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REMOTE SENSING FOR SITE SPECIFIC MANAGEMENT OF BIOTIC AND ABIOTIC STRESS IN COTTON

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Abstract

This study evaluates the applicability of remote sensing instrumentation for site-specific management of abiotic and biotic stress on cotton grown under a center pivot. Three different irrigation regimes (100%, 75%, and 50% ETc) were imposed in the cotton field to: 1) monitor canopy temperatures of cotton with infrared thermometers (IRTs) to pinpoint areas of biotic and abiotic stresses, 2) compare aerial infrared photography to IRTs mounted on center pivots to correlate areas of biotic and abiotic stresses, and 3) to relate yield and yield parameters relative to canopy temperatures. Pivot mounted IRTs and IR cameras were able to differentiate water stress between the irrigation regimes. However, only the IR cameras were effectively able to distinguish between biotic (cotton root rot) and abiotic (drought) stresses with the assistance of ground-truthing. Cooler canopy temperatures were reflected in higher lint yields. The 50% ETc regime had significantly higher canopy temperatures, which were reflected in significantly lower lint yields when compared to the 75 and 100% ETc regimes. Deficit irrigation up to 75% ETc had no impact on yield, indicating that for this year water savings were possible without yield depletion. Canopy temperatures were effective in monitoring plant stress during the canopy development.

Introduction

In 1996, the Texas Legislature placed water restrictions on the farming industry by limiting growers to a maximum use of 2 acre-foot of water per year in the Edwards Aquifer Region. Since then, maximization of agricultural production efficiency has become a high priority for numerous studies in the Wintergarden Area of Texas. Recent investigations have proposed Site-Specific Management (SSM) as an alternative to address this problem. SSM involves satellite-based remote sensing technology and mapping systems to detect specific areas suffering from stress within a field (i.e. water, insect, and disease stress). Crop canopy temperature has been found to be an effective indicator of plant water stress (Moran, 1994). Coupled with remote sensing technology, this concept allows collection and analysis of temperature data from crops using infrared thermometers (IRTs). IRTs mounted on irrigation systems or operated from aircraft can detect water stress by recording changes in leaf temperature caused by the alteration of the soil-plant water flow continuum (Hatfield and Pinter, 1993; Michels et al., 1999). However, similar plant response can be due to biotic stress (root rot). If remote sensing can distinguish between biotic and abiotic stress, remote sensing equipment and mapping systems can provide an excellent tool for producers to grow cotton under high water use efficiency, by implementing site specific irrigation management.

Objectives

The overall objectives of this project are as follow:

1. Use remote sensing instrumentations for locating areas showing biotic and abiotic stress signs and/or symptoms in a cotton field.
2. Compare aerial infrared photography to IRTs mounted on center pivots to correlate areas of biotic and abiotic stresses.
3. Relate yield and yield parameters relative to canopy temperatures.

Materials and Methods

The experiment was conducted at the Texas A&M Agricultural Research and Extension Center in Uvalde, Texas. Cotton variety Stoneville 4892 BRR® was planted in a circle at 50,000 ppa on 40-inch row spacing and grown under a center-pivot LEPA (Low Energy Precision Application) irrigation system. Furrow dikes were placed between beds to increase water capture and minimize run-off. The soil type is a Knippa clay soil (fine-silty, mixed, hyperthermic Aridic Calciustolls) with a pH of 8.1. Three irrigation regimes (100% ETc, 75% ETc, and 50% ETc) were replicated 16 times in a randomized block design. A 90-degree wedge was divided equally into twelve 7.5-degree regimes, which were maintained at the above mentioned

(ETc) values. Thirty Exergen (Irt/c.01-T80F/27C) infrared thermometers (IRTs) were mounted at approximately 15-foot spacing along the pivot length to scan the canopy temperature as the pivot moved. The IRTs recorded canopy temperatures every 10 seconds, and averaged temperature values every 60 seconds on a 21X Campbell Scientific datalogger. In addition, canopy temperature differences were determined among treatments using a helicopter equipped with an Indigo LWIR (Long Wave-length Infrared) camera operating in the in the infrared band between 8-14 microns. A single 80-foot pass was harvested from each of the plots within the irrigation regimes using a single-row picker. Temperature data were statistically analyzed by ANOVA and separated by Fisher's LSD at $\alpha = 0.05$. Aerial infrared temperature readings were analyzed by using the program Thermogram.

