WATER DEFICIT TIMING, RATE OF DEVELOPMENT IMPACTS ON SOME FIBER QUALITY CHARACTERISTICS

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Abstract

As part of an irrigation study evaluating impacts of irrigation method (drip versus furrow) and irrigation scheduling on Acala cotton growth and yield, cotton plants were partitioned into lower canopy, mid-canopy and upper canopy fruiting positions in order to evaluate irrigation treatment impacts on specific fiber quality characteristics. The strongest impacts of irrigation management on micronaire and strength were largely through impacts on the number of late-season bolls with limited time for development (high water treatments) and in late-season water stress impacts on the duration of fiber development (in low water treatments). Patterns of water stress impacts on fiber quality were similar under subsurface drip and furrow irrigation. Although not very large in magnitude, there was a trend toward more limited impacts of water stress on fiber strength and micronaire under the most water-stressed high-frequency drip irrigation than with the most-stressed furrow irrigation treatments.

Introduction

Variety choice remains the likely dominant factor impacting many components of cotton quality in varieties grown in the San Joaquin Valley of California. Strength, and to a lesser extent length, are characteristics that often are strongly influenced by the genetic makeup of the variety, with lesser impact of environment under many conditions. This is not to say that environment cannot have an impact, as was discussed in a recent review by Bradow and Davidonis (2000). It is known that quality components such as length, strength and micronaire vary with location in the plant canopy, representing the differences in timing of production and nutritional and environmental constraints in effect at different times of the production season (Kerby and Hake (1996); Kerby and Ruppenicker (1989)). The western U.S. cotton production area is also subject to significant changes in water availability from year to year, and increasing water costs, so growers have to deal with the threat of supply limits and impacts on crop yields and quality. With this in mind, seedcotton samples were collected as part of a larger irrigation management study involving drip and furrow deficit irrigation in cotton in order to evaluate potential impacts on some components of cotton fiber quality.

Materials and Methods

1992 through 1995 Studies

Irrigated cotton plots were established at the West Side Research and Extension Center of the University of CA, near Five Points, CA. Soil at this site is a deep clay loam, with past experience of 5 to 6 feet rooting depth potential most years. The soil water holding capacity is in the 1.8 to 2.1 inches per foot of soil depth range. The soil was tested pre-plant for N, P and K, and fertilizer applications made accordingly to avoid any nutrient limitations.

Both subsurface drip irrigated and furrow irrigated plots were utilized, and two cotton varieties were grown (GC-510 and an experimental columnar variety "C-2086" in the first year, and Maxxa and GC-510 in subsequent years). The subsurface drip irrigation system was operated daily to replace a set percentage of estimated daily crop evapotranspiration (Etc), with the percentage based upon the irrigation treatment desired (to be described later). Estimated Etc was determined using a Modified Penman-type calculation and a weather station from the CA Irrigation Management Information System located about 100 m from the plots in combination with a crop coefficient determined on-site for cotton at the West Side REC in earlier studies. The drip system was a hard tube type of system with 4 liter/hour emitters on 0.91 m spacing, with tubes placed 0.45 m deep below every other row on 0.76 m row spacing.

The subsurface drip irrigation system was operated daily to supply 60, 80 or 100% of the calculated Etc (Table 1). Leaf water potential was measured using a pressure chamber apparatus on the uppermost fully-expanded leaves between the hours of 1300 and 1530. Small furrow-irrigated plots were 30 m in length, and were irrigated using PVC delivery pipes, and were irrigated on a schedule that corresponded with attaining specific levels of leaf water potential (Table 2). Two years data have been analyzed for this report, one with an average bottom-10 first position fruit retention of >70% (called "HIGH retention" location/year ; and one with <50% retention in the same positions (to be called "LOW retention".

Following defoliant application (Prep/DEF/sodium chlorate), bolls were segregated into the following portions of the plant canopies, and adequate samples collected from each zone to total 2500 g seed cotton:

- BOTTOM = first position (FP1) bolls in the bottom 7 branches of the plants
- MID/OUT = second and third position (FP2, FP3) bolls in mid-canopy positions (fruiting branches 5 through 11)
- TOP = first and second position (FP1, FP2) bolls in the top 7 harvestable positions

Seedcotton was collected at harvest time, processed at the research gin, and sent to the USDA Classing Office for fiber evaluations. Results are averaged across two varieties for the low and high retention years presented in this report.

