DRIP vs. FURROW IRRIGATION OF COTTON ON SANDY SOIL WITH 1/4 MILE RUNS - INCLUDES: YIELD MONITORING, REMOTE SENSING, AND ELECTRONIC SOIL SURVEY

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Abstract

Subsurface drip irrigation was compared to furrow irrigation of cotton on 990-ft runs for 4 seasons on sandy soil. The first furrow irrigation after planting was difficult (as expected) and wasted a lot of water, up to 4 in. The drip system was less efficient than expected due to the startup time required. On the average for the season, the furrow system used 10.5 in. more water that the drip system, a difference which is very similar to results from published short-run (300 ft) tests. There was no difference in yield between the drip and furrow treatments. There were extreme variations in the infiltration rates across the 2 fields. An electrical conductivity (EC) cart, with rolling disk electrodes, was found to be a very fast and easy way to detect and precisely map areas of sharp changes in soil texture. Likewise, large differences in yield due to treatment, pests, or unusual soil conditions were quite obvious in our yield monitor work. Affected field areas were sharply delineated. The required weight coefficient, a correction factor for the yield monitor, was dependent on sensor blockage, and appeared to be a linear function of yield. Yields in a small calibration plot showed that severe moisture stress at peak bloom did not reduce yield, but the same stress one week after cut-out reduced yield drastically. By studying all of the available layers of spatially distributed parameters, such as soil properties, plant size and image reflectance, and yield, one can get a very good understanding of what's going on in a large field of cotton.

Introduction

Small field research plots are like some models; they can accurately reflect the relative degree and direction of change caused by various treatments. Large research plots can sometimes be a better indicator of real-world problems. It's difficult, however, to have large plots that don't have considerable variation in soil properties. As a result, one has to trade off some of the statistical accuracy to gain that more practical information. It was thought that furrow-versus-drip irrigation tests on small plots (4-row and 8-row) and short runs (300 ft), as in DeTar et al., 1992, 1994, and 1995, were perhaps not realistic comparisons. This is a report on four year's work with big plots (28 rows wide) and farm-size runs (990 ft), that served not only for the irrigation tests but also for our remote sensing program, and shows the spatial variability encountered.

Procedures

In early 1995, the plant rows in two 6.5-acre fields at the Shafter Research and Extension Center were re-oriented to run east and west, a distance of 990 ft, instead of their normal north-south direction with 300-ft rows. These two fields are indicated in Figure 1 as F41 and F42. The land was furrowed out with 30-inch row spacings, and dripperline placed 10 inches below grade in every plant row, running continuously the full length of the field, down a 1/2% slope, and fed by buried manifolds at the upper (east) end. Each field was divided into four 28-row plots. Two non-adjacent plots in each field were fed by one manifold and corresponding circuit valves, regulators, etc. The other 2 plots in each field were fed by a separate circuit, and there were a total of 4 drip circuits. Each 28-row plot had its own flush manifold at the lower end of the field. Fifteen-inch diameter PVC pipelines were buried also across the upper ends of each field, along with risers and alfalfa valves every 30 ft, to supply water for furrow irrigation through gated pipe. It was thus possible to irrigate each field entirely by drip, or entirely by furrow, or half one and half the other.

The plan was to compare drip to furrow in one field while the other field was in a rotational crop, alternating fields each year for 6 years. However, administrative changes in the mission of the unit and some logistical problems delayed the rotational part of this project. So far in one field (field 42), we have 3 years of drip vs furrow irrigation with continuous cotton, then one year of blackeye beans. In the other field (field 41), there was a construction delay of one year, a poor germination and a very late replant the next year of all drip-irrigated cotton, then another year of all drip-irrigated cotton, and finally one year of drip vs furrow treatments.

Acala Maxxa cotton was used for all tests except for the northern half of field 42 in 1997, which was planted to Acala NemX. The dripper line used was T-Tape TSX-710-12-220 (7/8" ID, 10-mil wall thickness, emitter outlets every 12 inches) which we operated at a pressure of 8 psi, producing 0.13 gph emitter flow. Water was applied once a day, using manually adjusted time clocks. A proportional pump was used to inject liquid urea (UN32) into the irrigation water, at a rate of 10 lbs N/acre for each inch of water applied from mid-May to the first week in August. The planting dates ranged from March 31, 1995 to April 20,1998. The final emerged plant population was 40,000 to 50,000 plants per acre. The soil is a uniform Wasco sandy loam (*coarse-loamy, mixed, nonacid, thermic Typic Torriothents*).

