DEVELOPMENT OF BIOTIC TO AUTOMATE DRIP IRRIGATION SYSTEMS

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Abstract

The Biologically Identified Optimum Temperature Interactive Console (BIOTIC) is an irrigation scheduling method developed by the USDA/ARS in Lubbock, TX. The method has been extensively tested under experimental conditions and issued a U.S. patent. A multi-year field test of BIOTIC was initiated by a research partnership in a cooperative project funded by the Oklahoma Center for the Advancement of Science and Technology. The purpose of the study is to evaluate BIOTIC in a production environment. Field studies were carried out in 1998 and 1999. In both years irrigation signals were generated almost daily during the growing season (77 of 87 days in 1998 and 72 of 86 days in 1999). The absence of significant in-season rainfall made for essentially complete reliance on irrigation. In both years the dates for which irrigations were not indicated were correlated with periods of low air temperatures. Rainfall events did not result in missed irrigation signals. In both years the system proved to be reliable, providing irrigation scheduling at least 99% of the time and was maintained in the field by non-technical personnel with minimum onsite time required.

Introduction

The BIOTIC protocol (**B**iologically **I**dentified **O**ptimum **T**emperature **I**nteractive **C**onsole) is an irrigation scheduling method developed by the USDA/ARS in Lubbock, TX. The method has been extensively tested under experimental conditions and issued a U.S. patent (Upchurch et. al., 1996). As part of an ongoing effort to promote the commercial development of the BIOTIC, a multi-year field test of BIOTIC was initiated by a research partnership in a cooperative project funded by the OCAST program of the state of Oklahoma (Oklahoma Center for the Advancement of Science and Technology). The research partners are Western Oklahoma State College, Southwest Research and Extension Center, and the USDA/ARS Plant Stress and Water Conservation Laboratory. The producer/private sector partner is Worrell Farms of Altus, Oklahoma.

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The Goals of the Project are to

1. Use BIOTIC technology to schedule irrigation of commercial cotton production land in Southwest Oklahoma.
2. Use education resources to disseminate information about BIOTIC technology to Oklahoma cotton producers.
3. Use the information gained from testing to develop an Oklahoma industry for commercialization of BIOTIC technology for irrigation systems.

The BIOTIC Protocol

Elevated canopy temperatures are widely known to be relatively sensitive indicators of plant water deficits. The BIOTIC determines the need for irrigation on the basis of the canopy temperature of the plant relative to a species specific temperature optimum (the "temperature threshold") and an amount of time (the "time threshold") that the canopy temperature is above the temperature threshold value (Wanjura et. al., 1995). Thus for an irrigation event to be "called" the temperature of the plant must exceed the temperature threshold for a period in excess of the time threshold. This is accomplished through continuous measurement of canopy temperature. High humidity can result in canopy temperatures in excess of the threshold value that are not a result of water deficits. Because of this potential problem, elevated canopy temperatures are continuously compared with relative humidity measurements before they are attributed to water deficits. If it is determined that the elevated temperatures are a result of high humidity they are not "counted" toward an irrigation signal. BIOTIC has been successfully used to schedule irrigation in a number of crop species using both drip and LEPA irrigation systems. In this report the results of the first two years of the field study will be reported.

Materials and Methods

Plant Material and Cultural Practices

Cotton (Deltapine 32B) was grown in a production field on Worrell Farms in Altus, Oklahoma. Cultural practices included normal inputs for irrigated cotton in the region. Seeds were planted on May 12 and 10 (1998, 1999) and the crop was terminated with Finish on September 26 and 27 (1998, 1999). Yield was 1355 kg/ha.

Irrigation

Irrigation was by subsurface drip with daily frequency for 60 days beginning on July 14 and ending on September 12 (DOY 196-256). Each irrigation applied 0.75 cm of water for total irrigation of 45cm.

Temperature Monitoring and Data Collection

The temperature of the canopy was monitored continuously by two infrared thermometers (Exergen model IRT/c 0.2K 80F/27C) suspended over the canopy in a nadir view (the devices have a circular viewing area with a diameter of approximately 8 inches). The temperature was averaged once every 15 minutes. Relative humidity, air temperature, global and net radiation, and rainfall were all monitored in an automated manner. Data was collected with a data logger/controller (Campbell Scientific CR10X). The data logger was connected to a cellular modem for remote access.

Temperature and Time Threshold Values

The temperature threshold of 28˚C and time threshold of 5.5 hours were used in the study. These threshold values have been previously used in irrigation scheduling of cotton with BIOTIC.

