# THE UTILITY OF PLANT WATER STATUS MEASUREMENTS AS A MEANS TO IMPROVE WATER USE EFFICIENCY IN GEORGIA COTTON PRODUCTION

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## Introduction

Current irrigation practices balance rainfall amounts and water loss due to crop evapotranspiration with supplemental irrigation (referred to as a “checkbook” approach). While this method has been successful at providing high crop yields, there is evidence that plant-based irrigation triggers could provide a means to conserve water resources, while maintaining profitable yields (Jones, 2004, 2007). Leaf water potential has been shown to integrate a plant’s total environment such that differences in evaporative demand, rooting depth, soil moisture and growth-stage-specific water requirements will be accounted for (Grimes and Yamada, 1982). Pre-dawn water potential ($\Psi_{PD}$) has been considered the best available measurement of crop water status for trees (Ameglio et al., 1999); however, its use for irrigation scheduling in cotton is limited. Additionally, canopy temperature has been shown to provide an indirect indication of plant water status in arid regions (Ehrler et al., 1978; Idso, Jackson, Pinter, Reginato, and Hatfield, 1981); however, its usefulness has not been clearly demonstrated in the southeastern United States. Furthermore, data collected during the 2012 growing season indicated that $\Psi_{PD}$ was clearly indicative of midday photosynthetic rates (Figure 1), allowing for the identification of a range of $\Psi_{PD}$ thresholds for irrigation scheduling. In the current study, we evaluated whether $\Psi_{PD}$ could be used to indicate the need for irrigation in cotton and if canopy temperature is a useful indicator of water stress in areas with humid growing seasons.

## Materials and Methods

To determine if $\Psi_{PD}$ (pre-dawn water potential) could be used to indicate the need for irrigation in cotton, two cotton cultivars PHY 499 WRF and FM1944 GLB2, were grown near Camilla, GA and were managed according to practices outlined by University of Georgia Extension except that five distinct irrigation treatments were established. These treatments included the following: 1) dryland, 2) well-watered conditions (100 percent Checkbook), and 3) three different $\Psi_{PD}$ triggers (-0.50, -0.70, and -0.90 MPa). For irrigation scheduling, $\Psi_{PD}$ was measured between 4:30 a.m. and 6:00 a.m. three days per week using a Scholander pressure chamber, and irrigation water was applied at 1/3 the weekly checkbook requirement. Plots were arranged in a randomized complete block design

Canopy temperature ($T_C$), air temperature ($T_a$), and relative humidity were recorded as afternoon averages from noon to 2 p.m., when photon flux density was above 600 W/m2, using SmartCrop sensors (Smartfield Inc., Lubbock, TX) and the weather data obtained from a weather station located at Stripling Irrigation Research Park. Canopy minus air temperatures for a non-water stressed ($T_{NWS} – T_a$) and a non-transpiring crop ($T_{dry} – T_a$) were estimated by regression analysis of $T_C – T_a$ versus VPD for a well-watered crop according to Idso et al. (1981). $T_C – T_a$ data of each plot were used along with estimates of $T_{NWS} – T_a$ and $T_{dry} – T_a$ to calculate a crop water stress index (CWSI) as described by Idso et al. (1981) using the equation: $CWSI = [(T_C – T_a) – (T_{NWS} – T_a)] / [(T_{dry} – T_a) – (T_{nws} – T_{air})]$, where positive values indicate water stress greater than the well watered control.

Seed cotton and lint yield were estimated from two 12 meter rows, and water use efficiency was determined for each plot by dividing lint yields by total water received from planting until defoliation. Season-long $\Psi_{PD}$, CWSI, seed cotton, lint yield, and WUE were analyzed via 2- way ANOVA with a random blocking factor. Post-hoc analysis was conducted using Fisher's LSD ($\alpha = 0.05$). No cultivar-specific differences were observed for any measured parameter. Data presented represent means for each irrigation treatment after data had been combined from both cultivars.

## Results and Discussion

Due to high rainfall during the 2013 growing season, when $\Psi_{PD}$ was averaged for the entire growing season for each plot, there are no statistical differences in predawn water potential for any of the treatments examined, and the average for all treatments was well below the highest water potential threshold (Figure 2). Figure 3 illustrates a strong linear relationship ($r^2 = 0.789$) between vapor pressure deficit and $T_c - T_a$ for canopy temperature data collected between noon and 2:00 p.m., under solar radiation ≥ 600 W $m^{-2}$, and for a well-watered crop (100 percent Checkbook).

