QUANTIFYING THE EFFECTS OF WATER DEFICIT STRESS TIMING ON COTTON GROWTH AND YIELD UNDER RAIN-SHELTERED CONTROLLED CONDITIONS

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Abstract

The cotton plant may show a different response to water deficits in terms of growth, yield and yield components, depending on the growth stage that the water deficit (WDS) is imposed. A study was conducted in the Drought Tolerance Laboratory at the Texas A&M AgriLife Research and Extension Center in Corpus Christi during the 2014 cotton growing-season to quantify the effect of water deficits applied at different growth stages. The study consisted of 4 treatments (fully irrigated throughout the season - control, stressed from match-head to first bloom, stressed from first bloom to mid bloom, and stressed from mid bloom to first cracked boll) in a complete randomized design with 4 replications. The results indicate that the timing of the WDS causes alterations in the development of the vegetative framework of the plant, which, ultimately, affects its yield potential.

Introduction

The exposure of plants to soil water deficits, which is a common occurrence when growing crops in dryland conditions or when using deficit irrigation techniques, results in the sequential inhibition of expansive growth, transpiration, and photosynthesis (Bielorai and Hopmans, 1975). Under these conditions, plants conserve water by limiting leaf area growth and/or closing stomata (McCree and Fernández, 1989). The water use efficiency of cotton plants increased as plants were exposed to progressively increasing soil water deficits until these become very severe (Fernández et al., 1992). The effect of water stress on yield depends on its timing and intensity (Jones and Rawson, 1979). Therefore, minimizing the negative impacts of water deficits on yield and lint quality becomes, therefore, an essential goal in cotton production. Most of the work on the effects of timing of water deficits on cotton has focused on yield under variable field growing conditions. A better understanding of the responses of growth, yield, and fiber quality would be achieved by quantifying these effects under controlled environmental conditions where soil variability can be eliminated and water supply accurately controlled. Therefore, the objective of this study was to evaluate the effects of the timing of soil water deficits on growth and yield of cotton plants grown under rain-sheltered and irrigated controlled conditions.

Materials and Methods

The study was carried out in 2014 at the Drought Tolerance Lab in the Texas A&M AgriLife Research and Extension Center at Corpus Christi. Cultivar PHY375 was planted on April 2nd, in 3.6-gallon pots filled with fritted clay soil. The study was laid out as complete randomized design with 4 treatments (Table 1) and 4 reps.

Table 1. Treatments description.

Treatment	Irrigation/stress schedule
1	Control (Fully irrigated throughout the study) - 2.4L/day
2	Stressed from Match Head (MH) to 1st Bloom (1B) - 1L/day
3	Stressed from 1st Bloom (1B) to Mid Bloom (MB) - 1L/day
4	Stressed from Mid Bloom (MB) to 1st Cracked Boll (CB) -1L/day

All pots were irrigated with 0.8 L/day until MH (May 07), when treatments were initiated. After the stress treatments were finished plants went back to full irrigation regime (2.4 L/day). Whole-plant transpiration was measured continuously using electronic weighing mini-lysimeters. The study was terminated on August 14th, when plants were harvested for measuring growth and yield parameters. The data were analyzed by ANOVA, and means separated by Fisher's LSD at $\alpha = 5\%$ using SAS.

Results and Discussion

Average daily transpiration data for the 4 treatments is shown in Fig. 1. Treatment 2 had a delayed response to the water stress, which can be explained by mild temperatures during that stage and small plant size, which caused slow soil water depletion. Additionally, fritted clay has a very large volumetric water holding capacity (0.46 L/L). Therefore, reductions on transpiration were only exhibited once the water stored on the pots was significantly depleted. Treatments 3 and 4 responses were instantaneous. After the water stress was imposed plants on Trt.3 decreased transpiration rates from 1.8 L/day to less than 1L/day, while plants on Trt.4 decreased from 2 L/day to less than 1 L/day.

