Initial Post Plant Irrigation Effects on Low Desert Upland Cotton Yields Using Leaf Water Potential Measurements

S. H Husman, D.J. Garrot, Jr., J.W. O'Leary, M. Moore, and R. Wegener

Abstract

Leaf water potential (LWP) measurements using a pressure chamber were used to determine optimum timing of the first irrigation following planting on Upland cotton in 1992 and 1993. Previous studies have indicated that leaf water potentials are dependent on the vapor pressure deficit (VPD) of the surrounding air. As a result, the VPD was accounted for in the development of a Leaf Water Potential Index (LWPI). The field studies consisted of three irrigation treatments with four replicates arranged in a randomized complete block design (RCB). Targeted treatment thresholds were 0.15 LWPI (wet), 0.30 LWPI (medium), and 0.45 LWPI (dry). Timing of the first irrigation for the 1992 study occurred at 36, 53, and 63 days after planting. Timing of the 1993 first irrigation occurred at 50, 61, and 77 days after planting for the wet, medium, and dry treatments respectively. There were no significant lint yield differences between irrigation treatments in both 1992 and 1993.

Introduction

Cotton production in Central Arizona is experiencing rapid change regarding traditional production practices. Input costs have increased significantly while commodity returns have remained stable. In addition, late season insect pressures are forcing growers to carefully evaluate the economics of late season production inputs. As a result, the production trend is one of a reduced season approach with the goal to maximize the primary fruit cycle production potential. However, production input efficiency is critical when late season compensation time is eliminated.

Traditional irrigation strategy is to withhold the initial irrigation following planting as long as feasible in order to develop a deep soil profile root system. The deep root system development would enable the plant to withdraw water reserves from the lower profile depths during periods of maximum evapotranspiration demand when water and labor supplies challenge the producer to meet water requirements.

With the production trend strategy shifting from a full season (double fruit cycle) to a reduced season (single fruit cycle) approach, this study was designed to investigate the effects of early season water stress on the final lint yield. In addition, due to the reduced cotton production period, more determinate varieties are being developed and utilized. As a result, information on stress tolerance is not clearly understood and warranted investigation.

Extensive field studies were conducted investigating the initial irrigation timing effect on lint yields using leaf water potentials by Grimes, Johnson, Kerby et. al., University of California during the 1980's. They found that the first irrigation was critical with excessive early season water stress resulting in significant final lint yield loss. Optimum yield was dependent on early season vegetative growth and development of adequate plant structure to maximize fruiting branch development. It was also determined that premature cut-out was the result when an optimum fruit load is supported by an inadequate leaf area. Expected lint yield loss when moderate pre-bloom water stress was induced generally exceeded 10%.

Grimes, et.al. determined that optimum timing of the first irrigation using leaf water potentials is -16 bars with subsequent in-season irrigations at -18 bars. They also conducted an extensive monitoring program and found that many producers were delaying the first irrigation to approximately -20 bars with a resultant yield loss. A review of Grimes work also revealed the necessity for leaf water potential measurement adjustments based on air temperature deviations from normals.

Idso, et.al., 1982, USDA Water Conservation Laboratory, Phoenix, Az., determined that under low desert conditions and high vapor pressure deficit conditions, leaf water potential is highly dependent on vapor pressure deficit and is curvilinear in nature (Figure 1). Idso, et.al. also found that the plant foliage minus air temperature (delta T) was dependent on the vapor pressure deficit. As a result, a technique called the Crop Water Stress Index was developed (Figure 2).

Several field studies were conducted by Garrot, Husman et.al from 1980-1992 using the Crop Water Stress Index to schedule irrigations on several crop species to successfully determine yield or quality and plant water stress relationships. Another study conducted by Garrot and K. Idso on Pima S-6 cotton in 1991 verified the dependence of leaf water potential on the vapor pressure deficit. From this study, it was determined that an upper leaf water potential of -30 bars existed whereby additional pressure exertion resulted in no additional petiole fluid flow.

