COTTON RESPONSE TO IRRIGATION INTERVAL AND LEVEL AS AFFECTED BY FIELD TOPOGRAPHY USING SUBSURFACE DRIP IRRIGATION

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Abstract

To determine potential yield reductions caused by infrequent subsurface drip irrigation, a cotton irrigation study was conducted in 2009 and 2010 at the Texas AgriLife Research Center's Helms Research Farm in Halfway, Texas. The objective of this study was to determine subsurface drip irrigated cotton response to irrigation intervals of 0.25-, 2- and 7-days at high and low irrigation levels in a field with slopes common to the Texas Southern Plains. The high irrigation level treatments provided approximately 80% of crop water needs using ET scheduling, while the low irrigation level was 50% of the high level. Cotton was planted at ~54,000 ppa with 30" row spacing on 1300 ft rows. Each of four blocks contained six 8-row treatments. Crop responses were determined by stripper-harvesting an area of 4 rows wide by ~60 feet in length at three field positions along the length of each 8-row plot, determining seed cotton weight with on-board scales, and establishing lint yield from turnout of 1 to 2 lb sub-samples from each replicate. Yield, loan value and seasonal irrigation water use efficiency were calculated and evaluated by standard analysis of variance with mean separation using Fisher's LSD method. In 2009 at the high irrigation level, lint yield, loan value, and seasonal irrigation water use efficiency were generally greater at 7-d intervals than at 0.25-d and 2-d intervals. However, the opposite was true at the low irrigation level where yield and seasonal irrigation water use efficiency were numerically greater at the 0.25-d interval than the 7-d interval. In 2010, differences in lint yield, loan value and seasonal irrigation water use efficiency among the three irrigation interval treatments were statistically the same, except near the supply manifold (high elevation) where yield and loan value were greatest when irrigated every 2 days.

Introduction

The depletion of groundwater available for irrigated agriculture in the Texas High Plains has resulted in increased implementation of advanced irrigation systems in order to maximize water use efficiency (*i.e.* cotton yield per unit of applied water). Adoption of subsurface drip irrigation (SDI) as a method to deliver water to field crops is growing, particularly in areas where irrigation efficiency is a vital concern (Caldwell et al., 1994). It is typically thought that *high frequency* SDI applications result in reduced plant stress and higher yields than irrigation at longer intervals. One premise is that, because SDI cannot efficiently overcome large soil water deficits, smaller and more frequent irrigations are necessary to maintain a constant soil water level near the root zone; thereby reducing plant stress and deep percolation of water into the soil (Caldwell et al., 1994). Caldwell et al. (1994) concluded that frequency of irrigation had no effect on corn yield when average soil water deficit is 20% or less. In addition, Camp (1998) observed that irrigation intervals shorter than seven days did not affect corn yield provided soil water was adequate. Radin et al. (1992) observed cotton response to high frequency furrow irrigation and found that increasing the frequency of irrigations during peak fruiting increased yield. They attributed this response to enhanced water uptake and transport capacity of the cotton plant (Radin et al., 1992). Enciso et al. (2003) investigated cotton yield and quality response to irrigation frequencies under deficit SDI, and reported no significant differences in yield, quality, or gross return due to irrigation frequency alone. Colaizzi, et al. (2004) reported, when compared to other irrigation methods, (*e.g.* MESA, LESA and LEPA) SDI tended to perform better than the alternatives at lower (25% & 50% of ET) irrigation levels. Although studies have shown that SDI tends to perform more efficiently than other irrigation systems, the high cost of implementing SDI systems capable of high frequency irrigation continues to be a deterrent to its large-scale adoption (Segarra, et al., 1999).

