Use of Leaf Water Potentials To Determine Timing of Initial Post-Plant Irrigation

A.J. Steger, J.C. Silvertooth, and P.W. Brown

Abstract

Presumably, from a physiological standpoint, early season water stress should be avoided to ensure early fruit initiation, good fruit retention, and optimum yield potential of cotton (Gossypium spp.). This study was conducted to determine the optimum timing of the initial post-plant irrigation and the long term effect of postponement on subsequent plant growth patterns, fruit retention, and yield. A short-season Upland variety, (G. hirsutum L.), DPL 20, was planted on 19 April in Marana, AZ, elevation 1970 ft., on a Pima clay loam (Typic Torrifluvent) soil. Plots (experimental units) consisted of eight 40 in. rows and extended the full length of the irrigation run (600 ft.). Experimental design was a randomized complete block with four replications. Initial post-plant irrigations, designated T1, T2, and T3, were applied when the midday leaf water potential (Ψ_x) of the uppermost, fully-developed leaf reached -15, -19, and -23 bars, respectively. All treatments received the same irrigation regime following the initial post-plant irrigation. Basic plant measurements were taken weekly from each experimental unit. These included plant height, number of mainstem nodes, location of first fruiting branch, fruit retention, number of nodes above the uppermost white bloom, bloom count within a 166-ft^2 area, and percent canopy cover. Soil-water data at seven 25 cm depth increments was collected from a total of 36 access tubes located within the field study, with three tubes per plot. Lint yields (lb. lint/acre) were 1112, 1095, and 977 for T1, T2, and T3, respectively. Yields were significantly lower when the initial post-plant irrigation was applied after Ψ_x dropped below -19 bars, confirming the results of a previous study conducted in 1992. Throughout the growing season, height-node ratios (HNR) of T1 and T2 plants were at or above the upper threshold established for DPL 20, while T3 HNR remained close to the expected baseline. Fruit retention was low for all three treatments due to season-long insect pressure from lygus bug. The low fruit retention data reflects the effects of high HNR. Future work will include efforts to separate changes in Ψ_x due to day-to-day climatic variations from those caused by soil-water depletion. A second objective will be to incorporate the data obtained from the neutron moisture meter probe into the study results in an effort to better describe the complete soil-plant-atmosphere continuum as affected by the various treatment regimes employed in this study.

Introduction

Cotton (Gossypium spp.) production in the desert Southwest has traditionally employed full-season varieties in an attempt to capitalize on the long growing season afforded by the climate. Growers have often attempted to control vegetative growth and encourage deep rooting by delaying the first irrigation after planting, particularly with full-season, more indeterminate varieties. In recent years, many farmers in Arizona have been planting more short- and medium-season varieties in an effort to reduce production costs and minimize late season insect problems. Due to the more determinate nature of these shorter season varieties, it may be important to avoid early season water stress to ensure early initiation of fruiting, good fruit retention, and adequate crop yield.

Guidelines for the optimum time of the first post-plant irrigation have not been established in Arizona. Simple timing systems, based on days after planting, are difficult to implement due to variable spring weather conditions. Systems using actual measurements of plant-water status have not been fully evaluated in Arizona. Examining the effects of irrigation timing on cotton yields requires a means of quantifying plant stress levels. The water status of the cotton crop can be determined by several methods which incorporate the entire soil-plant-atmosphere continuum. These measurements can then possibly be used to effectively determine when to apply the first post-planting irrigation based upon actual crop conditions. Leaf xylem potentials (Ψ_x) can be measured using the Scholander pressure chamber technique and can be used as estimates of plant leaf water potential (Grimes et al., 1987).