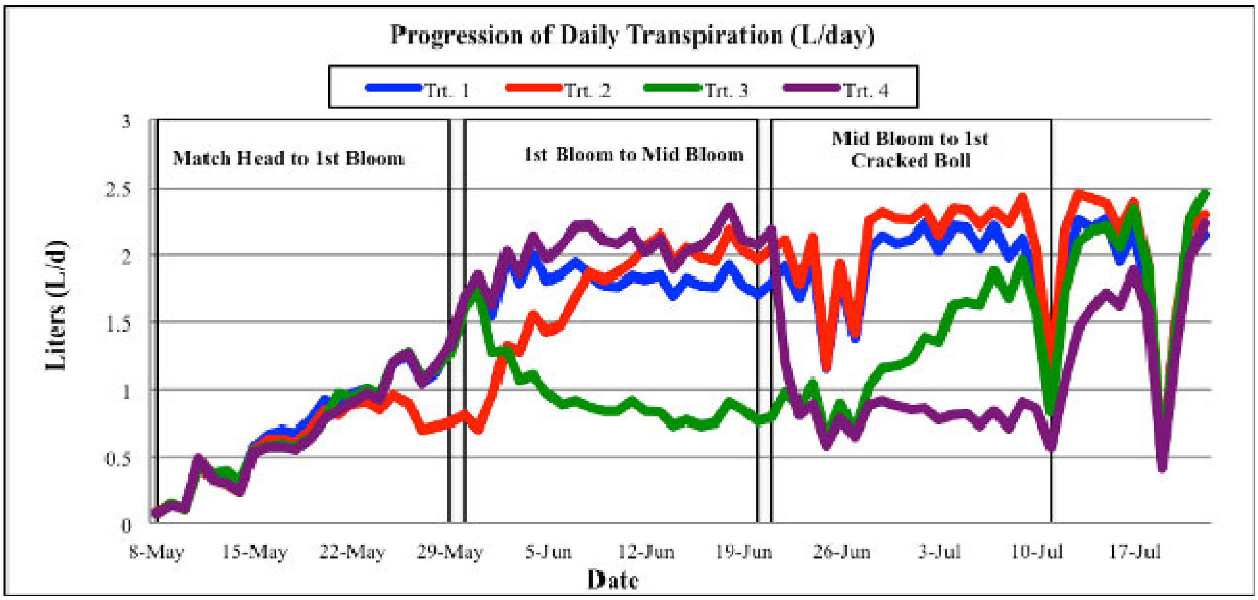

Figure 1. Average daily transpiration (L/day) data for the 4 treatments during the season.

The cumulative transpiration values per growth stage and across the season are shown in Table 2. From MH to 1B there were no significant differences between the treatments. From 1B to MB trt.3 transpired significantly less than the other treatments. Trt.4 transpired significantly less than the other treatments from MB to 1CB. Total transpiration throughout the season was significantly higher for Trts.1 and 2.

Table 2. Cumulative transpiration (L) per stage and total transpiration across the season (L) for the 4 treatments.

Treatments	Cumulative transpiration (L)			
	Match Head to 1st Bloom	1st Bloom to Mid Bloom	Mid Bloom to 1st Cracked Boll	Total
1	15.6 a	39.6 b	39.9 a	115.6 a
2	13.0 a	36.9 b	43.1 a	115.3 a
3	15.3 a	21.4 c	25.9 b	83.7 b
4	14.9 a	44.8 a	18.5 c	95.0 b

Means with different letters are significantly different at the 5% level.

The leaf area progression (m^2) data is shown in Fig. 2. At MH, when treatments were initiated, there were no significant differences. At 1B, Trt.2 was significant smaller than the other treatments. Trt.3 was significantly smaller than the others at MB. Even though Trt.4 shed many leaves, at 1CB there were no significant differences among treatments.

