Screening for Temperature Tolerance in Cotton

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RESEARCH PROBLEM

Cotton originates from hot climates, but does not necessarily yield best at excessively high temperatures. Recent research has indicated that high temperature is a major abiotic factor adversely affecting cotton yields (Oosterhuis 2002). The ideal temperature range for cotton is reported to be from 68 to 86 °F (Reddy et al., 1991). However, average daily maximum temperatures during boll development in July and August in the U.S. Cotton Belt are almost always above 95 °F, well above the optimum for photosynthesis and reproductive development. This is considered a major reason for lowered and variable yields experienced in cotton production. Cotton yields are less than half of the theoretical maximum (Baker and Hesketh, 1969). Therefore, the overall objectives of this study were (1) to determine the best technique to screen cotton germplasm for tolerance to high temperature, and (2) to use this information to evaluate contrasting cotton genotypes for temperature tolerance in a controlled environment, the results are to be used in cotton breeding selection for temperature tolerance.

BACKGROUND INFORMATION

A negative correlation between yield and high temperature during boll development has been reported, with high temperatures being associated with low yield and cooler temperatures being associated with high yields (Oosterhuis, 1999, 2002). High temperatures decrease carbohydrate, and reduce boll size by decreasing the number of seeds per boll and the number of fibers per seed. High temperatures can affect pollination (Burke and Oliver, 2004) and subsequent fertilization resulting in fewer seeds per boll (Snider et al., 2009).

This is an on-going project with the overall objective of developing a reliable and practical method for screening for high-temperature tolerance in cotton germplasm lines for selection and improvement in cotton tolerance to high temperature. In the first part of this study, we studied the most suitable physiological and biochemical methods to accurately and reliably detect plant

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response to high temperature (Bibi et al., 2008). We selected two measurements: chlorophyll fluorescence and membrane leakage as the best indicators of plant response to high-temperature stress. This information was used to develop a technique for measuring plant response to high-temperature stress and recovery for screening for high-temperature tolerance (Oosterhuis et al., 2009). Plants were grown at 30 °C day temperature for four weeks, after which they were subjected to 45 °C constant temperature for 4 hours, and then the temperature was lowered back to 30 °C until the next day to let the plants recover. Membrane leakage and chlorophyll fluorescence were measured at each of these stages. This provided a measure of how genotypes respond to high-temperature and how they recover from a period of high-temperature (Oosterhuis et al., 2009). This system was used in 2006 to screen 54 lines, in 2007 to screen 76 genotypes, and in 2008 we screened 20 lines from the Advanced Strains Test in the controlled environment chambers. However, the results were variable, and clear differentiation between genotypic response to high-temperature stress was not evident. In light of new research on plant response to temperature (Snider et al., 2010), the technique was refined with the addition of pre-stress measurements of membrane leakage, fluorescence and the antioxidant enzyme glutathione reductase.

**RESEARCH DESCRIPTION**

In the current study, a combination of diverse germplasm was used including: 2 sensitive cultivars (DP393 and CG3020B2RF selected from our previous growth room screening), 2 cultivars showing moderate tolerance (PHY370WR and DYNA2520B2RF), and 2 cultivars with substantial tolerance (VH260 a Pakistan cultivar that grows at temperatures of 45 °C and Arkot 9704 from the Arizona variety trials). Heat tolerance was determined using previously identified techniques (membrane leakage and fluorescence) and new methods including pre-stress glutathione reductase, fluorescence temperature response curves, and relative cell injury. Measurements were made on two-week old plants in a controlled environment in a randomized complete block design with 6 replications. The plants were grown in a large walk-in growth chamber at the Altheimer Laboratory in Fayetteville, Arkansas at 30/20 °C day/night temperature until two weeks after planting. At which time pre-stress measurements were made of glutathione reductase, fluorescence temperature response curves (using a thermoelectric cooler/heater and portable fluorometer), and relative cell injury (a modified membrane leakage technique). Following pre-stress measurements, the temperature was elevated to 45 °C, and after 1 hour, measurements were made of fluorescence and membrane leakage. The temperature was maintained for 4 hours, measurements made again, and then the temperature was lowered to pre-stress level (30 °C) and fluorescence and membrane leakage were measured again the following day (24 hours later) to evaluate recovery. For glutathione reductase measurements, the first expanded true leaf was stored in ziploc bags at -80 °C until measurement.
RESULTS AND DISCUSSION

The pre-stress measurements utilized in this study did not reveal any appreciable differences in genotype thermal stability. Although the quantum yield response curves exhibited temperature dependence in all cultivars examined (Fig.1), the threshold temperatures for quantum efficiency were not significantly affected by cultivar. Glutathione reductase activity and relative membrane stability were highly variable and showed no significant differences between cultivars.

The post-stress measurements did not find any significant effect of heat stress on the membrane leakage of the sensitive, moderate and heat tolerant cultivars (data not shown). Measurements of fluorescence yield before the initiation of stress showed variable results as DP393 (heat sensitive) and Arkot (heat tolerant) had similar values of fluorescence while DYNA2520B2RF (moderate tolerance) had significantly lower fluorescence values. No matter the significant differences on the fluorescence yield of cultivars during the pre-stress period, fluorescence of all cultivars, regardless of their heat sensitivity/tolerance, remained unaffected after 1 h and 4 h under 45 °C. The same results were observed in the fluorescence yield 24 h after the relief of stress.

The lack of significant differences between cultivars was likely related to the plant stage at which these measurements were made being too early, i.e., the plant material was too young and underdeveloped to show a true, easily identifiable response to high temperature. These techniques have previously been successful with plants in later stages of development (Snider et al., 2010). We will repeat this study with plants in later, more mature stages of development.

PRACTICAL APPLICATION

This project has quantified the effects of high temperature on cotton growth and identified methods of measuring the effects of high-temperature stress on cotton. A technique has been formulated to screen cotton genotypes for temperature tolerance. The technique is being used to screen entries from the Arkansas Cotton Variety Tests and Advanced Breeding lines for temperature tolerance. A few lines have been identified with appreciable temperature tolerance, but the majority of the entries have not shown any temperature tolerance and have been susceptible to high-temperature stress. Current commercial cotton cultivars do not appear to have significant tolerance to high temperatures (Brown and Oosterhuis, 2000). This is an ongoing project to screen available cotton germplasm for high-temperature tolerance, with the aim of improving the performance of cotton cultivars under conditions of high temperatures that are often experienced in the U.S. Cotton Belt.

ACKNOWLEDGMENTS

Support for this research was provided by Cotton Incorporated.
LITERATURE CITED


Fig. 1. Representative temperature response curve of quantum yield for six cultivars. Each data point represents the mean of six replications.