COMPARISON OF LYSIMETRIC WHOLE-PLANT WATER USE AMONG COTTON GENOTYPES

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Abstract

Soil water deficit is the most dominant yield-limiting environmental factor in drought-prone Texas croplands. The objective of this study is to characterize the water economy of a selected group of cotton genotypes, discern the associated anatomical and physiological attributes controlling their water use, and transfer this information back to breeders and geneticists to advance the development of drought-tolerant cultivars. This poster presents preliminary data obtained in the first year of this study and only displays data of genotypes exhibiting contrasting water economies in an attempt to demonstrate the potential of the methodology used. The progression of daily transpiration of two divergent genotypes exposed to well-watered and water-stressed conditions are shown and briefly discussed.

Introduction

Soil water deficit is the most dominant yield-limiting environmental factor in drought-prone Texas croplands and curtails the magnitude of the economic impact of cotton production. Statewide cotton production could be significantly increased and become more stable with the use of improved drought-tolerant cultivars, as this would reduce the negative impacts of water deficits on yield and lint quality.

Cultivars respond differently to soil water availability. Substantial cultivar-by-environment interactions have been repeatedly found in standard cultivar tests conducted under naturally or managed variable soil water regimes, but these differential responses of cultivars have not been explained nor quantified through proper identification of the responsible plant traits. Physiological studies, on the other hand, have shown that plant water economy is controlled by various anatomical and physiological plant attributes (traits), but this knowledge has not translated into improved breeding lines.

The objective of this study is to characterize the water economy of a selected group of cotton genotypes, discern the associated anatomical and physiological attributes controlling their water use, and transfer this information back to breeders and geneticists to advance the development of drought-tolerant cultivars.

This paper presents preliminary data obtained in the first year of this study and only displays data of two genotypes exhibiting contrasting water economies in an attempt to demonstrate the potential of the methodology used.

Materials and Methods

The study was conducted in the Drought Tolerance Laboratory at the Texas AgriLife Research and Extension Center in Corpus Christi during the 2010 cotton-growing season. This facility consists of two joined modified greenhouse structures housing a large number of electronic mini lysimeters capable of measuring continuous whole-plant transpiration under controlled watering regimes. Computerized systems monitored whole-plant plant water use and controlled watering with a nutrient solution. Data collected were automatically transferred to a dedicated Web server for archiving and analysis.

Seeds of 16 cotton genotypes supplied by Texas AgriLife Research cotton improvement programs in Lubbock and College Station and Monsanto Corporation were pre-germinated in wet paper towels at room temperature. After about 4-5 days, germinated seeds showing a healthy 1 ½" long radicle and with cotyledons still covered by the seed coat were hand-planted at the rate of two per pot in a wet soil medium on April 19. The soil medium consisted of fritted clay, which is known by its high water holding capacity (~43 % of volume). Large pots, 3.578–gallon (13.5-L) volume, were uniformly filled with the soil medium to minimize maximum soil water availability as a variable factor affecting plant growth and plant water economy. Upon planting, the soil surface was covered with aluminum foil to minimize soil evaporation but leaving a central opening to allow the seedlings to emerge through. Tiny holes were punctured in the aluminum foil to allow infiltration of irrigation water. After a week, one of the two emerged seedlings was removed. Twenty four fairly uniform plants of each genotype were grown and spatially arranged to conform a split-plot experimental design with three repetitions, where main plots were two water regimes (always well-watered and water-stressed from early flowering to maturity) and subplots were assigned to the genotype entries. Each subplot consisted of four plants of the same genotype. One of these four plants was permanently sat on the micro lysimeter for continuous measurement of plant water use. The other three plants were subjected to destructive harvest for discrete measurement of various plant growth and physiological attributes throughout the test period.

All experimental plants were individually irrigated daily to excess with a modified Hoagland solution made up with purified city water until the start of the water stress regime on June 18. The well-watered plants continued receiving daily nutrient solution in excess until harvest on August 10. A progressively intensifying water stress condition was imposed by gradually reducing the length of time of watering from 4 minutes to 1 minute, which reduced the volume of daily watering proportionally. This procedure allowed for a field-like onset of water stress on the test plants.

