EFFECTS OF HIGH NIGHT TEMPERATURES AT FLOWERING

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Abstract

The effects of high night temperatures on the physiology and biochemistry of cotton's first day flowers and their subtending leaves during reproductive development were evaluated in growth chamber experiments conducted at the Altheimer Laboratory of the University of Arkansas. Plants were exposed to higher than optimum temperatures (30ºC compared to 24ºC) from 18:00-24:00 for a total period of two weeks after plants had reached the flowering stage, approximately 8 weeks after planting. Measurements of photosynthesis and respiration were taken, while white flowers and their subtending leaves were collected and analyzed for their carbohydrate and antioxidant content at the end of each week. The results showed that high night temperatures significantly increased respiration rates while photosynthesis rates remained unaffected. Leaf sucrose concentrations also remained unaltered, while leaf starch content was significantly decreased. Leaf glucose levels were significantly increased and a similar pattern was observed in pistil glucose, sucrose and starch concentrations. Leaf glutathione reductase content was increased under conditions of elevated night temperatures, while pistil glutathione reductase content was decreased, however not significantly compared to the control.

Introduction

Global temperature is expected to increase by 1.4 to 5.8 ºC by the end of the 21st century due to increases in greenhouse gases concentrations (IPCC, 2007). High temperatures are considered to be a major environmental stress contributing to decreased yields; however, night temperatures are anticipated to increase faster than day temperatures due to increased cloudiness that will result in decreased radiant heat loss (Alward et al., 1999). Even though extensive research has been conducted on the effects of high day temperatures on cotton, limited information exists on the effects of high night temperature on cotton growth and productivity. Previous research has reported that higher than optimum night temperatures during cotton's vegetative stage of growth resulted in significant increases in respiration rates (Loka and Oosterhuis, 2010). Consequently, depletion in leaf carbohydrates content and significant reductions in leaf energy levels were observed (Loka and Oosterhuis, 2010) ultimately resulting in yield reduction (Arevalo et al., 2008). The reproductive stage appears to be more susceptible to heat stress compared to the vegetative stage (Hall, 1992). Research in other crops has indicated that high night temperatures during the reproductive phase have detrimental effects on yield due to increased male sterility and floral abscission (Warrag and Hall, 1984, Guinn, 1974), floral bud suppression, decreased pollen viability, spikelet fertility and grain filling (Mohammed and Tarpley, 2009), however, little or no attention has been given to the effects of increasing night temperatures on the reproductive forms of cotton.

Materials

Growth chamber studies were conducted in 2010-2011 in the Altheimer laboratory of the University of Arkansas in Fayetteville. Cotton (*Gossypium hirsutum* L.) cultivar ST5288B2F was planted into 2L pots containing a horticultural mix (Sun-Gro horticulture mix). The growth chambers were set for normal conditions of 30/20°C (day/night), ±60% relative humidity, and 14h photoperiod, while half-strength Hoagland's nutrient solution was applied daily in order to maintain adequate nutrients and water. At flowering (approximately 8 weeks after planting) plants were randomly divided in two groups: (1) Control (C), and (2) High Night Temperatures (HNT). Control plants were kept at normal temperatures of 32/24ºC while high night temperatures of 30ºC were imposed on the second group from 18:00-24:00. Plants were arranged in a completely randomized block design with twenty replications, while the experimental design was a 2x2 factorial design with the main effect being high night temperatures and the secondary effect being time. Photosynthetic and respiratory rates were measured weekly between 10:00-12:00 and 22:00-24:00, respectively, using the fourth main-stem leaf from each plant using the LiCor 6200 gas analyzer. Glucose, sucrose, and starch content as well as glutathione reductase levels were estimated from white flowers (pistils) and their subtending leaves that were collected at the end of each week. Carbohydrate extraction was done according to Zhao et al. (2008), while antioxidant extraction was done according to Lu and Foo (2001), and the supernatants were analyzed with a Multiscan Microplate Reader.