Results and Discussion

Environmental conditions for the 2002 and 2003 cotton season were similar for both years of the study. The minimum and maximum temperatures were normal for the area, but excessive rainfall occurred in the month of July and altered the imposition of differential irrigation regimes for 2002, but irrigation regimes were imposed in 2003 despite excessive rainfall. Significant differences in canopy temperature were detected in all three irrigation regimes, with a linear increase in canopy temperature resulting from a decrease in plant water availability. Extreme temperatures were detected early in cotton development and were related to the detection of bare soil and moisture availability. The IR camera was able to detect distinct canopy temperature differences between all 3 irrigation regimes early in the growing season, but detected no significant differences between the 75% and 100% regimes from the middle until the end of the growing season. Pivot mounted IRTs were effective in detecting significant differences in cotton canopy temperatures between the irrigation regimes. However, weekly IRT readings show that significant differences were not consistent throughout the growing season. IRT maps represent a spatial variation of canopy temperatures. Late in the season no significant temperature differences were found between 100% and 75% ETc. These results were also reflected in lint yields. No significant differences in lint yield were found between the 75% and 100% ETc regimes. Yield from the 50% regime were significantly less than the 75 and 100% ETc regime for 2002, but in 2003 the only significant difference was between the 100% and 50% ETc regimes. Yields were 1160 lb/acre, 1420 lb/acre, and 1600 lb/acre for 2002, and increased in 2003 to 2188 lb/acre, 1910 lb/acre, and 1622 lb/acre for the 50%, 75%, and 100% ETc treatments, respectively. The yield reduction is associated with increased canopy temperatures of the 50% regime. Biotic stress (root rot) was detected early in the growing season with the camera before symptoms could be seen visually. The progress of root rot was monitored until the end of the growing season by comparing the IR images to regular digital aerial images. Abiotic and biotic stress can be differentiated better by the Indigo camera than by the pivot mounted IRTs because of its increased image scanning resolution. The IR camera has a pixel size of 2 x 2 feet while the IRTs have a pixel size of 10 x 10 feet. Disease and water stress can be differentiated from each other using the temperature scale on the color IR image. The root rot temperature was between 37-42^{o}C while the irrigation stress was between 31-35^{o}C. The canopy temperature range for root rot varies with the stage of the root rot infection on the cotton plant and irrigation regime in which it was detected.

Conclusions

- Pivot mounted IRTs and IR cameras were able to differentiate water stress between the irrigation regimes.
- The IR camera was effectively able to distinguish between biotic and abiotic stress with the assistance of groundtruthing. The pixel size of the IRTs prevented the detection of root rot early in the season.
- Excellent correlation exists between canopy temperature and lint yield. Deficit irrigation up to 75% ETc had no impact on yield, indicating that water savings are possible without yield depletion.
- Canopy temperature can be an excellent tool to monitor plant stress.

References

Barnes, E.M., P.J. Pinter, B.A. Kimball, D.J. Hunsaker, G.W. Wall, and R.L. LaMorte. 2000. Precision irrigation management using modeling and remote sensing approaches. In 4th Decennial Nat. Irri. Symposium. 332-337.

Hatfield, J.L., and P.J. Pinter, Jr. 1993. Remote sensing for crop protection. Crop Prot. 12: 403-413.

Michels, Jr., G.J., G. Piccinni, C.M. Rush, and D.A. Fritts. 1999. Using infrared transducers to sense greenbug (Homoptera: Aphididae) infestations in winter wheat. Southwestern Entom. 24: 269-279.

Moran, M.S. 1994. Irrigation management in Arizona using satellites and airplanes. Irrig. Sci. 15:35-44.

Schepers, J.S., and D.D. Francis. 1998. Precision agriculture – what's in our future. Commun. Soil Sci. Plant Anal. 29: 1463-1469.

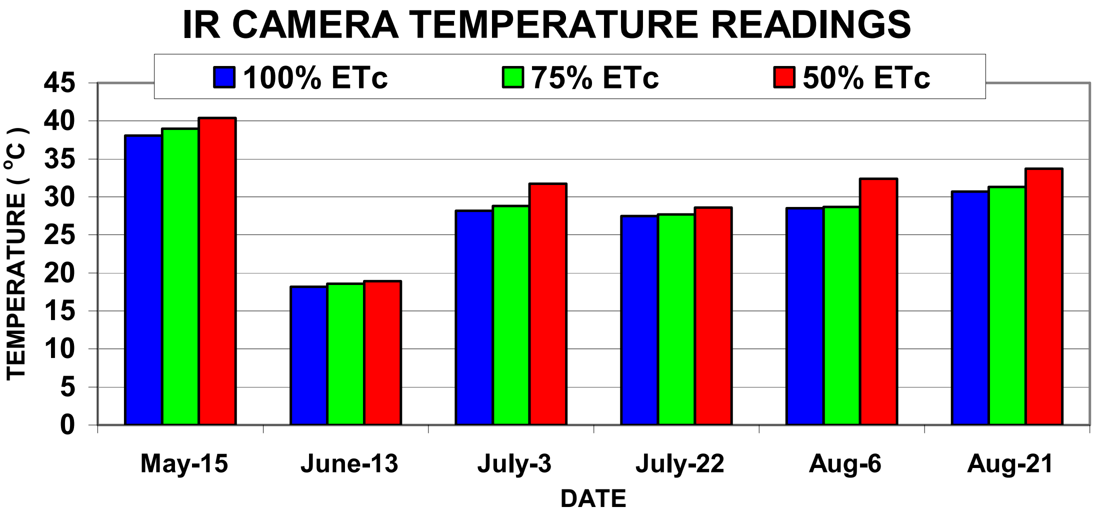

Figure 1. Cotton canopy temperature readings were taken throughout the season with IR camera. There were extreme temperatures early in the growth stage due to the IR camera detecting bare soil. There were no significant differences detected between the 75% and 100% ETc regimes throughout the season.