The destructive plant samples were taken at the start of the water stress regime (early flowering) on June 15, and throughout the onset of the water stress on June 28 and July 20, and at full maturity (harvest) on August 10. The discrete measurements included plant height, number of main-stem nodes, main-stem node of the first-position bloom if present, number of leaves, total leaf mass, and leaf water potential, petiole sugar content (Brix) of the youngest fully expanded leaf. In the fourth and last plant sampling other measurements included the number of total harvested bolls per plant, the number of harvested first-position bolls per plant, the mass of seed cotton per plant and the mass of seed cotton in first-position bolls. Leaf water potentials were measured with a 3005HGPL Plant Water Status Console (Soil Moisture Equipment Corp., Santa Barbara, CA), while petiole soluble sugar contents were measured with a Portable Refractometer and Horiba Cardy Compact Ion Meter C-141, respectively (Spectrum Technologies, Inc., Plainfield, IL). Leaf samples collected in the first plant sampling were subjected to dissection for measurements of stomata density, stoma dimensions and xylem properties.

Pot weights were measured continuously at 10-min intervals using a computerized automated system. Daily plant water use (daily plant transpiration) was calculated as the 24-hr sum of differences in pot weight between consecutive hours. This method removed almost all interference of plant growth in the calculation of plant transpiration. Environmental conditions inside the laboratory (air temperature and humidity, wind speed, and solar radiation) were also measured continuously at 10-min intervals with the same computerized system to enable calculations of atmospheric evaporative demand.

Results and Discussion

The genotypes' average progressions of daily whole-plant transpiration under well-watered and water-stressed regimes (Fig. 1) show the decline in daily transpiration values once the water supply restriction began on June 18 and confirms the efficacy of the water stress treatment imposed to the test plants. The day-to-day fluctuation of transpiration values was largely caused by variations in atmospheric evaporative demand. The production of new leaves was also immediately curtailed by the water supply restriction as shown by sharp diversion between the interpolated progressions of the genotypes' average leaf lamina mass of the well-watered and water-stressed treatments (Fig. 2).

In an attempt to demonstrate the potential of the methodology used, only daily transpiration data of two contrasting genotypes are shown, namely C-50 and 04-22-405. The progressions of daily transpiration for these two genotypes under both water regimes are compared against the respective averages of all 16 genotypes and displayed on a per unit leaf lamina mass basis to remove part of any variation caused by small differences in leafiness between them (Figs. 3 to 6). The overall decline through time in daily transpiration per unit leaf mass in both genotypes and both water regimes is caused by an increase in leaf shading as plants get older and leaf production increases. Decreases in leaf conductance due to stomata closure leads to further decreases in transpiration per unit leaf mass in the water stressed plants.

