Effect of 1-MCP on Ethylene Synthesis and Development of Cotton Flowers under Normal and High Temperature

Eduardo M. Kawakami, Derrick M. Oosterhuis, and John L. Snider

RESEARCH PROBLEM

With global warming and climate change, high-temperature stress has become a major factor affecting crop growth and yield. Cotton (Gossypium hirsutum L.) crops in the U.S. experience periods of extreme high temperatures during flowering and boll development, but information is lacking on the physiological response of cotton to high-temperatures stress and appropriate techniques to ameliorate this response.

BACKGROUND INFORMATION

Even though cotton originates from warm regions, the cotton plant responds negatively to high temperatures (Oosterhuis, 2002; Pettigrew, 2008). The optimum day temperature for cotton development is around 30°C (Reddy et al., 1992). However, in the U.S. Cotton Belt, temperatures reach levels above 35°C during reproductive development (Reddy et al., 1991; Boykin et al., 1995 cited by Pettigrew, 2008). Oosterhuis (2002) suggested that in the U.S. high temperature during reproductive development is the main factor causing lower and variable cotton yields.

Ethylene is produced by plants under stress conditions (Abeles et al., 1992), and plays a major role in the regulation of the abscission process in cotton fruits (Guinn, 1982a and 1982b; Lipe and Morgan, 1972). Cotton fruit abscission is largely controlled by ethylene, which initiates the formation of the abscission layer in the peduncle that results in fruit shed (Lipe and Morgan, 1973). Ethylene also plays a major role in the physiology of heat-stressed plants (Abeles et al., 1992), but it is not clear in the literature if ethylene increases or decreases under high temperature.

1-Methylcyclopropene (1-MCP) is a plant growth regulator that inhibits the action of ethylene by blocking the ethylene receptor sites in the plant cell (Blankenship and Dole, 2003). The effect of 1-MCP was tested by Hays et al. (2007) in a wheat (Triticum

1 Graduate assistant, distinguished professor, and graduate assistant, respectively, Crop, Soil, and Environmental Sciences Department, Fayetteville.
Summaries of Arkansas Cotton Research 2007

*aestivum* L.) cultivar susceptible to heat stress, and they found that 1-MCP enhanced wheat tolerance to high-temperature conditions. These authors reported that plants treated with 1-MCP did not exhibit the induction of kernel abortion and reduction in kernel weight as did the untreated heat-stressed plants.

The objective of this study was to determine the effects of 1-MCP on ethylene synthesis and development of cotton reproductive organs under normal and high temperature.

**RESEARCH DESCRIPTION**

The experiment was conducted in the Altheimer laboratory, Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) cultivar DP444 BG/RR was planted in 2-liter pots filled with Sunshine potting mix (Sun Gro Horticultural Distribution Inc., Bellevue, Wash.). The pots were arranged in two large walk-in growth chambers (Model PGW, Conviron, Winnipeg, Canada) with day/night temperatures of 30/20°C, 12-hour photoperiods, and a relative humidity of 70%. After 6 weeks (about one week prior to flowering), the temperature of one growth chamber was increased in 2°C increments every 2 days until the temperature reached 38°C; the temperature of the other chamber was maintained at 30°C. Plants were watered daily with a half-strength Peter’s nutrient solution (Spectrum Group, St. Louis, Mo.). The two chambers with high and normal temperatures were assessed as two distinct experiments. The chamber with normal temperature was label as “Chamber-normal” and the chamber with high temperature as “Chamber-high.” The chambers were assumed to be identical in all variables (e.g., light and relative humidity) with differences only in temperatures (30°C and 38°C). The experiments were arranged in a completely randomized design with two factors and six replications. The factors consisted of 1-MCP treatment (treated and untreated) and sample day (0, 1, 2, 4, and 8 days after the white flower stage).