Materials and Methods

In 2009 and 2010, cotton was planted on a 16-acre field located at Helms Research Farm in Halfway, Texas (3500 ft. elev., 34° 11' N, 101° 56' W). The field topography is characterized by decreasing elevations from the southwest to northeast, with 1300-ft rows oriented north–south. The soil is a clay loam with approximately 1.5 inches per foot of available water holding capacity. The field was irrigated with a SDI system, with lateral placement in alternate 30" furrows, and 0.18 gph emitters at 24-in spacing. Figures 1 and 2 illustrate the filtering and metering portions and the in-ground installation of the SDI system. Six 8-row by 1300-ft treatment areas were established within each of four blocks using a randomized block design. Two irrigation levels ("high" and "low") were used. The high irrigation level provided approximately 80% of crop water needs using ET scheduling, while the low irrigation level was 50% of the high. Irrigation intervals were 0.25-, 2- and 7-days at each of the two irrigation levels. Figure 3 shows in-season irrigations and rainfall for the low irrigation level in 2009. FiberMax 9180B2F was planted on 6 May 2009 and 13 May 2010 at approximately 54,000 ppa. In-season irrigation began on 10 July and continued through 2 September in 2009 and started 20 July continuing through 13 September in 2010. In both years, periodic soil water measurements were obtained using neutron scatter methods to a depth of 5 ft in all treatments and harvest positions within 2 replicates. Crop yield was determined by harvesting sub-plots that were 4 rows by approximately 60 feet long at three field positions along the length of each 8-row plot. Harvest was with a modified John Deere® 7445 stripper, equipped with on-board scales, which provided seed cotton weights at each field position. The three field positions were located at approximately 150 ft from the SDI supply-side manifolds, the middle of the 1300 ft plot, and 150 ft from the flush manifolds. These positions represented high, middle and low field elevations within plots with rows having average slopes of 0.8%. One- to two-lb subsamples from each seed cotton sample were ginned at the Texas AgriLife Research and Extension Center's gin in Lubbock, Texas. Lint yield was determined using harvested area, seed cotton harvest weight and turnout percentage. Lint quality was determined by HVI analysis performed on all lint samples at the Fiber & Biopolymer Research Institute at Texas Tech University in Lubbock, Texas. Loan values were determined based on HVI results. Seasonal irrigation water use efficiency (SIWUE) was calculated by subtracting dryland yield (Y_{DL}) from yield for each treatment and position (Y_P) then dividing the product by in-season irrigation (I_S), [$Y_P - Y_{DL}/I_S$]. Yield, loan value and SIWUE of the four replicates were averaged by treatment and comparisons made using standard analysis of variance with separation of means by Fisher's LSD method.

Figure 1. Installation of automated SDI system, Helms Research Farm, Halfway, Texas.

Figure 2. Installation of automated SDI system, Helms Research Farm, Halfway, Texas.