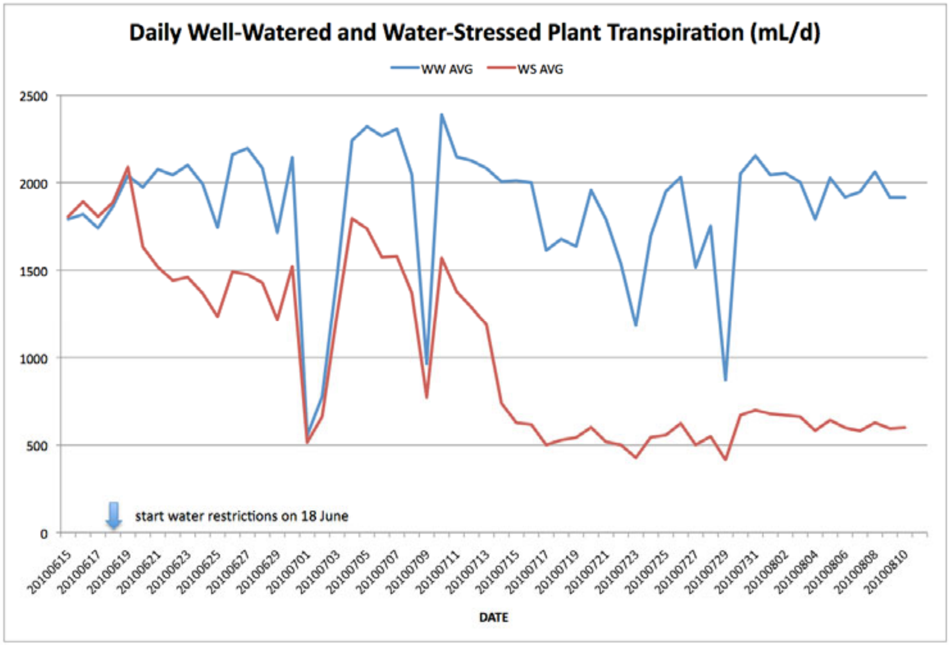

Figure 1. Cotton genotypes' average progressions of daily plant transpiration (mL/d) exposed to well-watered and water-stressed conditions.

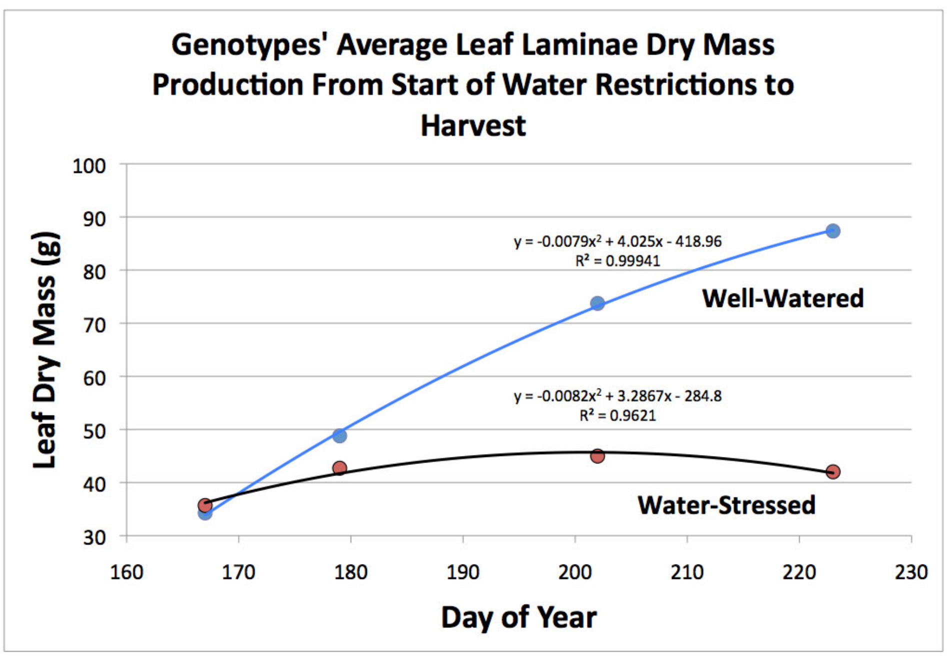

Figure 2. Cotton genotypes' average progressions of leaf lamina dry mass production exposed to well-watered and water-stressed conditions.

