Subsurface Drip Irrigation Design and Management for Cotton Production, Phase II
Project 02-210 TX

2006 Annual Report

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Introduction

Limited irrigation supplies and high pumping costs continue to be major concerns to profitable cotton production requiring the use of efficient delivery systems. Past research has shown subsurface drip irrigation (SDI) to be the most water efficient irrigation method available to producers on the High Plains (Bordovsky, 1998, 2001). On average, SDI has produced 10 to 15% more lint than LEPA, and 15-25% more than low elevation spray systems when using identical pumping capacities over the same period. Management of SDI also has a tremendous impact on economic return and, thus, the adoption of SDI. Lint yields and loan prices from 2002 through 2004 in a cotton systems experiment have showed an increase in gross return of $161/ac using *High Input* SDI management compared to *Normal Input* management (Bordovsky, 2005). Most of the increase in return of the *High Input* treatments was attributed to two items: 1) increased irrigation quantity and 2) changing from a standard, commonly used stripper cotton variety (PM 2326RR) to a less determinate cotton variety (Fibermax 989BR). However, the experimental results to date may be somewhat misleading in that in the months of July and August of both 2002 and 2003 set records in terms of low rainfall, both years were dry at plant causing late, irregular seed germination, and both years had virtually no insect pest pressure. The 2004 crop year presented the opposite extremes in terms of average temperature and rainfall resulting in yields, lint value and gross returns significantly favoring the *Normal Input* treatments.

The precipitation of manganese oxides (MnO_2) from irrigation water and the plugging of SDI emitters has occurred at the Helms research site as well as areas northwest and south of Lubbock. Successful maintenance procedures using continuous injection of H_20_2 in irrigation water were developed by this project, however, the cost of this maintenance solution during the 2003 and 2004 crop year was $57 and $50/ac, respectively. Also, replicated soil samples indicate the buildup of the Mn element around drip tape laterals. Modification of the H_20_2 maintenance protocol could reduce cost. Mn levels in wells and Mn deposits around SDI tapes need monitoring to determine if this element will impact cotton production over the long term.

With the exception of the MnO_2 emitter plugging, uniform cottonseed germination under low rainfall conditions has been the biggest SDI problem at our research site and in many areas on the South Plains. Based on soil profile monitoring (Bordovsky, 2001) and recent experience at our research site, 2 to 5 inches of preplant irrigation water is lost while achieving less than desirable plant stands. Beyond installing SDI tape at depths less than 12", possible solutions include alternative seedbed construction or the mechanical injection of wetting agents or surfactants in a path near the drip tape to an area near the seed drill. Methods need to be developed to improve uniform plant germination to fully take advantage of SDI's efficiency in this water short area.

Maintaining crop rows in SDI fields at precisely the same relative locations to the water supply lines, year after year, is very difficult. Crop row position affects seed germination as well as plant development, particularly in areas of limited irrigation capacity. The effects of horizontal distance from crop row to drip tape lateral in alternate-furrow SDI need evaluation. In addition, for various reasons, South Plains producers have planted cotton perpendicular to drip tape laterals, however, production response and long-term tape deterioration compared to traditional parallel plantings is not known.

The continued adoption of SDI as a water and energy saving tool will improve if initial SDI costs can be reduced, cotton lint production can be sufficiently increased, and the problems unique to SDI can be solved.

Objectives

The objective of this series of studies was to develop information about SDI that will provide improved water resource value on the Texas High Plains. The objectives of the final year of this 5-year extended project were:

1. Evaluate production inputs and resulting lint yields of two cotton management scenarios – *High Input* for maximum yield vs. *Normal Input* for sustainable yield.
2. Monitor Mn concentrations in irrigation well water and within drip emitters as the Mn maintenance program is altered to reduce costs.
3. Evaluate the mechanical injection of soil amendments into the soil profile to determine their effect on cottonseed germination using SDI under a no/reduced rainfall scenario.
4. Install a SDI system to quantify the effect on yield and WUE of 1) planting row distances (horizontal, not depth) from drip tape laterals ; and, 2) planting row orientation (perpendicular vs. parallel) relative to drip laterals.

Location and General Growing Conditions in 2006

Field experiments were conducted at the Texas Agricultural Experiment Station at Halfway, TX and at the Helms Research Farm 2 miles south of Halfway. Growing season conditions in 2006 were generally hot and dry. This coupled with the previous dry winter resulted in above normal demand for irrigation. Monthly rainfall at Halfway for 2006 as well as the 100-yr average rainfall at Plainview is shown in Figure 1. Cumulative seasonal heat units for 2002 through 2006 are given in Figure 2 with growing season temperatures in 2006 the highest of the past five years.. With no significant pest pressure, cotton responded very favorably when adequate irrigation was applied.

