PLANT WATER STATUS AND LEAF TEMPERATURE AS INDICATORS OF WATER DEFICIT STRESS IN COTTON

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Introduction

The future success of agriculture has been said to mainly be limited by water availability. In locations such as the humid southeastern United States, rainfall can supply much of the water needed for profitable crop production; however, the benefits of supplemental irrigation such as increasing yield and avoiding environmental unpredictability, lead many farmers to adopt an as-needed irrigation approach (Farahani and Munk, 2012). This has resulted in concerns over the sustainability of current irrigation practices. When rainfall deficits necessitate irrigation, uncertainty about the effect that overuse of water resources has on human and non-human ecosystems necessitates a better understanding of the underlying mechanisms that allow for drought tolerance as well as investigations into techniques that allow for decreased water use and maintenance of profitable yields.

Current irrigation practices seek to balance rainfall amounts and water loss due to crop transpiration with supplemental irrigation. 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). Specifically, pre-dawn water potential (Ψ_{PD}) has been considered the best available measurement of crop water status (Ameglio et al., 1999). Additionally, leaf temperature has been shown to provide an indirect indication of plant water status (Ehrler et al., 1978). In this study, we evaluated whether these two indicators of water-deficit stress could be linked to decreased photosynthetic rates and lint yield in dryland cotton, relative to fully irrigated cotton.

Materials and Methods

Plant Material and Study Sites

Experiments were conducted near Camilla, Georgia in 2012. Seeds of three commercially-available cultivars [PHY499 WRF (PhytoGen, Dow AgroSciences), DP 0912 B2RF, and DP 1050 B2RF (Delta and Pine Land, Monsanto Company] were sown on May 5, 2012 at a 0.91m inter-row spacing and at a rate of 11 seeds m^{-1} row. Plots for each cultivar (n = 4) were four rows wide, 12.2 m long, and had 3 m bare-soil alleys. Plots were arranged using a randomized complete block design. All cultivars were grown under both dryland and well-watered conditions to generate variation in leaf water supply at different times during the growing season. Dryland plots are defined as those plots only receiving water via rainfall during the growing season, and well-watered plots received supplemental irrigation to meet weekly water requirements for cotton as defined using University of Georgia Cooperative Extension “Checkbook” recommendations.

Quantification of Ψ_{PD}, P_N, and lint yield

To evaluate the relationships between canopy temperature (IRT), net photosynthesis (P_N), and Ψ_{PD} in field-grown cotton (*Gossypium hirsutum)*, IRT and P_N measurements were conducted at midday (1200-1400 h), under saturating light intensity (PAR > 1200 µmol m^{-2} s^{-1}) using the fourth main-stem leaf below the apical meristem. This measurement time was chosen because cotton plants are under the highest levels of water stress during this time frame (Grimes and Yamada, 1982). Single-leaf gas exchange (P_N quantification) was performed using an LI-6400 portable photosynthesis system (Li-Cor, Lincoln, NE), where all leaves were measured under natural irradiance (PAR > 1200 µmol m^{-2} s^{-1}) and chamber CO_2 concentration of 380 p.p.m. Ψ_{PD} measurements were taken on the same leaves, before sunrise (0500-0600 h). Lint yield data were obtained at the end of the growing season.

Statistical Analysis

Lint yield data were analyzed by two-way ANOVA using Sigma Plot 11 (Systat Software Inc., San Jose, CA). Prior to regression analysis, mean midday Ψ_{PD} and P_N values for each sample date × irrigation treatment were determined. A total of 6 means for each parameter were generated, where each value is the average of 12 replicate plots pooled across three cultivars. On the aforementioned data set, regression analyses to determine the relationship between IRT, Ψ_{PD}, and P_N were performed using Sigma Plot 11.

Results and Discussion

Overall, there was no evidence for variation in response to irrigation by cultivar, implying that either the cotton cultivars tested were not different in terms of drought tolerance, or the stress was not severe enough to differentiate genotypic differences in physiological and yield responses to water deficit.

Cotton grown under dryland conditions had significantly lower lint yields (~35%), when compared to fully irrigated cotton (Fig. 1). This was likely due to decreased P_N in dryland cotton (unpublished data). Regression analysis showed a strong, non-linear (quadratic; r^2=0.886) relationship between P_N and IRT (Fig. 2A) for temperatures between 30 and 38°C. This suggests that the use of canopy temperature as a possible irrigation trigger and an indirect measure of plant water status, despite concerns of the efficacy of this method in humid regions (Jones, 2004, 2007). Additionally, a strong, non-linear (quadratic; r^2=0.942) relationship between P_N and Ψ_{PD} was observed between -0.95 and -0.54 MPa (Fig. 2B), suggesting that this parameter was strongly indicative of water stress in cotton.