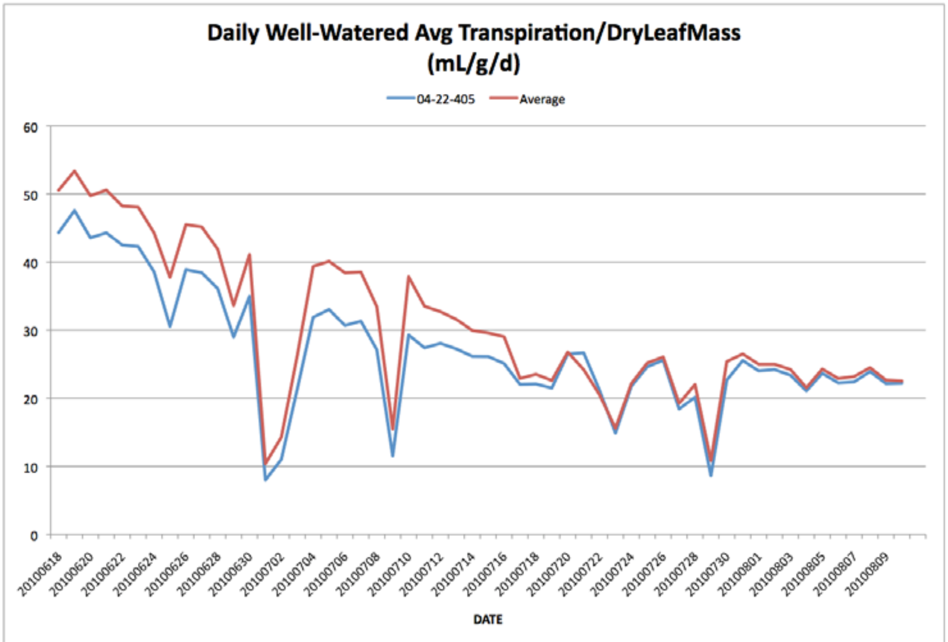

Figure 3. Progression of well-watered daily plant transpiration per unit leaf lamina dry mass (mL/d/g) of genotype 04-22-405 compared to the progression of the genotypes' average.

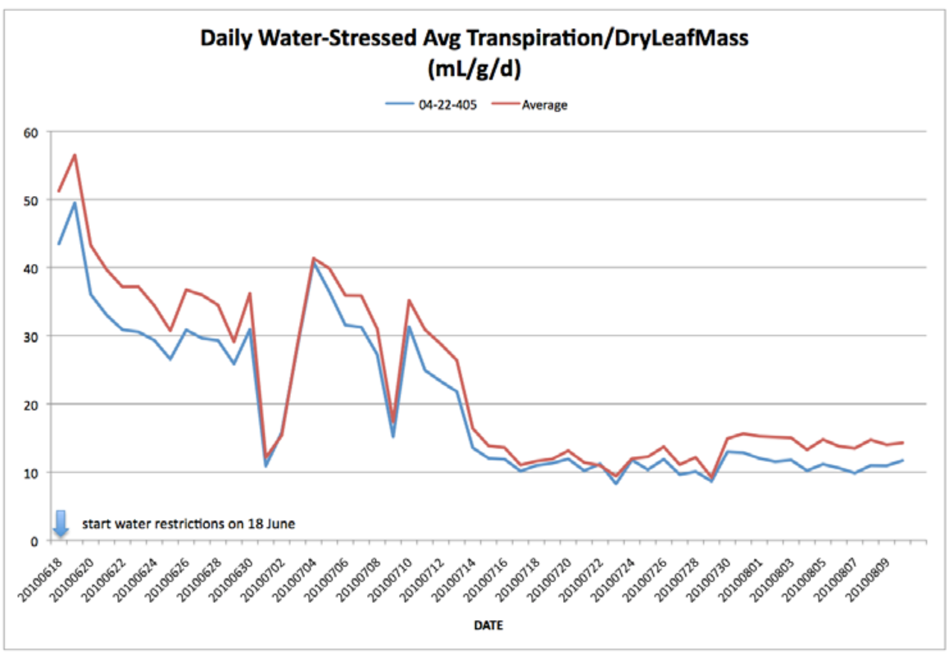

Figure 4. Progression of water-stressed daily plant transpiration per unit leaf lamina dry mass (mL/d/g) of genotype 04-22-405 compared to the progression of the genotypes' average.

