Water Stress Effects on Pima Cotton Lint Yields Using Infrared Thermometry to Schedule Irrigations

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Abstract

The Crop Water Stress Index (CWSI) was used to schedule irrigations on Pima S-6 cotton on a commercial scale in Waddell, Ariz. in 1991. The field study consisted of sixteen, one acre, surface irrigated plots. There were four water treatments with four replicates arranged in a randomized complete block design. There were no significant lint yield differences among water treatments. However, an additional two irrigations totalling an acre foot of water were needed to maintain the treatment thresholds.

Introduction

Cotton production economics are experiencing rapid rates of change. Input costs in recent history have increased steadily while the commodity prices have remained relatively constant. Water is the single most costly input into the system. This fact urges producers to maximize system input efficiencies if a profit is to be realized. Many farms now are being serviced by Central Arizona Project (CAP) water. Supply assurance has been reinforced due to the advent of CAP, but delivery and unit prices for the resource have risen significantly with respect to historical precedence. Decreasing supplies, increasing costs and agricultural/ urban conflicts are affecting the price of the water in the region that this field study was conducted. Growers operating under these conditions have a significant economic incentive to carefully evaluate their irrigation management strategy.

In addition, due to the Groundwater Management Act of 1980, four active management areas (AMA) have been created where the ultimate objective is to reduce groundwater extraction to a level of "safe yield" by the year 2025. The law is designed to accomplish its objective in increments of four 10 year management plan periods. We are now engaged in the Second Management Plan (SMP) that ends 31 December 1999. The SMP in the Phoenix AMA on the average, reduces a farm's water allotment from 5.74 acre feet per acre to 4.54 acre feet per acre in the year 2000. Due to a combination of all the factors described, it is crucial that efficient and cost effective water management strategies be identified and implemented if cotton production is to be profitable in the future in central Arizona.

Materials and Methods

The Crop Water Stress Index (CWSI) which correlates thermal infrared canopy temperature to the water content of the air has been used successfully to schedule irrigations on a number of commercially grown crops. The CWSI scale ranges from zero (no water stress) to one (severe water stress). The two driving variables in the CWSI relationship are the foliage temperature minus the air temperature, or delta T, and vapor pressure deficit (VPD). Most plant species exhibit a linear relationship between delta T and VPD. This relationship is referred to as the baseline. The hotter and drier the air (high VPD), the greater the delta T will be under well watered, non-water stressed conditions.

Once a baseline is determined, measurements can be made with a hand held infrared thermometer to determine the actual water status of the plant at a given time relative to the baseline. Previous research has investigated the effects of various degrees of plant water stress at time of irrigation on the lint yield component. These studies concluded that scheduling irrigations between 0.25 and 0.35 CWSI units consistently results in the greatest lint yields. The present field study was intended to further verify previous research results, and test the feasibility of using CWSI to schedule irrigations on a large scale commercial basis.

The CWSI was used to schedule irrigations on Pima S-6 extra long staple (ELS) cotton in 1991. The study was conducted on a commercial farm in Waddell, Ariz. The test consisted of sixteen, one acre, surface irrigated plots. There were four treatments based on plant water stress at time of irrigation, each treatment replicated four times in a randomized complete block design. Targeted CWSI treatment thresholds at irrigation were 0.15 (wet), 0.30 (medium), and 0.50 (dry) CWSI units. The fourth treatment was the standard farm irrigation scheduling practice, and was monitored for CWSI values.

Infrared and vapor pressure deficit measurements were taken between 1100 and 1300 hours a minimum of every other day. Infrared measurements were taken from each corner of the 18 row plots and averaged for a single value. Plots were treated independently due to soil variability. Each plot was irrigated when the targeted CWSI threshold was attained within the respective treatment. This procedure eliminated unacceptable variability that would be encountered if the four replicates were averaged for a single treatment value.

Soil moisture measurements were made regularly with a Campbell Pacific hydroprobe. Soil moisture content was measured in one foot increments to a depth of three feet. Frequent measurements were taken with primary emphasis on the soil moisture content immediately before the scheduled irrigation and again 24 to 48 hours after the irrigation. These measurements were used to determine the soil moisture deficit at time of irrigation for the respective irrigation treatments.

In addition, plant growth and development parameters were measured to determine water stress effects on plant height, number of fruiting branches, and fruit retention or abortion as a function of plant water stress. Routine petiole sampling was performed within all treatments to assure adequate nitrogen status during the growing season.