In future studies, we plan to evaluate the use of Ψ_{PD} as a direct indicator of crop water stress and irrigate accordingly. In addition, we plan to continuously monitor IRT and evaluate the efficacy of indirect, automated sensors of plant water status for use in irrigation scheduling.

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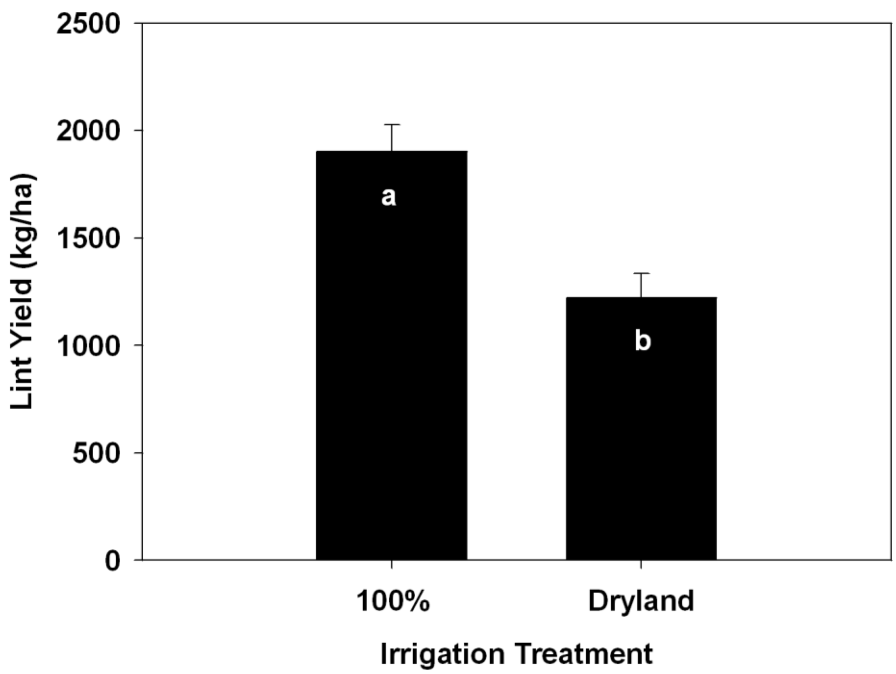

Figure 1. Effect of irrigation treatment on cotton lint yield. Bars not sharing letters are significantly different (P<0.05). Data are means for three cultivars ± standard errors (n=4).

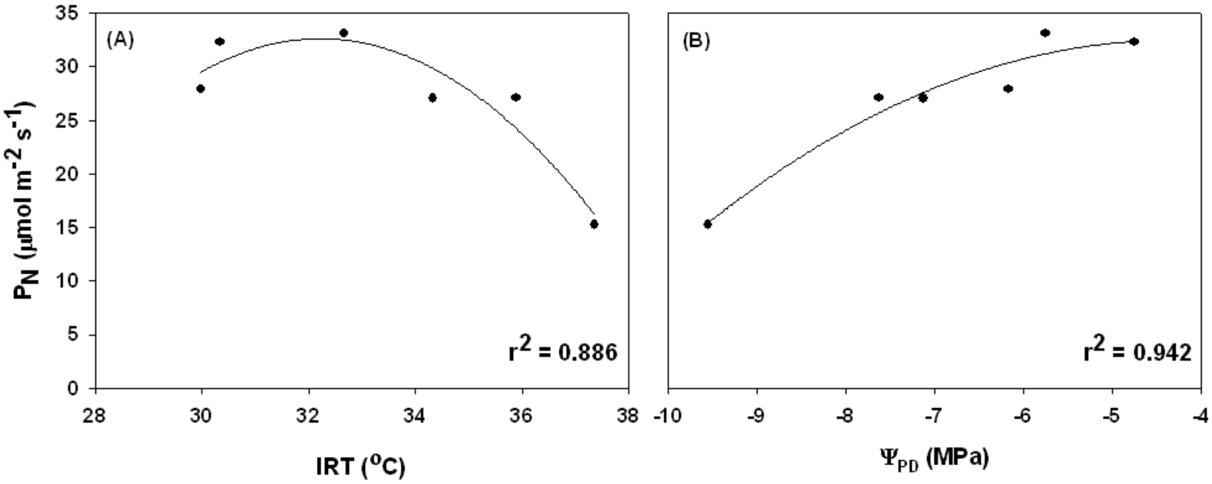

Figure 2. The relationship between net photosynthesis (P_N), canopy temperature (IRT, A), and predawn water potential (Ψ_{PD}, B). Each data point represents the average of 12 replicate plots, where three measurements were taken per plot.