

FINAL REPORT

TAES Water Conservation

GENETIC VARIABILITY FOR PHYSIOLOGIC TRAITS RELATED TO WATER USE EFFICIENCY IN SORGHUM

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Project Need and Description: Water is the lifeblood of Texas agriculture and the rural communities that depend upon it. Texas' growing urban populations are affected by the economic status of agriculture, and have increasing need of fresh water. In the central and southern parts of the state, water rationing has become a routine fact of life, while in the High Plains, rising energy costs, low commodity prices, and continued aquifer depletion threaten farm sustainability and therefore regional economy. These trends will accelerate conversion of irrigated cropping systems to dryland or deficit irrigation ones. Water-efficient crops that produce more yield for each amount of water used would help conserve water and increase farm profitability through both energy savings and higher yields.

Sorghum is an important Texas crop known for its drought tolerance. Recent genetic improvements in post-flowering drought tolerance of sorghum have been achieved through the stay-green trait. Pre-flowering adaptation to water-limited environments would also be advantageous, since it is during this period that stand, tiller number, number of heads, and especially number of seeds per head are determined (Squire, 1993). These are components of both yield and water-use efficiency (Eastin, 1983; Evans, 1993).

Pre-flowering leaf photosynthetic rate of sorghum has been found to be correlated with biomass and grain production under both well-watered and water-limited conditions (Peng et al, 1991). The rate of CO₂ fixation (A) is highly correlated with stomatal conductance (g), but the ratio of A to g, and of biomass production to crop transpiration, have been shown to be affected by both environment and genetics in C₄ plants (Kidambi et al., 1990; Payne et al., 1992). Genetic differences for A/g were convincingly demonstrated by Kidambi et al. (1990), who concluded that genetic differences in variation in intrinsic water-use efficiency could directly contribute to increased whole plant water-use efficiency and productivity. Their preliminary work suggested that one could select for higher A without large increases in g, and identified specific genotypes, such as Tx430, with enhanced rates of A. Despite these promising results, little has been done since to document genetic variability in intrinsic water-use efficiency of sorghum, to assess its heritability, or to further study its relationship to whole-plant water-use efficiency under different environments.

A long-term goal of the Crop Stress Physiology Program at Bushland is to identify genetic material with high A and A/g, and to develop diagnostic tools for more efficient

incorporation of these traits into sorghum hybrids targeted for water-limited cropping systems. The specific objectives of the funded research was 1) to further assess genetic variability in sorghum for A and g under both irrigated and dryland conditions, using modern breeding material, and 2) to assess the relation of the more recent physiological traits chlorophyll fluorescence and stay-green, which vary genetically, to pre-flowering A and A/g. Sorghum genotypes identified for high A and A/g would be used in existing or subsequent crosses with a view towards further examining heritability for these traits.

Methods

Measurements of A and g were made on a large number of entries that included both hybrids and converted lines of the Sorghum Breeding Program of Dr. Rosenow at TAES-Lubbock to more formally identify genotypes with superior A and A/g. Gas exchange measurements were made with the Li-Cor 6400 under irrigated and non-irrigated field conditions at Halfway, Texas, and under controlled condition in the growth chamber at Bushland. We had planned to also measure chlorophyll fluorescence at 720 nm wavelength using a PAM 2001 fluorescence sensor (Walz, Germany), but equipment failure prevented us from doing so.

Results

Data for A and g are shown for four contrasting parental lines (TX430, R1988, TX7078, and SC414) in Fig. 1. The lines TX430 and R1988 had high A/g slopes, but TX430 had higher A (~ 40 to $65 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) than R1988 (~ 30 to $50 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$). The enhanced A of TX 430 is consistent with results of Kidami et al. (1990). The lines TX7078 and SC414 had low A/g slopes, and SC414 had lower A than TX7078.

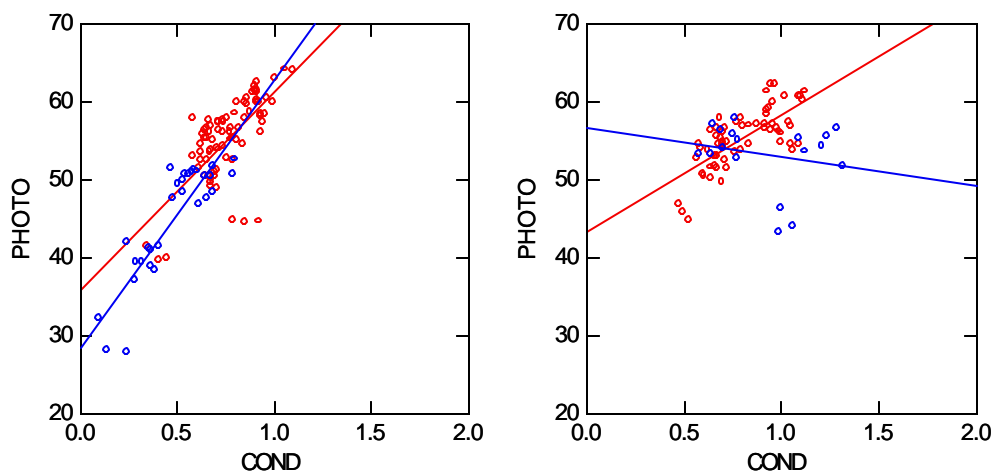


Figure 1. The relationship between A (Photo, in $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) and g (COND, in $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$) in four parental sorghum lines. Left: (TX430 – red) and low (R1988 – blue) A, and high A/g. Right: High (TX7078 – red) and low (SC414 – blue) A, and low A/g.

We have now begun a study of heritability of these traits. Fifteen diallel F1 generations, including reciprocal crosses, were developed by Dr. Rosenow at Lubbock in 2002 and in his winter nursery at Costa Rica in 2002-2003. To complete the diallel crosses, Dr. Rosenow developed one more F1 cross between TX7078 x R1988 at Lubbock in 2003.

Future Work

As soon as seed of the last missing cross is available (November or December of this year), all F1's, reciprocal F1's and their four parents will be planted at TAES Amarillo under 80 and 40% soil moisture in pot in a green house. While in the vegetative stage of growth, these will be moved to a growth chamber for precise evaluation of A and g. Whole-plant WUE will also be measured by preventing evaporation from the soil surface and weighing pots. Griffing's Model 1 (Method 1) will be employed to estimate general and specific combining abilities for A, g, A/g, and WUE. Half of the F1 diallel will be advanced to F2 generation (some of the F2 seed has already been produced), which will then be used to estimate variance components and heritabilities for these traits. Finally, with the reparation of the PAM 2001 sensor, we will be able to compare A measurements determined by gas exchange and chlorophyll fluorescence for speed, precision, and ease of operation.

References

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