From the above described work, the Leaf Water Potential Index (LWPI) was developed by authors. LWPI was used as the criteria for initial irrigation scheduling in this study. Calculation of the LWPI is accomplished identical to the CWSI calculation (Figure 2) except that LWP is substituted for foliage minus air temperature or delta T. Following the example in figure 2 illustrates the CWSI calculation (CWSI = B-C/A-C). The LWPI was calculated using the same method substituting LWP for foliage - air temperature (Figure 3).

The objectives of the 1992-1993 study were to determine the technique feasibility and determine early season water stress effects on lint yield.

Materials and Methods

Two field studies were conducted in 1992-1993 to investigate the effects of early season water stress effects on lint yield using leaf water potentials measured with a pressure chamber. As described previously, accounting for the relationship of leaf water potential and vapor pressure deficit, a Leaf Water Potential Index (LWPI) was developed and used for irrigation treatment thresholds. The test was conducted on a commercial site in Waddell, Arizona. The test consisted of twelve, six row plots running the entire field length (715 ft.). The plots were randomized resulting in a randomized complete block design (RCB) with three irrigation treatments and four replicates.

The non-water stressed baseline developed for Pima S-6 in previous research by Garrot, Idso, 1991 (Figure 3) was used for scheduling irrigations. In season water potential and vapor pressure deficit measurements under well watered conditions were used for baseline development on Upland cotton. The baseline developed for Upland cotton was based on data points measured in 1992. The Upland baseline developed in 1992 was used to schedule the 1993 irrigations. (Figure 4).

The LWPI was calculated identically to CWSI calculations (Figure 2). However, instead of the foliage minus air temperature (delta T) on the y-axis, the LWP is substituted resulting in the same calculation of LWPI = B-C/A-C (Figure 2). The index scale ranges from 0 (well watered, fully transpiring) to 1 (transpiration cessation). Target treatment thresholds were 0.15 (wet), 0.30 (medium), and 0.45 (dry).

Leaf water potential measurements were taken from noon to 2:00 p.m. with three plants sampled per plot. The three measurements were averaged for a representative water potential measurement. Vapor pressure deficit measurements were taken at the beginning and end of daily data collection period. Vapor pressure deficit measurements were taken with a hand held aspirated psychrometer approximately one foot above the canopy and averaged. In addition, soil moisture measurements were taken with a Campbell Pacific hydroprobe on all plots during the same period (1992). Leaf water potential measurements were taken a minimum of three times per week (1992/1993).

Upon successful completion of initial irrigation scheduling objectives, subsequent in-season irrigations were scheduled according to standard grower practices. Lint yields were measured by harvesting the center four rows of each six row plot running the entire field length with a commercial spindle picker. Seed cotton weights were measured with portable electronic field scales. Plots were harvested on October 16 and again on November 2 on the 1992 study. The 1993 plots were harvested on September 29.

Results and Discussion

The baseline developed by Garrot, K. Idso, 1991 was used for scheduling irrigations according to targeted thresholds on the 1992 study. However, this baseline was developed on Pima and was found to be different than an Upland baseline. The 1992 Upland baseline was developed from LWP and VPD measurements taken in plots within two days post irrigation under well watered conditions. This baseline is different and LWPI calculations change with differing baselines.

Non-water stressed baseline precision is critical for accurate utilization of the LWPI technique. Since 1992 was the first year of a multi year study, the Pima baseline was adequate for testing the validity of the LWPI. The 1992 non-water stressed Upland baseline was used in the 1993 test.

The actual average LWP at time of irrigation for 1992 were -13.6, -16.8, and -19.2 bars. In 1993 LWP were -17.0, -20.4, and -21.3 bars for the wet, medium, and dry treatments respectively at time of first post-plant irrigation. LWPI values when irrigated were 0.20, 0.33, and 0.47 in 1992. LWPI values when irrigated were 0.16, 0.35, and 0.46 in 1993. Treatment target thresholds were 0.15, 0.30, and 0.45 LWPI. for the wet, medium, and dry treatments respectively (Table 1).

