, 0.68, and 0.62 inches, respectively. Cumulative heat units were 618, 1204, 1757 and 2128 DD_{60} at the end of June, July, August, and September.

Precipitation contributing to cotton yield, that occurring from 1 March to 31 August, was much higher in 1999 at 18.64 inches than in 2000 at 9.58 inches. Irrigation and rainfall totals from 1 March to 31 August are given in Table 1 for each treatment. The high rainfall in 1999 resulted in total irrigation amounts between respective 0.1 and 0.2 in./d irrigation capacity treatments being relative small for that year. For example, within the spray x *limited* preplant treatments, the 0.1 in./d treatment was irrigated 6.58 in. compared to 7.49 in. in the 0.2 in./d treatment where twice the pumping capacity was available. Low rainfall in the summer of 2000 resulted in irrigation amounts increased by 14 to 82% over those in 1999 depending on treatment. In both years, combined rainfall in July and August totaled less that 15% of the annual precipitation compared to the historical average of 25%.

Lint Yields

Soil water measurements made at irrigation initiation in 1999 indicated that the large rainfalls following preplant filled the root zone and would mask any yield response due to *limited* versus *full* preplant treatments. This proved only partially true. Respective *limited* and *full* treatments were irrigated identically during the growing season. Lint yield means from the twelve primary irrigation treatments and preplant only and non-irrigated treatments in 1999 are in Table 2. Although there were no significant differences between *limited* and *full* treatments (except SDI at 0.2 in./d capacity), lint yields were generally higher in all treatments that received the larger preplant irrigation amount. As expected, irrigation pumping capacity of 0.2 in./d resulted in larger total irrigation quantity and higher yield (although not significant) than did the 0.1 in./d capacity. Average yields for the spray, LEPA, and SDI were significantly different at 745, 850, and 1060 lb/acre, respectively.

In 2000, *full* preplant significantly increased yield over *limited* preplant in treatments where the delivery system had lower relative application efficiencies or the irrigation delivery rate was more limited. Table 3 contains cotton lint yield data for year 2000. At the 0.1 in./d capacity, the spray and LEPA treatments where *full* preplant irrigation occurred resulted in yields that were 36 and 21% larger that respective *limited* treatments. At the 0.2 in./d capacity, the spray x *full* preplant treatment resulted in yields that were 15% larger that the spray x *limited* treatment. Conversely, cotton yields irrigated by the SDI system or by the LEPA system with irrigation capacity of 0.2 in./d did not suffer by applying *limited* rather than *full* preplant irrigations in an extremely dry growing season. Lint yield was significantly higher in the 0.2 in./d irrigation capacity treatments than the 0.1 in./d treatments, 964 lb/acre vs. 692 lb/acre, respectively. The dry weather in July and August highlighted the differences in yield response due to irrigation system with lint yield means of 681, 814, and 989 lb lint/acre irrigated by spray, LEPA, and SDI, respectively.

Water Use Efficiency

Water use efficiencies (WUE) describe treatment yields as a function of the total water resource consumed and are determined by dividing lint yields by the total water used to produce those yields (measured soil water depletion from planting to harvest, effective seasonal rainfall, and seasonal irrigation). WUE for each of the twelve primary irrigation treatments are given in Tables 4 and 5 for the years 1999 and 2000. The most significant differences in WUE were among the irrigation delivery systems. The average of the WUE means of SDI were 59 lb/acre-in. of water, over 40% higher than the WUE of spray at 42 and 41 lb/acre-in. in 1999 and 2000, with LEPA efficiencies falling between those of SDI and spray methods. These values point to the magnitude of LEPA and spray losses relative to SDI in the short growing season of 1999 and the extreme dry summer of 2000.

In 1999, WUE were not affected by either preplant scenario or irrigation capacity. However, in 2000, WUE were significantly increased by *full* over *limited* preplant treatments at the 0.1 in./d capacity by all irrigation systems and at the 0.2 in./d capacity by the spray system. WUE was consistently higher at the 0.2 in./d delivery rate that at the 0.1 in./d rate for respective treatments, suggesting water would be better used by irrigating more fully on a limited number of acres in dry years.

Fiber Quality

Fiber properties and loan values were affected by the different treatment factors with the largest response occurring in year 2000. Table 6 displays fiber property and loan price means significantly affected by the three main treatment factors in this study. In 1999, irrigation system and preplant scenario treatments significantly affected loan prices. The price of cotton produced by SDI methods averaged $0.01/lb higher than that produced by spray and LEPA methods and the price of cotton in *full* preplant treatments was worth $0.01/lb more that cotton from *limited* treatments. The value of this cotton was low due to short fiber length of the replant cotton variety.