Using this relationship, the $T_c - T_a$ of a non-water-stressed crop ($T_{NWS} - T_a$) and a non-transpiring crop ($T_{dry}$) can be estimated under a given VPD and air temperature. Importantly, the relationship in Figure 3 allows for the calculation of the crop water stress index (CWSI). When the season-long CWSI is averaged for each plot, CWSI does not differ significantly from zero (no water stress) for any of the treatments examined (Figure 4). Figure 5 shows average lint yields, seed cotton yields, and water use efficiencies (WUE) for all five irrigation treatments. Importantly, seed cotton yields and lint yields were unaffected by irrigation treatment. However, due to the differences in irrigation water applied during the growing season, WUE was significantly affected by irrigation treatment, where the -0.7, -0.9, and dryland treatments had significantly higher water use efficiency than the checkbook method.

Our findings indicate that water use efficiency could be increased above current irrigation practices with plant-based methods and that remote sensing of canopy temperature may be a viable method for detecting the need for irrigation; however, care should be taken in the analysis of canopy temperature data so as not to include data points under heavy cloud cover.

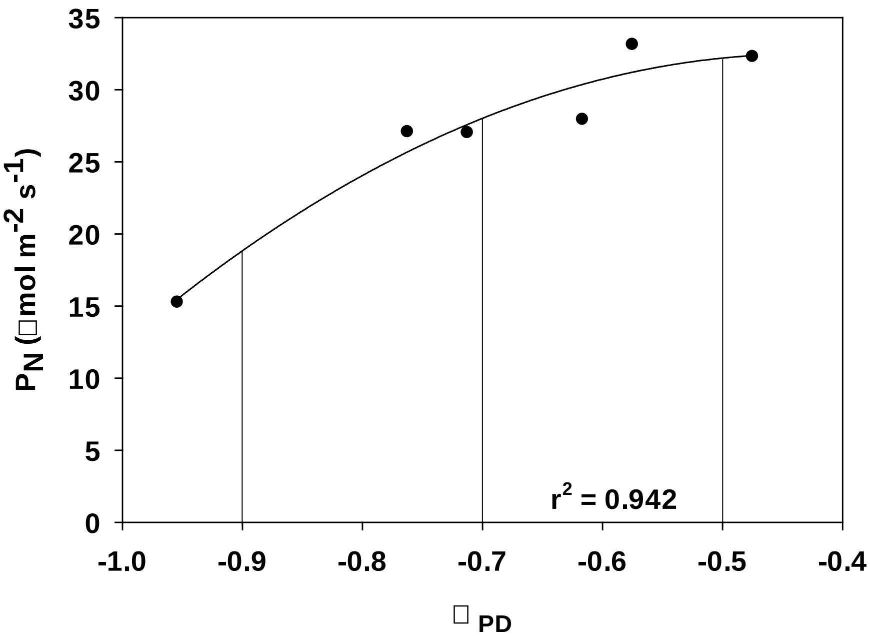


**Figure 1. The Relationship Between Net Photosynthesis ($P_N$) and Predawn Water Potential ($\Psi_{PD}$). Each Data Point Represents the Average of 12 Replicate Plots Where Three Measurements Were Taken Per Plot. Data Were Obtained During the 2012 Growing Season. The Vertical Lines Indicate the -0.5, -0.7, and -0.9 MPa $\Psi_{PD}$ Irrigation Thresholds Selected for the 2013 Growing Season.**

