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SOIL, LEAF, AND SPECTRAL INDICATORS OF IMPENDING WATER STRESS

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Abstract

Drought conditions and water demands from nonagricultural sources can limit the water available to grow a cotton crop during a given year. In water-limited situations, crop yield is affected by the severity and timing of drought events. The effects of water stress on cotton (DP 555 BG/RR) were studied at various stages of plant growth using soil moisture, plant evapotranspiration, and remote sensing measurements of plant health. In another experiment, the effects of irrigation rate during the growing season were measured with irrigation rates of 160%, 100%, and 50% of normal, as well as an unirrigated treatment. Results from these experiments suggest that plants can recover from short periods of water stress; however, fruit development and retention can be affected by these events.

Introduction

South Georgia typically receives about 50 inches of precipitation per year, more than twice the amount needed to grow a quality cotton crop. However, the sandy Coastal Plain soils hold only one inch of water per foot. Extra water runs off or leaches through the soil profile, rather than being stored in the soil. This makes stress events possible even during wet years. Irrigation capacity can easily increase yield potential by several hundred pounds during most growing seasons. In addition, soil water availability can influence or even control the production of potential fruiting points and fruit retention. An estimated one-third of the variation in average national yield is associated with the percentage irrigated, because rainfed crops experience droughts of varying severity even during wet years.

The increasing urban demands of water have made the water supply a hot political topic in the southeast, particularly in Alabama, Georgia, and Florida. Despite the above-average precipitation experienced during the summer of 2003, it is likely that water issues will continue to be dominant factors in future cotton production. The establishment of the Stripling Irrigation Research Park in Camilla, Georgia is a conspicuous example of the investment into research to improve irrigation efficiency.

My proposed research continues in the tradition of this research by attempting to improve the understanding of irrigation management through the following objectives:

1. Define the soil water content vs. plant water stress boundary.
2. Compare these measurements to determine plant reaction to water stress.
3. Determine the long-term effects of short-term water stress.

Materials and Methods

Rainout Shelter

Characteristics of water-stressed cotton were determined in concrete-enclosed plots under a mechanical rainout shelter in Tifton, Georgia. Each plot measured 56-¼ square feet (7 ½ x 7 ½ foot) laid out in a 3 x 6 randomized block with 6 treatments and 3 replicates of each treatment. Delta Pine 555 BG/RR cotton seeds were hand-planted on May 7, 2003 in plots with 3 rows spaced 3 feet (0.95 m) apart in a Tift sandy loam soil. The rows, oriented in the east-west direction, were thinned to a population of 9 plants per meter (3 plants per foot) after the stands were established. Mepiquat chloride was applied 7 weeks after planting at a rate of 0.6 L ha^{-1}. Irrigations were performed at about three day intervals to avoid allowing the soil to dry out at greater depths, and consisted of 0.5" to 1.0" waterings, which remained consistent throughout all watered plots on a given day.

Soil water content at depths of 20, 40, and 60 cm was measured in two replicates of each treatment using buried Watermark sensors (Irrometer Company, Inc., Riverside, CA) and a handheld reader. Leaf water content was measured using a LI-COR 6400 Porometer (LI-COR, Inc., Lincoln, NE). Leaf solute concentration was measured on an upper unshaded leaf from each plot using calibrated leaf-cutter psychrometers (JRD Merrill, Logan, UT). Spectrometer (Apogee Instruments, Logan, UT) and Sony DSC-717 digital camera (Sony Corp., New York City) measurements of canopy ground cover and plant health were used to identify the onset of water stress. Measurements began 35 days after planting and continued at 3 to 4 day intervals as weather permitted. Measurements were made between 1230 and 1430 hours to minimize solar angle effects of spectrometer measurements and keep conductance measurements consistent. Plant growth estimates with the spectrometer were made by using the normalized difference vegetation index (NDVI), which uses a normalized ratio of visible and near-infrared reflectance ((Near-infrared – Visible)/(Near-infrared + Visible)).