Environments with minimal day-to-day variations in cloud cover and temperature are suitable for measuring minimum Ψ_x and relating it to vegetative and fiber growth. Solar radiation, temperature, wind velocity, and vapor pressure deficit can influence Ψ_x and the plant stress level. Grimes and Yamada (1982) conducted a study in the San Joaquin Valley to assess the effectiveness of using minimum leaf water potential (Ψ_l) as a guide for scheduling irrigation. (Author's note: $\Psi_l \approx \Psi_x$). High yields were obtained with Upland variety, Acala SJ-2, when irrigation was applied before minimum Ψ_l dropped below -19 bars. Stem elongation and fiber growth were two plant parameters that were also affected negatively by a further reduction in Ψ_l. Seasonal bloom counts by Johnson et al.(1989) demonstrated that when the first post-plant irrigation was postponed until Ψ_l reached -23 bars, the more determinate varieties, SJC-1 and GC-510, produced a greater number of blooms early in the season, and led to early cut-out. Maximum yields occurred when the first irrigation was applied at a Ψ_l of -15 bars. Brown et al. (1992) evaluated the work of Johnson et al. (1989) in Arizona with the determinate, short-season Upland variety (G. hirsutum L.), DPL 20. They observed a significant decrease in lint yield when the first post-plant irrigation was delayed until Ψ_x was less than -19 bars.

The purpose of this study was to 1) determine the optimum timing of the initial post-plant irrigation using Ψ_x measurements obtained from a pressure chamber, and 2) measure the long term effect of delayed irrigation on subsequent plant growth parameters.

Materials and Methods

A single field experiment was conducted on a Pima clay loam soil (Typic Torrifluvent) at the University of Arizona Marana Agricultural Center (Field E2). The center is located 25 miles northwest of Tucson, at an elevation of approximately 1970 ft above sea level.

A pre-plant irrigation of 6.0 acre-inches of water was applied on 1 April 1993. On 19 April, Upland cotton (DPL 20) was planted with a 40 in. row spacing. Heat unit (HU, 86/55 F threshold), accumulation since 1 January for this location totaled 554 at planting. Treatments, designated T1, T2, and T3, consisted of applying the first post-plant irrigation when the Ψ_x reached -15,
-19, and -23 bars, respectively. All irrigation water was applied via furrow irrigation. The experimental design was a randomized complete block with four replications. Each plot (experimental unit) was eight, 40 inch rows wide, and extended the full length of the irrigation run (600 ft).

Leaf xylem potential (Ψ_x) was measured at midday (13:00 to 15:00 MST) on the uppermost, fully-developed leaf exposed to full sunlight. Daily measurements were made with a pressure chamber (PMS Model 600) from 31 May through 6 July. Leaves were covered with a damp cotton cloth, excised at the petiole, placed in a plastic bag, and transported to the pressure chamber. The measurement station was located at the edge of the field, immediately adjacent to the appropriate treatment. The leaf, enclosed in a plastic bag, was placed into the chamber with the petiole inserted through the hole in the pressure chamber gasket and exposed for observation. With the head reattached, the chamber was pressurized with N_2 gas until moisture appeared at the cut surface of the petiole. The resulting pressure was converted to Ψ_x by assigning Ψ_x = -P (negative xylem pressure). Time expended from sample excision to final measurement was two to four minutes, depending on the level of plant water stress. Two leaves per experimental unit were sampled per day.

Soil water content was monitored using a neutron moisture meter probe (CPN 503 DR Hydroprobe). Steel, two-inch diameter electrical conduit served as access tubes and were inserted to a depth of five ft. in one of the middle rows of each plot. Three access tubes were equally spaced 150 ft. apart from one another, and from the head and tail ends of the field in each plot. Neutron probe readings were taken on 17 May, 25 May, and again on 1 June. After that, readings were made one day before, and six days following an irrigation event. Readings were taken at depths of 150, 125, 100, 75, 50, 25, and 15 cm, in each access tube.

Basic plant measurements were taken weekly from each experimental unit from 24 May until 4 August. These included plant height, number of mainstem nodes, location of first fruiting branch, fruit retention at the first two positions on each fruiting branch, number of nodes above the uppermost white bloom (NAWB), bloom count in a 166-ft^2 area, and percent canopy closure.

The final irrigation was applied on 11 August, and the study area was defoliated on 20 September. The entire center four rows of each plot were harvested with a mechanical two row picker on 11 October and again on 8 November.

