A NOVEL SCREENING METHOD OF 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. The identification of these changes can help with the selection of varieties both in breeding programs and in grower selection for desirable attributes. We propose a method for screening large numbers of plots using multiple remote sensing technologies to identify crop growth habits that contribute 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. The study was replicated in a irrigated and non-irrigated scenarios. Instruments to detect the normalized difference vegetation index (NDVI), plant height, plant temperature, and plant light capture were used to track the growth and health of the varieties during the season. At the end of the growing season, crop yield and quality were measured for each variety, and these were compared with the in-season measurements. We found that all of the measurements had unique relationships with the final growth and yield of the cotton varieties, suggesting that with more familiarity, this can be used as a valid screening method in the future.

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:

(1) Identification of plant stress response mechanisms that can be used as screening tools to select cotton for improved drought tolerance.

(2) The addition of physiology to the cotton breeding equation.

(3) Cost analysis of the yield and quality parameters in each variety.

Materials and Methods

This study was conducted during the summer of 2008. A 3-foot wide aluminum adjustable height research cart with a platform on top was used as a platform for the sensing equipment. The cart was designed to allow it to move over the top of a single cotton row without touching the cotton. The cart was designed by the University of Georgia Machine Shop in Athens, Georgia. Equipment on the cart included a DataQ DI-710 datalogger (DataQ Instruments, Akron, OH), GreenSeeker spectrometer (NTech Industries, Inc., Ukiah, CA), a SI-111 IRT sensor, quantum sensor, line quantum sensor (Apogee Instruments, Logan, UT), and a distance sensor (Trossen Robotics, Inc., Westchester, IL).

The GreenSeeker measures NIR and red reflectance from the plant canopy. Vegetation indices, such as the normalized difference vegetation index (NDVI) are calculated from these reflectance values. In our study, we used the NDVI (NIR-Red)/(NIR+Red) to measure canopy growth. The IRT sensor measures thermal infrared emittance, which is used to calculate temperature to within 0.2 ^{o}F. The line quantum sensors measure incoming light, and light capture by the plant is measured as 1-$light_{transmitted}$/$light_{incoming}$, where $light_{incoming}$ is the measurement of light above the crop canopy and $light_{transmitted}$ is the measurement of light under the crop canopy. The distance sensor measures distance based on sonar, and we calibrated distance measurements in a controlled environment to the output signal. Variance in the controlled system was +/- 1 inch. The datalogger was connected by a USB cable to a Sony Vaio handheld computer mounted on the research cart. All of the sensors except for the GreenSeeker were connected to the datalogger, while the GreenSeeker was connected through a separate USB cable to the computer. Twenty measurements in each plot were collected while the cart moved through, and the measurements were averaged to give an integrated measurement of each sensor per plot.

Both irrigated and non-irrigated plots were harvested with JD 9930 research spindle cotton picker. The picker has been customized, the auger has been removed from the basket and a solid shoots implemented into the basket for individual plot bagging purposes. The picker enables for production equivalent harvesting.

The cotton was ginned at the University of Georgia's Microgin. There quality sub-samples were collected and sent for further lint assessment at the USDA Classing Office in Macon, GA.

From each plot three feet of plants were removed for boxpicking. Boxpicking is the hand removal of the seed cotton and is separated by node and position. Plant mapping consisted of removing each individual boll from a plant and placing the boll in a grid box compartment that corresponded to the main-stem node (the cotyledon node being 0) and fruiting position. A marker was placed in the compartment for each fruit as well, allowing measurements of total boll number by node and position. The removed fruit was weighed by node and position to measure boll mass by node and position. Fruiting positions greater than three were rare, and were combined with the third position bolls when observed. Bolls produced by vegetative branches were placed in a separate compartment to minimize the confounding influence. One drawback of plant mapping method is that some bolls and locules come off during the harvest, transport, and storage. Special care was taken to minimize these losses, and the lost cotton in each bundle was measured. The cotton will be hand ginned, and lint and seed weights will be taken for data.