SDI Management (Obj. 1)

In 2001, a 12-acre SDI system was installed with drip lines in alternate 30-inch furrows. Ten 1.2-acre zones were constructed with zone sizes of 1300 ft by 16 rows. Each zone was independently controlled and metered. From 2002 through 2006, two cotton management strategies were compared in this area. The first strategy was a high-input, high-yield management scenario with the production goal of 3.5 bales per acre and no restriction on input levels (*High Input*). Following this strategy, one would install SDI in a limited area and apply all available supplemental water resources through the SDI system, with the remainder of the area devoted to dryland production. The second strategy (*Normal Input*) provided traditional input levels with annual yield goals of 2.5 bales per acre. Following this strategy, one would install SDI on a larger area (compared to the *High Input* scenario) to stretch available irrigation water, but would be unable to meet 100% of crop water needs during peak irrigation demand periods.

The *High Input* protocol called for early planting with a "less determinant" cotton variety. Nutrients were applied through the growing season with the SDI system based on yield potential and crop development. Fleahoppers, lygus bugs, and aphids were monitored on a weekly basis from emergence through mid-August and controlled at thresholds to prevent fruit loss or plant stresses. Growth regulators were applied to prevent excessive vegetation. Irrigation water was applied daily in quantities that slightly exceed estimated ET using local climatic conditions.

The *Normal Input* protocol had been used in irrigation systems experiments from 1999 to 2001 (Bordovsky, et al., 2001). Irrigations were limited by a pumping capacity of 3.6 gpm/acre; most of the nitrogen applied prior to planting by ground application; a popular storm-proof cotton variety was planted; limited growth regulators were applied; and insect pests were treated at locally established thresholds.

The two management treatments were replicated four times. Two additional drip zones were treated as "dryland" areas receiving no seasonal irrigation. Cotton was harvested and lint yields were determined by machine stripping two rows, 30 feet long at five locations within each plot and ginning a sub-sample to determine lint turnout and yields.

2006 Crop Year

Early field preparations for this experiment included soil fertility sampling, shredding stalks, plowing with a field cultivator and re-establishing tractor paths parallel to drip laterals with GPS guided equipment. An attempt to improve cotton germination was made by planting 2 rows on 60-inch beds with SDI laterals in the center of each bed. An attachment on the front of each planter unit was used to better prepare the seed zone for planting.

Following pre-plant irrigation, cotton was planted in the *High* and *Normal* test areas on 3 May. Uniform germination was, again, a problem, but typical of SDI irrigated cotton in the area. Seasonal irrigations began on 5 June, with nitrogen, zinc, growth regulator, and fleahopper applications occurring on the *High Input* treatment. Table 1 contains specific agronomic data for the experiment in 2006. Each 16-row plot (both treatments) was planted in each of two varieties, PM2280RR, the more determinate variety, and FM989B2R, the less determinant variety. Seasonal irrigations totaled 17.36 and 12.95 inches in *High* and *Normal Input* treatments, respectively. Irrigations were terminated on 28 Aug. Insects were scouted weekly with negligible pest pressure during the growing season. Harvest aids were applied by mid October.

Summary of Results from 2002 to 2006

Table 2 shows lint yield, loan values, gross production values and seasonal irrigation water use efficiencies for the 2002, 2003, 2004, and 2005 test years. Only lint yield and seasonal irrigation water use efficiencies are given for 2006 as fiber data is not yet available. Until 2004, the *High Input* methodology resulted in significantly higher lint yield, better fiber quality resulting in higher loan values, and higher seasonal irrigation WUE than the *Normal Input* treatments. However, in 2004, the *High Input* treatment produced 49 lb/ac less than the *Normal* treatment with respective yields of 1606 and 1655 lb/ac. Of the two late planted varieties in 2005, the High Input treatments resulted in numerically higher yields than the normal treatment, although there were no significant differences. In 2005 estimated gross lint value was slightly higher in the *High Input* treatment than the *Normal* treatment, however, this was due to the slightly high yields and not to differences in fiber values as in previous years.

