A METHOD FOR QUANTIFYING CUMULATIVE WATER STRESS IN COTTON

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Abstract

Competition for water supplies has been heightened in recent years and is particularly true in regions that produce irrigated cotton. Growing interest has developed in identifying cotton varieties, Gossypium hirsutum L. and Gossypium barbedense L., susceptible to and tolerant of water stress as a way to maximize yield and minimize production losses when water is limited. Both soil, plant and combination soil-plant based irrigation scheduling approaches have been developed for irrigated cotton that have been shown to be successful to the grower and researcher. We propose a plant based approach that requires monitoring cotton during critical developmental periods in a way that links cumulative crop water stress with field productivity level. Our approach is developed from several years of data obtained from replicated water deficit trial work conducted in California's San Joaquin Valley and we suggest these methods can be useful when transferred to other irrigated cotton growing areas.

Introduction

Water stress evaluation and indexing in cotton has been met with reasonable successes over the past two decades with some of the research being adapted and applied to improving irrigation scheduling on farm. Researchers have incorporated crop water stress evaluation methods that include temperature stress indexing using infra-red thermometry (IRT) and focused on various spectral bands used in developing remote sensing data. Drawbacks to RS/IRT: sample size, time, and processing-interpretation.

Monitoring plant water potential has also shown some promise and is currently being used routinely by researchers, agronomist and growers for making determinations on scheduling irrigations with specific production goals in mind. Monitoring leaf water potential using the pressure chamber allows the user to obtain a relatively quick and accurate measurement of plant water status in the sensitivity range that is useful to both growers and researchers. The pressure chamber generally requires small sample sizes and requires little or no supplemental data processing for interpretive needs.

While the pressure chamber has long been a tool for irrigation management in cotton by assisting with proper timing of irrigation events, (Grimes and Yamada,1982*)* additional utility of the measurement has been limited. Some crop managers have used the tool to assist in directing plant growth goals and in turn to crop production goals by regulating crop vigor and the timing of that vigor along with plant growth regulators to improve productivity. But additional water stress management tools are needed particularly as they relate to improving our understanding and management of deficit irrigation treatments when water supplies are limited. A tool that would establish and accurately quantify both intensity and duration of plant water stress would be useful if it was determined to be related to yield and yield loss estimates when deficit irrigation management is required.

Methods

Long-term irrigation management studies were conducted at the University of California's West Side Research and Extension Center in Five Points CA, on deep and well-drained Panoche clay loam soils. Cotton varieties were planted on the 1997 through 2000 season and included the predominant Acala and predominant Pima cotton variety being grown in the San Joaquin Valley each year. From year to year, plot location varied within a one quarter mile radius with generally small differences in soil type and soil water storage. Each year, three to four irrigation treatments were imposed in a randomized complete block design with irrigation management regime assigned as the main effect. Each cotton variety was grown on 4-1 m beds approximately 90 m in length with each irrigation/variety combination replicated 4 times. Four guard rows were placed between each of the irrigation treatments blocks to reduce the chance for lateral water transfer between treatments. Each irrigation event was scheduled using a pressure chamber with the optimum irrigation treatment developed according to UC cotton production guidelines. The optimum irrigation treatment was schedule when LWP readings reached -15 bars for the first irrigation and subsequent irrigations scheduled just prior to LWP reaching -18 bars. The excessive water treatment included one additional late-season irrigation following the ideal termination treatment, while one to two irrigations were withheld on the deficit irrigation treatment(s). Applied irrigation water was measured on each treatment using propeller type flow meters mounted to aluminum gated pipe while crop water stress was measured using the pressure chamber. Following crop emergence, soil water was monitored weekly in each plot using the neutron scatter technology with steel access tubes read every 30 cm to a depth of 240 cm. The crop was grown using production management practices that work to achieve optimum yield. A plant growth regulator (Mepiquat Chloride) was applied most years to the optimum and excessive irrigation treatments according to UC guidelines while no plant growth regulators were used on deficit irrigated cotton.

Weekly measurements of mid-day LWP were conducted during a period that we considered to be most critical to water stress with respect to crop productivity. LWP measurements were initiated when the plants contained 7 to 8 fruiting branches and continued until 14 days past plant cutout. By assuming a linear decline in LWP following an irrigation event we were able to assign a daily value for LWP and accumulated crop stress values that were above a lower threshold of -10 bars. Readings were collected on two plots and replicated with 5 plants per plot.

Results and discussion

There is widespread recognition as well as research data demonstrating that as plant water stress values decrease below LWP of -10 to -12 bars, leaf and stem expansive growth begins to decline with a sharp decline at -15 bars. By accumulating stress bars below a conservative limit of leaf expansive growth we developed relationships between crop productivity and LWP across multiple years with very different climatic conditions, and yield potentials. Data presented in Figure 1 expresses the variation in yield as related to the cumulative stress or stress-bar index that was developed. Although peak yields for the guideline irrigation treatments varied by nearly 1,000 pounds of lint per acre, there was a fair relationship between cumulative bar days and crop productivity.