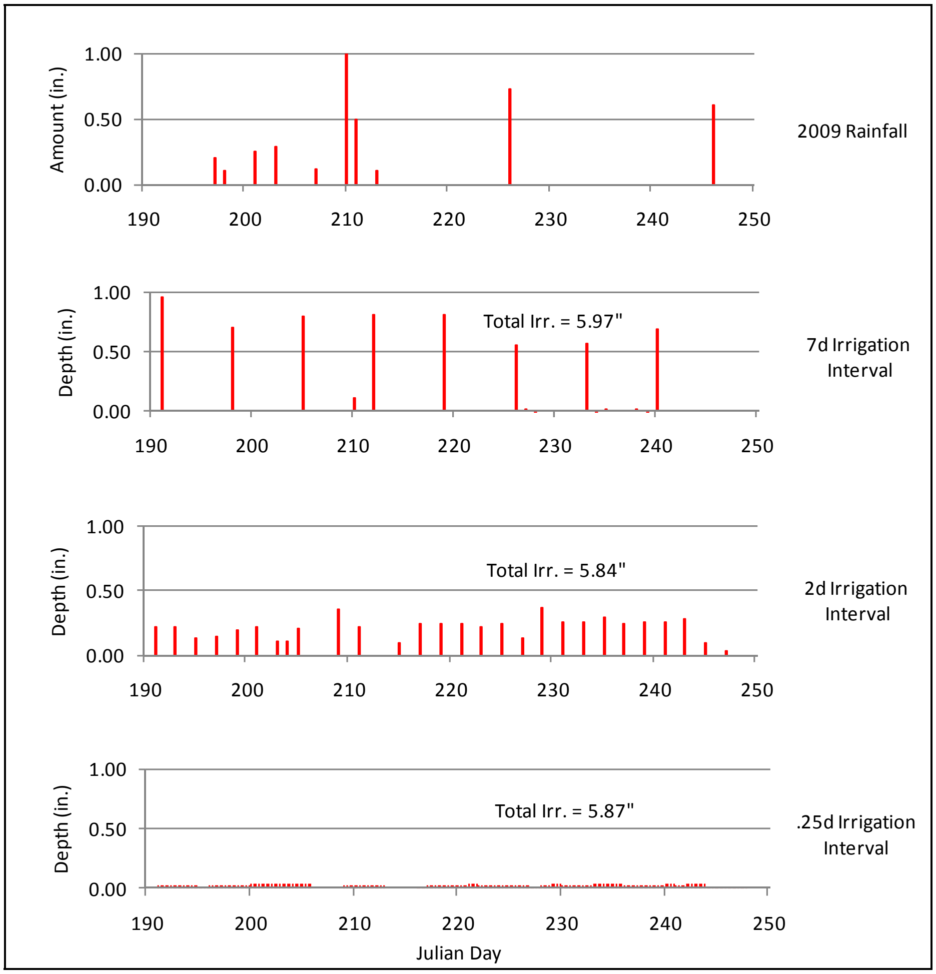

Figure 3. In-season irrigation amounts and times at 0.25-, 2- and 7-day intervals at the low irrigation level in 2009. Also included is rainfall.

Results and Discussion

Tables 1 and 2 contain average lint yield, loan values and SIWUE by irrigation interval and relative elevation (field position) for 2009 and 2010. As mentioned earlier, past research has generally supported the concept of *high frequency* SDI applications in field crops partially based on the reduction in extreme plant stresses within a given irrigation capacity. It was assumed that the downhill row slope going from south (supply manifold side) to north (flush manifold side) would result in greater SDI lateral drainage to the lower field elevations, particularly in treatments with more frequent irrigations (0.25 d versus 7 d). Intuitively, this should result in higher soil water and possibly higher lint yield at the low elevations of the 0.25-d interval than the 7-d interval. However, there were no significant differences (α=.05) in lint yield at the low field elevations among irrigation intervals in either year or at either irrigation level. Furthermore, figure 4 shows that, at the low elevation field position in 2010, the volumetric water content of the 0.25-d interval started and ended the growing season with less volumetric water content than that of the 7-d interval.

Lint Yield

At the low irrigation level in 2009, average yield results tended to support the concept discussed above. Cotton lint yields decreased from 1292 to 1244 to 1222 lb/A at 0.25-d, 2-d, and 7-d irrigation intervals, respectively. However, this yield trend did not hold at the low irrigation level in 2010 or at the high irrigation levels in either 2009 or 2010. At the low irrigation level in 2010, yields were within 33 lb/A of each other at 1271, 1304, and 1302 lb/A from intervals of 0.25, 2, and 7 d, respectively. At the high irrigation level in 2009, average yields were 1378 lb/A in the 0.25-d intervals compared to 1500 lb/A at the 7-d intervals. In 2010, the 0.25- and 7-d treatments resulted in yields of 1530 and 1548 lb/A, respectively. There were yield increases due to the field position closest to the lateral supply manifold (higher elevation) at the high irrigation level in the 2- and 7-d compared to the 0.25-d treatments (1555 and 1538 lb/A versus 1420 lb/A in the 2-d, 7-d and 0.25-d treatments, respectively in 2009, and 1647 and 1601 lb/A versus 1502 lb/A in 2010). This result supports the theory that extremely short irrigation intervals, *i.e.*, 0.25-d, at irrigation levels close to the evaporative demand result in less uniform irrigation distribution when SDI laterals are on a slope.

Loan Value

Loan values integrate the value contribution of several cotton fiber parameters that are affected by cotton plant stress and/or irrigation level. During this experiment, the 7-d irrigation interval resulted in average loan values that were above or equal to those of the 0.25- and 2-d intervals at both irrigation levels in both years. The 2009 loan values were $0.56/lb versus $0.548/lb in the 7-d versus the 2- and 0.25-d intervals, respectively, at low irrigation; and $0.530/lb versus $0.506/lb and $0.512/lb, respectively, at the high irrigation level. In 2010, all average loan values were within $0.01/lb of each other with the highest values resulting from the 7-d interval treatments at both irrigation levels. At no field position (elevation) was loan value significantly higher in the 0.25- or 2-d treatments than the 7-d treatments. Therefore, irrigation at 7-day intervals using SDI was not detrimental in terms of cotton loan value compared to SDI applications made every 0.25 or 2 days in this experiment.

SIWUE

Seasonal irrigation water use efficiency is a measure of effectiveness of seasonal irrigation. Within a given irrigation capacity or volume, irrigation practices having the highest SIWUE are typically encouraged. Although there were some slight variations of in-season irrigation quantities among irrigation intervals, the SIWUE's among treatments followed the exact trends as those of the lint yield in both years. The only significant difference in average SIWUE occurred in 2010 at the high irrigation level where the 2-d interval resulted in greater SIWUE at 80 lb/A-in than the 0.25- and 7-d intervals at 74 and 74 lb/A-in. No significant differences (α=.05) in SIWUE's among irrigation intervals were due to field position (elevation) in either year.