Results

Measured Ψ_x values decreased with increasing plant water stress (Figure 1). Treatment 1 received the initial post-plant irrigation on 4 June when Ψ_x measured -15 bars and the plant growth stage was first pinhead square. Immediately following irrigation, Ψ_x of T1 increased to greater than -10 bars. This may have been due in part to the arrival of abnormally cool weather, which lowered evaporative demand, rather than simply as a result of reduced soil water deficit. This is evidenced by the fact that Ψ_x of T2 and T3 increased slightly during the same period. Plants in T2 were irrigated on 18 June when Ψ_x reached -19 bars, which corresponded to the very early stages of the bloom period for the crop. A second irrigation was applied to T1 plots on 22 June to prevent water stress. On 29 June, when the entire study was in early bloom, T3 plants were irrigated when Ψ_x reached an average level of -22 bars. The T1 and T2 plots also received an irrigation on 29 June. Following the application of water, Ψ_x in all three treatments increased to greater than -15 bars, with T1 and T2 recovering more than T3. All irrigations following 29 June, were made on a common basis for all treatments. Total irrigation inputs for the three treatments are given in Table 1.

Lint yields were 1112, 1095, and 977 lbs. lint/acre for T1, T2, and T3, respectively (Table 2). Yield was significantly lower when the initial post-plant irrigation was withheld until Ψ_x dropped below -19 bars. This confirms results of a previous study conducted in 1992 at this location (Brown et al., 1992). These results are highly significant statistically with an observed significance level (OSL) = 0.0014 and a very low level of variability (CV = 2.82%). A comparison of lint yields vs. measured leaf water potential values for 1992 and 1993 (Figure 2) shows a consistent trend towards reduced yields with increasing plant water stress.

Rainfall amounts from pre-plant irrigation (1 April) until defoliation (20 September) totalled 5.2 in., with approximately 85% occurring after the final irrigation (11 August). The significant decrease in yield for T3 indicates that the timing of the initial post-plant irrigation has a long-term effect on the yield potential of the crop.

Height-node ratios (HNR) of T1 and T2 plants were at or above the upper threshold established for DPL 20, throughout the growing season (Figure 3). While the HNRs for T3 remained close to the expected baseline. High HNRs directly reflect low fruit retention levels. In fact, measured fruit retention was low for all treatments, due in part to season-long lygus pressure (Figure 4).

Conclusions

When the first post-plant irrigation was applied at Ψ_x = -15 bars, the plants produced adequate yield, but exhibited increased vegetative growth. There was reduced HNR without a significant decrease in yield when the irrigation was applied at -19 bars. Delaying the first irrigation (Ψ_x = -23 bars) and allowing the plants to experience early season water stress reduced yields. Late season developing bolls were not harvestable and did not make up for early season fruit loss.

Plants did experience lower stress levels when the environmental demand for water was reduced. This could signal the need for adjustment of measured Ψ_x using calibration techniques similar to those developed by Grimes et al.(1987). Since corrections are empirical in nature, local calibration for use in Arizona would be necessary. An additional objective for 1994 will be the development of a technique to separate changes in Ψ_x due to day-to-day climatic variations from those caused by soil-water depletion. Incorporation of data obtained from the neutron moisture meter probe into the study results will allow for a better description of the entire soil-plant-atmosphere continuum as affected by the treatment regimes employed in this study.

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Table 1. Total Irrigation Inputs. Ψ_x at time of initial post-plant irrigation are in parentheses. Irrigation Timing Expt. Marana, AZ, 1993.

TI (-15 bars)		T2 (-19 bars)		T3 (-23 bars)	
Date	**Amount**	**Date**	**Amount**	**Date**	**Amount**
4/01	6.0"	4/01	6.0"	4/01	6.0"
6/04	4.0"	6/18	4.0"	6/29	4.6"
6/22	2.0"	6/29	4.4"	7/15	3.6"
6/29	4.4"	7/15	3.6"	7/30	3.6"
7/15	3.6"	7/30	3.6"	8/11	4.8"
7/30	3.6"	8/11	4.8"		
8/11	4.8"				
Totals	28.4"		26.4"		22.6"

Table 2. Lint yields for each treatment. Irrigation timing experiment, Marana, AZ, 1993.