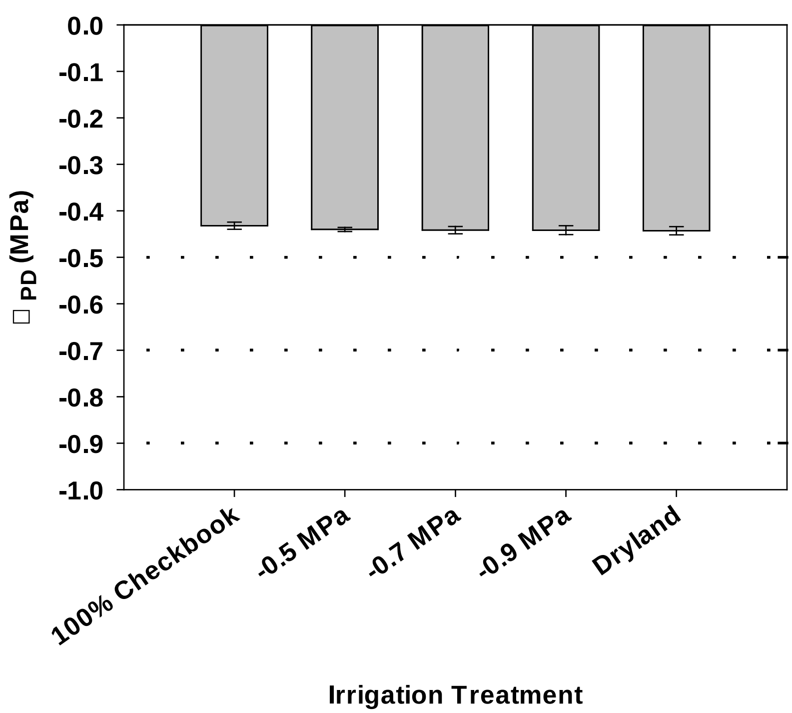


**Figure 2. Seasonal Average Predawn Water Potential (ΨPD) for Cotton Grown in 2013. Significant Differences Due to Cultivar, Treatment, or Interaction Were Not Observed. Data Are Means ± SE (n = 8).**

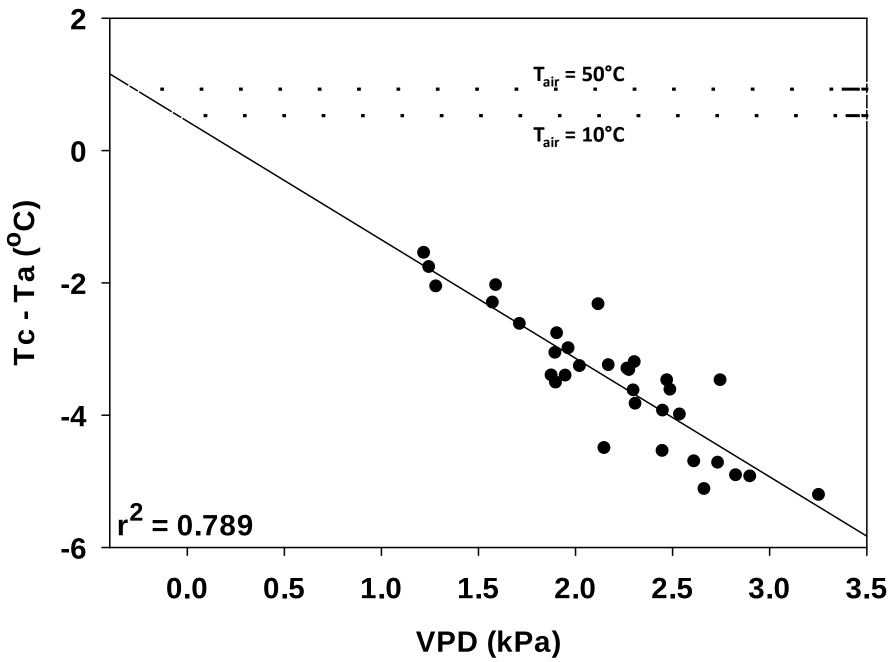


**Figure 3. Canopy to Air Temperature Differential ($T_c$-$T_a$) vs. Vapor Pressure Deficit (VPD) for Well-Watered, Drip-Irrigated Cotton from Noon to 2:00 p.m. on Dates Where Solar Radiation Was ≥ 600 W $m^{-2}$. Horizontal Dashed Lines Represent Canopy Temperatures for Non-Transpiring Crop ($T_{dry}$) Under Two Different Air Temperature Scenarios. Data Are Means For a Given Sample Date (n = 8).**

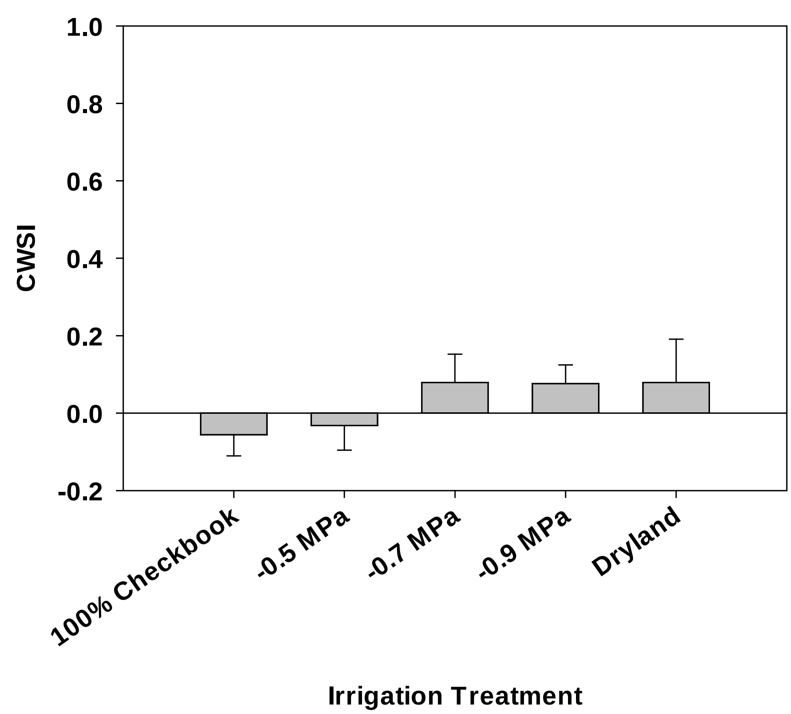


**Figure 4. Seasonal Average Crop Water Stress Index (CWSI) for Cotton Grown in 2013. Significant Differences Due to Cultivar, Treatment, or Interaction Were Not Observed. Data Are Means ± SE (n = 8).**