Variable Rate Center Pivot

Characteristics of water-stressed cotton were determined in field research that was conducted at the Stripling Irrigation Research Park near Camilla, Georgia using a variable-rate center pivot and plots laid out with four water level treatments: 160%, 100% control, 50%, and no irrigation appplied. Soil water content, leaf water content, leaf solute concentration, and ground cover measurements were performed in all four replicates of each treatment using the same instrumentation as in the Tifton Rainout shelter experiment. Measurements began 37 days after planting and continued as weather permitted until 85 days after planting. Measurements were made within two hours of solar noon on sunny days to minimize the effects of solar angle on spectrometer measurements and to keep conductance and soil water content measurements consistent.

Results and Discussion

Rainout Shelter

Water stress was detected using soil water content estimates, porometer conductance readings, and overhead imaging techniques during the first two stress treatments. These evidences of stress included more negative tension readings of soil water content, decreases in leaf conductance, and decreases in NDVI. Soil water content for all depths increased over time with water stress, but the Watermark readings at the 20 cm depth showed the quickest response to both drought and water addition, followed by both the 40 cm depth. The 60 cm depth showed a noticeable lag (several days in some cases).

NDVI measurements showed a tendency of stressed plants to increase growth after irrigation was reinstituted. After the recovery period, the NDVI was indistinguishable between stressed and unstressed plots for the remainder of the growing season (Figure 1).

Variable Rate Center Pivot

Water stress was detected on the unirrigated plots on day 53 after planting (Figure 2). Rain events between day 54 and day 73 prevented further measurements of the onset of water stress in these plots. However, measurements on day 73 showed a complete recovery of the water-stressed treatment based on NDVI and porometer readings. Final yield differences were not statistically significant between any of the treatments, suggesting that early treatment of water stress can help cotton plants recover most or all of their yield potential in the humid Coastal Plain climate of Camilla, Georgia.

References

Cutler, J.M., and D.W. Rains. 1977. Effects of irrigation history on responses of cotton to subsequent water stress. Crop Sci. 17:329-334.

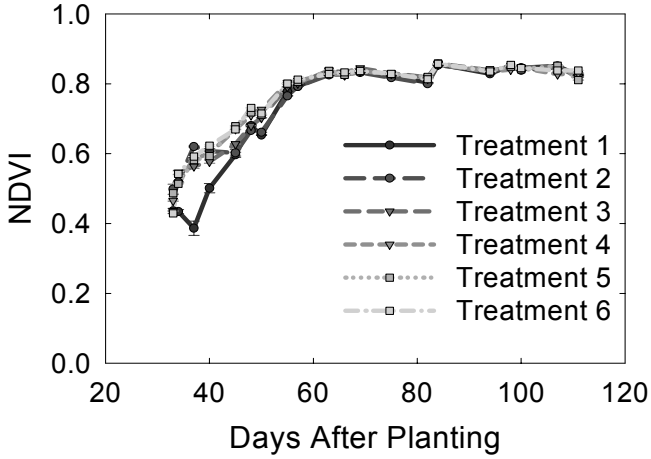

Figure 1. Comparison of the NDVI vegetation index for all treatments in Tifton rainout shelter. Treatments 1 and 2 showed a significant decrease in NDVI due to water stress during the time that irrigation was witheld from them.

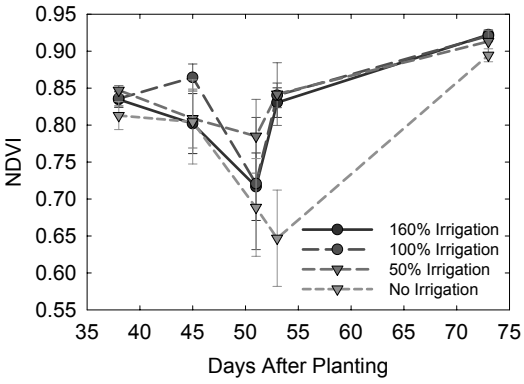

Figure 2. Comparison of NDVI for 4 irrigation treatments at Camilla, Georgia. Water stress was evident in the unirrigated treatment on day 53 by a decrease in NDVI and an increase in the variation between replicates in this treatment.