Treatment	Lint Yield lbs lint/acre
1	1112 a
2	1095 a
3	977 b
$LSD_{0.05}$	52
OSL	0.0014
CV%	2.82

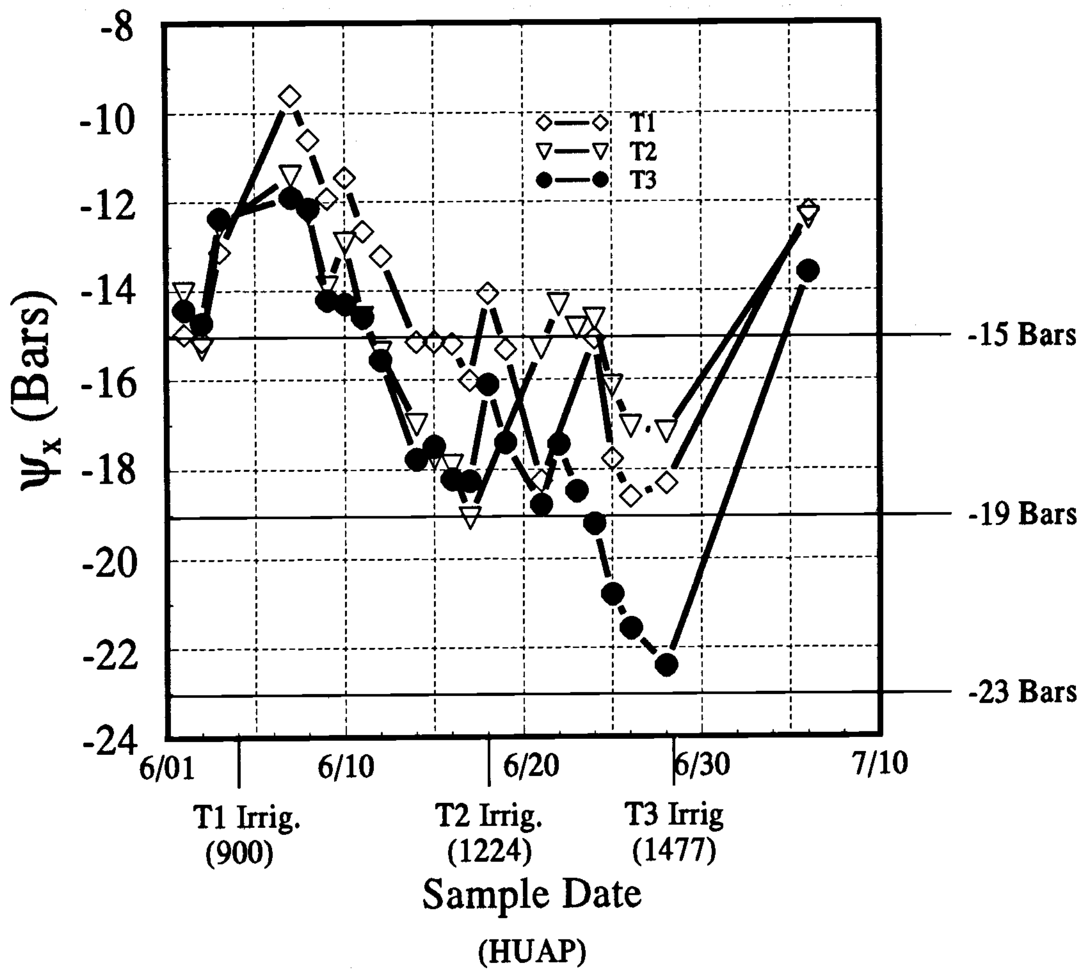

Figure 1. Mean value of ψ_x for T1(-15 bars), T2(-19 bars), and T3(-23 bars) from 1 June through 10 July. Each point is a mean of eight ψ_x measurements. Irrigation Timing Experiment, Marana, AZ, 1993. (HUAP:86/55°F Heat Units Accumulated after Planting)