In 2006 cotton lint yields were high in all treatments. Yields and seasonal IWUE were much higher for the FM989B2R than for the PM2280BR variety at 2074 vs. 1630 lb/ac and 104 vs. 81 lb/ac-in, respectively, in *Normal* treatments and 1895 vs. 1654 lb/ac and 74 vs. 65 lb/ac-in, respectively, in the *High Input* treatments. Although seasonal irrigation quantities were 4.4 inches higher, yields from the *High Input* treatments were no better than *Normal* treatments, and, for the FM989B2R variety, less than the *Normal Input* treatment. This may have been due to the application of an early season growth regulator on *High Input* treatments which appeared to have severely slowed plant development in June. This data highlights the importance of finding appropriate variety and management inputs to achieve maximum returns for available water inputs.

The average yield difference between the two management treatments over the five-year test period is 177 lb lint/ac/yr in favor of the *High Input* treatment. The difference in the average gross value from 2002 to 2005 was $131/ac/yr in favor of the *High Input* treatment (2006 gross value data not available). Based on the results to date, concentrating available water resources in a smaller area, meeting evaporative demand, and utilizing higher levels of production inputs appears to the better economic choice. Following complete data analysis, economic comparisons will be made on the 5-year data set.

Manganese Oxide (Obj. 2)

Field monitoring of SDI emitters and elements of the drip filter station and visual monitoring at specific water pipeline locations indicated that the continuous injection of H_2O_2 in slightly acidic irrigation water eliminated problems with manganese oxide precipitants and plugged SDI emitters. The cost of this treatment was expensive, but could be reduced by intermittent injection of acid and H_2O_2 instead of continuous injection. Through the 2006 irrigation season, Mn treatment chemicals were halted during 2-week irrigation periods in June, July and August. Evidence of manganese oxide deposits at the drip filter station at the end of these two-week periods resulted in the resumption of chemical treatments for 7 to 14-days. Following the 2006 growing season and after final system flushing, several drip emitters were excavated and examined in the laboratory for signs of MnO_2 deposition. Figure 3 shows the magnification of a drip emitter excavated in 2005. As in 2005, none of the excavated emitters showed signs of MnO_2 precipitation, however, sand particles were seen in the emitter pathways of those emitters farthest from the filter station. This indicates that intermittent injection of H_2O_2 in slightly acidic irrigation water will prevent SDI emitters from plugging due to MnO_2

precipitation and that periodic "high pressure" flushing of drip emitters must be maintained to prevent emitter plugging with sand particles.

Seed Germination with SDI (Obj. 3)

A field experiment was initiated to evaluate the mechanical placement of soil amendments into the soil profile to determine their effect on water movement into the seed germination zone using SDI under a no/reduced rainfall scenario. Drip laterals were installed at a 12-inch depth in clay, loam soil in September of 2005 at the TAES research facility (Helm Farm). Water supply and flush manifolds were installed and the entire area bordered and furrow irrigated to settle soil around drip tape laterals.

Four soil amendments and a "check" were placed from near drip laterals to near the soil surface at 20 sites (Figure 4). Soil amendment treatments included two starch-based polymers (Pam and Zeba^{TM} both at 20 lb/ac equivalent), composted cow manure (400 lb/ac), cow manure and gypsum (400 + 400 lb/ac), and an untreated check. One-hundred and fifty TDR (time domain reflectometer) sensors were constructed, calibrated, and used to measure volumetric water content within seedbeds as the seedbeds are were irrigated. Figure 5 shows the installation of TDR sensors in an array above and to each side of the drip lateral; the field where amendments and sensors are located with corn planted to dry the profile prior to irrigating with SDI; measuring soil water content while "drying" test areas with corn plants; and treatment sites with "rainout" shelters while wetting with SDI. The rainout shelters were constructed and used to prevent rainfall from interfering with soil profile wetting with the drip irrigation system. Wetting of seedbeds in controlled conditions occurred from 31 July through 30 Aug with drip applications of 0.1" applied at 12 hour intervals. Volumetric soil water content was measured twice daily through 12 Aug and daily thereafter by TDR and periodically by neutron attenuation during this period.

The average changes in volumetric water content from the initiation of irrigation (day 208) through the 30-day irrigation period; through a "drydown" period where the plots were protected by the shelters: and through to November is shown in Figure 6. This graph shows differences caused by the five soil amendment treatments. The detection of soil water first occurred 11 days following irrigation initiation at the top most soil sensor in the check treatment, followed by the Pam and compost treatments, then the other treatments. The check treatment resulted in the highest TDR readings during irrigation with the lowest in the Zeba^{TM} and compost plus gypsum treatments. These results were somewhat disappointing, but followed trends seen in laboratory experiments conduced in 2005. Tests will be continued in 2007 with sensors and treatments evaluated in undisturbed soil profiles. On a positive note, some of the treatments reduced the rate of surface soil water change following irrigation termination. Figure 7 highlights the rate of soil water loss following the termination of SDI irrigation measured by top TDR sensors. Zeba^{TM} resulted in the slowest rate of soil water loss with the check treatment resulting in the quickest loss.