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:375-380 (1999)
National Cotton Council, Memphis TN

The general irrigation scheduling procedure used was to apply

$$E_t = C_p * E_p / E_f \qquad [1]$$

where E_t is the depth of water to apply, in inches, E_p is the evaporation from a USDA Class A evaporation pan, in inches, C_p is the pan coefficient, and E_f is the efficiency of the irrigation system. The pan coefficient is a variable, normally dependent on plant development, and in this case

$$C_p = F_t * C_n \qquad [2]$$

where C_n is the crop canopy (ground cover), as a decimal fraction, and for $C_n < 0.85$, $F_t = 1$. For $C_n \geq 0.85$, $C_p = 0.85$.

The efficiency of the system was variable and assumed to be dependent on startup time and useful run time. Each dripperline had a volume of 30 gal., which all drained to the lower end of the field when the pump was turned off. For our particular supply pump and system restrictions, it took about 10 minutes of pumping time before the 56 dripper lines came up to operating pressure. For example, in the early season when the useful daily run time was 60 min, the pump had to run 70 minutes, so the efficient was 60/70 = 86%. Later on, at peak use, with 160 min of useful run times, the efficiency was much better at 160/170 = 94%. The time clocks, which were adjusted twice a week, were set by estimating the pan evaporation for the coming 3 or 4 days, using the 21-year normal pan evaporation and adjusting it by as much as 20% depending on weather forecast information. Ground cover was measured weekly (dividing the average width of the plant canopy by the row spacing), and estimates were made by forward extrapolation to help with the time clock setting. The moisture in the soil profile was measured weekly with a neutron probe. One neutron probe access tube was located near the center of each of 5 subplots. Each of the 20 tubes was 2" in diameter (OD) and five foot long, made of an aluminum alloy. Readings were taken at one-foot intervals. The scheduling procedure used in the furrow treatments was to try to replace most of the soil moisture that disappeared since the previous irrigation, aiming for a slight deficit irrigation. Once the season was well under way the furrow treatments were irrigated weekly, with all flows into and off of the field monitored. Flow meters, calibrated at least once each season, were used to measure inflow to the furrows, and a bucket and stopwatch was used to periodically (hourly) measure the outflow through discharge pipes into a tail-water return ditch.

Results and Discussion

The arrangement of the drip and furrow treatments for cotton in field 41 for 1998 are shown in Figure 1. The lower field (southern) field, F42, was in blackeye beans, and all furrow irrigated. Near-infrared (NIR) images from our remote sensing project showed the treatments effects in F41 standing out sharply, as the drip-irrigated plants are larger. The effects of moisture stress treatments were visible in field 41A, which had 16-row plots, with rows running north-south; this field was dead level. Darker areas in F42 indicated larger bean plants and better soil conditions. Part of this good soil was hidden by treatment and nematode effects in prior years. The beans were hard to irrigate with furrows, and this was indicated by the light areas at the lower end (left end) of F42, which did not receive sufficient water. The "pock mark" that appeared in the upper, left-hand side (NW corner) of F41 were found to be spider mite hot spots.

Background on the spatial variability of the soil at the test site are shown in Figures 1, 2, and 3. Figure 1 shows the electrical conductivity of the soil in the two fields as measured by a Veris 3100 conductivity cart, on March 20, 1998. The device has rolling disc electrodes, which in this case produced the average EC for the top 3 ft of soil. It took about two hours to obtain this data. Sharp delineations of high EC soils were discovered in the NW corner of field 41 and in the western 2/3 of the south half of field 42, with EC's above 20 mS/m. These areas correspond with sandy loam soils known to have high silt content (above 30%). Sand streaks in the area are known to generally go from NE to SW (which is the direction of slope of the land), as shown here, with a large area having an EC of less than 15 mS/m. The soils with EC's between 15 and 20 mS/m turn out to be very nice soils, sandy but productive.

