

PHOTOSYNTHETIC RESPONSE OF TWO COMMERCIAL COTTON CULTIVARS TO IMPOSED DROUGHT USING PREDAWN LEAF WATER POTENTIAL AS AN IRRIGATION TRIGGER

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Introduction

Cotton producers in southern Georgia typically adopt a rainfall budget or more commonly a checkbook approach to irrigation scheduling, where water lost to evapotranspiration is replaced by balancing rainfall with supplemental irrigation. With increased interest in resource conservation, many irrigation-scheduling methods based on estimates of crop water status have been proposed. Previous research on cotton indicates that direct measurements of plant water status before sunrise are strong indicators of midday leaf metabolic trends (Chastain et al., 2014; Snider et al., 2014). In these studies, low predawn leaf water potentials in dryland, relative to fully irrigated cotton were observed. When these differences were detected, dryland treatments typically had lower photosynthetic rates. Carbon loss mechanisms, such as respiration and photorespiration were also shown to increase. All cultivars responded similarly to drought stress. In the current study, we were interested in assessing the feasibility of using predawn leaf water potential as an irrigation trigger to induce a range of water-deficit stress. In addition, it was our objective to determine if differences in physiological response to drought stress existed between two different, commercially available cotton cultivars.

Methods

To evaluate the photosynthetic response of two common cultivars [PHY 499 WRF (Dow AgroSciences) and FM 1944 GLB2 (Bayer CropScience)] to water deficit, experiments were conducted at C.M. Stripling Irrigation Research Park near Camilla, Georgia (31°16'55.5"N, 84°17'39.9"W), in 2014. Soil type was classified as Lucy loamy sand (loamy, kaolinitic, thermic Arenic Kandiudults). A common rye cover crop was established and treated with glyphosate prior to planting. Seeds were planted on 2 June 2014, at a 36 in. inter-row spacing and at a rate of four seeds ft⁻¹ under a strip-till system with a common rye cover crop. To ensure proper stand establishment, plots were irrigated at 1.0 in. per week⁻¹, via overhead sprinklers. Fertilization and pest management practices were conducted according to University of Georgia Cooperative Extension cotton production recommendations. Climactic data were provided by the Georgia Automated Environmental Monitoring Network (www.georgiaweather.net) weather station located at the C.M. Stripling Irrigation Research Park, near Camilla, GA. Field observations were conducted on 10 July, 26 July, and 08 Aug. 2014, both during a predawn (0400-0600 h) and midday (1200-1300 h) time window; hereafter referred to as predawn and midday, respectively.

To provide a range of water deficit conditions, cotton plants were grown under five distinct irrigation regimes (Treatments 1 through 5; T1-5). Treatment 1 was irrigated according to University of Georgia Cooperative Extension "Checkbook Recommendations" (Collins et al., 2014). Treatment 5 was grown with no supplemental irrigation beyond the four-leaf stage (referred to as T5 or dryland). Treatments 2-4 consisted of three distinct plant-based irrigation

triggers (-0.5, -0.7, and -0.9 MPa, respectively), as determined by predawn leaf water potential (Ψ_{PD}). The Ψ_{PD} was determined by excising the uppermost, fully expanded leaf of one plant per plot, immediately sealing the leaf petiole within the adjustable compression gasket of a Scholander pressure chamber. Positive pressure was then applied until xylem sap reached the cut surface of the petiole. When the average leaf water potential of a treatment reached its respective threshold, one-third of the weekly water prescribed by the Checkbook was then applied via subsurface drip tape at ~12 in. below the soil surface (Netafilm, Fresno, CA)

Single leaf gas exchange was performed using a LI-COR 6400 Portable Photosynthesis System (LI-COR, Lincoln, NE) on the uppermost, fully expanded leaf both predawn (400-600 h) and midday (1200-1400 h) on 10 and 26 July and 8 Aug. 2015. Flow rate was set to 500 $\mu\text{mol s}^{-1}$, and CO_2 was maintained at 400 ppm. Carbon dioxide exchange rates were logged when rates reached a steady state ($< 0.2 \mu\text{mol m}^{-2} \text{s}^{-1}$). Midday dark respiration rates were estimated according to Valentini et al. (1995).

Plots were arranged according to a split plot, randomized complete block design. Statistical analysis was conducted using JMP 11. Data were analyzed by two-way analysis of variance. Each sample date was analyzed separately. Factors were as follows: whole plot factor = irrigation treatment and split plot factor = cultivar. Post-hoc differences were determined using Fisher's LSD ($\alpha = 0.05$)