Limiting Humidity Calculation

Humidity limitations were calculated on the basis of the temperature optimum of cotton as previously described. A "limiting relative humidity" was established by calculating a relative humidity value for the air temperature at each measurement point that canopy temperature exceeded 28˚C (the temperature threshold), using a "wet bulb temperature" of 26˚C (2 degrees below the temperature threshold). When the "limiting relative humidity" value was below the ambient relative humidity, measured by the BIOTIC device, a relative humidity limitation was noted and the time period of the elevated temperature was not "counted" toward the time threshold.

Results

BIOTIC Interface

Figure 1 represents the BIOTIC display that was used in 1998. The device had two LEDs, one that was lighted whenever the canopy temperature exceeded the temperature threshold and the second that was lighted for 24 hours when the time threshold was exceeded indicating an irrigation signal. This display was deemed to be of limited value because the irrigation indicator was almost continuously lighted. The display was modified in 1999 in an effort to provide more insight into the status of the crop. Figure 2 shows the BIOTIC display that was used in 1999. The digital display shows the real-time temperature as monitored by the IRTs. The accumulation of time relative to the time threshold is displayed in two sets of LEDs. As time accumulates the LEDs are activated sequentially to give an indication of the progress toward the generation of an irrigation signal. The upper series of LEDs shows the current status of the accumulation while the lower series presents the time accumulated on the previous day. At midnight the status of the upper series is transferred to the lower series and the process of accumulation resumes.

1998

The BIOTIC was operational for 86 days between July 1 (DOY 183) and September 27 (DOY 270). Data was collected 99% of the time during this interval with only one interruption (DOY 258). Figure 3a shows the pattern of air and canopy temperatures over the season. The vertical lines on the x-axis indicate the amount and timing of rainfall events. The shaded "boxes" indicate the periods when the BIOTIC did not indicate the need for an irrigation event. There were 11 rainfall events (figure 3a) totaling 4.9 cm during the season, with 65% accounted for by a single rainfall of 3.2 cm on DOY 240. Seven of the rainfalls were trace amounts of less than 0.3 cm. Irrigation signals were generated on 77 of 87 days during the growing season (figure 3a). There were 4 periods for a total of 9 days when irrigation signals were not generated. This represents 10% of the total irrigations that potentially could have been eliminated even in a very harsh year. Figure 4a shows the pattern of occurrence and the duration of humidity limitations over the experimental interval. There were 18 days when a humidity limitation occurred. The total time that humidity was limiting was 8.75 hours representing only 1.1% of the time that humidity could theoretically limit plant temperature. With the exception of DOY 237 and 240 when 120 and 65 minutes accumulated, no single humidity limitation exceeded 60 minutes. At no time was the length of a humidity limitation sufficient to account for the failure to exceed the time threshold and thus humidity was not responsible for "blocking" an irrigation at any time during the season. The daily accumulation of canopy temperature above the threshold temperature is shown in figure 5a. The horizontal line indicates the time threshold value of 5.5 hours (330 minutes). The vertical lines indicate the amount and timing of rainfall events.

1999

The BIOTIC was operational for 86 days between July 1 (DOY 183) and September 26 (DOY 269). Data was collected 100% of the time during this interval. Figure 3b shows the pattern of air and canopy temperatures over the season. The vertical lines on the x-axis indicate the amount and timing of rainfall events. The shaded "boxes" indicate the periods when the BIOTIC did not indicate the need for an irrigation event. There were 15 rainfall events (figure 3b) totaling 7.7 cm during the season. Nine of the events were trace amounts of less than 0.3 cm. Irrigation signals were generated on 72 of 86 days during the growing season (figure 3b). There were 6 periods for a total of 14 days when irrigation signals were not generated. This represents 16% of the total irrigations that potentially could have been eliminated even in a very harsh year. Figure 4b shows the pattern of occurrence and the duration of humidity limitations over the experimental interval. There were 17 days when a humidity limitation occurred. The total time that humidity was limiting was 25.5 hours representing only 3% of time that humidity could theoretically limit plant temperature. On 7 days the humidity limitation exceeded 60 minutes. On DOY 218 a 15-minute humidity limitation resulted in a failure to exceed the time threshold and, thus, an irrigation signal was blocked by humidity on that date. At no other time was the length of a humidity limitation sufficient to account for the failure to exceed the time threshold. The daily accumulation of canopy temperature above the threshold temperature is shown in figure 5b. The horizontal line indicates the time threshold value of 5.5 hours (330 minutes). The vertical lines indicate the amount and timing of rainfall events.

