DETECTION OF WATER STRESS IN COTTON USING MULTISPECTRAL REMOTE SENSING

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Abstract

A study was conducted 1n 1998 to investigate the feasibility of using remote sensing to monitor the onset and progression of water stress in cotton *(Gossypium hirsutum* L.). The study involved thermal infrared observations on a set of field plots subjected to intermittent water stress. Both ground- and aircraft-based observations showed a pattern of increasing canopy temperatures for plots deprived of irrigation, followed by recovery of the plant canopy after irrigation was restored. Differences between temperature conditions observed on the ground and in remote sensing imagery were attributed to canopy ground cover effects.

Introduction

In most arid and semiarid portions of the world, management of irrigation is critical to the successful production of agricultural crops. The yield of crop plants is reduced when they are stressed as a result of insufficient application of water. The determination of when crops will become water stressed has been the subject of numerous agronomic studies aimed at scheduling irrigation to prevent yield loss.

Plant canopy temperature has been recognized as a sensitive indicator of plant water status, and has lead to the development of stress-related indices based on the difference between plant canopy and ambient air temperature (Jackson et al., 1981; Idso, 1982). This concept has been extended to remotely sensed measurements of canopy temperature under incomplete ground cover conditions (Moran et al., 1996). The objective of this presentation is to describe preliminary results from a study designed to monitor the onset and progression of water stress in cotton using frequent remote sensing observations.

Materials and Methods

The study was conducted on a 1.7-acre (0.7-ha) field at the Shafter Research and Extension Center, Shafter, CA, during 1998. The field was planted on April 17 with the Acala cotton variety 'MAXXA' in 30-in (0.76-m) rows. Row direction was oriented north-south. The soil belonged to the Wasco series of sandy loams (coarse-loamy, mixed, nonacid, thermic Typic Torriothents).

The field was irrigated using subsurface drip irrigation, with one drip line located at a depth of 10 in (25.4 cm) below each row. The field was divided lengthwise into 6 plots, each plot being 16 rows wide. Irrigation could be controlled separately for each plot using an automated system capable of replacing each day's evapotranspiration (Phene et al., 1992). A strip of bare soil approximately 40 ft (12 m) wide was maintained weed-free along the north end of the field.

Plots were numbered 1 through 6 from west to east in the field. Two water stress treatments were used in the study. The first, called the early stress treatment, involved turning off the irrigation to plots 1 and 4 between July 20 (day 201) and July 28 (day 209). The second, called the late stress treatment, involved turning off the irrigation to plots 2 and 5 between August 10 (day 222) and August 18 (day 230). Irrigation was maintained at levels sufficient to prevent water stress throughout the season in plots 3 and 6 and in the other plots before and after their respective stress treatments.

Thermal infrared imagery of the study field was obtained weekly during most of the growing season, and daily (except weekends) during the two stress treatments. Imagery was obtained using an Inframetrics model 760 thermal imager (Inframetrics, Inc., North Billerica, MA) flown at 3000 ft (914 m) AGL on a light aircraft. Imagery was obtained at local solar noon (approximately 1:00 pm PDT) to minimize the amount of shadows cast by plants between the rows.

Ground-based measurements of plant canopy and bare soil temperature were made on most days with aircraft overflights using a handheld infrared thermometer (Everest Interscience, Inc., Fullerton, CA). Measurements were made at the same time as the aircraft overflights. Bare soil temperature was measured at 10 random locations within the bare soil strip at the north end of the field. Plant canopy temperature was measured at 10 random locations within each plot. Plant canopy temperature was measured by pointing the infrared thermometer at an oblique angle to the surface of the crop so that leaves would obscure any bare soil surface between the rows of plants.

Results and Discussion

Results of ground-based canopy temperature measurements are shown in Figure 1. After the irrigation system was turned off for plots 1 and 4, the canopy temperature of these two plots was observed to progressively increase over the duration of the early stress treatment. The difference between the canopy temperatures for the irrigated and stressed plots was over 10^{o}C on day 208. A rapid decrease in canopy temperature was observed for plots 1 and 4

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immediately following the resumption of irrigation. Canopy temperatures for all six plots were approximately equal a week after the resumption of irrigation to the stressed plots. A similar response was observed for the late stress treatment involving plots 2 and 5. Although the passage of a cold front on day 227 reduced overall temperatures on the succeeding days, a large temperature difference was still observed between the irrigated and stressed plots on day 229. Canopy temperatures for all six plots were approximately equal 5-6 days after the resumption of irrigation to the stressed plots.

