SCREENING WATER STRESS IN MULTIPLE COTTON VARIETIES

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Abstract

One of the challenges with genetic selection of cotton for yield and fiber quality is the assessment of phenological changes in the plant that impart improved yield and quality. Understanding in-season growth will help determine beneficial water application schedules for yield and quality. We propose a method for screening large numbers of plots using multiple remote sensing technologies to identify factors that can be identified as contributors to final yield and quality in irrigated and non-irrigated situations. The plot study consisted of fifteen varieties grown in randomized complete block planted in two-row, 40-ft. plots in irrigated and nonirrigated conditions. All of the in-season measurement parameters, as well as final yield and quality, were variety-related.

Introduction

Water is the most common environmental factor that limits crop productivity. Many of the exotic relatives of domestic cotton (genus *Gossypium*) are well-adapted to heat and drought stress, but domestication and selection for crop yield have narrowed the genetic variability for drought resistance in modern cultivars. In addition, new varieties have limited in-season growth comparisons with other competing varieties, due to the large amounts of time required to make growth measurements.

Drought tolerance is attractive both for dryland growing conditions and during times of water shortage. Identification of stress mechanisms can also help in the selection for attributes that will improve yield stability under water limiting conditions. This work will improve our knowledge of physiological parameters that may identify adaptations to water deficit and improved drought tolerance.

Several types of adaptations to water stress have been observed in cotton, including shifts in fruiting patterns (including leaf or fruit abscission), osmotic regulation, changes in leaf expansion, decreased transpiration rates, and changes in partitioning of carbohydrates (Dumka et al., 2004; Gerik, 1996; Guinn and Mauney, 1984; Ritchie, 2007). Identifying the specific adaptation(s) that are operational in particular genotypes, together with their influence (if any) on other aspects of plant productivity and quality, facilitates selection for those adaptations that are most likely to result in more water efficient but still commercially acceptable cotton. We seek to characterize the mechanism(s) used by cotton varieties in adaptation to or tolerance of drought stress and associated temperature stress.

Some specific outcomes that we expect to result from this research are the identification of plant stress response mechanisms that can be used as screening tools to select cotton for improved drought tolerance, the addition of in-season physiological parameters to the cotton breeding equation, and cost analysis of the yield and quality parameters in each variety.

Materials and Methods

This was the continuation of a project that was begun in 2008, but began its funding cycle in 2009. In 2008, 12 varieties were planted in randomized complete block designs with 4 replicates in irrigated and non-irrigated fields. The tillage was conventional to allow consistent germination, and production practices were standard for Tifton with preventative weed and insect sprays. In 2008, a height-adjustable research cart was used as a platform to carry a GreenSeeker portable spectrometer, a DataQ DI-710 datalogger, Apogee Instruments SI-111 IRT sensor, Trossen Robotics distance sensor, Apogee Instruments Quantum sensor, and Apogee Instruments Line Quantum sensor. In 2009, the instrumentation was mounted on a Spider research sprayer, and the measurements were conducted on-the-fly. Because of the increased speed of the system, it was possible to collect all of the samples for both the irrigated and dryland plots quickly (<30 minutes per location).

Each instrument was chosen because of its ability to measure a specific plant growth parameter. The GreenSeeker measures NDVI, a vegetative index based on crop reflectance commonly used to estimate crop growth and leaf area. The distance sensor measures the distance from the cart platform to the cotton canopy, allowing the calculation of crop height without having to pause for ruler measurement. The IRT sensor measures plant temperature (temperature is an indicator of crop stress, particularly water stress). The light sensors allow the measurement of light capture by the plant canopy (light capture is related to plant size and health). The Apogee Instruments Quantum sensor and the Apogee Instruments Quantum Line sensor collected radiation capture using the equation ($1\text{-radiation}_{\text{transmitted}}/\text{radiation}_{\text{incoming}}$). Calibration and additional ground-truthing methods were used to verify remote sensing measurements.

Measurements were collected near noon during both growing seasons by either pushing the research cart or driving the sprayer down each row center and collecting data on the DI-710 datalogger ported into Excel. Each plot had twenty measurements at 0.2 second intervals, which were averaged for the plot mean. In the irrigated study, a 5^{th} rep was used for destructive sampling in 3-ft sections. Leaves and fruit were removed from the stems, and the plant parts were dried and weighed to determine the relative fraction of these above-ground components at each sampling date. At the end of the season, an additional destructive sample was collected from each plot for box mapping.

In 2008, the relationships between all parameters measured were examined in this study. Several interesting results were seen in-season. First, NDVI tended to plateau or reach a maximum at about 56 cm in height. NDVI has been criticized in the past for not being sensitive to higher levels of vegetative cover, but it is a widely used standard.