Figure 2 shows the water content of the soil near field capacity, as determined from neutron probe readings to a depth of 3 ft. It shows the same heavy-soil area in the NW corner of F41 as was seen in the EC map. But a distinguishing feature is shown in F42. The high-EC area of F42 holds much more water than the same level of EC in F41. The sandy areas of F41 hold an average of 1.6 to 1.8 in/ft of water, which is very low in comparison to most soils on the station. The NW corner of the same field holds 2.4 to 2.6 in/ft, which is slightly above normal for our soils. By comparison, the sandier areas of F42 hold 1.8 to 2.1 in/ft and the heavy areas of F42 hold 2.6 to 2.9 in/ft! This large difference in soil property is definitely not indicated by the EC alone.

Figure 3 shows the percent fines (silt plus clay) in F41. Again, the NW corner stands out in the same manner as EC and water holding capacity, averaging about 35% fines, while the rest of F41 averages about 17%.

Tables 1, 2, 3, and 4 are samples of some of the infiltration data taken during furrow irrigations. Table 1 is for the south half of field 42 in 1995, and Table 2 is for the north half. This area contains the heaviest of all the soils in the experiment. The first irrigation after planting was rather typical of all the furrow tests, with the infiltration rate of 1.0 in/hr at the end of the irrigation, a situation which is difficult but manageable. The inflow required is near 30 gpm/furrow, but due to the cohesive nature of the soil, erosion was not extreme. By contrast the July 18, in the south half, infiltration rate dropped off to 0.0214 in/hr, due to surface sealing of the soil. This rate is unmanageable. At that rate, to get the required 2.2 in/wk would have required over 100 hours of irrigation set time, once every week! The low infiltration problem was resolved in 1996, shown in Table 3, by adding a cup of gypsum to the upper end of each furrow before each irrigation, starting in mid-July. The minimum infiltration rate that year was 0.075 in/hr, which was manageable, but still required long set times. A sharp contrast is shown in Table 4, for field 41 in 1998. Although the infiltration rate at the end of the first irrigation was not extremely high, compared to other tests, the non-cohesive nature of the soil particles in this field made any inflow higher than 15 gpm/furrow very difficult to manage. Constant vigilance was required to prevent the beds from washing out due to erosion. The problem is accentuated with 30-inch row spacings because the beds are small and the furrows are not very deep compared to standard row spacings of 38 to 40 inches. After the first irrigation in field 41, there was less surface sealing, minimum infiltration rates of 0.24 in/hr, and set times of only 7.7 hours, i.e., these irrigations were easy to manage. Another clue to the unusual nature of the soil in field 41 was in the low capillary rise above the dripper lines, the first irrigation after installation in 1996. We could not germinate the seed with the drip system! This had never been a problem on even the sandiest soils on the station. After the soil settled and consolidated there were no such problems in subsequent drip irrigations.

The average depth of water applied during the first furrow irrigation after planting was 6.13 inches for the long-run (990 ft) tests run from 1995 to 1998, with a range of 4.6 to 8.4 inches. For short run (300 ft) tests on the station from 1990 to 1994, the average was 4.32 inches, ranging from 2.6 to 6.6". So the long-run furrows used 1.81 in more water than the short run furrows. After the first furrow irrigation, the long runs required more advance time than the short runs, but due to soil sealing, there was not a great difference in water use.

Figures 4 and 5 show how well moisture was maintained in the soil throughout the season in 1998. As a reference, the soil moisture for the drip-irrigated, high-efficiency system in Field 41A is shown in Figure 4, where we were able to produce an average deficit rate of 0.03 in/d. Figure 5 shows that both the drip and furrow treatments in field 41 had about the same deficit rate of 0.01 in/d, suggesting that we could have applied a little less water to both treatments. The effect of the extra water applied during the first furrow irrigation is quite noticeable.