Results and Discussion

Water Stress Levels

Leaf water potentials (LWP) in subsurface drip irrigated treatments ranged from –14 to –17 in the 100/100/100 % Etc treatment to as low as –24 bars in the 60/60/60 treatment in mid-August (data not shown). In the furrow irrigated treatments, LWP differed in pattern from the drip irrigated plants. The drip-irrigated plants exhibited a general decline in LWP as the plants developed and soil water levels declined during the growing season, a very gradual rate of soil water deficit. In contrast, LWP values in the furrow-irrigated plants exhibited a more pronounced cycling that corresponded with irrigation cycles (data not shown). LWP in the most-stressed treatments were as low as –25 to –26 bars in late-August and early September.

Differences in plant growth and development were apparent across treatments (data not shown). The more water-stressed drip and furrow-irrigated plants were smaller, with fewer leaves and fruiting sites, and reduced total node development in the 16/23/23 and 20/23/25 bar LWP furrow treatments and in the 80/60/60 and 60/60/60 drip treatments (data not shown). The primary growth difference between reduced water application furrow and drip treatments was that leaf areas were lower and plants more compact in deficit irrigated drip plots than in the most-stressed furrow irrigated plants. LWP and leaf conductance measurements, however, showed deficit-irrigated drip plots to be less stressed (at the single leaf level) than the low water furrow-irrigated plants (data not shown).

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Fiber Quality Impacts

Across most irrigation treatments in both the high early fruit retention and low fruit retention years, there is a distinct pattern of differences in strength, length and micronaire with time of boll development (lower, mid or upper canopy positions) and position on fruiting branches (Tables 3, 4, 5). Strength, length and micronaire values generally declined with outer position and upper canopy fruiting positions. This is generally quite consistent with results obtained in earlier Acala cotton studies in California by Kerby and Ruppernicker (1989).

Fiber strength was reduced most by water stress in the upper canopy ("top") bolls under both drip and furrow irrigation (Table 3). At higher irrigation levels under both drip and furrow, more late-season "top" bolls were produced, resulting in lower upper canopy fiber strength than under more moderately water-stressed conditions (such as drip treatment 100/80/60 or furrow irrigated treatments 16/21/21 or 18/21/21. With higher levels of water stress (drip treatments 60/60/60 or furrow treatment 20/23/25), there were fewer late-developing bolls with fiber strength affected more in the low-water furrow treatments than in the low-water drip treatments (Table 3). Similar patterns were seen in the high and low fruit retention years, although with fewer late-season bolls in high fruit retention conditions, average fiber strength was less-affected.

Impacts of irrigation method and levels on fiber length (Table 4) were generally much lower than impacts on strength. A trend existed toward lower fiber length in the upper canopy in all irrigation treatments, but average lengths generally varied by less than 10 percent. In the most water-stressed furrow-irrigated treatments, fiber length in the upper canopy was reduced to a significantly greater degree than in the most-stressed drip treatments (Table 4). This could be related to the more gradual, slowly-developing stress occurring with deficit drip irrigation. This difference was most apparent in the low fruit retention year, where the upper plant canopy represented a larger portion of the total crop.

As with earlier studies by Kerby and Ruppernicker (1989), micronaire was strongly impacted by fruiting position and location within the canopy (Table 5). Under conditions of lower early fruit retention, higher water treatments tended to have higher microaire in the mid and lower canopy (likely due to continued leaf area development, high photosynthetic rates with lower fruiting loads, and resulting high carbohydrate production). Also under lower fruit retention conditions and higher water availability treatments, upper canopy micronaire values tended to be lower due a greater number of late, less-developed bolls than in lower applied water treatments (Table 5). Late-season severe water stress reduced micronaire most significantly in more stressed furrow treatments such as treatment 20/23/25. In all cases, bulk micronaire values in all treatments stayed outside of the discount range.

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Table 1. Subsurface drip irrigation treatments in irrigation study, as a percent of daily evapotranspiration (% of Etc) and growth stage. * other treatments were in study but only seedcotton samples were from these treatments.

Irrigation treatment name	Pre-bloom stage-irrig. Rate (% Etc)	First bloom through 1 week prior to cutout - irrig. Rate (% Etc)	Cutout through irrigation termination - irrigation rate (% Etc)
100/100/100	100	100	100
100/80/60	100	80	60
80/60/60	80	60	60
60/60/60	60	60	60

Table 2. Furrow irrigation treatments in irrigation study, defined by irrigations scheduling by attainment of the ranges of leaf water potential (LWP) shown below for each growth stage.