Radiation capture appeared to be sensitive to a wider range of plant height, suggesting that this measurement may give a more accurate full-season view of crop growth than simple overhead NDVI ratings. In 2009, radiation capture did not reach a maximum until about 75 cm plant height or higher, depending on the variety (Figure 7). The relationship between radiation and plant height was also variety-specific, as shown in Table 3. The slope of the relationship between height and radiation capture was almost twice as high for some of the varieties as others, and the equation fit, as determined by the r^2 values, was high for each individual variety (0.690 to 0.888).

Slopes for the dryland test were also variety-specific (Table 3), although the goodness of fit based on the r^2 values was lower overall (r^2 = 0.38 – 0.78). Two of the varieties had similar radiation capture:height slopes for both the irrigated and dryland treatments, and we were curious about whether this seeming resistance to changes in morphology due to water stress might result in more yield stability for these varieties. The relationship between the radiation capture:height slopes was compared with the ratio of yield between dryland and irrigated locations in Figure 8. The varieties with the most similar radiation capture:height relationships actually had the poorest yield stability. This suggests that adaptive responses made by the plants, such as a more erectophile phenology or smaller leaves, may improve yield stability in response to water stress. This will be analyzed for the 2008 data to test this trend.

Crop temperature was of added interest, because it was less closely tied to either crop height or radiation capture, but followed the same general pattern. This suggests that temperature may allow the detection of stress even in tall or lush canopies, even in the humid climate of South Georgia.

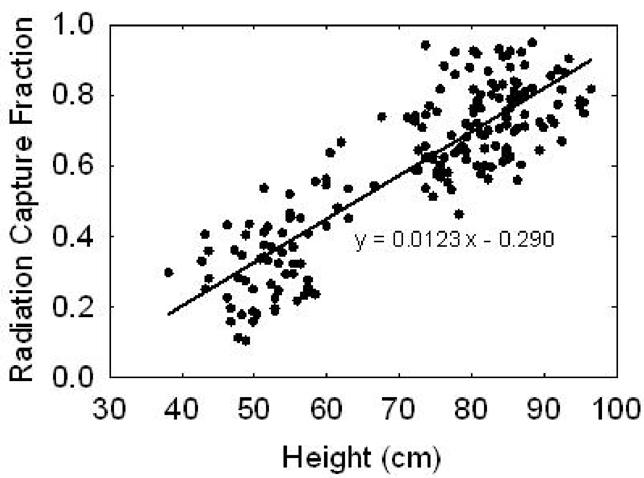

Figure 7. Pooled relationship between radiation capture fraction and plant height (cm) for the irrigated plots in 2009.

Table 3. Relationship between height (x) and radiation capture (y) over the 2009 growing season for both irrigated and non-irrigated pots.

	Irrigated Rad'n Capture vs. height (cm)			Non-Irrigated Rad'n Capture vs. height (cm)		
Variety	Slope	Intercept	r^2	Slope	Intercept	r^2
ST 5327 B2RF	0.0088	-0.029	0.69	0.0078	0.224	0.66
PHY 565 WRF	0.0099	-0.115	0.714	0.0053	0.407	0.531
09R621 B2R2	0.011	-0.2	0.888	0.0058	0.305	0.432
DP 555 BG/RR	0.011	-0.183	0.857	0.0068	0.308	0.699
BCSX 1010 B2F	0.011	-0.186	0.803	0.0112	0.02	0.765
PHY 375 WRF	0.012	-0.255	0.836	0.0061	0.358	0.58
DP 174 RF	0.012	-0.231	0.699	0.0069	0.301	0.62
DP 0949 B2RF	0.012	-0.363	0.756	0.006	0.333	0.38
DP 161 B2RF	0.013	-0.342	0.807	0.0067	0.302	0.559
PHY 480 WR	0.013	-0.329	0.776	0.0089	0.153	0.778
ST 5288 B2F	0.015	-0.533	0.789	0.0082	0.187	0.555
DP 0935 B2RF	0.016	-0.493	0.71	0.0067	0.333	0.662
ST 5458 B2RF	0.017	-0.536	0.751	0.0096	0.181	0.628
DP 164 B2RF	0.017	-0.623	0.846	0.0039	0.453	0.473