Long runs were not just a problem for furrow irrigation. The drip irrigation system had two important problems. One was misalignment of the beds with respect to the dripper lines. The beds move around-- always have and always will. But on long runs they move farther. It's more difficult for a tractor driver to drive a straight line. We found a dripperline that had "moved" 15 inches, ending up under the middle of the furrow, where it is more subject to damage by farm machinery. By comparison, in field 41A (328 ft run), the largest offset found was only 5 inches. The other problem with long-run drip irrigation is startup time, the 10 minutes it takes to fill up the empty dripper lines when the pump first starts. As mentioned earlier, it reduces the efficiency of the system, and requires that more water be applied. But perhaps the more important effect of this problem is the draining of the water to the lower end of the field when the pump is turned off. The over-watered plants went vegetative, grew to over 6 ft tall, had a reduced yield and a lot of un-opened bolls at harvest.

Now for the yields and water use. As seen in Table 5, there was no difference in the 4-year average for yield between the drip and furrow irrigation treatments, both about 1.5 bales/acre. The years 1995 and 1998 were bad years for cotton all over the San Joaquin Valley, and some of the soils on our south 40 are not known for high yields. The water use varied a lot, but the drip treatment always used less than the furrow treatment. The 4-year average water use for the drip treatment was 29.1 inches, and for the furrow treatment it was 39.6 inches, with a difference of 10.5 inches. Forty inches of water on furrows is typical for the area (Dept. Water Res., 1974); twenty nine inches for drip is at the upper end of the range we have experienced in short-run tests. The water saved by using drip over furrow irrigation was no better in long-run tests than in short-run tests. The high water use in 1997 was due to a very long, hot summer. The low water use in 1998 was due to a very short, cool season, sometimes blamed on "El Niño".

A yield monitor (Zycom Corp., Bedford, MA) was used during the harvest of field 42 in 1997, and also in the harvest of fields 41 and 41A in 1998. An example is shown in Figure 6, for field 41A. After three years of continuous cotton, the nematode population exploded in the SE corner of field 42, resulting in seed cotton yields of less than 1200 lbs/ac, and showing up well in the yield map. Actually that corner of the field had very small plants with the canopy covering perhaps 30% of the ground area, and the yield was much closer to zero than it was to 1200 lbs/ac. The problem was obvious to the casual observer. It appears that the nematode problem extended downslope more in the furrow plot than in the drip plot, perhaps spread by water movement. Near-infrared (NIR) imagery taken in August, 1997, confirms the effect. However, NIR images of the blackeye beans in the same area in 1998 show that there is a larger area of poor plant growth, and thus probably a larger area of poor soil (not nematodes) at the east end of the furrow plot. Electrical conductivity (EC) and field capacity data for SE corner of field 42 do not show much more sandy soil in the furrow plot than in the drip plot. The problem could be mechanical, i.e., soil compaction, which is known to be a serious problem on these sandy loam soils.

Two straight lines running N-S across the drip and furrow plots in the south half of field 42 were seen in the 1997 yield map at the same place where visual observations of stair-step jumps in plant height occurred. Some of this effect shows up in the EC map too. Once thought to be a residual from previous experiments (when plant rows ran N-S), now appear to be real changes in soil texture. The high-yield area in the west half of the south part of field 42 corresponds to the highest EC levels, high field capacity, and large plants. The soil between the two straight-line stair steps was heavy, but not the highest-yielding. The plot in the upper part of the yield map for field 42 was a furrow-irrigated treatment planted to Acala NemX. The high yield was obvious in the yield map, and was actually measured at 2.5 bales/ac. for the entire plot, showing by contrast the extreme damage the nematodes were causing in the Acala Maxxa plots to the south.

Field 41A, shown in Figure 6, was used for a small stress test experiment in 1998, all drip irrigated daily. For the early-stress treatment the water was turned off completely for one week during peak bloom. For the late-stress treatment, the water was turned off for one week, starting one week after cut-out. Early stress did not reduce yields from the control, but the late stress caused a drastic reduction in yield. Average yields were 1.31, 0.71, and 1.36 bales/ac for the early-stress, late-stress, and control treatments, respectively. These differences show up really well in the yield map in Figure 6.

The only big effect seen in the 1998 yield map of field 41 was in the heavy soils at the lower end where drip plants got over-watered and where spider mite hot spots occurred. By looking at the yield map, one could almost guess that there were no differences in yield due to the irrigation treatments, and, in fact, there were none.