Row Offset and Orientation with SDI (Obj. 4)

A field experiment was initiated involving the installation of ~ 5 acres of SDI with sets of drip tape laterals oriented parallel and perpendicular to crop rows (Figure 8). The objectives were to quantify the effect on cotton yield and WUE of planting row distances (horizontal, not depth) from drip tape; of planting row orientation (perpendicular vs. parallel); and of 30 vs. 40 inch crop rows irrigated by SDI.

Sixty treatment plots were established with the use of a John Deere 7420 tractor using a Trimble AgGPS Autoplot system (Figure 9). Following tape installation, tape laterals were excavated at 192 sites in the field and UTM coordinates of the laterals obtained to reference their locations using portable RTK-GPS equipment. Differences in desired and actual tape location were documented. Water supply manifolds, flush lines, and a filter station were then installed (Figure 10). Plantings occurred in 2006 using RTK-GPS equipped tractors to provide accurate offset distances from SDI tape laterals. The experiment was designed as a two factor-split plot. The main factor was irrigation capacity with treatments of 0.2 in/d and 0.3 in/d. The sub-factor was seed drill orientation and location relative to drip tape position. The seven sub-factor treatments are parallel planted row offsets to SDI tape of zero, 5,10,and 15 inches (treatments 1-4, Figure 11) and perpendicular planted rows to SDI tape with tape spacings of 30, 40, and 60 inches (treatments 5 – 7, Figure 13). Planted rows were 30 inches apart with plot size of 8 rows x 90 ft. Four blocks provided replication. In addition, four areas of 40-inch wide rows were installed within this field experiment, all with zero drip lateral offset to allow comparisons of 30 and 40-inch row spacing (60 and 80 inch drip lateral spacings).

Cotton lint yield by row resulting from the two levels of irrigation, two crop row spacings and four offsets of crop row to drip tape lateral are given in Table 3. At both irrigation capacities, cotton yields decline with increases in lateral offset. At 0.2 in/d capacity, yields fell 10% from 1486 to 1338 lb/ac at 0 to 15” offset, and at 0.3 in/d capacity, yields fell 13% from 1505 to 1314 lb/ac at 0 to 15” offset. The average difference in yield of the row closest to the drip lateral compared to the row farthest from the lateral was much greater at the lower irrigation capacity (1618-1142=476 lb/ac at 0.2 in/d) than that of the high irrigation capacity (1584-1306=278 lb/ac at 0.3 in/d) indicating the higher capacity is less affected by offset distance. Cotton lint yields were slightly higher from 40” row vs. 30” crop row production at 1547 and 1495 lb/ac, respectively. Statistical analysis will be conduced when fiber data is available.

Cotton lint yield resulting from crop rows planted perpendicular to drip laterals at two crop row spacings, two irrigation capacities, and three drip lateral spacings is given in Table 4. Within the 30” crop row spacings, the average yield across irrigation capacity fell 12% from 1651 to 1447 lb lint/ac when moving from 30” to 60” drip lateral distances. However, within the 40” crop row spacings, average yields were reduced much less falling only 5% from 1660 to 1582 lb lint/ac. Additional analysis will be conduced when fiber data is available and experiments will be continued over the next several years.

Conclusions

SDI Management

Based on the results to date, concentrating available water resources in a smaller area, meeting evaporative demand, and utilizing higher levels of inputs and management than normally used with traditional irrigation systems appears to the better option when using SDI systems on the South Plains. Evaluations will continue to better define optimum economic and water conserving options with SDI.

Manganese Oxide

Intermittent injection of H_2O_2 in slightly acidic irrigation water will prevent SDI emitters from plugging due to MnO_2 precipitation. Intermittent injection will reduce drip irrigation maintenance costs compared to continuous H_2O_2 injection.

Cottonseed Germination

Preliminary data shows the untreated check resulted in the highest volumetric soil water readings in the seed germination zone during the irrigation period compared to starch-based polymers, compost, and compost and gypsum. The rate of soil water loss from near the seed germination zone following the termination of SDI irrigation appeared to be reduced by soil amendment treatments as measured by the upper level TDR sensors. The starch based product, Zeba^{TM}, resulted in the slowest rate of soil water loss with the check treatment resulting in the quickest loss.

