EFFECT OF HIGH NIGHT TEMPERATURES ON COTTON GAS EXCHANGE AND CARBOHYDRATES

Dimitra A. Loka
Derrick M. Oosterhuis
University of Arkansas
Fayetteville, AR

Abstract

High temperatures are considered to be one of the main environmental factors contributing to variable yields in cotton. This is apparently due to a negative effect on respiration and carbohydrate accumulation, but the evidence for this is lacking. Yield comparisons between geographical locations with the same day temperatures and different night temperatures have shown that the locations with higher night temperatures have lower yields. In this study it was hypothesized that high night temperatures have a negative effect on cotton respiration and energy balance that results in a significant loss of carbohydrates and ultimately in a yield decrease. Growth chamber studies were conducted in 2007, at the Altheimer Laboratory, University of Arkansas. Treatments consisted of normal and elevated night temperature regimes, and measurements were made of respiration, energy balance and carbohydrates status. The results showed an increase in respiration with elevated temperatures which led to a decrease in leaf ATP and a depletion of leaf carbohydrates.

Introduction

The unpredictability of cotton yields is a great concern to cotton industry. The five-year average yield for cotton in the U.S.A. is 718lb lint/acre, whereas the theoretical maximum lint yield is 3720 lb lint/acre. U.S. Cotton production suffers from extreme year-to-year yield variability which has been attributed to genetics, management practices and unfavorable weather (Robertson, 2001). High temperatures are considered to be one of the main environmental factor contributing to variable yields (Oosterhuis, 1994), but limited information exists on the effects of high temperature on cotton growth and yield. Although cotton originates from hot climates, the ideal temperature range for its growth is between 20º and 30ºC (Reddy et al., 1991) with the optimum being 28ºC (Burke et al., 1988). However, at higher temperatures, as often experienced in the U.S. Cotton Belt, plant metabolism decreases dramatically compromising the reproductive efficiency of the crop.

Additionally, reports in the literature suggest that high night temperatures cause respiration rates to increase resulting in furthermore depletion of carbohydrates and yield reduction (Arevalo, 2005). This suggestion is supported from comparisons of yield and temperature regimes between Arkansas and Greece (Oosterhuis, 2002). Greece has comparable production systems, with similar day temperatures but lower night temperatures than Arkansas, especially during the boll development period, and produces nearly fifty percent more lint yield per acre than Arkansas (Bibi et al., 2006).

Most reported studies of the effects of night temperature on growth do not involve solely the night temperatures as a contributing factor to lower yield. When night temperature was raised, the day temperature was also raised, making it impossible to determine the specific effect of increased night temperature alone. Therefore, the objective of this study was to determine the effect of increasing night temperatures at similar day temperatures on respiration, energy balance and carbohydrate accumulation.

Materials and Methods

Growth chamber studies were conducted in 2007 to determine the immediate effect of high night temperatures on cotton respiration, energy balance and carbohydrate accumulation.

1. Effect of long-term high night temperature on respiration, energy balance and carbohydrate accumulation

Cotton (*Gossypium hirsutum* L.) cv. DP444BR was planted in July and August 2007 at the Altheimer Laboratory, University of Arkansas into 1 L pots containing Sunshine potting media MIX #1 (SunGro Distribution Inc., Bellevue, WA). The growth chambers (Conviron PGW 36, Conviron Inc., Winnipeg, Canada) were set for 14/10-h photoperiods and a relative humidity of 60%. Plants were arranged in a completely randomized block design with 8 replications. All pots received half-strength Peter's (Spectrum Group, St. Louis, MO) nutrient solution daily to maintain adequate nutrients and water.

Cotton was grown until pinhead square under normal day/night temperatures of 30º/20ºC. Then the plants were divided in two groups and one night temperature regime (28ºC) was imposed on the treated group for 4h (20:00-24:00) for an overall duration of 4 weeks, while the control plants remained under normal temperatures (30º/20ºC). Respiration measurements were taken on the 1st, 2nd and 4th week at 22:00h on each plant using the fourth main-stem leaf from the terminal with a LICOR-6200 infra-red gas analyzer (LICOR Inc., Lincoln, NE). Carbohydrates were measured from fresh fourth-position-main-stem leaves sampled at 6:00h. The samples were oven-dried for 3 days at 50ºC prior to being extracted and analyzed with a MultiScan Ascent Microplate Reader (Thermo Fisher Scientific Inc., Waltham, MA). Six leaf disks were excised from fourth placed main-stem leaves from each plant at 20:00h (immediately before the initiation of the dark period) and placed in TRIS solution for the extraction of adenosine triphosphate (ATP). The aliquot was then stored at -80ºC and used later for ATP determination with a 20/20n Luminometer (Turner Biosystems Inc., Sunnyvale, CA).