The cotton was wet planted in both 1992 and 1993 into rain fed soil moisture. Initial irrigations scheduled with the LWPI for 1992 were applied on May 12 (wet), May 29 (wet, medium), and June 8 (wet, medium, dry). Initial irrigations were 36, 53, and 63 days after planting for the wet, medium, and dry treatments respectively. The 1993 initial irrigations scheduled with the LWPI were applied on May 14 (wet), May 25 (wet, medium), and June 10 (wet, medium, dry). The 1993 initial irrigations were 50, 61, and 77 days after planting for the wet, medium, and dry treatments respectively. Following completion of test objectives of initial irrigation timing, subsequent in-season irrigations were scheduled according to standard farm practices and were uniform.

Soil moisture measurements were taken in 1992 with a neutron probe at the same time LWPI measurements were recorded. Soil moisture deficit (field capacity -actual) per two feet were calculated at time of irrigation. Deficit values were 29.4% (1.59"), 39.3% (2.13") and 41.5% (2.25") for the wet, medium, and dry treatments respectively (Table 1).

Total applied irrigation water was 44 (wet), 38 (medium), and 32 (dry) inches in 1992. The 1993 total applied irrigation water was 42 (wet), 38 (medium), and 34 (dry) inches. Total number of irrigations were 8, 7, and 6 for the wet, medium, and dry treatments respectively 1992/1993. Total applied irrigation volume was lower than expected for both the 1992 and 1993 growing season due to the ability to avoid an establishment irrigation due to the previously mentioned excessive winter rainfall.

There were no significant yield differences between irrigation treatments. Lint yields for 1992 were 1633, 1648, and 1635 pounds per acre for the wet, medium, and dry treatments respectively. The 1993 lint yields were 1082, 1077, and 1029 pounds per acre for the wet, medium and dry treatments respectively. Irrigations scheduled with the 1991 Pima baseline resulted in greater LWPI values than those LWPI values re-calculated using a derived Upland baseline from actual 1992 data. Irrigations were applied within a range of days after planting that would be representative of a majority of standard farm practices in Central Arizona.

Conclusions

Leaf water potentials can be used to schedule irrigations on cotton, however they are not a practical or suggested management tool. Measurements are time consuming with the potential for considerable variability. The practical management disadvantages exceed potential advantages to the time and labor intense technique.It is generally agreed upon that the maximum allowable soil moisture depletion should not exceeed 50% to avoid yield reduction. In the 1993 study, the dry treatment resulted in a 42% soil moisture depletion level. Essentiaaly, in both studies, even when the first post plant irrigations were applied at 63 and 77 days after planting in 1992 and 1993, yields were not reduced. As a result knowing your soil water holding characteristics and managing accordingly is recommended.

With a management objective of maximizing input efficiency and reducing total input costs, delaying the first post plant irrigation as long as possible makes sense. A manager should know the available soil water holding capacity of their soils or fields and time the first post plant irrigation when the evapotranspiration demands are approaching the 40-50% maximum allowable depletion range irrespective of the calendar date. The first post plant irrigation on the driest treatments occurred on June 8 in 1992 and June 10 in 1993 with a planting date of early April. These dates are fairly representative of current standard irrigation practices in Central Arizona. There is a commercial tendency to apply the first post plant irrigation sooner than may be necessary in most cases. This serves no purpose other than to increase production costs.

This study would indicate there is considerable flexibility in first irrigation timing. Significant input cost reductions can be realized if irrigations are applied on a timely basis.

Acknowledgements

Sincere appreciation is extended to Mike Moore, Moore Ranches, Waddell Arizona for graciously providing the test site, enthusiasm, and willingness to cooperate on applied research field studies.

Literature Cited

Brown, P., Silvertooth, J., and Malcuit, J. 1993. Evaluation of the Pressure Chamber for Timing Early Season Irrigations. 1993 Cotton Report. Series P-94, pp.181-187.

Cutler, J.M., and D.W. Rains. 1977. Effects of irrigation history on responses of cotton to subsequent water stress. Crop Science, 17:329-334.

Grimes, D. W., W. L. Dickens, and H. Yamada. 1978. Early-season water management for cotton. Agron. J. 70:1009-1012.

Grimes, D. W., H. Yamada, and S. W. Hughes. 1987. Climate-normalized cotton leaf water potentials for irrigation scheduling. Agric. Water Manag. 12:293-304.

Grimes, D. W., and H. Yamada. 1976. Relation of cotton growth and yield to minimum leaf water potential. Crop Science. 22:134-139.