Figure 7 shows the what the weight coefficient (a manually programmed calibration factor) would have to be for the yield monitor to show the correct total weight of seed cotton for each picker basket dumped into a cotton trailer, for fields 41 and 41A, in 1998. The cotton trailer weights were taken with electronic wheel scales placed under each of the four tires. The same type of data was taken in 1997 for field 42. Although based on very limited data, it appears by covariance analysis, that the proper weight coefficient is proportional to the yield. Figure 7 also shows that the degree of sensor blockage (by dust and trash) can have a very large effect on the required weight coefficient. The same data for field 41 is shown, but is not part of the statistical analysis. Because of the size of the plots in field 41, it was thought that sensor blockage could range from none at the start to severe at the end, and probably not in a linear fashion, so that average weight coefficients were not as accurate as in small plots. Some of the field 41 data, with partially blocked sensors seem to line up well with the data from field 41A. The one high outlier occurred at about the same time that a picker breakdown occurred, and the monitor froze up. The 2 lower outliers for field 41 resulted when one of the 3 lenses in a sensor became completely blocked.

Summary

Over the four years (1995-1998) there was no difference in the yield between these long-run drip and furrow irrigation treatments, both averaging about 1.5 bales/acre. The seasonal water use over the same time period averaged 39.6 inches for the furrows and 29.1 inches for the drip treatment, a difference of 10.5 inches, which is similar to averages published for short-run tests. Soil properties were highly variable, with July infiltration rates ranging from 0.021 in/hr to 0.24 in/hr, a more than 10-fold difference, increasing from south to north, within a distance of 600 ft. Trying to run enough water down 990 ft rows, with 30 in. row spacing on sandy soil, was at times, very difficult and frustrating, because the beds washed out near the gated pipe. There were some unexpected problems with the long-run drip system: (a) misalignment of the dripperline with respect to the plant row was greater in long runs than in short run; (b) there was a longer startup time with the long runs, reducing the efficiency of irrigation system by possibly 5 to 10%; (c) water draining to the lower end of the field from the long dripper lines after shut down, caused over-irrigation, and was a possible cause for reduced yield at the lower end of the drip plots. The yield monitor and the electrical conductivity cart both succeeded in accurately mapping sharp changes in the soil properties. The effect of the treatments and pests were obvious on the yield maps. Yield monitor data was compared to weighed data for every picker basket dumped. In many cases the correction factor (weight coefficient) required changed from area to area and with time. The required weight coefficient seemed to by slightly dependent on yield, and it jumped around considerably with sensor blockage. A stress-test plot showed that extreme moisture stress at peak bloom did not reduce yield. The same stress one week after cut-out caused the yield to drop to 53% of the un-stressed treatment.

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Table 1. Infiltration data for the 1995 furrow irrigations in the south half of field 42, South-40, Shafter, CA., using canal water (EC=0.02mS/cm) except as noted otherwise.

Date	Initial infiltr. function (in & hr)	Final rate (in/hr)	Net depth[a] of water applied to field (in)	Set time (hrs)
May 24	$I=1.6t^{.79}$	1.00	4.6	4.2[c]
June 6	$I=1.1t^{.84}$	.99	2.4	2.6[c]
June 16	$I=.89t^{.63}$	.23	2.8	7.8[c]
June 25	$I=.53t^{.56}$	.15	1.8	7.8
June 30	$I=.73t^{.59}$	.185	2.24	7.6[c]
July 4	$I=.25t^{.51}$	.061	0.98	10.0
July 11	n/a	.0244	2.18	49.5
July 18	$I=.19t^{.55}$	.0214	1.41	28.2
July 20	$I=.12t^{.55}$	.0260	1.43	46.2
July 27	$I=.18t^{.66}$	.0470	1.72	25.9
Aug 4	$I=.32t^{.57}$	.105	3.0	27.7[b]
Aug 10	$I=.45t^{.70}$	.149	4.8	23.2[b]
Aug 18	$I=.52t^{.66}$	.227	2.26	9.3[b]
		SUBTOTAL	31.62"	
		Effective rainfall	6.87"	
		TOTAL	38.49"	

(a) Net application is total applied less runoff.
(b) Well water (EC= 0.61 mS/cm).
(c) Loose soil, no crust.