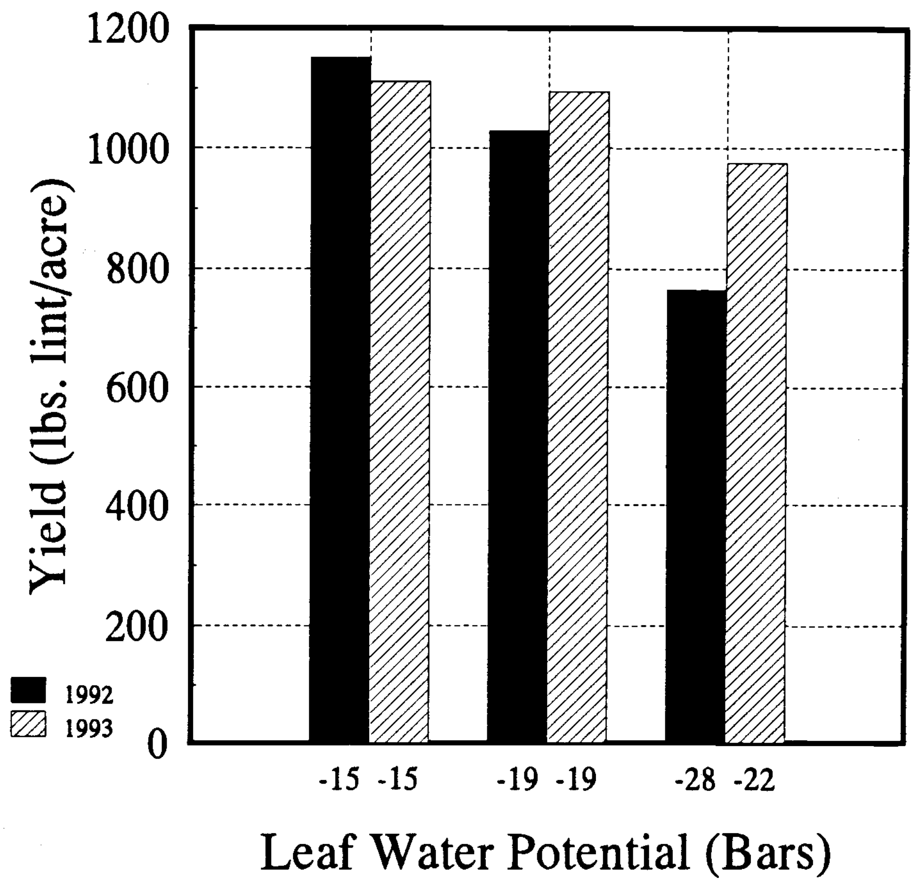

Figure 2. Lint yield vs. measured LWP values for 1992 and 1993 Irrigation Timing experiment, Marana, AZ, 1993.

