Effect of High Night Temperatures on Cotton Respiration, ATP Content, and Carbohydrates

Dimitra A. Loka and Derrick M. Oosterhuis

RESEARCH PROBLEM

The unpredictability of cotton yields is a great concern to the cotton industry. High temperatures are considered to be one of the main environmental factors contributing to variable yields in cotton (*Gossypium hirsutum* L.). This has been attributed to a negative effect on respiration and carbohydrate accumulation, but the evidence for this is lacking. In this study it was hypothesized that high night temperatures have a negative effect on cotton respiration and energy (adenosine 5-triphosphate, ATP) levels that results in a significant loss of carbohydrates.

BACKGROUND INFORMATION

United States cotton production suffers from extreme year-to-year yield variability that has been attributed to genetics, management practices, and unfavorable weather (Robertson, 2001). High temperatures are considered to be one of the main environmental factors 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 20° and 30°C (Reddy et al., 1991) with the optimum for photosynthesis being 28°C (Burke et al., 1988). However, at higher temperatures, as are 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 further depletion of carbohydrates and yield reduction (Arevalo, 2008). This suggestion is supported from comparisons of yield and temperature regimes between Arkansas and Greece (Oosterhuis, 2002). 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

---

1 Graduate assistant and distinguished professor, respectively, Crop, Soil, and Environmental Sciences Department, Fayetteville.
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 long-term and short-term high night temperatures and similar day temperatures on respiration, ATP content, and carbohydrate accumulation.

RESEARCH DESCRIPTION

Two sets of experiments were conducted at the Altheimer Laboratory, University of Arkansas. Cotton (*Gossypium hirsutum* L.) cultivar ‘DP444BR’ was planted in 1-L pots containing Sunshine potting media mix. The growth chambers were set for a 12-h photoperiod with day/night temperatures of 30/20°C. All pots received half-strength Peter’s nutrient solution daily to maintain adequate nutrients and water.

For the first set of experiments, cotton was grown until the pinhead square stage under normal day/night temperatures of 30/20°C. Plants were then divided in two groups and one group was transferred into a second identical growth chamber, with similar conditions of photon flux density, humidity, and photoperiod as the first chamber, but with the night temperature raised to 28°C for 4 h at the start of the dark period (20h00-24h00) for an overall duration of 4 weeks, while the control plants remained under normal temperatures (30/20°C). Measurements of respiration, ATP content, and carbohydrate status were conducted at the end of the first, second, and fourth week using the attached fourth main-stem leaf from the terminal of the plant. The experimental design was a two-factor factorial (time and temperature) with eight replications.

For the second set of experiments, cotton was grown until pinhead square under normal day/night temperatures of 30/20°C. At the pinhead square stage, temperatures of 24, 27, and 30°C were imposed on the plants for one night starting at 19h00 (at the initiation of the dark period) with 2-h intervals between each incremental temperature regime. Measurements of respiration rates, leaf ATP content, and leaf carbohydrate status were taken at the end of each night temperature treatment, 2 h, 4 h, and 6 h into the dark period, from fresh leaves from the fourth main-stem node from the terminal. The experimental design was a completely randomized design with eight replications.

Respiration measurements were taken with a LI-COR 6200 infra-red gas analyzer (LI-COR Inc., Neb.). Leaf ATP content was determined according to a bioluminescent technique using substrate-enzyme complex of firefly luciferin-luciferase (ATP bioluminescent assay kit, Sigma Chemical Company, St Louis, Mo.) that converts the chemical energy associated with ATP into light. The light produced (proportional to ATP content) was measured with a 20/20n Luminometer (Turner Biosystems Inc., Sunnyvale, Calif.). Soluble carbohydrate content was measured according to a modification of the Hendrix (1993) protocol and readings were taken with a MultiScan Ascent Microplate Reader (Thermo Fisher Scientific Inc., Waltham, Mass.).

RESULTS AND DISCUSSION

Long-term high night temperatures had no effect on respiration rates during the first week of the temperature regime (Fig. 1). However, during the second and fourth
week, plants grown under high night temperatures (28°C) had significantly higher rates of respiration, compared to plants grown under normal night temperatures (20°C). Leaf ATP energy levels proved to be more sensitive to the elevated night temperatures, showing a decline at the end of the first week after the night temperatures had been raised (Fig. 2). The pattern was similar for the second and fourth weeks, with leaf ATP levels of the plants exposed to elevated night temperature regimes having significantly lower ATP levels compared to those of the control. The effect of high night temperatures on carbohydrate content was similar to that of leaf ATP levels. Both hexose and sucrose content were significantly decreased, due to the elevated night temperature regime across all weeks of the study, but leaf starch content remained unaffected by the high night temperatures (data not shown). This led us to speculate that the duration of the high temperature regime (4 h during the night) was sufficient to cause a depletion of soluble carbohydrates but not enough to cause mobilization of starch.

Short-term incremental increases to the night temperatures had an immediate effect on the respiration rate. Both high temperature regimes, 27 and 30°C, caused an increase in respiration rates of the plants, compared to those kept at 24°C (Fig. 3). There was also an immediate response in ATP content to the elevated night temperatures, with ATP content of the plants at 27 and 30°C being significantly lower than that of plants at 24°C (Fig. 4). A similar decline was not observed in the carbohydrate content (data not shown). In contradiction to our expectations, leaf hexose and sucrose levels remained unaffected by either of the high night temperature regimes (27 or 30°C), leading us to assume that a longer imposition of high temperatures might be needed to significantly deplete leaf carbohydrates.

**PRACTICAL APPLICATION**

High night temperatures caused a significant increase in respiration rates, which resulted in a reduction of leaf energy levels and carbohydrate content. This was due to the immediate short-term (i.e., two hour) effect of increasing night temperatures on respiration and ATP content, while the effects on carbohydrates were more cumulative over a longer period of time.

Since carbohydrates are considered to be the basic building components for the majority of crops and especially for cotton, where 94% of the fiber consists of cellulose, we understand that the detrimental effect of high night temperatures on the energetics and consumption of carbohydrates will have a significantly detrimental effect on yield.

It is apparent that more research is needed in order to quantify the effect of high night temperatures on cotton’s dry matter production, partitioning into fruit and yield.

**LITERATURE CITED**


Fig. 1. Effect of high night temperature 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 with normal night temperature (20°C), T=high night temperature (28°C).
Fig. 2. Effect of high night temperature on leaf ATP content, presented as a percentage of the control, one, two, and four weeks after the night temperatures were raised. Pairs of columns within each time interval with the same letter are not significantly different (P=0.05). C= control with normal night temperature (20°C), T= high night temperature (28°C).

Fig. 3. Effect of short-term high night temperatures on respiration at 2 h intervals at the start of the dark period. Columns with the same letter are not significantly different (P≤0.05). Bars of ± 1 SE are shown.
Fig. 4. Effect of short-term high night temperatures on ATP content at 2 h intervals at the start of the dark period. Columns with the same letter are not significantly different (P≤0.05). Bars of ± 1 SE are shown.