Row Offset and Orientation

With only one year's data, meaningful conclusions cannot be made. However, cotton yields were reduced by increased drip lateral offsets and yields from plots with drip laterals perpendicular to the crop row were within a few percent of those parallel to the crop row.

References

Bordovsky, J.P. 1998. Evaluation of high frequency cotton irrigation for planned soil water depletion with LEPA and subsurface drip systems. Project 96-286TX. 1998 Final Report to Cotton Incorporated and the Texas State Support Committee.

Bordovsky, J.P., W. M. Lyle, and E. Segarra. 2001. Economic evaluation of Texas High Plains cotton irrigated by LEPA and subsurface drip. Texas Journal of Agricultural and Natural Resources, 13(1): 67-73.

Bordovsky, J. P., M. Parajulee, J. Gannaway, D. Porter, and E. Segarra. 2005. Subsurface drip irrigation design and management for cotton production. Project 02-210 TX. 2004 Annual Report to Cotton Incorporated. 17pp.

Table 1. Agronomic inputs of *Dry, High, and Normal Input* treatments of the SDI management experiment, Helms Farm, 2006.

2005 Operation	Date	Treatment		
		Dry	*Normal Input*	*High Input*
Variety				
	5/3	FM 989 B2R	FM 989 B2R	FM 989 B2R
	5/3	PM 2280 BR	PM 2280 BR	PM 2280 BR
Nutrients				
P_2O_5	5/26	25 lb/ac	75 lb/ac	75 lb/ac
N Ground Rig	5/26	60 lb/ac	60 lb/ac	60 lb/ac
N Thru SDI			76 lb/ac	109 lb/ac
Zinc Thru SDI			3 lb/ac	3 lb/ac
Growth Regulator				
Pentia		None	None	24 oz/ac
Pesticides				
Temic	5/3	3 lb/ac	3 lb/ac	3 lb/ac
Irrigations (in)				
Pre & At Planting		2.52	5.86	5.86
Seasonal	5/30 - 8/27	0	12.95	17.36

Table 2. Comparison of cotton lint yield, loan values, and water use efficiency from *Normal* and *High Input* treatments irrigated by SDI at TAES, Helms Farm, 2002, 2003, 2004, 2005, and 2006.

		Normal Input	High Input	Difference
Yield (lb lint/ac)				
2002		1055 b[1]	1566 a	511
2003		1015 b	1419 a	404
2004		1655 a	1606 a	-49
2005	PM2167R	541	560	29
	ST2448R	442	603	161
2006	FM989B2R	2074 a	1895 b	-179
	PM2280BR	1630 a	1654 a	24
Loan Values ($/ac)				
2002		0.443 b	0.482 a	0.039
2003		0.519 b	0.538 a	0.019
2004		0.510	0.530	-
2005 (avg. normal & high)	PM2167R	0.438	0.438	-
	ST2448R	0.510	0.510	-
2006	FM989B2R	[2]	[2]	
	PM2280BR	[2]	[2]	
Gross Value @ Loan ($/ac)				
2002		451	691	240
2003		527	763	236
2004		844	851	7
2005	PM2167R	237	245	8
	ST2448R	226	307	81
2006	FM989B2R	[2]	[2]	-
	PM2280BR	[2]	[2]	-
Seasonal Irr. WUE (lb lint/ac-in)				
2002		60.8 b	71.4 a	10.6
2003		82.5 b	105.4 a	22.9
2004		68.1 a	47.9 b	-20.2
2005	PM2167R	-55.0	-39.0	-16.0
	ST2448R	-121.0	-34.0	-87.0
2006	FM989B2R	104.3 a	73.9 b	-30.4
	PM2280BR	81.2 a	65.4 b	-15.8

[1] Means followed by the same letter in the same row are significantly different ($P<0.05$, Duncan)

[2] Fiber data analysis and loan values were not yet available.

Table 3. Cotton lint yield (lb/ac) by row resulting from two levels of irrigation, two crop row spacings, and different offsets of crop row to drip tape lateral, TAES, Halfway, 2006.

