Acclimatization of Cotton Exposed to High-Temperature Stress

T.R. FitzSimons and D.M. Oosterhuis

RESEARCH PROBLEM

Abiotic stress accounts for a large proportion of total harvest yield losses every year. Like any plant, cotton must adapt accordingly to the conditions at hand and likewise mitigate possible future effects. High-temperature stress is commonly experienced across the Mississippi river delta regions of Arkansas multiple times during the season. Higher temperatures above a critical threshold do generally correlate with decreased yields (Oosterhuis et al., 2000; Bibi et al., 2008). However, what has not been sufficiently investigated is the speed at which modern cultivars can adapt to changing conditions in the field. Therefore, the objective for this study was to examine possible acclimation of cotton to high-temperature stress using established screening techniques for temperature tolerance of membrane leakage and fluorescence.

BACKGROUND INFORMATION

High temperature negatively affects both metabolic (Mahan and Mauget, 2005) and reproductive (Snider et al., 2010) efficiencies. Ideal temperatures for cotton are between 23 °C and 32 °C with the optimal growth rates achieved when temperatures do not exceed 35 °C (Oosterhuis, 2002). Plants grown in conditions that exceed 35 °C exhibit a decrease in both photosynthetic efficiency and carbohydrate production (Bibi et al., 2008). Respiration and photosynthesis do not share similar ideal temperature curves with photosynthesis exhibiting a narrower temperature band than respiration due to the increased sensitivity of thylakoid membranes (Reddy et al., 1997). Fluorescence investigation of photosynthesis indicate that it becomes less efficient as temperatures exceed 28 °C (Brown and Oosterhuis, 2004). This drop in efficiency creates alternate pathways for electrons to flow leading to higher rates of oxidative stress (Kotak et al., 2007).

Bibi et al. (2008) demonstrated that using chlorophyll fluorescence and membrane leakage were most effective to identify a plant’s response to stress. These techniques have been developed as potential screening techniques to identify cultivars that are tolerant to heat stress (Oosterhuis et al., 2000). This study exam-
in the daily changes of membrane leakage and fluorescence to determine how rapidly a plant may show signs of stress and its acclimation response in two areas: a primary response to temperature stress and a secondary response a week following.

**RESEARCH DESCRIPTION**

A growth chamber study was conducted at the Altheimer Laboratory, Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) cultivar ST5288 was grown in two large growth chambers (Model PGW36, Controlled Environments Ltd., Winnipeg, Canada) set for identical temperature and light profiles. The experimental design was a randomized single factor examining high-temperature response and was replicated once. Temperatures were maintained at a 24 °C during the night and 32 °C during the day with a 14 hour light and 10 hour night cycle. Forty plants in 2-L pots were planted in each growth chamber and watered daily with half-strength Hoagland’s solution. At first flower, a randomly assigned chamber had the temperature increased during the day to 40 °C and maintained for one week. Membrane leakage and fluorescence measurements were taken daily from ten randomly selected plants in each growth chamber at the first fully expanded main-stem leaf. Temperatures in the treatment chamber were lowered to previous experimental temperatures of 32 °C for one week and then were raised again to 40 °C for one week. Membrane leakage and fluorescence measurements were taken again daily from ten randomly selected plants at the first fully expanded main-stem leaf.

**RESULTS AND DISCUSSION**

Membrane leakage exhibited a marked increase in relative conductivity the day following the temperature increase (Fig. 1). Thereafter the conductivity steadily decreased to levels that were only within 10% of the controls after three days indicating that the leaves were acclimating to the warmer environment. Carryover of these protective effects were seen in the first day of the second temperature increase when conductivities were more than 40% less than when temperatures were imposed in the first day of week one. It again took three days for the membranes to stabilize and exhibit leakages that were only 10% higher than the controls. It appears that the cotton plant is capable of reaching a modest stabilization with protective effects that are indeed carried over from one extreme temperature period to another. This lends credence to an acclimation effect present in cotton.

There was no clear trend for the effect of high temperature on electron transport (Fig. 2). During the first week of high temperature, relative electron transport rates measured via fluorescence appeared to drop in rates after the first day of temperature stress in week one, and by day three, rates had rose to their highest levels but dropped slowly over the next three days. When the second temperature regime was initiated on the treatment plants, no significant differences were found
indicating a possible acclimation effect that was carried over from week one. The rise in rate efficiency corresponds to the stabilization of the membranes by day three, demonstrating the close relationship that exists between the two methods of analysis. The plants exhibited no significant difference in electron rate response during the second week which may be evidence of an adaptation to the higher temperatures presented in week one.

**PRACTICAL APPLICATION**

High temperature is considered one of the more serious abiotic factors contributing to the reduction in cotton yields. This yield reduction has led to screening techniques that can rapidly assess whether a particular cultivar is tolerant to the high temperature stress. By demonstrating that cotton has the potential to acclimatize to a given effect demonstrates the need to be cognizant when developing sampling periods in future experiments.

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**LITERATURE CITED**


Fig. 1. Daily membrane measurements taken for six days during each high temperature manipulation. Membrane leakage expressed in relative electrical conductivity from the control is shown for week one of the experiment and for the third week of the experiment when temperatures were increased to 40 °C. Dark bars with the same capital letters are not significantly different ($P = 0.05$). Light bars with the same lowercase letters are not significantly different ($P = 0.05$).
Fig. 2. Electron transport rates are shown for five days of both weeks the third week of the experiment when temperatures were increased to 40 °C. Darker bars with the same capital letters are not significantly different ($P = 0.05$). Lighter bars with the same lowercase letters are not significantly different ($P = 0.05$).