Table 1. Average yield (lbs/A), loan values ($/lb) and SIWUE (lbs/A-in) at two irrigation levels, three irrigation intervals and three field elevations, Helms Research Farm, Halfway, TX 2009.

		Low Irrigation Level				**High Irrigation Level**			
	Irr. Int. (d)	High Elev.	Mid	Low Elev.	**Avg**	High Elev.	Mid	Low Elev.	**Avg**
2009 Yield	*.25*	1291[Aa]	1271[Aa]	1313[Aa]	**1292[A]**	1420[Aa]	1331[Aa]	1335[Aa]	**1378[A]**
	2	1210[Aa]	1201[Aa]	1320[Aa]	**1244[A]**	1555[Ba]	1401[Aa]	1489[Aa]	**1460[A]**
	7	1276[Aa]	1133[Aa]	1257[Aa]	**1222[A]**	1538[Ba]	1429[Aa]	1535[Aa]	**1500[A]**
	Avg.	**1259**	**1202**	**1297**		**1504**	**1387**	**1453**	
2009 Loan Values	*.25*	0.567[Aa]	0.553[Aa]	0.524[Ab]	**0.548[A]**	0.529[Ab]	0.509[Aa]	0.497[Aa]	**0.512[AB]**
	2	0.562[Ab]	0.554[Aab]	0.529[Aa]	**0.548[A]**	0.525[Ab]	0.509[Aab]	0.483[Aa]	**0.506[A]**
	7	0.556[Aa]	0.569[Aa]	0.556[Aa]	**0.56[A]**	0.548[Ba]	0.523[Aa]	0.519[Aa]	**0.53[B]**
	Avg.	**0.562**	**0.559**	**0.536**		**0.534**	**0.513**	**0.500**	
2009 SIWUE	*.25*	100[Aa]	97[Aa]	104[Aa]	**100[A]**	65[Aa]	57[Aa]	57[Aa]	**60[A]**
	2	86[Aa]	84[Aa]	105[Aa]	**92[A]**	78[Ba]	64[Aa]	72[Aa]	**71[A]**
	7	96[Aa]	71[Aa]	92[Aa]	**86[A]**	76[Ba]	66[Aa]	76[Aa]	**73[A]**
		94	**84**	**100**		**73**	**62**	**68**	

Means with the same letters are not significantly different (Fisher's LSD Method; α=.05). Upper case letters indicate vertical comparison; lower case letters indicate horizontal comparison.

Table 2. Average yield (lbs/A), loan values ($/lb) and SIWUE (lbs/A-in) at two irrigation levels, three irrigation intervals and three field elevations, Helms Research Farm, Halfway, TX 2010.

		Low Irrigation Level				High Irrigation Level			
	Irr. Int. (d)	High Elev.	Mid	Low Elev.	**Avg**	High Elev.	Mid	Low Elev.	**Avg**
2010 Yield	*.25*	1218[Aa]	1206[Aa]	1388[Aa]	**1271[A]**	1502[Aa]	1561[Aa]	1526[Aa]	**1530[A]**
	2	1308[Aa]	1223[Aa]	1382[Aa]	**1304[A]**	1647[Ba]	1572[Aa]	1647[Aa]	**1622[A]**
	7	1326[Aa]	1255[Aa]	1326[Aa]	**1302[A]**	1601[ABa]	1530[Aa]	1512[Aa]	**1548[A]**
	Avg.	**1284**	**1228**	**1365**		**1583**	**1554**	**1562**	
2010 Loan Values	*.25*	0.554[Aa]	0.556[Aa]	0.558[Aa]	**0.556[A]**	0.552[Aa]	0.564[Aa]	0.563[Aa]	**0.56[A]**
	2	0.569[Ba]	0.559[Aa]	0.561[Aa]	**0.563[A]**	0.574[Bb]	0.565[Aab]	0.547[Aa]	**0.562[A]**
	7	0.572[Ba]	0.562[Aa]	0.564[Aa]	**0.566[A]**	0.564[Aba]	0.564[Aa]	0.56[Aa]	**0.562[A]**
	Avg.	**0.565**	**0.559**	**0.561**		**0.563**	**0.564**	**0.557**	
2010 SIWUE	*.25*	87[Aa]	85[Aa]	112[Aa]	**95[A]**	72[Aa]	77[Aa]	74[Aa]	**74[A]**
	2	102[Aa]	89[Aa]	113[Aa]	**101[A]**	82[Aa]	76[Aa]	82[Aa]	**80[B]**
	7	101[Aa]	91[Aa]	101[Aa]	**98[A]**	79[Aa]	73[Aa]	71[Aa]	**74[A]**
		97	**89**	**109**		**77**	**75**	**76**	

Means with the same letters are not significantly different (Fisher's LSD Method; α=.05). Upper case letters indicate vertical comparison; lower case letters indicate horizontal comparison.