2. Effect of short-term high night temperatures on respiration, energy balance and carbohydrate accumulation

Cotton (*Gossypium hirsutum* L.) cv. DP444BR was planted in October 2007 at the Altheimer Laboratory, University of Arkansas into 1 L pots containing Sunshine potting media MIX #1. The growth chambers were set for 14/10-h photoperiods and relative humidity of 60%. Plants were arranged in a completely randomized block with 6 replications. All pots received half-strength Peter's nutrient solution daily to maintain adequate nutrients and water.

Cotton was grown until pinhead square (4th week) under normal day/night temperatures of 30º/20ºC. Three night temperature regimes (24º, 27º and 30ºC) were imposed at 19:00 at the initiation of the dark period with 2h-intervals in between each regime. Measurements of respiration, carbohydrates and ATP content were taken at the end of each temperature regime.
All results were statistically analyzed using JMP software (SAS Institute, Cary, NC).

Results and Discussion

1. Long-term high night temperatures

The analysis showed a numerical increase in respiration for the high temperature treatment at the 1st week that became highly significant at the 2nd week of the high night temperature treatment. These differences were not observed at the 4th week due to the acclimation of plants to the high temperature (Fig. 1).

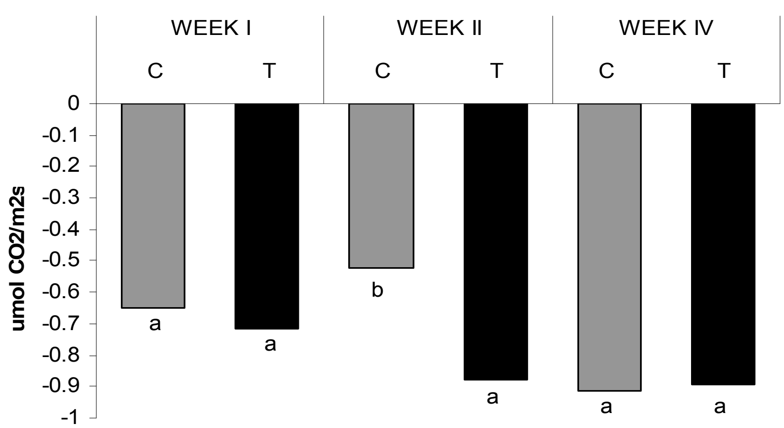

Fig. 1: Effects of long-term high night temperatures on respiration one, two and four weeks after the night temperature was raised. Pairs of columns within each time interval with the same letter are not significantly different, (P<0.05). C= control, T= treated.

There was a consistent trend for high night temperatures to decrease leaf ATP (energy) levels across all measurements (Fig.2). This was expected due to the increased night respiration rates caused by the high night temperatures treatment.

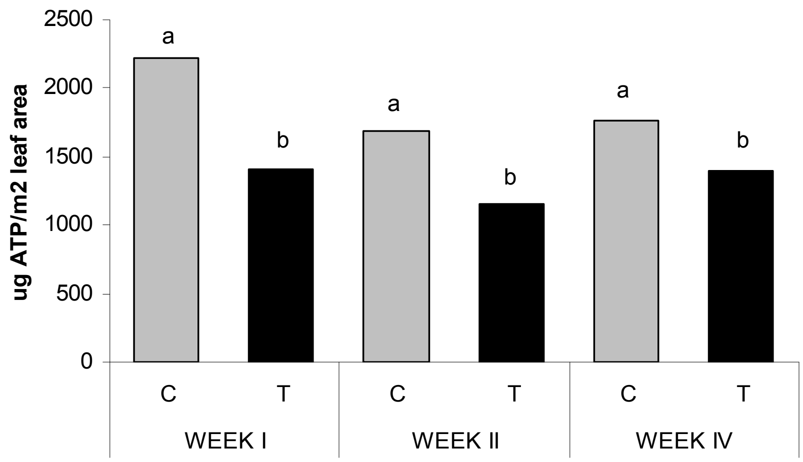

Fig.2: Effects of long-term high night temperatures on ATP content one, two and four weeks after the night temperature was raised. Pairs of columns within each time interval with the same letter are not significantly different ($P<0.05$). C= control, T= treated.

Similarly to ATP content, leaf non-structural carbohydrates concentration of the treated was significantly lower than that of the plants that remained under normal temperatures. These observations support the hypothesis that high night temperatures consist a factor that leads to carbohydrate decrease.