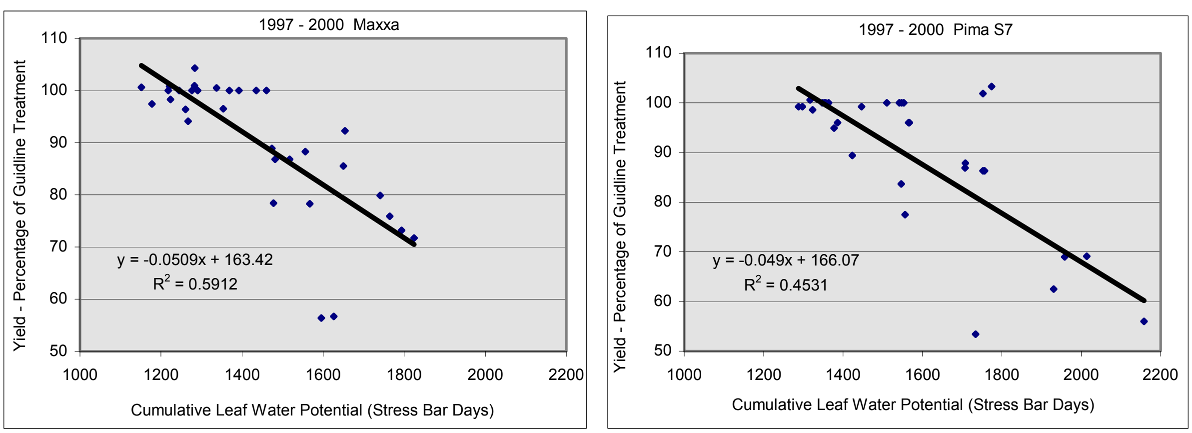

Figure 1. Relative cotton yield and stress bar days developed for each year on deficit irrigated Pima and Acala cotton types.

When year to year effects were isolated by grouping each year of data, a strong correlation was observed between stress-bar days and yield. These data emphasize the variation in yield that occurs from season to season even when soil type, fertility, pest management and soil water regimes are held relatively constant. Nevertheless, we observed that when stress bar days went above 1400 in the Acala cotton varieties and 1500 for the Pima cotton varieties. Yield declines were expected on deficit irrigated cotton and were found to be proportional to the stress bar values.

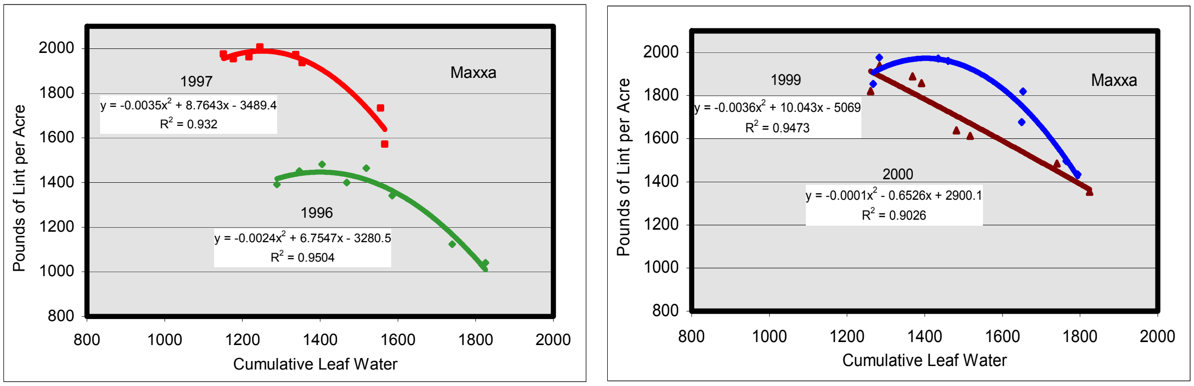

Figure 2. Cotton lint (in pounds per acre) produced for each year over similar water regime ranges.

We suggest that using a stress bar day concept in cotton can be a practical tool to assess the cumulative effects of water stress on crop productivity during the time when the crop is most sensitive to stress events. This approach may be used to improve irrigation scheduling methods in cotton and could be particularly useful in improving the timing of irrigation when deficits are expected. Adjusting the irrigation schedules and volumes in a manner that minimizes the accumulation of stress bar days can yield more flexibility that simply using threshold values for irrigation scheduling events. Depending on plant drought response mechanisms of specific varieties and plant genotypes, this approach can also be useful in distinguishing drought tolerant and drought sensitive cottons especially when compared side by side.

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