Results and Discussion

Lint yields were 724, 764, 654, and 713 lbs. per acre for the wet, medium, dry and grower treatments, respectively (Table 1). Regression analysis showed no statistical significance between lint yield and plant water stress (CWSI). Lint yields were relatively low throughout this central Arizona region. As indicated earlier, previous field studies have concluded that maximum yields are attained when irrigations are scheduled between 0.25 and 0.35 CWSI units. The trends to support this are evident in the presently reported yields.

The medium treatment resulted in the greatest yield with irrigations scheduled at 0.28 CWSI units. This yield was 40 pounds greater than the wet treatment with two less irrigations resulting in a water savings of an acre foot per acre. The medium treatment resulted in 50 pounds more lint than the standard farm practice with one less irrigation for a water application reduction of six acre inches per acre.

Although yield differences were not statistically significant, production economics were significant. In this study a yield increase of 50 pounds per acre and six acre inches per acre water reduction equate to a net revenue increase of 75 dollars per acre using a one dollar lint price and 50 dollar per acre foot water costs. In many cases, these economics can be the difference between profit and loss.

There are explanations for the relatively low lint yields experienced in this study. Central Arizona experienced an extremely cool and wet Spring that delayed planting into April. Following planting, April and May conditions also were relatively cool resulting in diminished plant growth and a resultant delay in fruiting. Conditions from June through August were extremely favorable and the vast majority of fruit set occurred during this period. Coupled with these factors, extremely heavy whitefly pressures were encountered in late August. Decisions were made to terminate irrigation in late August to minimize lint quality degradation potential.

Pima cotton is traditionally produced in a long, full season manner due to the indeterminate growth characteristic of the species. Maximum lint production usually is achieved when the production season is extended. This crop was produced under reduced season constraints, accounting for the less than maximum lint production. The planting date was 4 April 1991. With these factors taken into consideration, it may be hypothesized that differences among CWSI treatments with respect to lint yield would have been greater during a more normal growing season.

Another point of interest is the soil moisture content or deficit at time of irrigation for the respective treatments. Measured soil moisture deficits at time of irrigation in a three foot soil profile were 1.82, 2.72, 3.33 and 2.57 inches for the wet, medium, dry and grower treatment, respectively. Each irrigation resulted in a six acre inch per acre application. In order to refill the three foot soil profile in the medium treatment, applications of 3.5 acre inches per acre would result in maximum application efficiencies. This suggests that more frequent shallow irrigations would be desirable. Most commercial irrigation systems are not designed for this level of efficiency and a future consideration may be cost effective system modifications to assure future profitability and sustainability.

It also should be noted that total applied water volumes seem low for maximum lint production potential. Due to the cool wet spring, the crop was planted under dryland conditions into soil moistened with rain water. Pre-season soil probing determined that the effective root zone profile was full and irrigation application would be extremely cost ineffective. Therefore, reported water application volumes do not accurately reflect plant water use. Generally, pre-plant or water up irrigations account for the greatest irrigation application of the season, approaching 10 to 12 acre inches per acre. It could be assumed that a value approaching these could be added to the total water applied.

In addition, as previously indicated, extremely heavy whitefly pressures forced early irrigation termination. Irrigations were terminated on 23 August 1991. A longer production season would have resulted in a greater water application volume.

Conclusions

Scheduling irrigations on Pima S-6 cotton when the CWSI approached 0.30 units resulted in optimum yields. Scheduling irrigations at reduced stress levels actually reduced yield while increasing water application volumes. The CWSI is a viable and practical irrigation scheduling technique that can assist the commercial cotton producer with water management decisions.

Table 1. Effects of scheduling irrigations at various CWSI levels on lint yield, soil moisture deficit, and irrigation practices on Pima S-6 cotton at Waddell, Ariz. in 1991.

Treatment	CWSI at Irrigation	Average CWSI for Season	Lint Yield (lb/acre)	Total Applied Water (in)	No. of Irrigations	Soil Moisture Deficit (in per 3 ft)
WET	0.14	0.06	724	48	8	1.82
MEDIUM	0.28	0.13	764	36	6	2.72
DRY	0.32	0.13	654	30	5	3.33
GROWER	0.16	0.08	713	42	7	2.57

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