Furrow irrigation treatment name	Pre-bloom LWP target for irrigation Scheduling (bars)	First bloom through 1 week prior to cutout LWP target for irrigation sched. (bars)	Cutout through irrigation termination - LWP target for irrigation sched. (bars)
16/18/18	-16	-17 to -18	-17 to -18
16/21/21	-16	-21 to -22	-21 to -22
16/23/23	-16	-23 to -24	-23 to -24
18/21/21	-18	-21 to -22	-21 to -22
20/23/25	-20	-23 to -25	-25 to -26

Table 3. Average fiber strength measurement (in g/Tex) averaged across two varieties, as a function of year (high or low fruit retention year), location within the plant canopy, and irrigation type and treatment.

Irrig Method	High or Low Fruit Retent	Canopy Location	Irrigation Treatments (% Etc in drip; LWP in furrow)				
Drip			100/ 100/ 100	100/ 80/ 60	80/ 60/ 60	60/ 60/ 60	
	Low	Bottom	34.7	35.2	34.2	34.4	
		Mid/Out	32.6	33.6	32.9	32.2	
		Top	29.1	30.7	31.4	28.0	
	High	Bottom	33.9	34.0	33.5	33.5	
		Mid/Out	31.6	32.6	32.9	33.2	
		Top	30.1	29.6	30.4	30.6	
Furrow			16/ 18/ 18	16/ 21/ 21	16/ 23/ 23	18/ 21/ 21	20/ 23/ 25
	Low	Bottom	34.5	35.2	34.1	34.5	33.7
		Mid/Out	33.1	33.5	32.2	33.0	30.3
		Top	28.7	31.4	28.1	30.9	27.4
	High	Bottom	33.5	34.0	33.1	33.4	32.1
		Mid/Out	32.0	31.9	30.4	31.0	29.8
		Top	27.9	30.4	29.8	29.5	27.9

Table 4. Average fiber length (in 32nd inch) averaged across two varieties, as a function of year (high or low fruit retention year), location within the plant canopy, and irrigation type and treatment.

Irrig Method	High or Low Fruit Retent	Canopy Location	Irrigation Treatments (% Etc in drip; LWP in furrow)				
Drip			100/ 100/ 100	100/ 80/ 60	80/ 60/ 60	60/ 60/ 60	
	Low	Bottom	37.4	37.7	37.0	36.8	
		Mid/Out	37.1	38.0	37.3	36.6	
		Top	34.6	36.9	36.3	33.6	
	High	Bottom	37.7	37.2	37.2	37.7	
		Mid/Out	36.3	36.6	35.8	36.0	
		Top	35.1	35.5	33.4	34.6	
Furrow			16/ 18/ 18	16/ 21/ 21	16/ 23/ 23	18/ 21/ 21	20/ 23/ 25
	Low	Bottom	37.4	37.6	37.0	37.3	36.8
		Mid/Out	37.3	37.3	37.6	36.9	35.6
		Top	33.9	35.9	34.5	35.8	31.4
	High	Bottom	37.4	37.8	37.5	37.2	37.3
		Mid/Out	36.7	36.0	35.3	36.0	35.0
		Top	36.2	35.6	35.2	34.4	32.1

Table 5. Average fiber micronaire averaged across two varieties, as a function of year (high or low fruit retention year), location within the plant canopy, and irrigation type and treatment.

Irrig Method	High or Low Fruit Retent	Canopy Location	Irrigation Treatments (% Etc in drip; LWP in furrow)				
Drip			100/ 100/ 100	100/ 80/ 60	80/ 60/ 60	60/ 60/ 60	
	Low	Bottom	4.73	4.62	4.38	4.39	
		Mid/Out	4.42	4.17	4.45	4.29	
		Top	3.41	3.89	3.79	3.60	
	High	Bottom	4.52	4.48	4.51	4.67	
		Mid/Out	4.25	4.21	4.41	4.29	
		Top	3.78	3.74	3.93	3.96	
Furrow			16/ 18/ 18	16/ 21/ 21	16/ 23/ 23	18/ 21/ 21	20/ 23/ 25
	Low	Bottom	4.89	4.74	4.39	4.45	4.58
		Mid/Out	4.52	4.36	4.29	4.09	4.39
		Top	3.55	3.78	4.06	3.88	3.38
	High	Bottom	4.45	4.52	4.51	4.42	4.57
		Mid/Out	4.19	4.26	4.37	4.22	4.35
		Top	3.61	3.68	3.74	3.75	4.01