Table 2. Infiltration data for the 1995 furrow irrigations in the north half of field 42, south 40, Shafter, CA., using canal water (EC=0.02mS/cm) except as noted otherwise.

Date	Initial infiltr. function (in & hr)	Final rate (in/hr)	Net depth[a] of water applied to field (in)	Set time (hrs)
May 24	$I=1.9t^{.81}$	1.20	5.6	4.2[c]
June 6	$I=1.4t^{.83}$	1.23	2.9	2.6[c]
June 16	$I=.89t^{.63}$	.28	3.0	7.8[c]
June 26	$I=.57t^{.56}$	.19	1.9	7.8
June 30	$I=.74t^{.53}$	.175	2.16	7.6[c]
July 4	$I=.29t^{.50}$	.053	1.05	10.0
July 11	n/a	.0476	1.66	49.5
July 18	$I=.17t^{.69}$	.0507	1.71	28.2
July 20	$I=.12t^{.62}$	.0343	1.84	46.2
July 27	$I=.25t^{.68}$	.0696	2.00	25.9
Aug 4	$I=.39t^{.50}$	.129	3.6	27.7[b]
Aug 10	$I=.48t^{.64}$	.160	4.8	23.2[b]
Aug 18	$I=.49t^{.65}$	.218	2.24	9.3[b]
		SUBTOTAL	34.46"	
		Effective rainfall	5.25"	
		TOTAL	39.71"	

(a) Net application is total applied less runoff.
(b) Well water (EC=0.61 mS/cm).
(c) Loose soil, no crust.

Table 3. Infiltration data for the 1996 furrow irrigations in field 42, South-40, Shafter, CA., using all canal water (EC=0.03mS/cm).

Date	Initial infiltr. function (in & hr)	Final rate (in/hr)	Net depth[a] of water applied to field (in)	Set time (hrs)
May 24	$I=1.6t^{.78}$	.92	4.7	4.7[c]
June 7	$I=1.4t^{.84}$	1.03	3.0	2.7[c]
June 18	$I=.97t^{.60}$	.25	3.3	11.0[c]
June 28	$I=.56t^{.66}$	.192	2.0	8.0
July 5	$I=.60t^{.52}$	.142	1.8	8.0
July 11	$I=.52t^{.47}$	.093	3.3	31.0
July 18	$I=.36t^{.54}$	.082	3.1	31.0[b]
July 25	$I=.30t^{.56}$	.075	2.7	31.0[b]
Aug 1	$I=.37t^{.53}$	.082	3.0	31.0[b]
Aug 8	$I=.28t^{.58}$	.070	2.6	30.5[b]
Aug 19	$I=.70t^{.50}$	.109	3.9	30.0[b]
		SUBTOTAL	33.4"	
		Effective rainfall	6.9"	
		TOTAL	40.3"	

(a) Net application is total applied less runoff.
(b) Gypsum (200 ml) applied at upper end of each furrow.
(c) Loose soil, no crust.

Table 4. Infiltration data for the 1998 furrow irrigations in field 41, South-40, Shafter, CA., using all canal water (EC=0.03mS/cm).

Date	Initial infiltr. function (in & hr)	Final rate (in/hr)	Net depth[a] of water applied to field (in)	Set time (hrs)
June 18	$I=1.4t^{.78}$	.82	6.3	7.7
July 1	$I=.74t^{.67}$	.29	2.5	7.5[c]
July 9	$I=.54t^{.72}$	.25	2.0	7.7
July 16	$I=.47t^{.77}$	.25	2.2	7.7[c]
July 23	$I=.42t^{.78}$	.23	2.1	7.7[b]
July 30	$I=.54t^{.65}$	.24	2.1	7.6[b]
Aug 6	$I=.52t^{.68}$	.24	2.2	7.7[b]
Aug 13	$I=.57t^{.70}$	.27	2.4	7.7[b]
Aug 20	$I=.53t^{.72}$	.26	2.3	7.5
Aug 27	$I=.46t^{.73}$	.25	1.9	6.7
		SUBTOTAL	26.0"	
		Effective rainfall	6.0"	
		TOTAL	32.0"	

(a) Net application is total applied less runoff.
(b) Gypsum (200 ml) applied at upper end of each furrow.
(c) Loose soil, no crust.