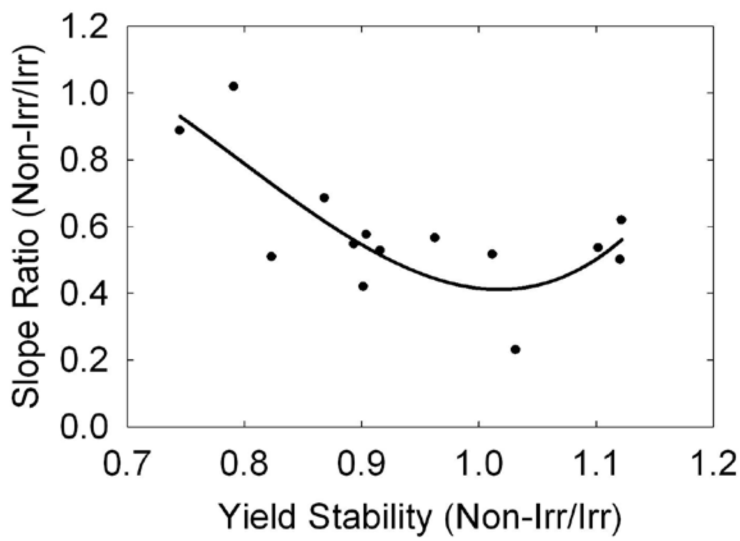

Figure 8. Comparison of the ratio of radiation capture:height slope to the ratio of yield between non-irrigated and irrigated varieties.

Yield Distribution

Yield distribution is a complex factor and difficult to summarize. Table 2 shows the relative yield distribution of all of the varieties to DP555. DP555 was chosen for the comparison, since it is currently the most commonly grown variety in Georgia, and it has a very distinct yield distribution. DP555 produces less cotton on the lower nodes and more cotton at the upper nodes than other commercial varieties, so the relative distribution of the other varieties to DP555 is of some interest. Relative distribution was calculated as the 1st position boll number at each node of DP555 minus the 1st position boll number of the other variety listed in the table. As shown in Table 2, some of the varieties (most notably 09R621) produced substantially more fruit near the base of the plant than DP555. Conversely, all of the varieties produced less fruit at the top of the plant than DP555, with 11 of the varieties significantly different from DP555 from node 19 to node 21.

Table 4. Relative 1st position yield distribution by node for 2009 varieties compared to DP555BG/RR under irrigated conditions.

	Relative 1st Position Yield Distribution by Node (DP555-Variety in Column)												
node	PHY 480	DP 09R621	BCS 1010	DP 0935	DP 0949	DP 161	DP 164	DP 174	PHY 375	PHY 565	ST 5288	ST 5327	ST 5458
5	-0.25	-5.25**	-0.25	-0.50	-0.50	-2.00*	-0.25	-0.50	-1.00	-1.00	-1.75†	-1.75†	-1.25
6	-1.00	-5.25**	0.00	-2.50†	0.25	-1.50	0.50	-1.25	0.00	0.50	-2.75†	-1.50	-1.25
7	-0.75	-3.00*	-1.00	-2.75†	0.00	-2.50†	0.25	-2.75†	-2.25	-1.00	-1.75	-3.00*	-2.00
8	-1.50	-1.75	0.75	-1.25	-0.25	-3.75**	-1.75	1.00	-0.75	-0.25	-2.75*	-3.50**	-2.00†
9	-0.75	3.50±*	2.00	-0.50	0.75	1.25	0.25	3.50**	-0.75	1.50	1.00	0.25	1.75
10	1.00	-0.50	1.50	-0.50	-0.75	-1.00	-1.25	1.75	-1.25	0.25	0.25	-1.00	-0.75
11	1.25	-0.50	0.25	0.00	-1.00	-2.00	-2.25†	1.50	0.25	-0.50	0.75	-0.50	-0.50
12	0.75	-1.50	1.75	-0.25	-0.50	-0.75	-1.50	1.00	0.00	0.75	-1.75	-1.00	0.50
13	-0.75	-0.25	0.75	0.75	-2.00	-0.75	-1.25	1.00	0.25	1.00	-1.00	0.25	-0.50
14	2.00*	2.00*	2.00*	2.25*	0.75	1.25	0.00	2.00*	0.00	0.75	1.25	1.25	2.50*
15	0.00	0.25	0.75	2.25*	-0.75	1.00	-1.00	0.75	1.00	0.75	0.50	1.75	1.75
16	1.00	3.50**	2.00†	3.25**	0.75	1.25	1.75	3.00**	3.50**	1.25	1.50	2.75*	3.50**
17	1.50	2.00†	1.25	1.75	1.00	1.25	1.00	1.25	1.75	-0.50	0.25	1.75	2.75*
18	1.50	1.50	1.50	0.75	1.25	1.75†	1.25	1.00	2.50*	0.75	1.00	2.50*	2.25*
19	1.75*	1.75*	1.75*	1.50*	2.50**	1.25†	1.25†	2.00**	1.75*	1.00	1.00	2.25**	1.50*
20	2.25**	2.75**	2.25**	2.75**	2.25**	2.00**	1.25*	2.50**	2.25**	2.00**	1.50*	2.50**	2.50**
21	4.25**	4.50**	4.25**	4.50**	4.50**	3.50**	3.75**	4.50**	4.25**	4.00**	3.50**	4.25**	4.25**

** Significantly different at P<0.01
* Significantly different at P<0.05
† Significantly different at P<0.10

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