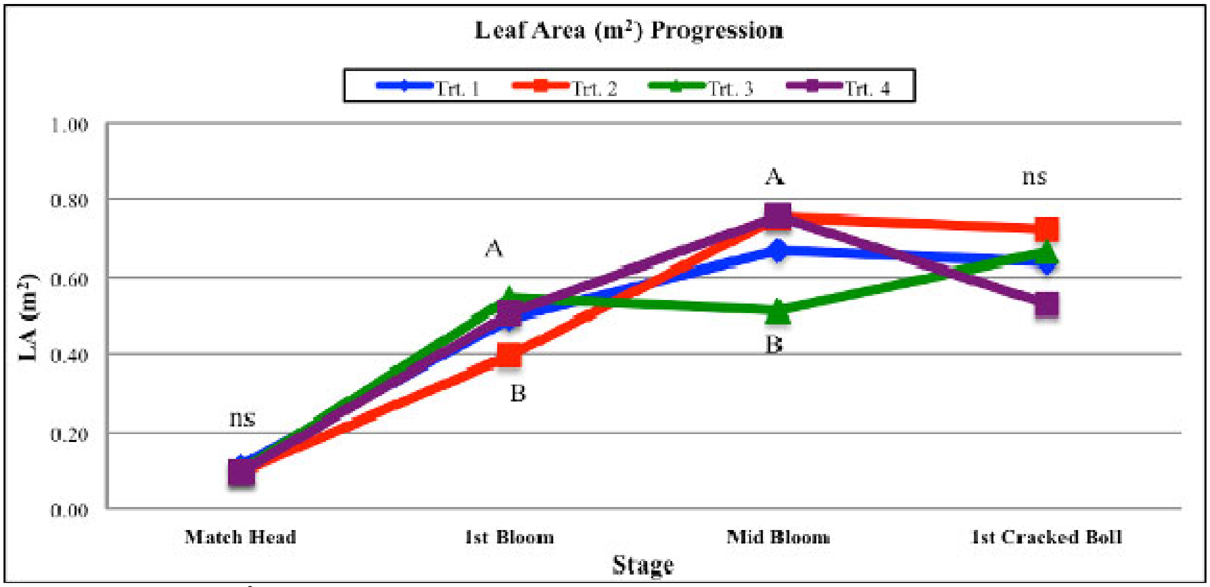

Figure 2. Leaf area (m^2) progression for the 4 treatments. Means with different letters are significantly different at the 5% level, ns= non-significant at 5% level.

There were significant differences in terms of total dry matter yield (Fig. 3). Treatments 1 and 2 yielded significantly higher than 3 and 4. Total dry matter yield was partitioned into two main components in this study: Biological yield (sum of mainstem, branches, burs, roots, and leaves dry weight) and Economic yield (sum of seed and lint weight). Treatment 3 yielded significantly less than the other treatments regarding biological yield (Fig. 4). As to economic yield, treatments 1 and 2 yielded significantly more than 3 and 4 in terms of seedcotton/plant and lint/plant (Fig. 5).

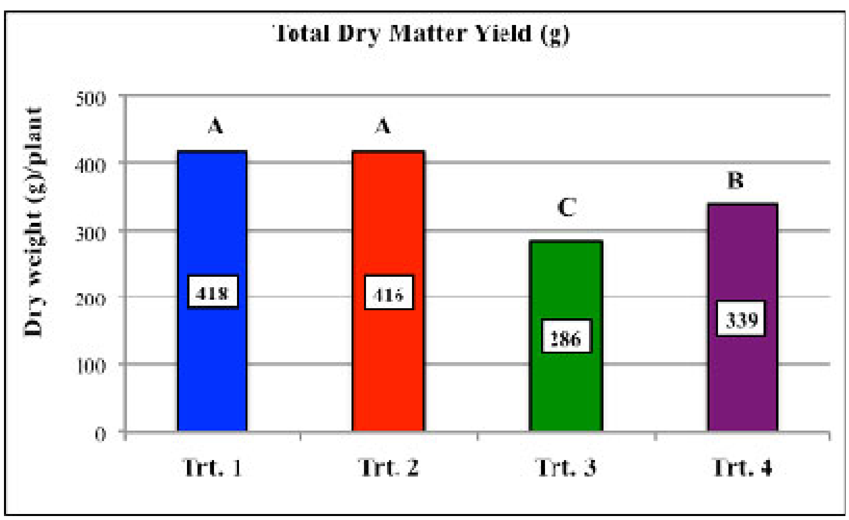

Figure 3. Total dry matter yield (g/plant) for the 4 treatments. Means with different letters are significantly different at the 5% level.