Table 5. Net irrigation water applied and yields for Acala cotton grown with subsurface drip and furrow irrigation in the fields 41 and 42, South-40, 1995 - 1998, Shafter, CA. Acala Maxxa was used except where noted otherwise.

Net Water Applied (inches)				Lint Cotton Yields (bales/acre)				
					Drip		Furrow	
	Drip	Furrow	Diff.	plots	B	D	A	C
FIELD 42								
1995	27.1	39.1	12.0		0.76	0.62	0.74	0.48
1996	34.8	40.3	5.5		2.17	2.29[n]	2.15	2.57[n]
1997	29.6	46.9	17.3		1.80	2.50[n]	1.64	2.58[n]
				3-yr Avg	**1.69**		**1.69**	
FIELD 41								
1997	29.9	n/a[d]			2.11	2.17	2.23	2.06
1998	24.9	32.0	7.1		1.22	1.07	1.15	0.95
				1998 Avg	**1.15**		**1.05**	
4-yr avg.	29.1	39.6	10.5		1.56		1.53	

*Net applied water on furrows is total water applied to field less runoff to tail water return system.
(n) Acala NemX
(d) All 4 plots (A,B,C & D) in field 41 were drip-irrigated in 1997. Drip vs furrow started again in 1998.

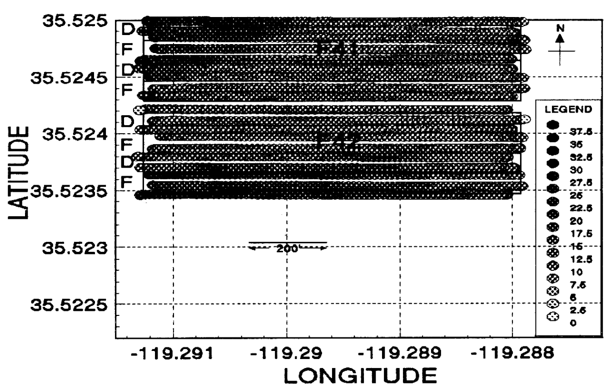

Figure 1. Electrical conductivity of soil, mS/m, using Veris Conductivity Cart. Treatments: D=drip, F=furrow irrigation.

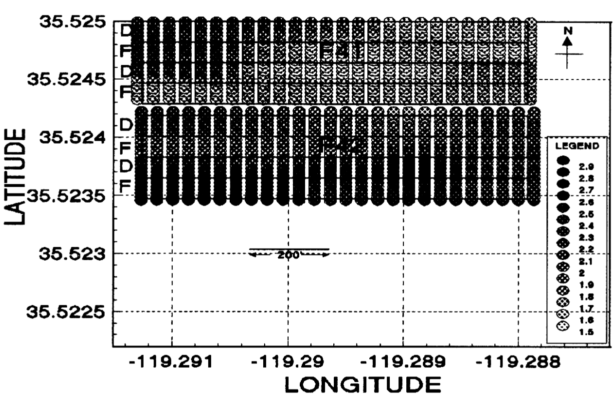

Figure 2. Field Capacity, in inches of water per ft. of soil, avg. for top 3 ft. Estimated from neutron prove data.

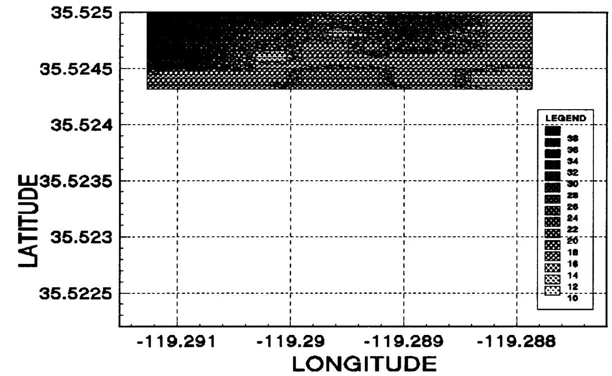

Figure 3. Average percent fines (silt and clay) in top 3 ft of soil in field 41.