Idso, K. E. 1992. The recovery of physiological processes following irrigation of water stressed extra long-staple cotton. Thesis. Dept. of Plant Sciences, The University of Arizona.

Idso, S.B., R. J. Reginato, D. C. Reicosky, and J. L. Hatfield. 1981. Determining soil-induced plant water potential depressions in alfalfa by means of infrared thermometry. Agron. J. 73:826-830.

Jordan, Wayne R. 1970. Growth of cotton seedlings in relation to maximum daily plant-water potential. Agron. J. 62:699-701.

Wenkert, W., E. R. Lemon, and T. R. Sinclair. 1978. Changes in water potential during pressure bomb measurement. Agron. J. 70:353-355.

Table 1. Effects of Initial Irrigation Scheduling Using the Leaf Water Potential Index on Yield and Soil Moisture 1992.

Trt.	Target LWPI	LWPI & Irr.	LWPI	Days to lst Irr.	Soil Moisture Def/2 ft.	Lint Yield (lb./ac)
Wet	0.15	13.60	0.20	36 May 12	29.4% 1.59 in	1633 a*
Med	0.30	16.80	0.33	53 May 29	39.3% 2.13 in.	1648 a
Dry	0.45	19.20	0.47	63 June 8	41.5% 2.25 in.	1635 a

* Means followed by the same letter are not significantly different.
Planting Date: April 4

Table 2. Effects of Initial Irrigation Scheduling Using the Leaf Water Potential Index on Yield 1993.

Trt	Target LWPI	LWP @ Irr.	LWPI	Days to lst Irr.	Lint Yield (lb/ac)
Wet	0.15	17.00	0.16	50 May 14	1082 a*
Med	0.30	20.40	0.35	61 May 25	1077 a
Dry	0.50	21.30	0.46	77 June 10	1029 a

* Means followed by the same letter are not significantly different.
Planting Date: March 26

Table 3. Irrigation Treatments, Application Dates, and Applied Water (Inches) 1992.

Date	Wet (0.15)	Medium (0.30)	Dry (0.45)
5-12	6*		
5-29	6*	6*	
6-8	6*	6*	6*
6-26	6	6	6
7-4	4	4	4
7-8	6	6	6
7-21	6	6	6
8-12	4	4	4
Total Irr.	44"	38"	32"
# Irrs.	8	7	6

* scheduled with LWPI

Table 4. Irrigation Treatments, Application Dates, and Applied Water (Inches) 1993.

Date	Wet (0.15)	Medium (0.30)	Dry (0.50)
5-14	4*		
5-25	4*	4*	
6-10	4*	4*	4*
6-22	6	6	6
7-4	6	6	6
7-13	6	6	6
7-22	6	6	6
8-3	6	6	6
Total Irr.	42"	38"	34"
# Irrs.	8	7	6