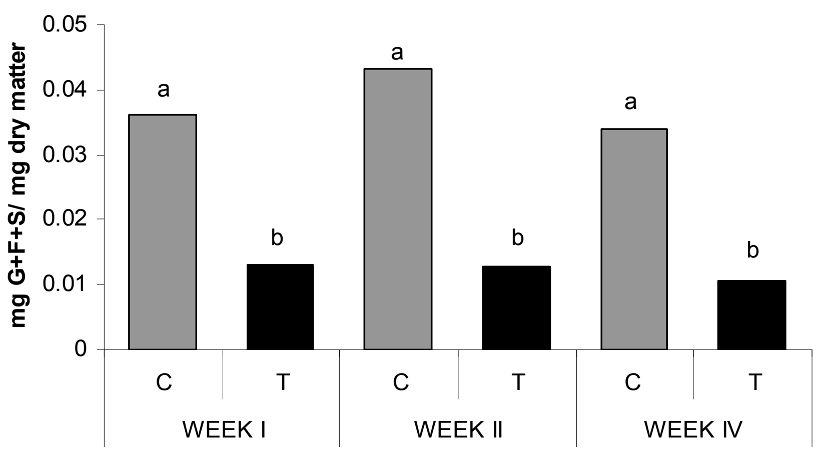

Fig. 3: Effects of long-term high night temperatures on non-structural carbohydrate content one, two and four weeks after the night temperature was raised. Pairs of columns within each time interval with the same letter are not significantly different, ($P=0.05$). C= control, T= treated

2. <u>Short-term high night temperatures</u>

Significant decreases were observed in the ATP content between the control (24°C) and the high temperature regimes (27°C, 30°C) and also within the high temperature regimes.

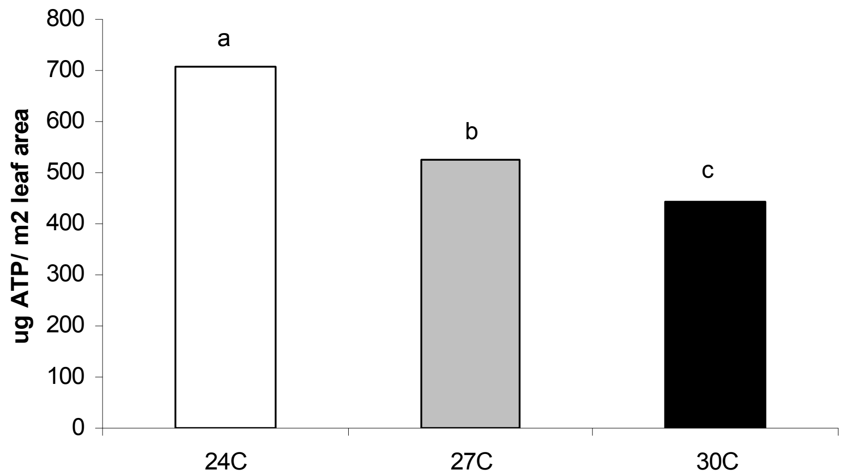

Fig. 4: Effect of short-term high night temperatures on ATP content at 2h intervals at the start of the dark period. Columns with the same letter are not significantly different (P=0.05).

There was a significant increase in respiration (P=0.05) for both temperature regimes (27°C, 30°C) compared to the control (24°C), even though there was no significant difference between the two high temperature regimes (Fig.5).

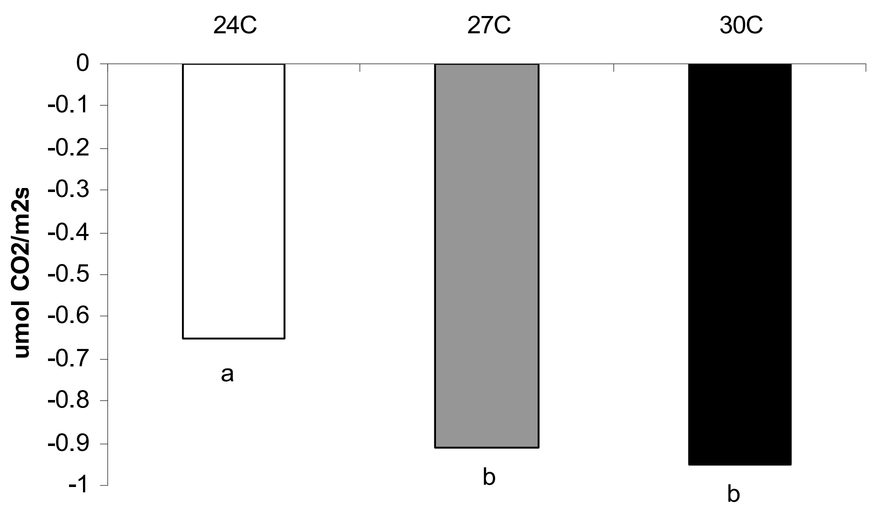

Fig.5: Effect of short-term high night temperatures on respiration at 2h intervals at the start of the dark period. Columns with the same letter are not significantly different (P=0.05).

Conclusions

Overall our research has shown that high night temperatures have a detrimental effect on respiration, energy levels, and subsequent carbohydrate concentration. In related studies in our laboratory, this has been associated with decreased fiber per seed. This information could be used to formulate strategies for screening germplasm for tolerance to high night temperature.

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