		0.2 in/d			0.3 in/d			
	Offset (in)	Row Closest to Lateral	Row Farthest From Lateral	Pair of Rows	Row Closest to Lateral	Row Farthest From Lateral	Pair of Rows	Offset Average
30" Crop Row Spacing	0	1523	1448	1486	1607	1403	1505	1495
	5	1564	1219	1392	1540	1471	1506	1449
	10	1703	906	1305	1664	1249	1457	1381
	15	1680	996	1338	1526	1101	1314	1326
	Avg.	1618	1142	1380	1584	1306	1445	
40" Crop Row Spacing	0	1546	1480	1513	1662	1501	1582	1547

Table 4. Cotton lint yield (lb/ac) resulting from crop rows planted perpendicular to drip laterals at two crop row spacings, two irrigation capacities, and three drip lateral spacings, TAES, Halfway, 2006.

Drip Lateral Spacing	30" Crop Row Spacing			40" Crop Row Spacing			Crop Row Spacing
	0.2 in/d	0.3 in/d	Avg.	0.2 in/d	0.3 in/d	Avg.	
30"	1545	1757	1651	1648	1672	1660	1656
40"	1468	1642	1555	1537	1591	1564	1560
60"	1367	1546	1457	1577	1587	1582	1519
Avg.	1460	1648	1554	1587	1617	1602	

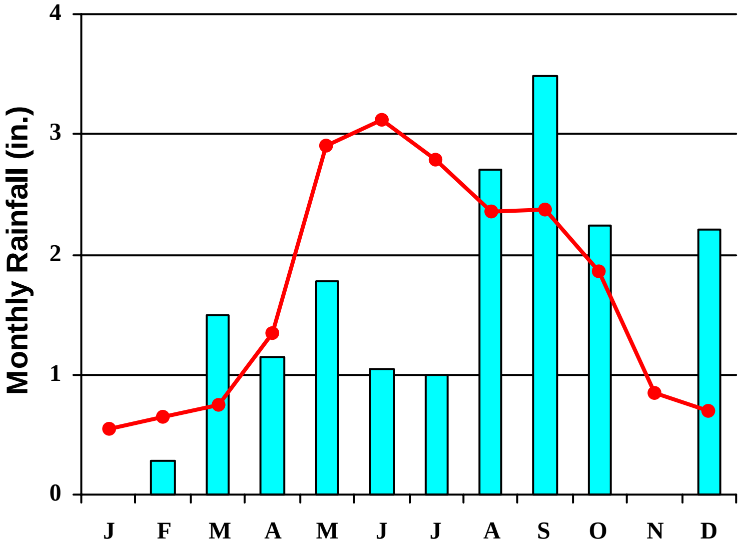


Figure 1. Monthly rain totals at the Helms Research Farm and 100 year average rain (red line) at Plainview, 2006.

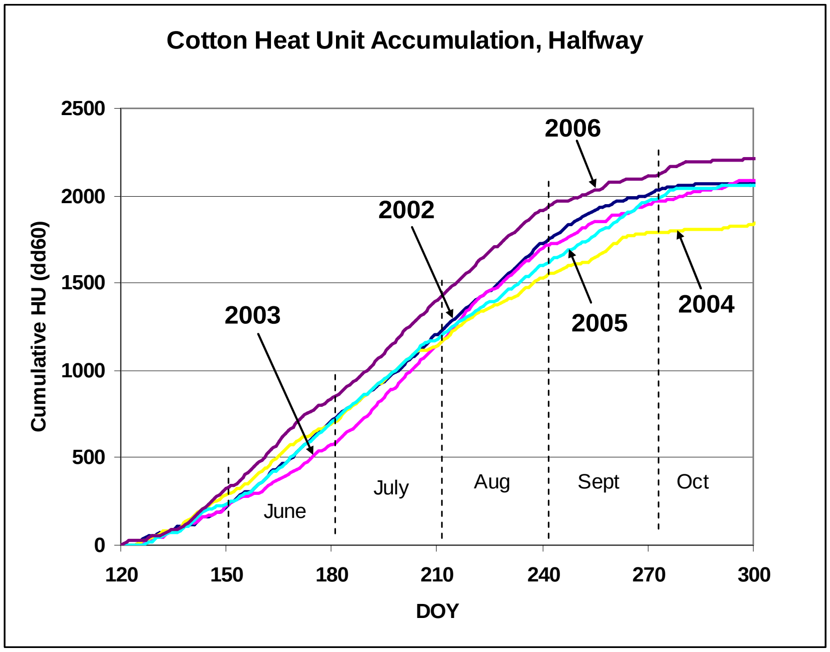


Figure 2. Cumulative cotton growing degree days for 2002-2006, TAES, Halfway.