* scheduled with LWPI

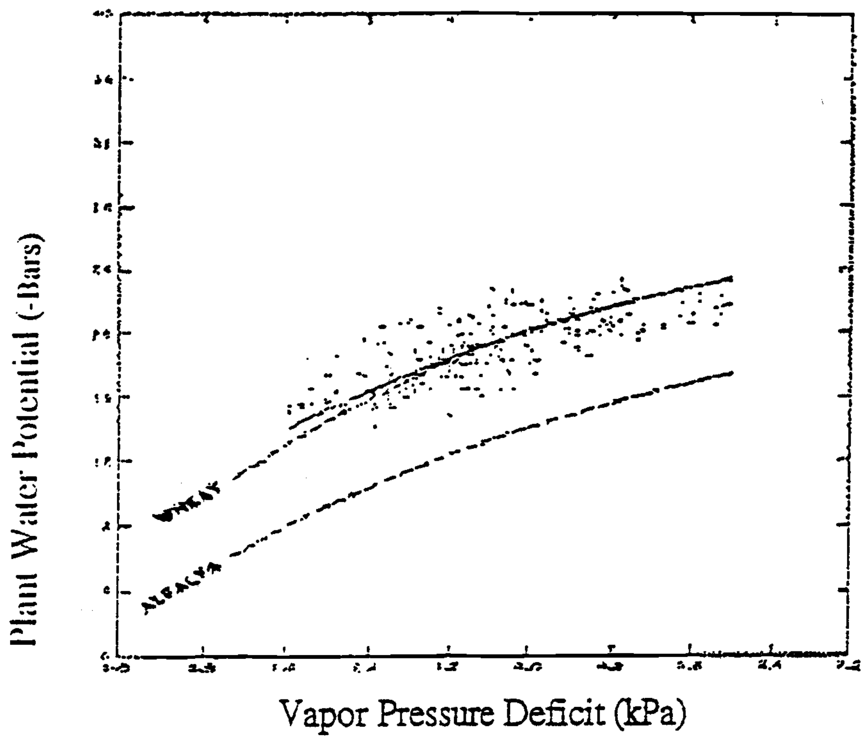

Figure 1. Plant Water Potential versus Air Vapor Pressure Deficit Transpiring at the Potential Rate (Idso, et. al)

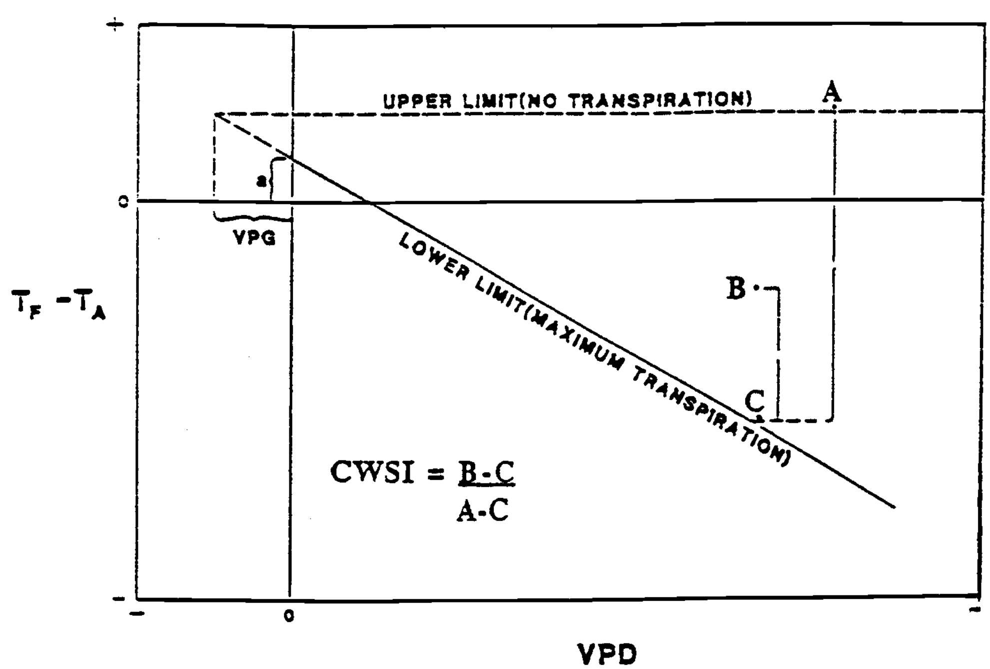

Figure 2. General Relationship of Foliage - Air Temperature and Air Vapor Pressure Deficit Under Well Watered Conditions (Idso, et. al)