Conclusions

In both years irrigation signals have been generated almost daily during the growing season. The absence of significant in-season rainfall made for essentially complete reliance on irrigation. Under such harsh conditions it is not surprising that irrigation was needed on a daily basis. In both years the dates for which irrigations were not indicated correlated with periods of low air temperatures. None of the missed irrigation signals in either year were related to rainfall events. The system proved to be reliable, providing irrigation scheduling at least 99% of the time and was maintained in the field by non-technical personnel with minimum onsite time required. Instrument failures were minimal and minor. They were detected and repaired on the day of the failure.

References

Upchurch, D. R., D.F. Wanjura, J. J. Burke and J. R. Mahan. 1996. Biologically-identified optimal temperature interactive console (BIOTIC) for managing irrigation. U.S. Patent 5,539.637

Wanjura, D.F., D. R. Upchurch, and J. R. Mahan. 1995. Control of irrigation scheduling using temperature-time thresholds. Transactions of the ASAE , 38(2):4039-409.

Figure 1. The in-field display of the BIOTIC as implemented in 1998 field study. The two LEDs indicate the thermal status of the crop. The thermal stress LED is lighted whenever the temperature of the canopy is in excess of the temperature threshold. The irrigation LED is lighted whenever the 5.5 hour time threshold has been exceeded and an irrigation is appropriate.

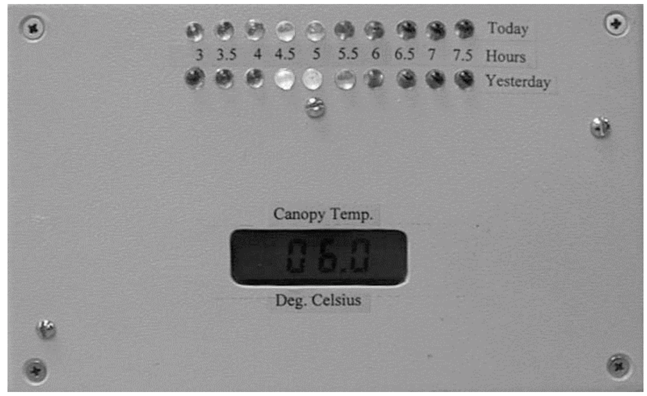


Figure 2. The in-field display of the BIOTIC as implemented in 1999 field study. The digital display indicates the scene temperature of the IRT. The LED series shows the current accumulation of time above the temperature threshold (upper) and the time accumulated on the previous day (lower). The LED indicating an irrigation is turned on at 5.5 hours.

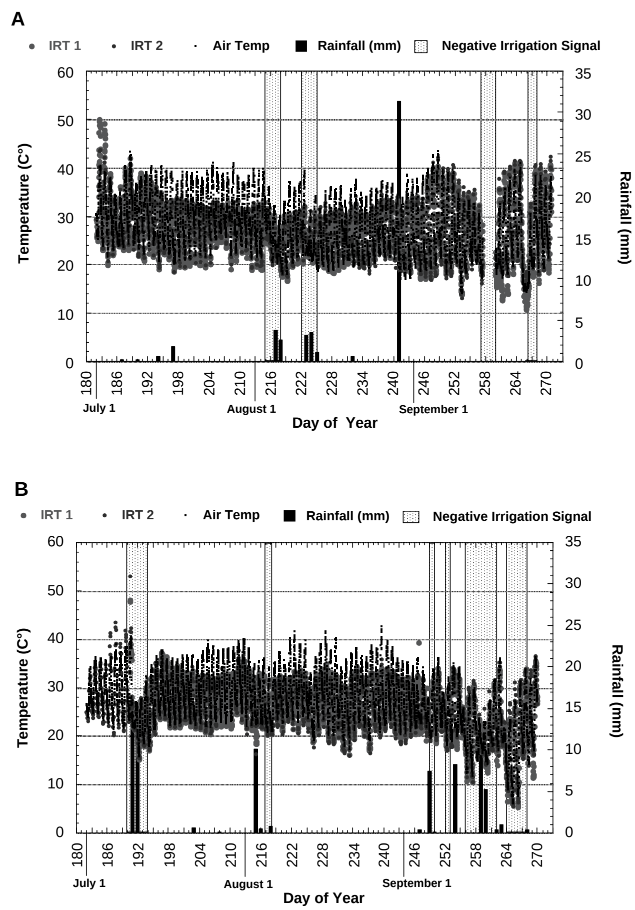


Figure 3. Air and canopy temperatures over the 1998 (A) and 1999 (B) experimental intervals. The vertical lines on the x-axis indicate the amount and timing of rainfall events. The

shaded "boxes" indicate the periods when the BIOTIC did not indicate the need for an irrigation event.