In 2000, multiple fiber properties were affected by the irrigation treatments. Fiber length was the most significantly affected by irrigation capacity contributing to an average of $0.036/lb higher loan price for treatments irrigated at the 0.2 in/d capacity over those irrigated at 0.1 in/d.

Conclusions

Heavy rainfall following preplant irrigation in 1999 masked cotton lint yield differences of the *limited* and *full* preplant irrigation treatments. Unusually dry conditions in July and August of 2000 resulted in significantly higher yields in *full* over *limited* preplant in treatments where irrigation systems had lower efficiencies (spray and LEPA) or where irrigation capacity was low (0.1 in./d). Irrigation by spray, LEPA, and SDI resulted in significant differences in average cotton lint yields of 745, 850, and 1060 lb/acre in 1999 and 681, 814, and 989 lb/acre in 2000. WUE were also significantly different at 42, 49, and 59 lb/acre-in. in 1999 and 41, 50, and 59 lb/acre-in. in 2000 for spray, LEPA, and SDI, respectively. Although the differences in yields and WUE resulting from delivery system treatments were similar for 1999 and 2000, economic decisions by growers to install SDI over spray or LEPA systems should be based on more than these two years of data.

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Table 1. Total irrigation quantities and precipiation from March 1 to August 31 of spray, LEPA, and SDI treatments at two irrigation capacities and two preplant irrigation scenarios at the TAES, Halfway, TX, 1999 and 2000.

			1999		2000	
Irr. Cap.	**System**	**PP Scenario**	**Tot. Irr.**	**Precip.**	**Tot. Irr.**	**Precip.**
PP Only	All	Limited	2.43	18.64	2.55	9.58
		Full	5.15	18.64	5.76	9.58
0.1	Spray	Limited	6.58	18.64	10.28	9.58
		Full	9.38	18.64	11.26	9.58
	LEPA	Limited	6.43	18.64	9.63	9.58
		Full	9.23	18.64	11.39	9.58
	SDI	Limited	6.90	18.64	9.87	9.58
		Full	9.48	18.64	10.85	9.58
0.2	Spray	Limited	7.49	18.64	13.74	9.58
		Full	10.29	18.64	15.19	9.58
	LEPA	Limited	7.22	18.64	14.59	9.58
		Full	9.91	18.64	15.63	9.58
	SDI	Limited	7.79	18.64	14.23	9.58
		Full	10.46	18.64	15.30	9.58

Table 2. Cotton lint yield (1b/acre) resulting from limited and full preplant (PP) irrigation at irrigation capacities of 0.1 and 0.2 in./d applied by spray, LEPA, and SDI at TAES, Halfway, 1999.

			Preplant Scenario[1]			
Period of Irr.	**Irr. Cap. (in/d)**	**System**	**Limited PP**	**Full PP**	**Avg.[2]**	**Irr. System Avg.[2]**
None					378	
PP Only			439	480	459	
PP Plus Seasonal	0.1	Spray	673 a	737 a		
		LEPA	808 a	854 a		
		SDI	1080 a	996 a		
		Avg.	854 a	862 a	858 A	
	0.2	Spray	783 a	785 a		
		LEPA	856 a	886 a		
		SDI	1002 b	1165 a		
		Avg.	880 a	945 a	913 A	
	Avg. of 0.1 & 0.2	Spray	728 a	761 a		745 C'
		LEPA	832 a	869 a		850 B'
		SDI	1041 a	1080 a		1060 A'
		Avg.	867 a	903 a		

[1] Means within a row followed by the same letter (small caps.) are not statistically different at the 0.05 probability level (LSD).
[2] Means within a column followed by the same letter (large caps.) are not statistically different at the 0.05 probability level (LSD).

Table 3. Cotton lint yield (1b./acre) resulting from limited and full preplant (PP) irrigation at irrigation capacities of 0.1 and 0.2 in./d applied by spray, LEPA, and SDI at TAES, Halfway, 2000.