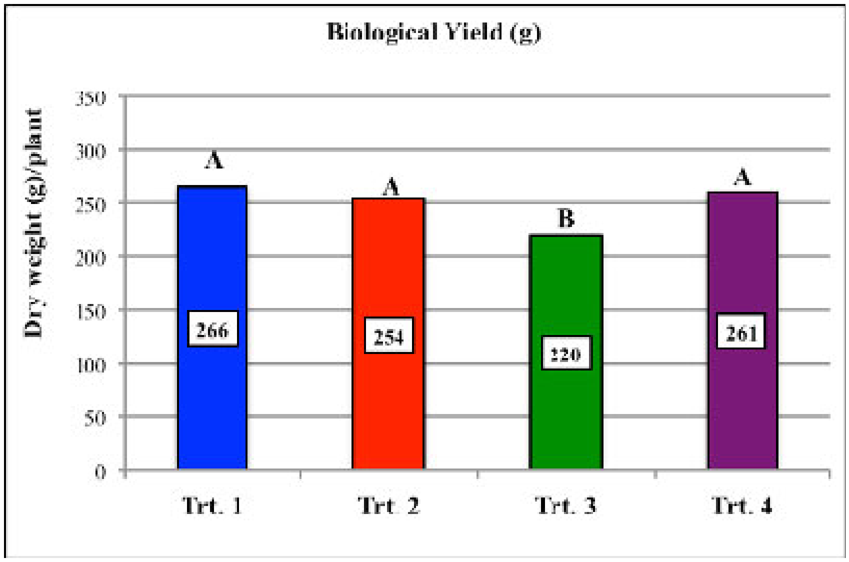

Figure 4. Biological Yield (g/plant) for the 4 treatments. Means with different letters are significantly different at the 5% level.

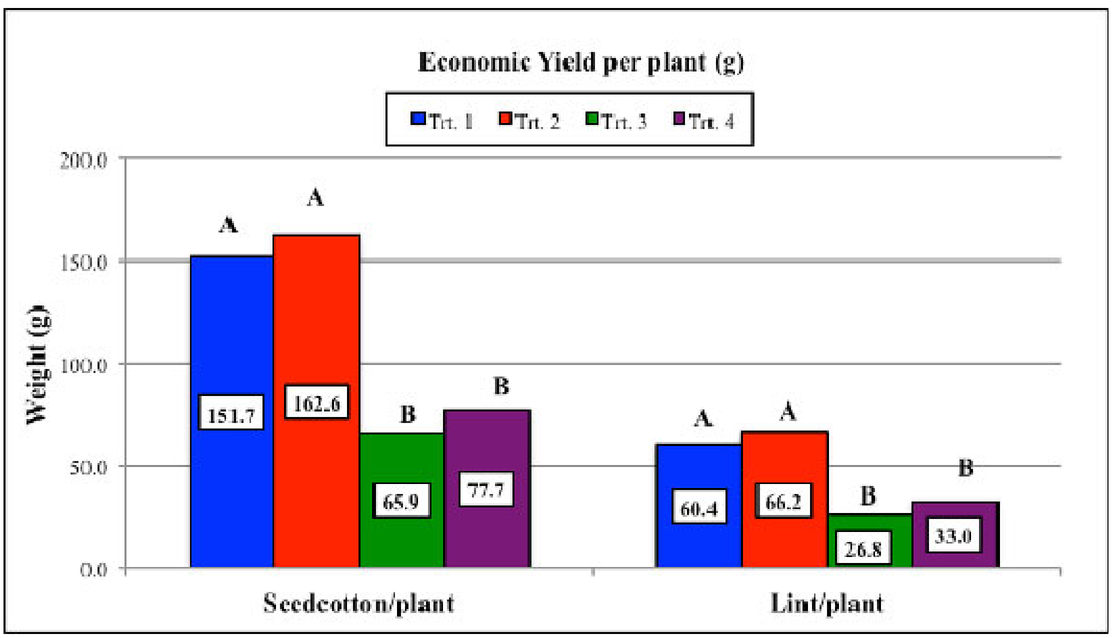

Figure 5. Seedcotton and lint yield (g/plant) for the 4 treatments. Means with different letters are significantly different at the 5% level.