In the 1-MCP treatment, white flowers from the first sympodial position of nodes 5 to 9 were sprayed using an airbrush (Iwata HP-BCS, Iwata Medea, Portland, Ore.). Flowers were sprayed at 9:00 AM with 0.046 ml of a solution containing 0.053 g of 1-MCP active ingredient per liter. This dose corresponded approximately to the recommended field application of 10 g of 1-MCP active ingredient per hectare. A 0.375% v/v of adjuvant (AF-400, Rohm Hass, Philadelphia, Pa.) was added to the spraying solution. A preliminary study was conducted with the objective of analyzing the effect of spraying adjuvant alone compared with untreated flowers and no significant differences were observed in any parameters collected (ethylene production, boll weight, and antioxidant enzymes). These results eliminate the possibilities of the adjuvant interfering in the measurements of the effects of 1-MCP treatment.

Measurements were made of ethylene production and boll weight. Ethylene synthesis was measured by placing a small flexible chamber around each flower at 9 AM and air samples were collected at 3 PM and run through a gas chromatograph. Boll weight was recorded right after ethylene sampling, and ethylene production was expressed as microliters of ethylene produced per gram of fresh weight per hour (μl of ethylene g⁻¹h⁻¹).
RESULTS AND DISCUSSION

Statistical analysis of ethylene data showed that there was no significant three-way interaction effect between 1-MCP treatment, sampling days, and chambers. However, the model showed significant interaction between 1-MCP treatment-by-sampling days (P=<0.001) and chambers-by-sampling days (P=0.0005). Since there was a two-way interaction, the factors chamber and 1-MCP treatment were analyzed throughout each sampling day, by averaging chambers over 1-MCP treatments and 1-MCP treatments over chamber, respectively.

The effect of 1-MCP on ethylene concentration compared to the untreated control showed a significant 1.5-fold decrease at day 1 (Fig. 1). However, at 2 days after 1-MCP application, there were no significant differences between 1-MCP treated and untreated control treatments. Thereafter, ethylene concentration declined naturally in both treatments to low background levels at day 8.

Chamber high-temperature had a significant effect on the pattern of ethylene synthesis (Fig. 2). Plants in the chamber-high exhibited a significant decrease in ethylene production at sampling day 2, whereas there was a significant peak in ethylene concentration in the normal temperature treatment at day 2.

Cotton boll weight measurements indicated no significant three-way interaction effect between 1-MCP treatment, sampling days, and chamber, but there were significant two-way interactions between 1-MCP treatment-by-sampling days (P=<0.008) and chamber-by-sampling days (P=0.028). Therefore, the factors treatment and chambers were averaged over each other, by each sampling day. The 1-MCP treatment resulted in a significant increase in boll weight 8 days after application (Fig. 3), in which treated bolls exhibited a gain of 1 g in comparison to untreated bolls. Similarly, the chamber high-temperature also significantly increased the weight of cotton bolls at day 8 (Fig. 4) but there was no significant effect at sampling days 0, 1, 2, and 4.

PRACTICAL APPLICATION

In conclusion, high temperature and 1-MCP changed the pattern of ethylene production of cotton reproductive organs; a decrease in ethylene synthesis was observed in the 1-MCP treatment 1 day after application and in the high temperature 2 days after anthesis. In addition, high temperature and 1-MCP treatment caused an increase in the weight of cotton bolls collected 8 days after anthesis.

LITERATURE CITED


Fig. 1. Effect of 1-MCP on ethylene concentration of cotton flowers measured at 0, 1, 2, 4, and 8 days after anthesis; 1-MCP application was made at day 0. Data points of means with an asterisk are significantly different (P=0.05). Error bars represent ± one standard error. Data were averaged across chambers.
Fig. 2. Effect of temperature on ethylene concentration of cotton flowers measured at 0, 1, 2, 4, and 8 days after anthesis. Data points of means with an asterisk are significantly different (P=0.05). Error bars represent ± one standard error. Data were averaged across 1-MCP treatments.

Fig. 3. Effect of 1-MCP on boll weight. Day zero represents the day of 1-MCP application. Pairs of columns with an asterisk are significantly different (P=0.05). Error bars represent ± one standard error. Data were averaged across chambers.
Fig. 4. Effect of temperature on boll weight. Day zero represents the day of 1-MCP application. Pairs of columns with an asterisk are significantly different (P=0.05). Error bars represent ± one standard error. Data were averaged across 1-MCP treatments.