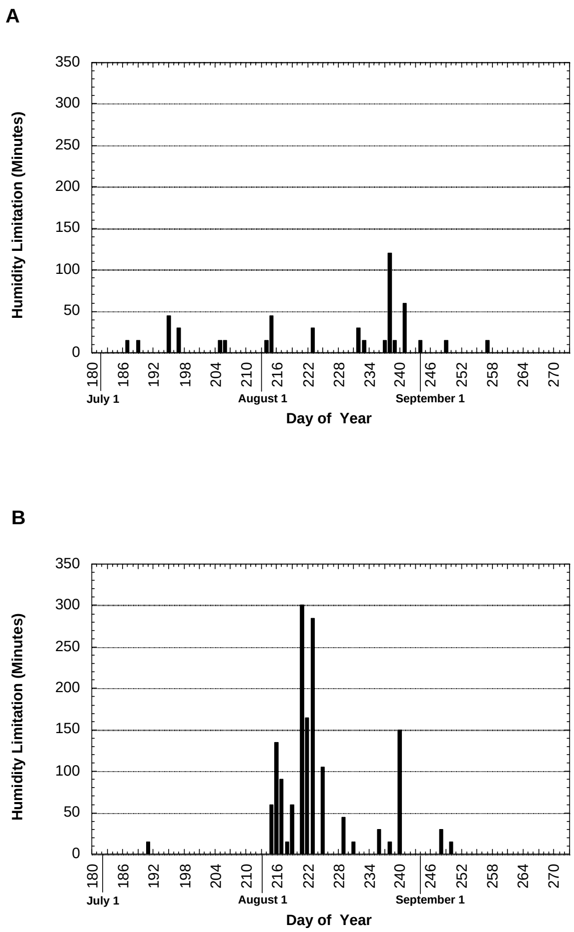
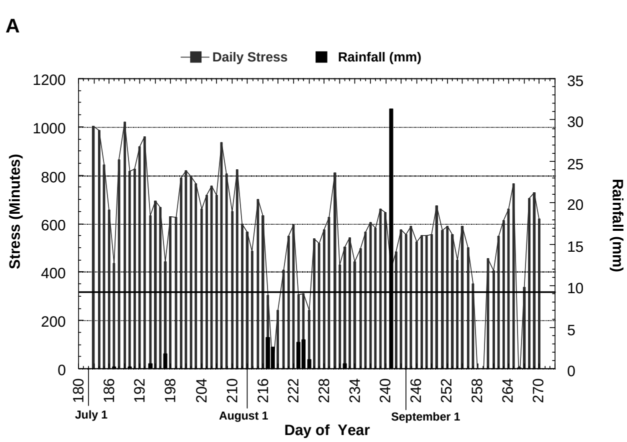


Figure 4. The pattern of occurrence and the duration of humidity limitations over the 1998 (A) and 1999 (B) experimental intervals. Humidity limitations are calculated from the biologically identified temperature optimum, air temperature and the ambient relative humidity data.



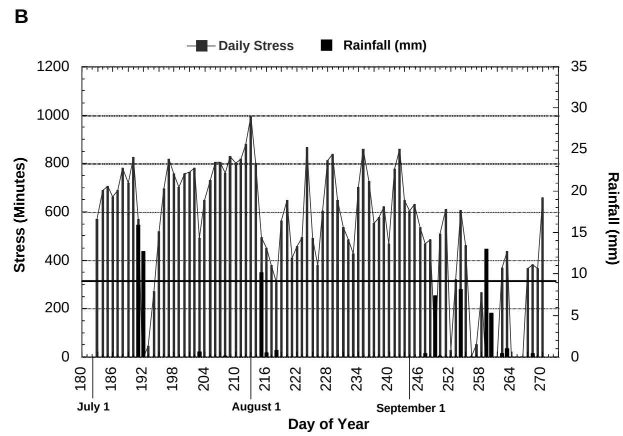


Figure 5. The daily accumulation of canopy temperature above the threshold temperature for 1998 (A) and 1999 (B). The horizontal line indicates the time threshold value of 5.5 hours (330 minutes). The vertical lines indicate the amount and timing of rainfall events.