Period of Irr.	Irr. Cap. (in/d)	System	Preplant Scenario[1] Limited PP	Preplant Scenario[1] Full PP	Avg.[2]	Irr. System Avg.[2]
None					161	
PP Only			221 b	365 a	293	
PP Plus Seasonal	0.1	Spray	464 b	629 a		
		LEPA	624 b	756 a		
		SDI	841 a	836 a		
		Avg.	643 b	741 a	692 B	
	0.2	Spray	758 b	872 a		
		LEPA	934 a	941 a		
		SDI	1129 a	1151 a		
		Avg.	940 a	988 a	964 A	
	Avg. of 0.1 & 0.2	Spray	611 b	750 a		681 C'
		LEPA	779 a	849 a		814 B'
		SDI	985 a	994 a		989 A'
		Avg.	792 b	864 a		

[1] Means within a row followed by the same letter (small caps.) are not statistically different at the 0.05 probability level (LSD).
[2] Means within a column followed by the same letter (large caps.) are not statistically different at the 0.05 probability level (LSD).

Table 4. Water use efficiency (WUE[1], lb lint/acre-in. of water) resulting from limited and full preplant (PP) irrigation at irrigation capacities of 0.1 and 0.2 in./d applied by spray, LEPA, and SDI at TAES, Halfway, 1999.

Period of Irr.	Irr. Cap. (in/d)	System	Preplant Scenario[2] Limited PP	Preplant Scenario[2] Full PP	Avg.[3]	Irr. System Avg.[3]
None					30	
PP Only			33	37	35	
PP Plus Seasonal	0.1	Spray	38 a	43 a		
		LEPA	48 a	50 a		
		SDI	61 a	57 a		
		Avg.	49 a	50 a	50 A	
	0.2	Spray	42 a	45 a		
		LEPA	48 a	49 a		
		SDI	55 a	62 a		
		Avg.	48 a	52 a	50 A	
	Avg. of 0.1 & 0.2	Spray	40 a	44 a		42 C'
		LEPA	48 a	49 a		49 B'
		SDI	58 a	59 a		59 A'
		Avg.	49 a	51 a		

[1] WUE = cotton lint yield divided by the sum of soil water depletion from planting to harvest + effective rainfall + seasonal irrigation.
[2] Means within a row followed by the same letter (small caps.) are not statistically different at the 0.05 probability level (LSD).
[3] Means within a column followed by the same letter (large caps.) are not statistically different at the 0.05 probability level (LSD).

Table 5. Water use efficiency (WUE[1], lb lint/acre-in. of water) resulting from limited and full preplant (PP) irrigation at irrigation capacities of 0.1 and 0.2 in./d applied by spray, LEPA, and SDI at TAES, Halfway, 2000.

Period of Irr.	Irr. Cap. (in/d)	System	Preplant Scenario[2] Limited PP	Preplant Scenario[2] Full PP	Avg.[3]	Irr. System Avg.[3]
None					23	
PP Only			24 b	40 a	32	
PP Plus Seasonal	0.1	Spray	32 b	44 a		
		LEPA	41 b	53 a		
		SDI	52 b	62 a		
		Avg.	42 b	53 a	47 B	
	0.2	Spray	41 b	48 a		
		LEPA	51 a	54 a		
		SDI	58 a	63 a		
		Avg.	50 b	55 a	52 A	
	Avg. of 0.1 & 0.2	Spray	36 b	46 a		41 C'
		LEPA	46 b	54 a		50 B'
		SDI	55 b	63 a		59 A'
		Avg.	46 b	54 a		

[1] WUE = cotton lint yield divided by the sum of soil water depletion from planting to harvest + effective rainfall + seasonal irrigation.
[2] Means within a row followed by the same letter (small caps.) are not statistically different at the 0.05 probability level (LSD).
[3] Means within a column followed by the same letter (large caps.) are not statistically different at the 0.05 probability level (LSD).

Table 6. Fiber property and loan price means significantly affected by the irrigation treatment factors of irrigation capacity, irrigation system, and preplant scenario at TAES, Halfway, 1999 and 2000.

Year / Fiber Property / Loan Price	Irrigation Capacity 0.1 in./d	Irrigation Capacity 0.2 in./d	Irrigation System Spray	Irrigation System LEPA	Irrigation System SDI	Preplant Scenario Limited	Preplant Scenario Full
1999							
Loan Price ($/lb)			.431 b	.429 b	.443 a	.430 b	.439 a
2000							
+b	8.76 a[1]	8.54 b	8.87 a	8.51 b	8.58 b	8.76 a	8.54 b
Elongation (%)	7.76 b	8.02 a	7.83 ab	7.72 b	8.11 a		
Micronaire			4.49 a	4.23 b	4.33 ab		
Uniformity (%)	82.8 b	83.4 a					
Length (1/100 in.)	104 b	108 a				105 b	106 a
Loan Price ($/lb)	.510 b	.546 a					

[1] Fiber property/loan price means (within a treatment factor) followed by the same letter are not statistically different at the 0.05 probability level (LSD).