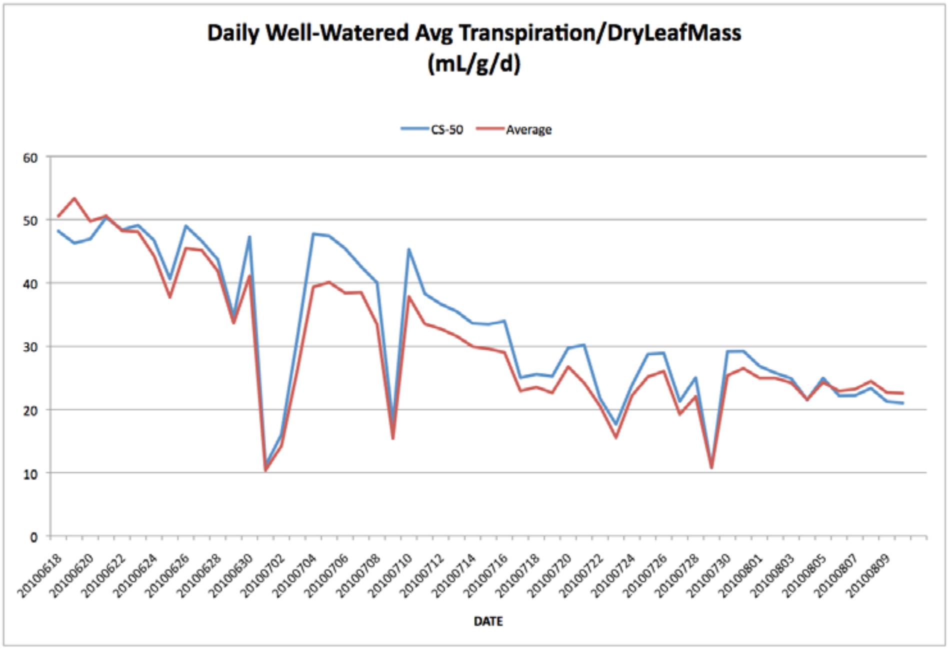

Figure 5. Progression of well-watered daily plant transpiration per unit leaf lamina dry mass (mL/d/g) of genotype C-50 compared to the progression of the genotypes' average.

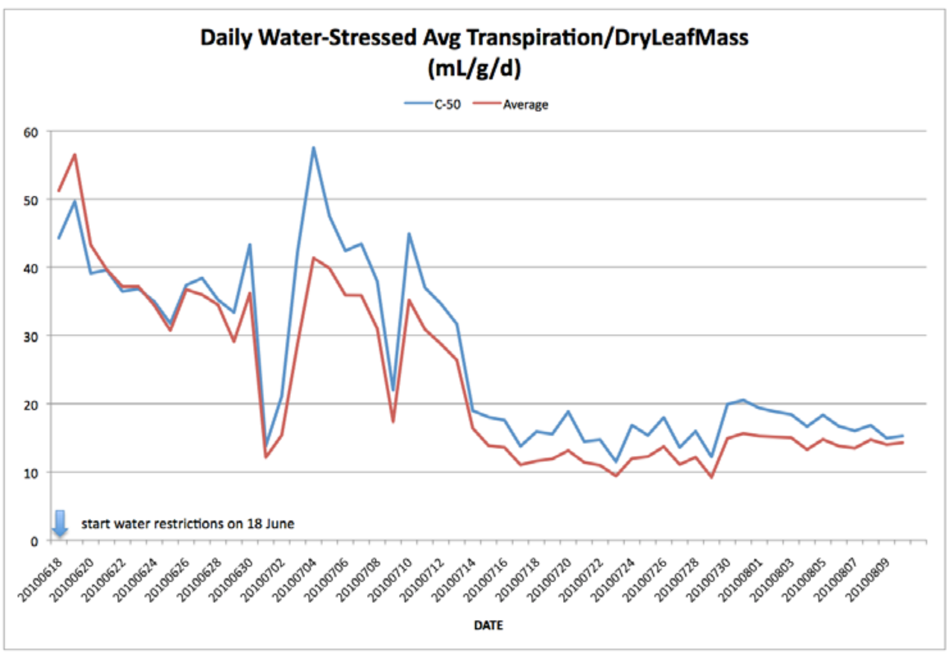

Figure 6. Progression of water-stressed daily plant transpiration per unit leaf lamina dry mass (mL/d/g) of genotype C-50 compared to the progression of the genotypes' average.

While genotype 04-22-405 exhibited below-average transpiration per unit leaf mass during most of the test period under both water regimes, genotype C-50 exhibited above-average values also under both water regimes. One or more plant traits may have contributed to these differences, including leaf type, leaf spatial distribution, leaf conductance for water vapor, stomata density and stoma size, xylem's dimensions. All these plant traits have been measured in this study but their effects on whole-plant transpiration have not been analyzed yet. A mechanistic simulation model, such as the models *McStress* (McCree and Fernandez (1989) and *PlantWaterDynamics* (Fernandez and McCree, 1991), capable of integrating these various measured plant traits, along with primary physiological and physical processes controlling plant water economy and the environmental conditions during the study will serve as a useful tool to identify the traits conferring the water economy characteristics of the various genotypes included in this study.

References

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Acknowledgements

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