Results

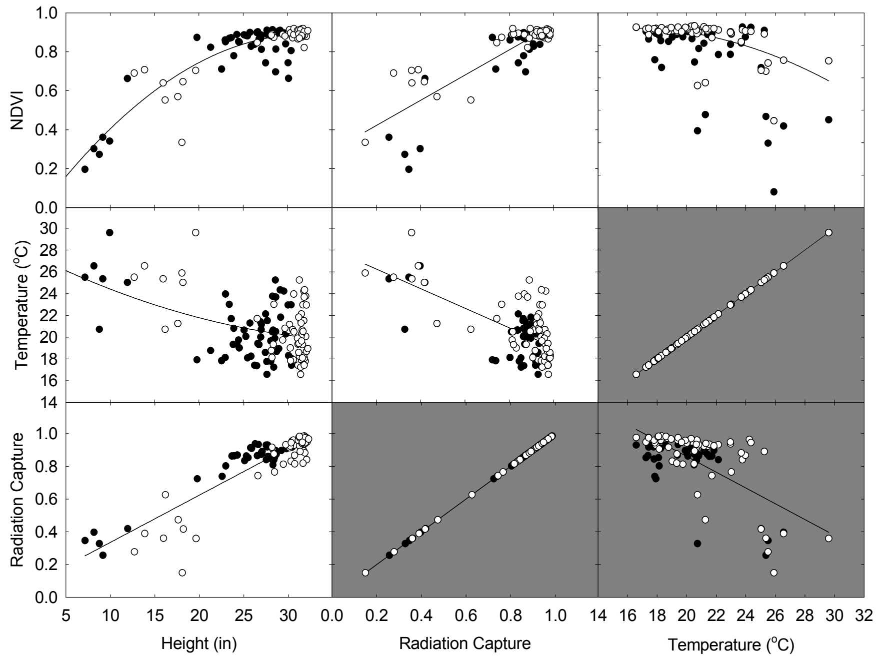

Figure 3. Relationship between NDVI, height, temperature, and radiation capture

The relationship between height and NDVI became nonlinear at about 22.5 inches. The NDVI measurements stayed constant after this point while the plant continued to grow taller. Radiation capture and NDVI were linearly correlated, and temperature was negatively correlated with NDVI.

Height and temperature were negatively correlated. As the height increased the temperature of the plants decreased. Radiation capture and temperature also had a negative slope. The height and radiation capture had a positive slope.

In 2008, the relationships between all parameters measured were examined in this study (Figure 2). Several interesting results were seen in-season. First, NDVI tended to plateau or reach a maximum at about 22 inches 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. 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.

Irrigated Plots July 9, 2008

Variety	Height (in)	NDVI	Temp (°C)	Radiation Capture	Lint Yield Lbs/acre	Micronaire
1	26.4 AB	0.886 A	19.8 CD	0.118 BC	1746 A	3.8 CDE
2	27.1 AB	0.821 A	20.2 CD	0.109 BC	1448 BC	3.83 CDE
3	8.2 C	0.258 B	24.3 AB	0.477 A	815 D	3.38 F
4	27.8 AB	0.875 A	20.5 BCD	0.06 C	1443 BC	4.13 ABC
5	28 AB	0.891 A	18.9 CD	0.116 BC	1378 BC	4.23 AB
6	26.6 AB	0.861 A	21.6 BCD	0.059 C	1402 BC	4.13 ABC
7	26.6 AB	0.8 A	19.8 CD	0.14 BC	1408 BC	3.55 EF
8	28.2 A	0.892 A	21.8 AB	0.05 C	1577 AB	3.85 BCDE
9	26.8 AB	0.818 A	17.6 D	0.082 C	1495 ABC	3.9 ABCDE
10	7.8 C	0.345 B	25.7 A	0.336 AB	964 D	3.63 DEF
11	25.2 B	0.871 A	17.9 CD	0.078 C	1291 C	3.78 CDE
12	27.4 AB	0.844 A	21.5 BCD	0.114 BC	1540 ABC	4.25 A
13	25.4 AB	0.863 A	19.9 CD	0.035 C	1408 BC	3.9 ABCDE
14	28.2 A	0.877 A	21.9 AB	0.068 C	1529 ABC	3.7 DEF
15	25.9 AB	0.848 A	19.1 CD	0.052 C	1428 BC	3.98 ABCD

All measurements from the research cart detected differences between varieties. Varieties 1 and 8 prove to be the highest yielding in our study. The varieties proving to have the lowest yields were 3 and 10. All parameters collected differed dramatically except for NDVI and micronaire compared to other varieties.

Discussion

This was the first year of a multi-year study testing this system of screening methods of water stress as a practical solution of in-season growth measurements over a wide area. Further analysis and improved techniques will improve and quantify measurement in the upcoming year. Future plans with this project include measuring the interaction of water stress with variety, mounting these instruments on a Spider research sprayer, and comparing these with more quality parameters.

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