Harvest index (HI) was calculated by dividing economic yield per total dry matter yield. Treatments 1 and 2 were significantly higher than 3 and 4 (Fig. 6). From the plant mapping analysis, boll retention (%) was calculated by diving the number of bolls per total number of reproductive sites (Fig. 7). Treatments 1 and 2 were significantly higher than 3 and 4.

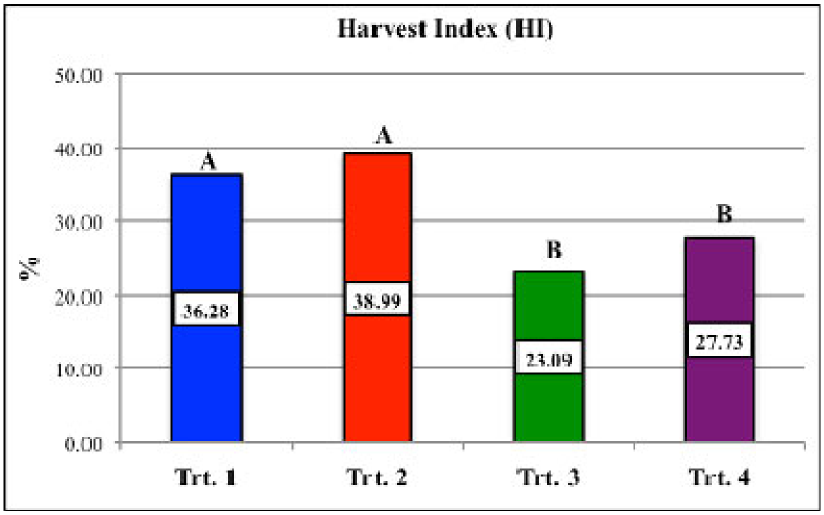

Figure 6. Harvest index (%) for the 4 treatments. Means with different letters are significantly different at the 5% level.

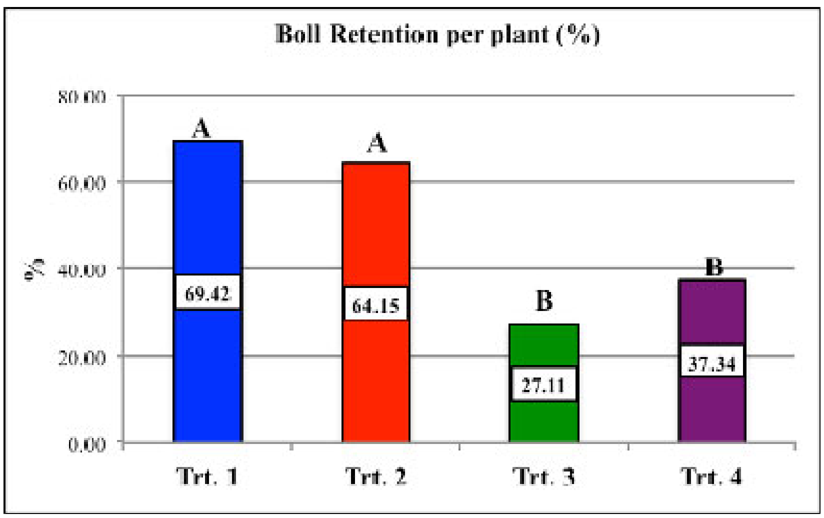

Figure 7. Boll retention (%) for the 4 treatments. Means with different letters are significantly different at the 5% level.

Water use efficiency (g/L) was divided into 3 components: total, economic, and lint (Fig. 8). WUEtotal was calculated by diving the total dry matter yield per total cumulative transpiration; WUEeconomic was calculated by dividing seedcotton yield per total cumulative transpiration; WUElint was calculated by dividing lint yield per total cumulative transpiration.