Results

High night temperatures significantly increased respiration rates (Fig. 1) while photosynthesis rates remained unaffected (Fig. 2). Additionally, leaf glucose concentrations were increased while the opposite was observed for leaf starch concentrations. However, leaf sucrose concentrations remained unaltered. Under conditions of elevated night temperatures pistil glucose, sucrose and starch levels were increased (Table 1). Leaf glutathione reductase content was increased while pistil glutathione content decreased, however not significantly compared to the control (data not shown).

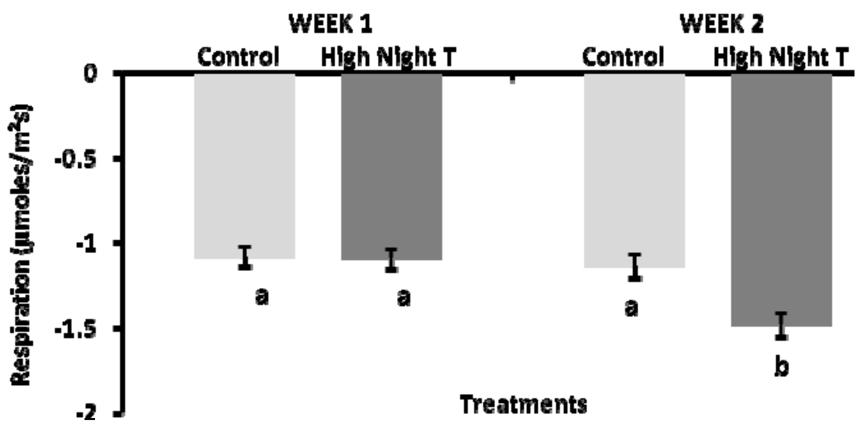

Figure 1: Effect of high night temperatures on leaf respiration (P=0.05).

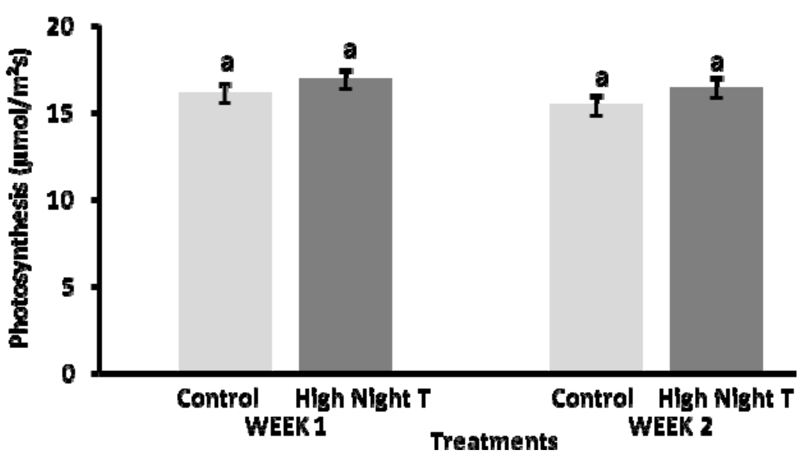

Figure 2: Effect of high night temperatures on leaf photosynthesis (P=0.05).

Table 1: Effect of high night temperatures on leaf and pistil glucose, sucrose and starch concentrations (P=0.05).

	GLUCOSE		SUCROSE		STARCH	
	LEAF	PISTIL	LEAF	PISTIL	LEAF	PISTIL
CONTROL	b	b	a	b	a	b
HNT	a	a	a	a	b	a

Summary

In summary, leaf antioxidant mechanism appeared to be more efficient in protecting leaf photosynthetic machinery and carbohydrate metabolism. No reductions were observed in photosynthesis rates, while leaf glucose content increased, despite the elevated respiration rates, possibly due to the efficient starch and sucrose breakdown. On the other hand, pistil antioxidant mechanism appeared more sensitive to the high night temperatures regime resulting in accumulation of glucose, sucrose and starch concentrations indicating a perturbation in carbohydrate metabolism that could lead to inefficient use of carbohydrates.

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