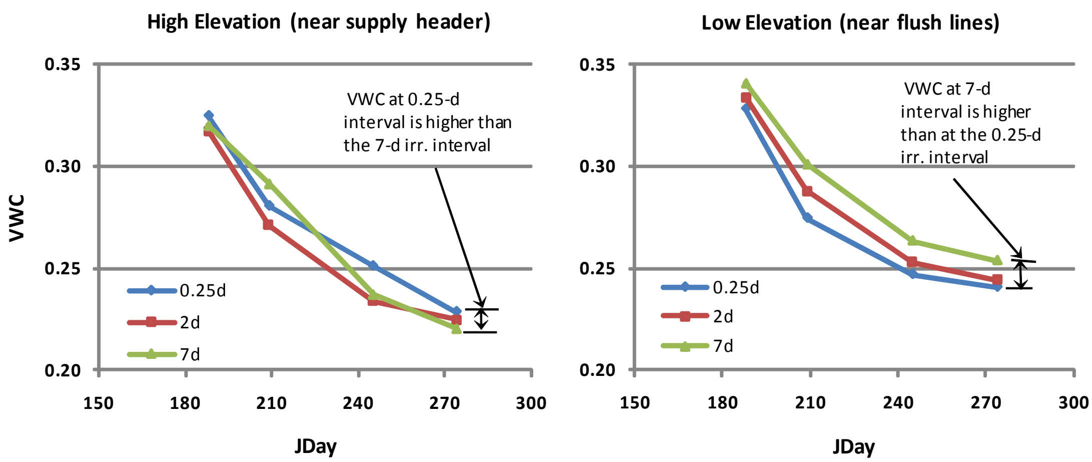

Figure 4. Seasonal volumetric soil water content of irrigations occurring at 0.25-, 2-, and 7-day intervals at high (lateral supply side) and low (flush side) elevations in the field.

Summary

The objective of this study was to determine SDI cotton response to three irrigation intervals (0.25-, 2- and 7-days) at two irrigation levels (high and low) in a field with slopes common to the Texas Southern High Plains. Past research has generally supported the concept of *high frequency* SDI applications in field crops partially based on the reduction in extreme plant stresses within a given irrigation capacity. Results showed that there were no significant differences (α=.05) in average lint yields caused by irrigation interval in this experiment. There were yield increases at field positions closest to the lateral supply manifold (high elevation) at the high irrigation level treatments that were irrigated every 2 and 7days compared to every 0.25 day. Based on an analysis of cotton loan values, SDI irrigations at 7-day intervals did not reduce loan values compared to those applied every 0.25 or 2 days in this experiment. SIWUE's among treatments followed the same trends as those of the lint yield treatments in both years.

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References

Caldwell, D.S., W.E. Spurgeon and H.L. Manges. 1994. Frequency of irrigation for subsurface drip-irrigated corn. *Trans. ASAE*, 37(4): 1099-1103.

Camp, C.R. 1998. Subsurface drip irrigation: A review. *Trans. ASAE*, 41(5): 1353-1367.

Colaizzi, Paul D., Steven R. Evett and Terry A. Howell. 2004. Comparison of SDI, LEPA, and spray irrigation performance for cotton in the North Texas High Plains. *Trans. ASAE,* 47(5): 1477-1492.

Enciso, J.M., B.L. Unruh, P.D. Colaizzi and W.L. Multer. 2003. Cotton response to subsurface drip irrigation frequency under deficit irrigation. *Trans. ASAE*, 19(5): 555-558.

Radin, J.W. L.L. Reaves, J.R. Mauney and O.F. French. 1992. Yield enhancement in cotton by frequent irrigations during fruiting. *Agron. J.*, 84(4): 551-557.

Segarra, E., L. Almas and J. Bordovsky. 1999. Adoption of advanced irrigation technology: LEPA v. drip in the Texas High Plains. In *Proc. Beltwide Cotton Conf.*, 1: 324-328. Memphis, TN: National Cotton Council.