Figure 3. Deposits of sand particles with no indications of MnO_2 precipitation in a magnified drip emitter pathway, TAES, Halfway (picture taken in 2005).

Figure 4. Installation of soil amendment treatments from drip laterals to the location of the seed drill in replicated plots at TAES, Halfway, 2006.

Figure 5. Installation of TDR sensors for measuring volumetric soil water content in an array above and to each side of the drip lateral (A); field where amendments and sensors are located, corn planted to dry the profile prior to irrigating with SDI (B); measuring soil water content with TDR equipment (C); and treatment sites with "rainout" shelters used while wetting with SDI (D).

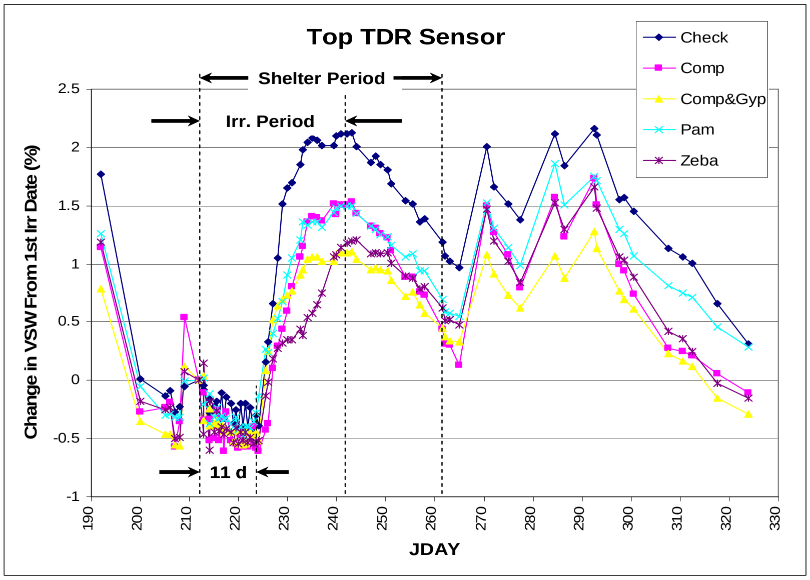


Figure 6. Average changes in volumetric water content from day 208 during a 30-day irrigation period measured by top TDR sensors within soil amendment treatments at TAES, Halfway, 2006.

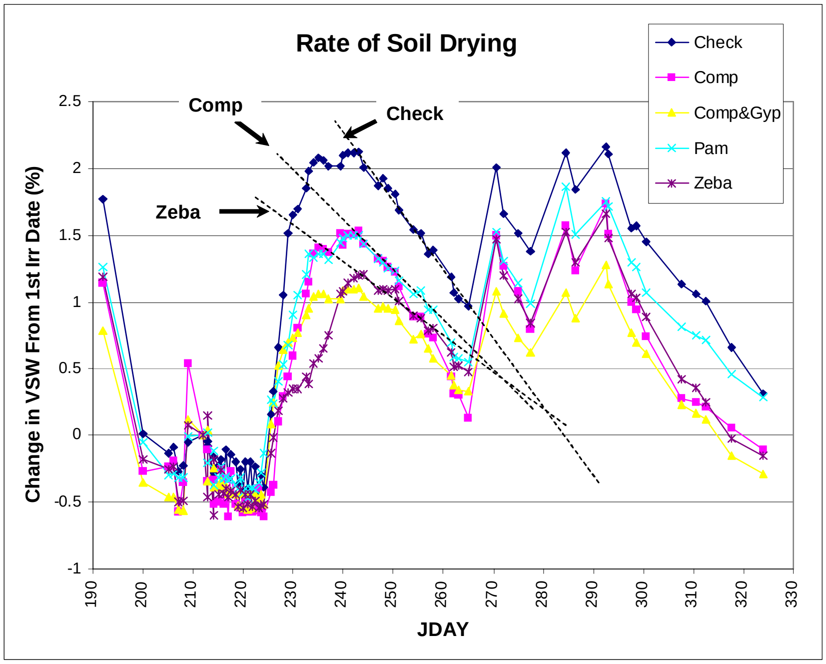
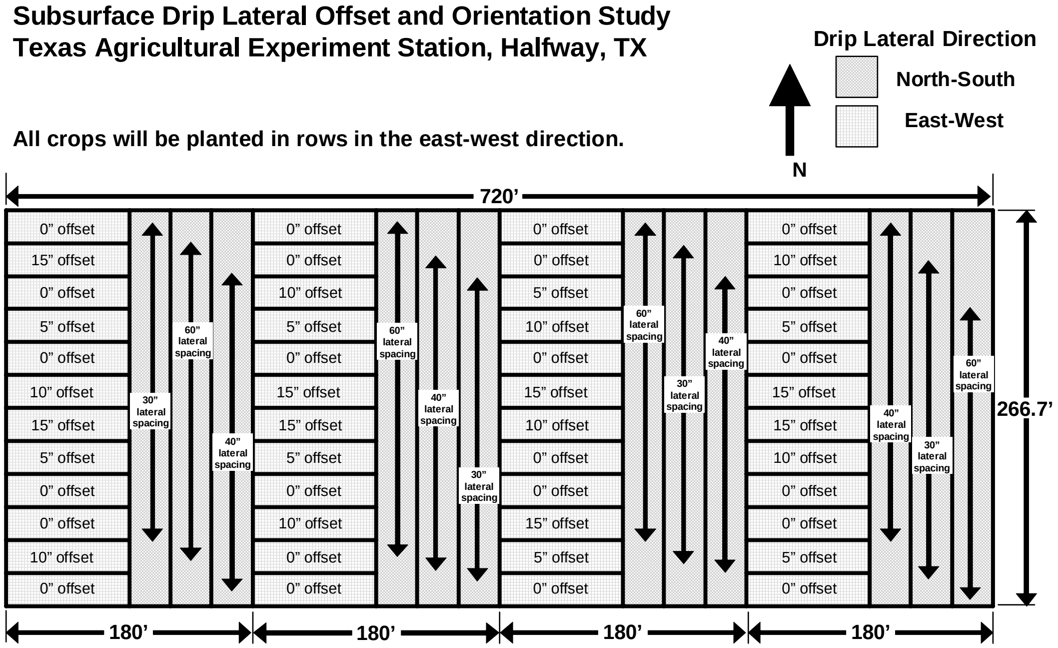