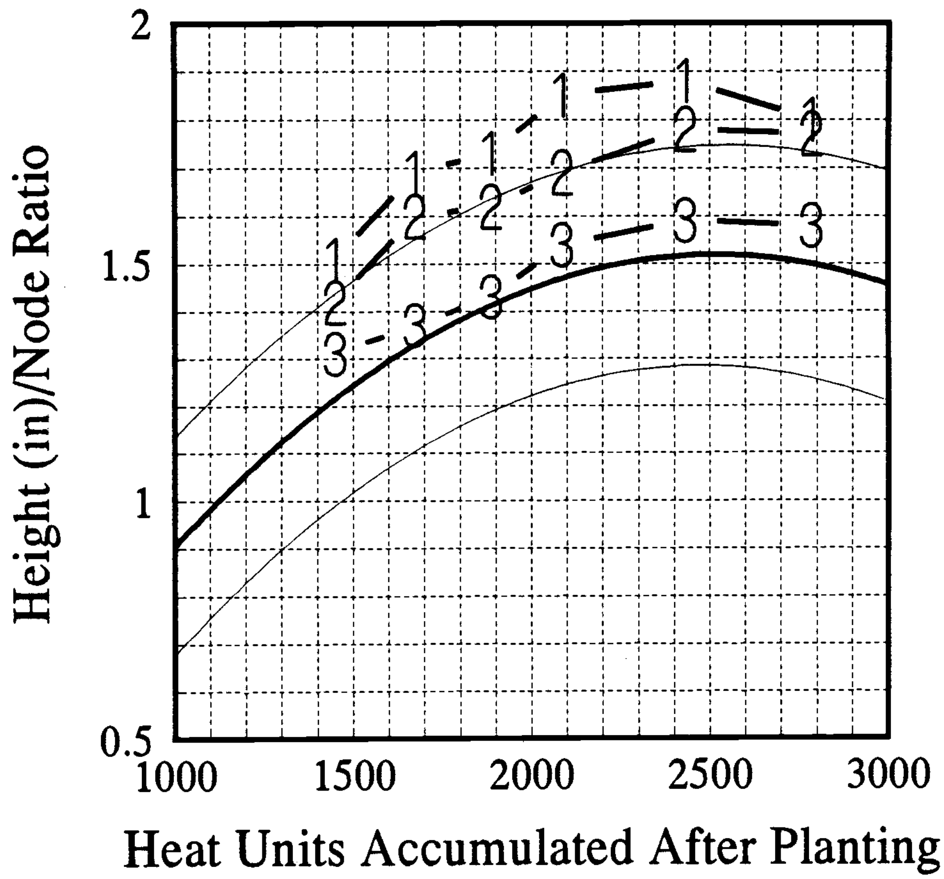

Figure 3. Height(in)/Node ratios vs. HUAP for T1, T2, and T3 Irrigation Timing experiment, Marana, AZ, 1993.

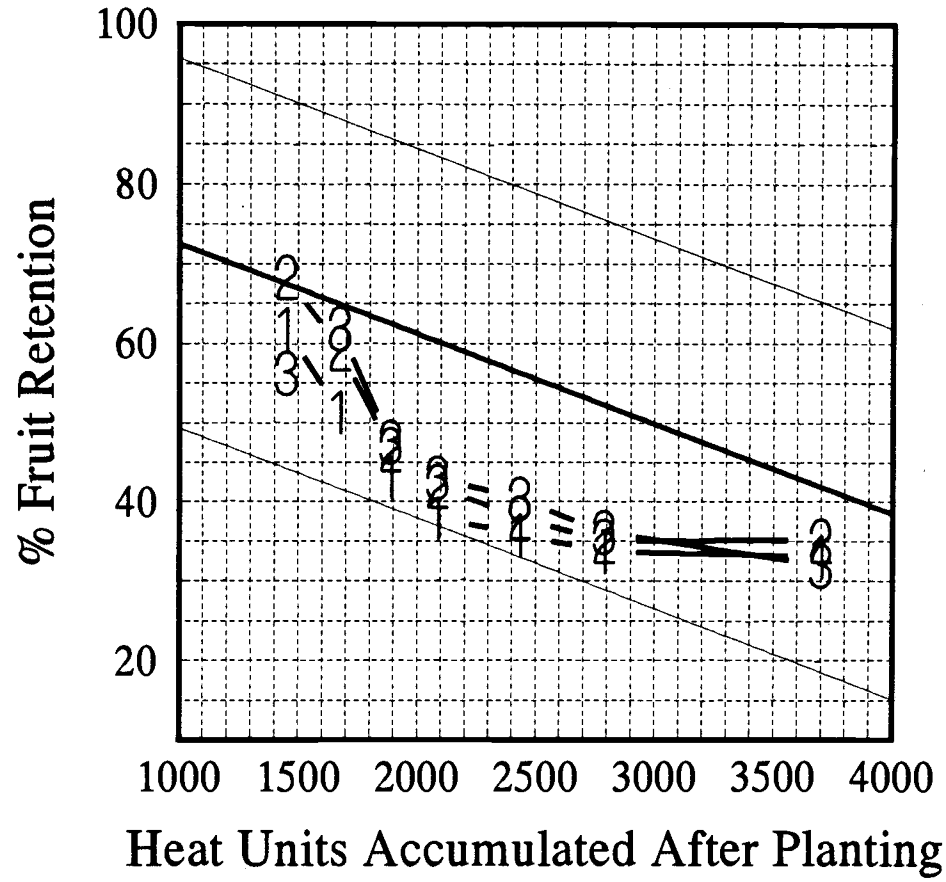

Figure 4. Fruit retention levles vs. HUAP for T1, T2, and T3 Irrigation Timing experiment, Marana, AZ, 1993.