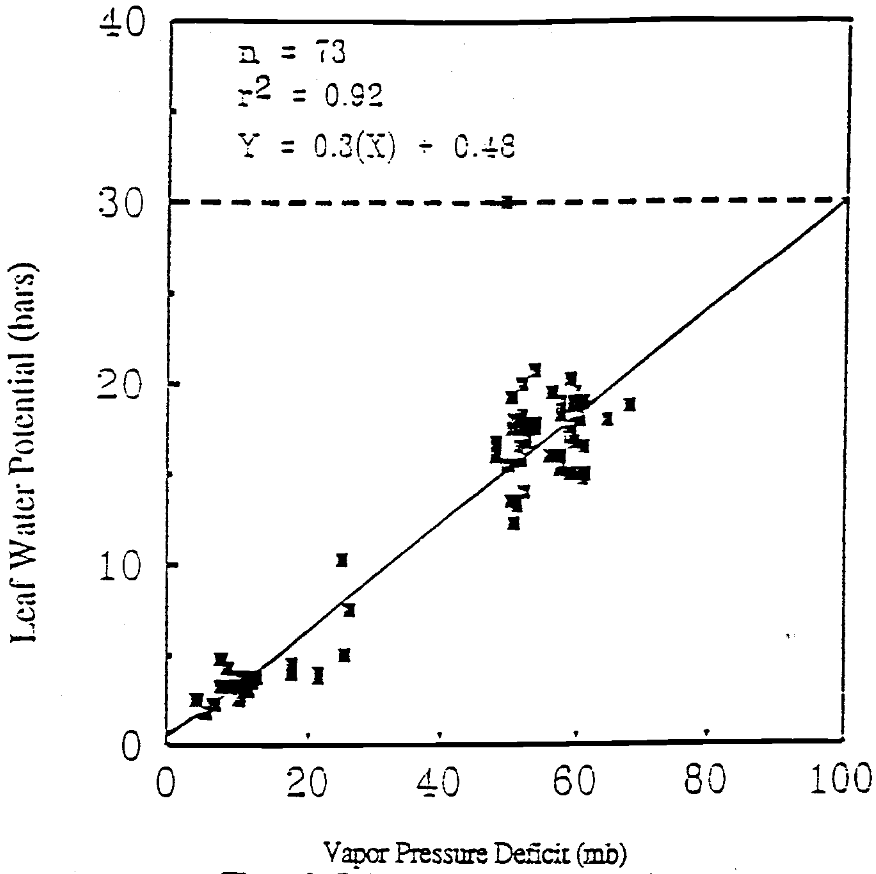

Figure 3. Relationship of Leaf Water Potential versus Vapor Pressure Deficit for Pima S-6 Cotton Under Well Watered Conditions. (Garrot, K. Idso et.al)

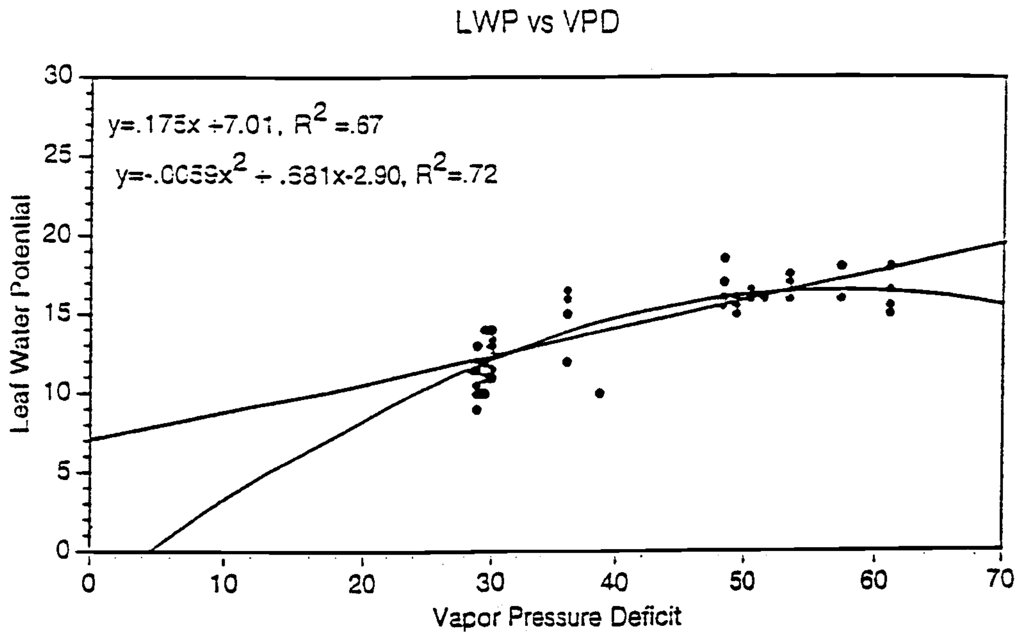

Figure 4. Relationship of Leaf Water Potential versus Air Vapor Pressure Deficit for Upland Cotton.