Results and Discussion

Early in the growing season (pre-bloom; 10 July), predawn leaf water potentials were similar for all irrigation treatments (between -0.45 and -0.6 MPa). Consequently, no observable effect of irrigation treatment was observed and cultivars responded similarly (Figures 1 A, D, and G). Later in the growing season (during first flower), a drought event lasting approximately 26 days resulted in greater separation amongst irrigation treatments. Specifically, on 26 July T4-5 leaf water potentials (-0.56 MPa) were ~17% lower than T1-2 (-0.47MPa), with T3 forming an intermediate between the two. This decrease in plant water status resulted in decreased midday photosynthetic rates for T3-5, relative to T1-2 (Figures 1 B and E). Interestingly, a cultivar effect was observed on this date, with FM 1944 performing slightly better overall than PHY 499 (~5%). However, no cultivar by treatment interaction was observed. Respiration was shown to increase under water deficit, similar to that reported by Chastain et al. (2014). Specifically, Treatments 3-5 respiration rates were ~35% higher than T1-2 (Figure 1 H). Late in the growing season (during peak bloom; 8 Aug.), treatment differences became more pronounced; however, treatment separation was similar to the previous sample date. Specifically, treatments with the highest leaf water potentials (T1-2, -0.65 MPa) had the highest photosynthetic rates. Treatment 3 (-0.88 MPa) and T4-5 (-1.06 MPa) photosynthetic rates were ~52 and 82% lower than T1-2, respectively. No cultivar effect or two way interaction was observed for this date. No irrigation effect on midday respiration was observed.

This study produced similar photosynthetic and respiratory responses under drought to those reported by Chastain et al. (2014). Evidence was noted for some differences between cultivars. However, there was no supporting data for increased respiration for the 8 Aug. sample date, as drought stress increased. One possible explanation currently under investigation is a confounding effect of leaf expansion and senescence under drought. Typically, when physiological measurements are made, researchers focus on the uppermost, fully expanded leaf. Under drought, low plant water status limits turgor pressure and, thus, slows expansion (Hsiao, 1973). This adds to the difficulty of making comparisons amongst treatments because uppermost, fully expanded leaves likely differ in leaf age as well as water status in a treatment-dependent manner. We are conducting an investigation of the interaction between leaf development and drought stress.

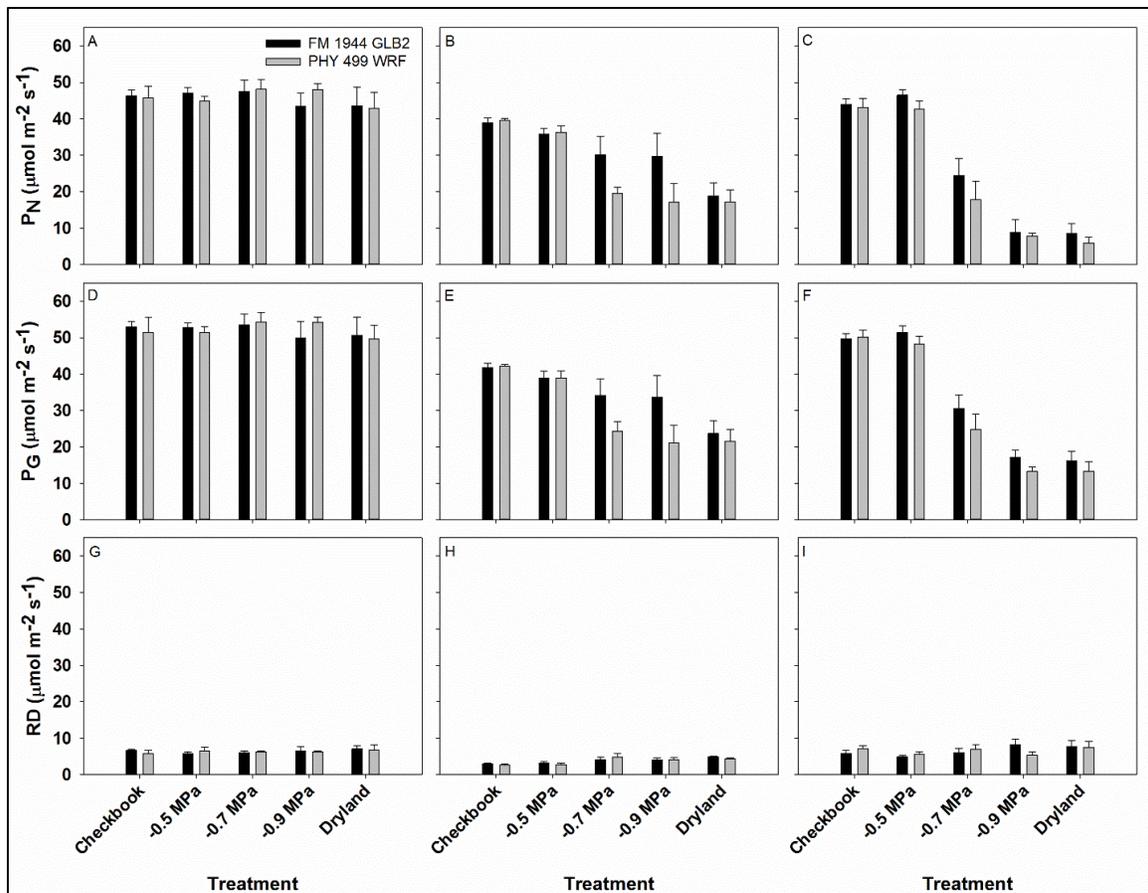


Figure 1. Net photosynthesis (A, B, C), gross photosynthesis (D, E, F), and respiration (G, H, I) for two cultivars on 10 July (left), 26 July (center), and 8 Aug. (right) for 2014. Means \pm SE (n = 4).

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