Figure 7. Changes in the rate of soil water loss following SDI irrigation measured by top TDR sensors within soil amendment treatments at TAES, Halfway, 2006.


Subsurface Drip Lateral Offset and Orientation Study
Texas Agricultural Experiment Station, Halfway, TX

All crops will be planted in rows in the east-west direction.

Figure 8. Subsurface drip irrigation installation showing perpendicular and parallel drip lateral orientation to the planted crop row. Drip lateral offsets and 30 and 40-inch crop row spacings are also included in this field layout.

Figure 9. Installation of SDI laterals with GPS guided tractor, TAES, Halfway, 2006.

Figure 10. Connecting SDI laterals to manifolds and flush lines at TAES, Halfway, 2006.

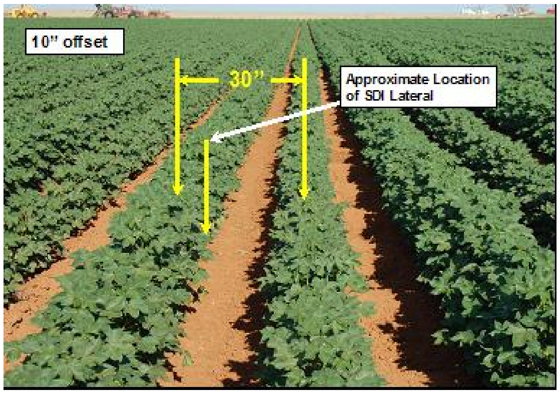


Figure 11. SDI irrigated cotton plot with 10” drip lateral to crop row offset, TAES, Halfway, 2006.

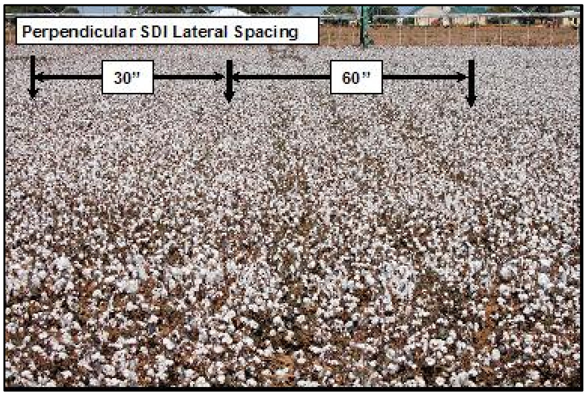


Figure 12. Perpendicular drip laterals to crop rows with SDI spacings of 30 and 60”, TAES, Halfway, 2006.