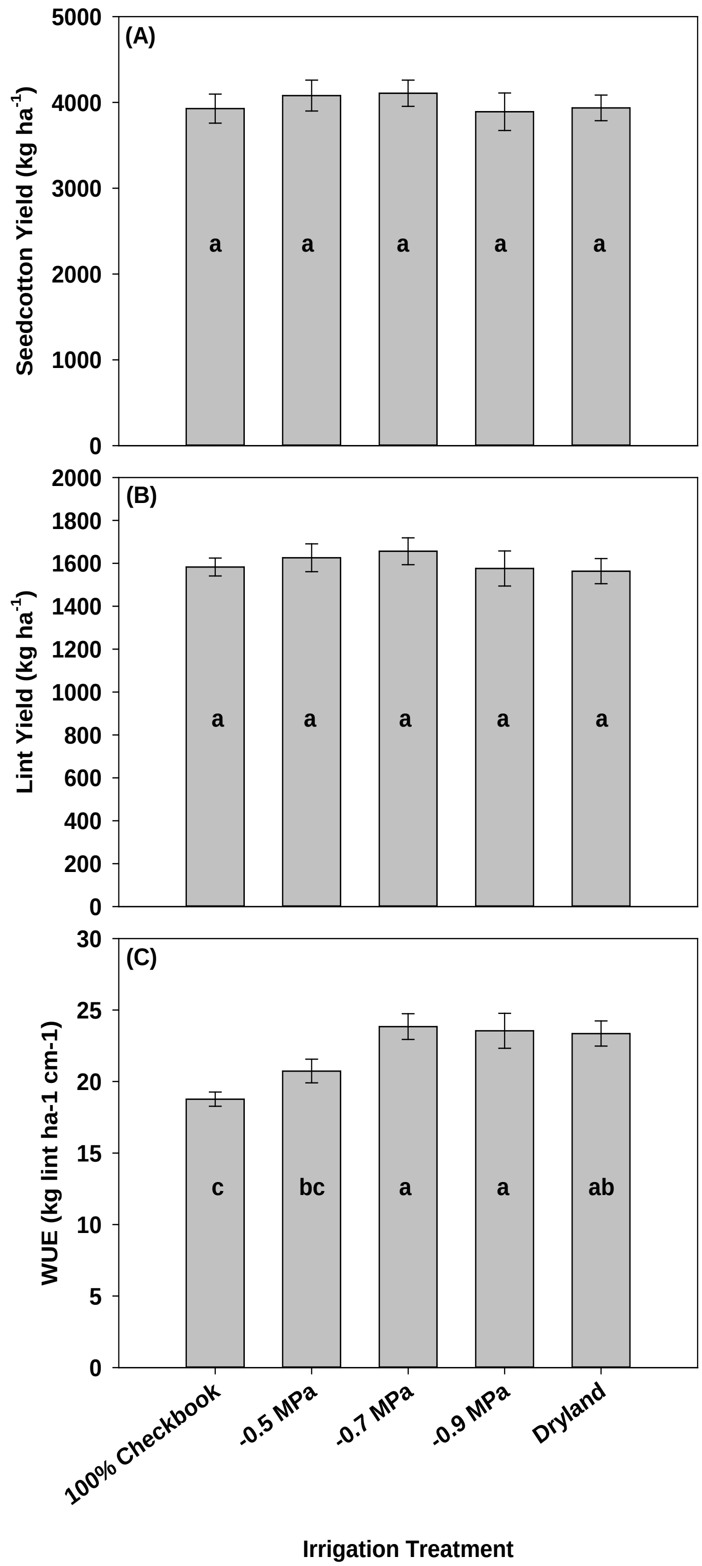


**Figure 5. Seed Ccotton (A), Lint Yield (B), and Water Use Efficiency (C) for Cotton Grown Under Five Different Irrigation Regimes Near Camilla, GA, in 2013. Bars Sharing the Same Letter are Not Ssignificantly Different ($P \geq 0.05$), and Data Represent Means ± SE ($n = 8$).**

## References

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