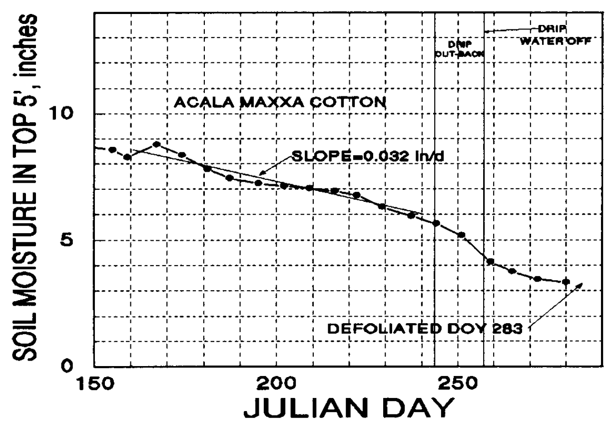

Figure 4. Soil moisture in field 41A in 1998, total inches of water in top 5 ft of soil. All drip irrigated.

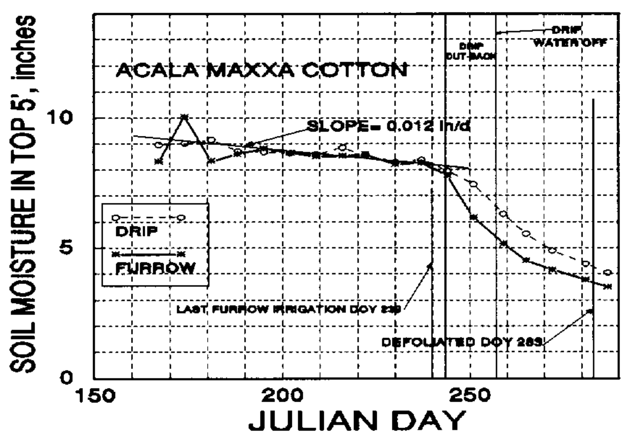

Figure 5. Soil moisture for drip and furrow treatments in field 41 in 1998, total inches of water in top 5 ft of soil.

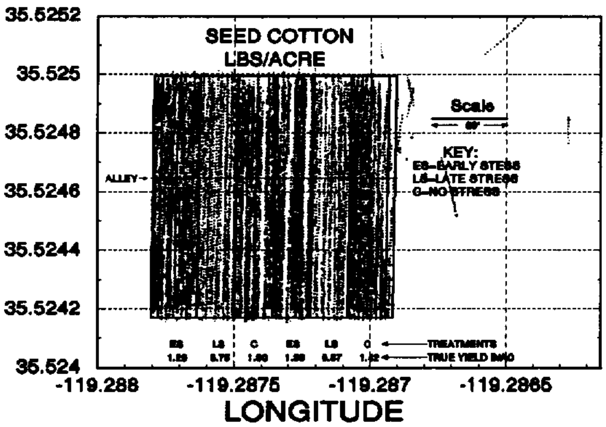

Figure 6. Zycom yield monitor data for field 41A, seed cotton yields in lbs/acre, for 1998. Drip-irrigated stress test.

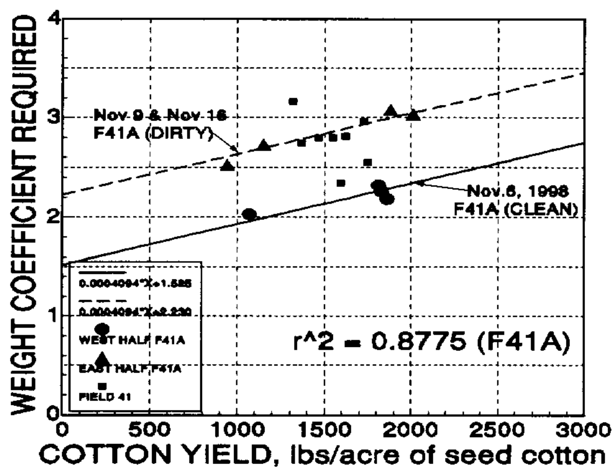

Figure 7. Effect of sensor blockage and yield on required weight coefficient of Zycom yield monitor. Fields 41 & 41A, 1998.