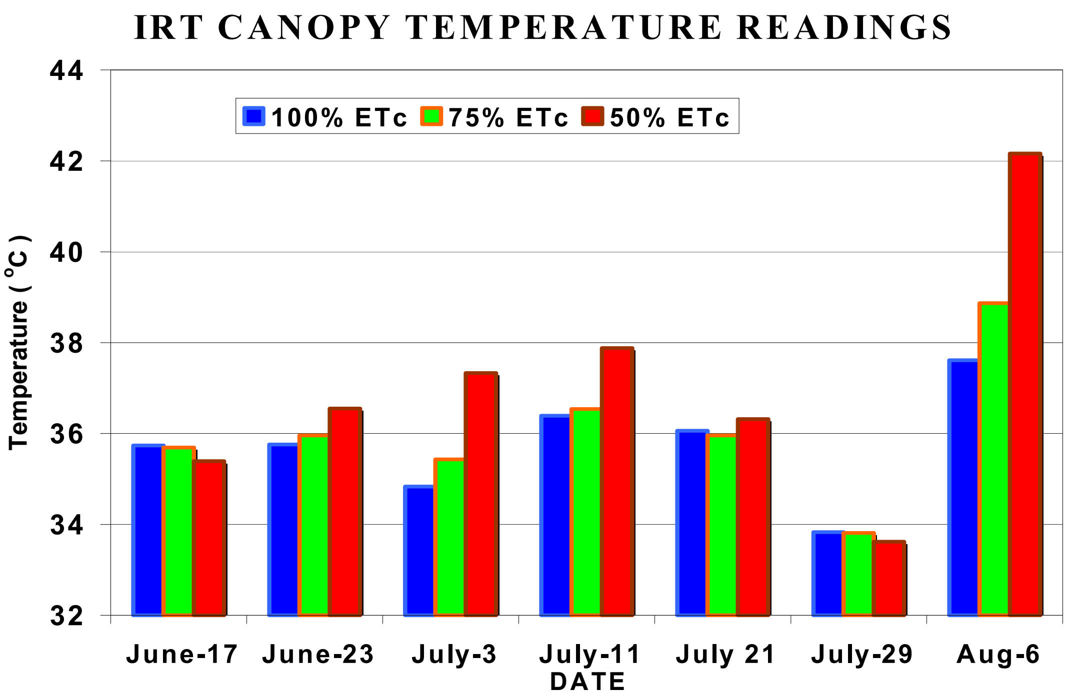

Figure 2. Weekly cotton canopy readings were taken at different stages of development. Significant differences were not detected early in the growing season due to rainfall, but no significant differences were detected between 75% and 100% ETc regimes during the middle of the growing season. These differences occurred again at the end of the growing season.

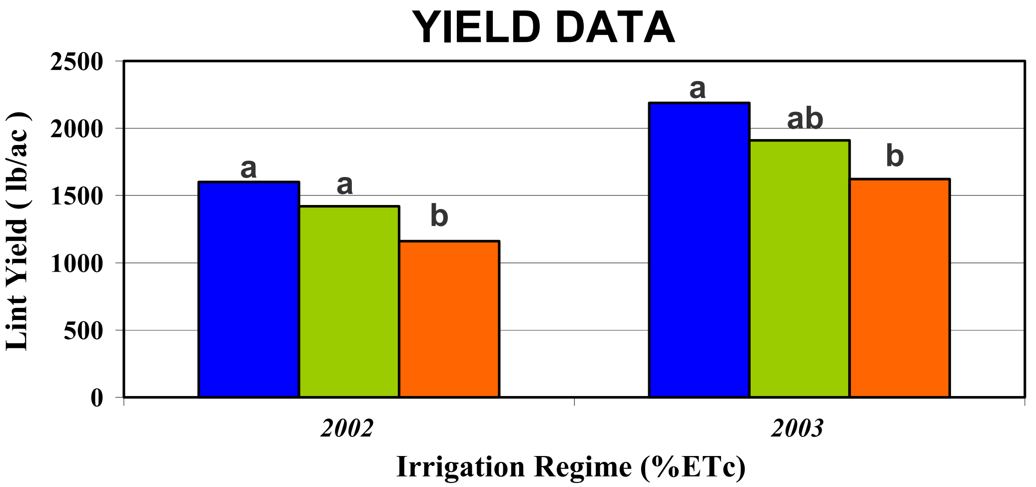

Figure 3. Lint yield comparison for the different irrigation regimes: There were no significant differences between the 75% and 100% ETc irrigation regimes for both years of the study.