Remotely sensed thermal imagery for the field is shown in Figure 2 for the early stress treatment and in Figure 3 for the late stress treatment. Differences in brightness across the field on day 201 result from variations in canopy ground cover, not differences in leaf canopy temperature. After the irrigation system was turned off for plots 1 and 4, a corresponding increase in brightness (i.e., temperature) of these plots was observed in the imagery (Figure 2). A trace of these features in still visible in plots 1 and 4 on day 215, even though Figure 1 indicates that leaf canopy temperatures for the stressed and unstressed plots were approximately equal on that day. This can be attributed to reductions in canopy ground cover resulting from the stress treatment. A similar response was observed in the imagery for the late stress treatment (Figure 3).

Conclusions

Remote sensing thermal imagery can effectively monitor the onset and progression of water stress in the cotton canopy. Additional analysis is needed to disamabiguate the effects of leaf canopy temperature from canopy ground cover in the remote sensing imagery.

Disclaimer

Mention of trade names in this manuscript does not imply endorsement by the United States Department of Agriculture.

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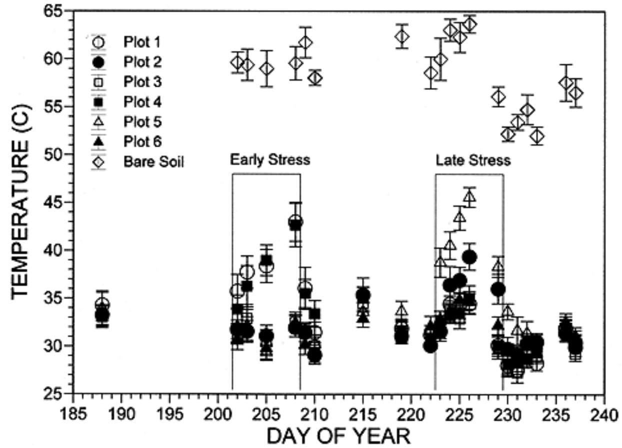

Figure 1. Ground-based canopy temperature measurements for plots 1-6, and bare soil temperatures. Vertical bar on each symbol represents one standard deviation above and below the mean.

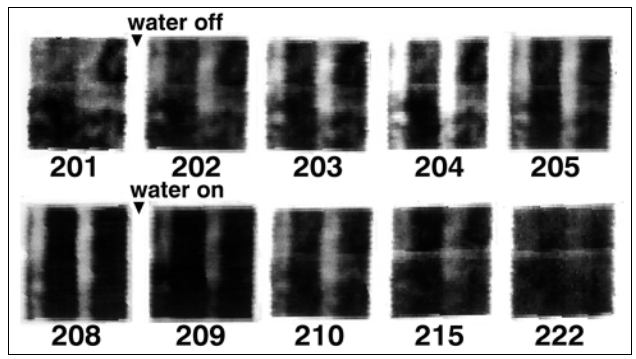

Figure 2. Thermal infrared imagery obtained for the early stress treatment. Darker portions of the image are cooler, brighter portions are warmer. Number under each image is the day of year.

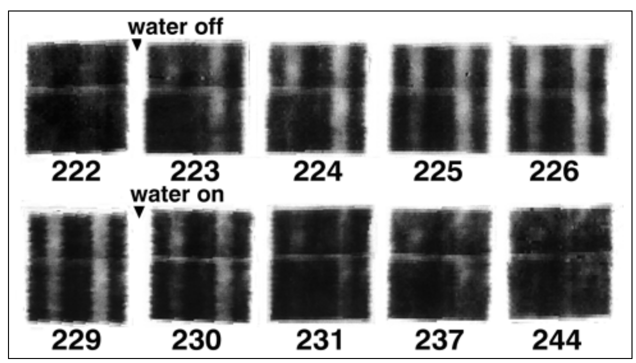

Figure 3. Thermal infrared imagery obtained for the late stress treatment. Darker portions of the image are cooler, brighter portions are warmer. Number under each image is the day of year.