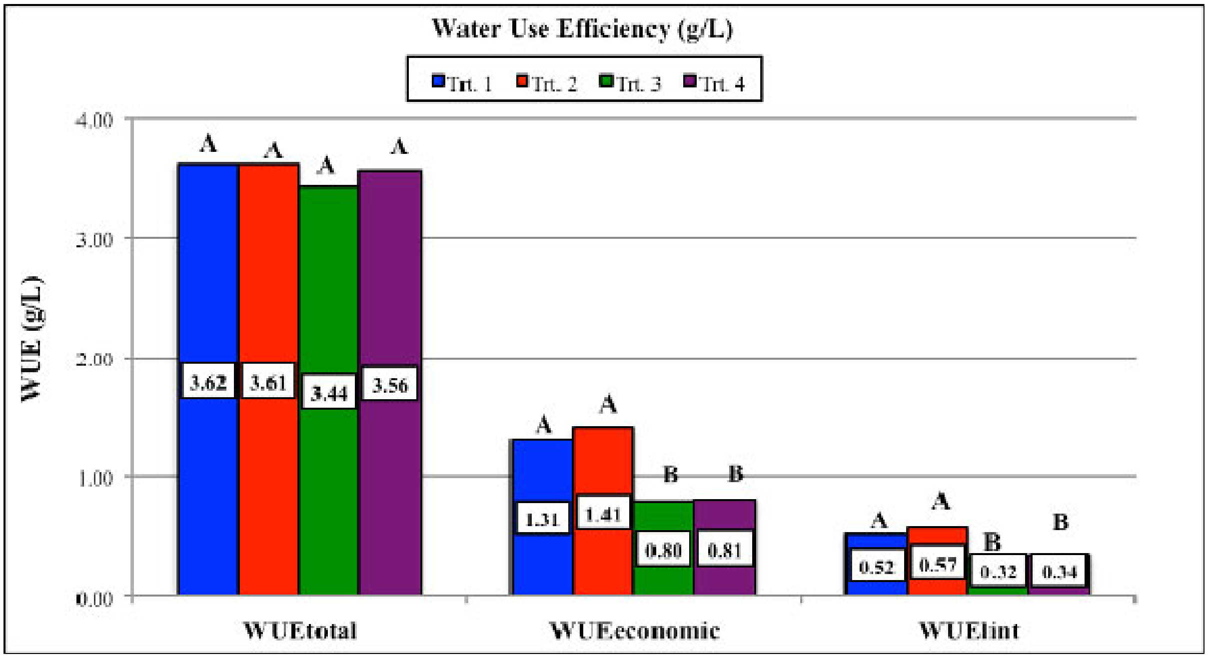

Figure 8. WUE (g/L) components for the 4 treatments. Means with different letters are significantly different at the 5% level.

There were no significant differences in terms of WUEtotal. As to WUEeconomic and WUElint, treatments 1 and 2 were significantly higher than 3 and 4. These results indicate that the overall dry matter production per L of water transpired along the cycle was not affected by the timing of the water stress. However, because the partitioning of the dry matter produced into economic components was affected by the water deficits, the efficiency of water use decreased in treatments 3 and 4.

Conclusions

Based on these results, the study shows that the timing of water deficit stress decreased substantially daily transpiration rates and caused alterations in the vegetative/reproductive ratio of the plants.

Water deficits from 1st Bloom to Mid Bloom and from Mid Bloom to 1st Cracked Boll had severe effects cotton's dry biomass production and partitioning, primarily through its decreasing effects on fruit retention, which led to lower economic yield and lower water use efficiency.

References

Bielorai, H., and Hopmans, P.A.M., 1975. Recovery of leaf water potential, transpiration, and photosynthesis of cotton during irrigation cycles. Agron. J., 67, 629-632.

McCree, K.J. and C.J. Fernandez. 1989. A simulation model for studying physiological water stress responses of whole plants. Crop Science 29:353-362.

Fernandez, C.J., J.T. Cothren, and K.J. McInnes. 1992. Carbon and water economies of well-watered and water-stressed cotton plants treated with mepiquat-chloride. Crop Science 32: 175-180.

Jones, M.M., and H.M. Rawson. 1979. Influence of rate of development of leaf water deficits upon photosynthesis, leaf conductance, water use efficiency and osmotic potential in sorghum. Physiol. Plant. 45:103-111.