Effect of 1-Methylcyclopropene on the Cotton Flower Under Water-Deficit Stress

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RESEARCH PROBLEM

Drought is the main abiotic factor limiting more than 70% of the arable land around the world. Ethylene, a plant hormone, has often been observed to increase under environmentally unfavorable conditions, resulting in abscission of leaves and fruiting forms and ultimately in yield reduction. Concerning cotton, however, the effects of water-deficit stress on ethylene production have been uncertain. In this study it was hypothesized that application of an ethylene inhibitor 1-Methylcyclopropene (1-MCP) would prevent ethylene production and result in alleviation of water-deficit stress effects on the cotton flower and consequently prevent yield loss.

BACKGROUND INFORMATION

Water deficit is a major abiotic factor limiting plant growth and crop productivity around the world (Kramer, 1983). Cotton (Gossypium hirsutum L.) is considered to be relatively tolerant to drought, i.e. by osmotic adjustment (Oosterhuis and Wullschleger 1987; Nepomuceno et al., 1998). However, plant growth and yield are compromised when water supply is limited (Basal et al., 2005).

Production of ethylene, a senescence promoting hormone, is usually increased under conditions of environmental stress such as drought, high or low temperatures and hypoxia (Morgan and Drew, 1997). In cotton, studies with detached leaves (Morgan et al., 1990) and petioles (McMichael et al., 1972) indicated that ethylene production is increased under water-deficit conditions whereas, the opposite was observed for intact cotton plants (Morgan et al., 1990). In addition, Guinn (1976) observed an increase in ethylene synthesis in 4-day-old bolls under water-deficit conditions and speculated that boll abscission was caused by ethylene production. However, Bugbee (2011) in experiments that were conducted with intact plants observed a decrease in ethylene production under conditions of water-deficit stress.

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1-Methylcyclopropene (1-MCP), an ethylene inhibitor that acts by binding on ethylene receptors (Sisler and Serek, 1997) has been shown to result in a decrease or a delay of the ethylene activity (Blankenship and Dole, 2003). Kawakami et al. (2010) observed that application of 1-MCP on 4-week-old plants resulted in a decrease in leaf stomatal resistance, however no data exist on the effect of 1-MCP on the biochemistry of the cotton flower under water-deficit stress conditions. The objective of these studies was to evaluate the possible ameliorating effect of the anti-ethylene plant regulator, 1-MCP on cotton’s floral buds and subtending leaves under conditions of limited water supply during reproductive development.

**RESEARCH DESCRIPTION**

Growth chamber studies were conducted in 2008-2009 in the Altheimer laboratory of the University of Arkansas in Fayetteville. Cotton (*Gossypium hirsutum* L.) ST5288B2F was planted into 1-L pots containing a horticultural mix (SunGro horticulture mix). The growth chambers were set for normal conditions of 30/20 °C (day/night), ± 60% relative humidity, and 14/10 h photoperiods, while half-strength Hoagland’s nutrient solution was applied daily in order to maintain adequate nutrients and water. Plants were arranged in a completely randomized block design with 15 replications and the experimental design was a 2 × 2 factorial with water-deficit stress being the main effect and 1-MCP application the secondary effect.

1–MCP was applied at 10g ai/ha with a CO₂-backpack sprayer calibrated to deliver 20 gal/acre and using the adjuvant AF-400 at 0.375% v/v the second day after the initiation of stress (after water was withheld from the plants). The treatments consisted of: 1) an untreated control, where an optimum quantity of water was applied throughout the duration of experiment; 2) an untreated control + 1-MCP, where an optimum quantity of water was applied throughout the duration of the experiment and plants were sprayed with 1-MCP; 3) a water-deficit stress during flowering treatment, where water was withheld during flowering and the plants were subjected in two cycles of drying for six days each and; 4) a water-deficit stress during flowering + 1-MCP treatment, where water was withheld during flowering and the plants were subjected in two cycles of drying for six days each and were sprayed with 1-MCP.

Measurements of leaf stomatal conductance were taken daily between 11:00 am-1:00 pm from the fourth main-stem leaf from each plant using a leaf porometer Decagon SC-1 (Decagon Inc., Pullman, Wash.). Photosynthetic and respiratory rates were measured the first and fourth day after spraying, between 11:00 am-1:00 pm from the fourth main-stem leaf from each plant using the LiCor 6200 gas analyzer (LiCor Inc., Lincoln Neb.). Total non-structural carbohydrate content was estimated from white flowers (pistils) and their subtending leaves that were collected when available from all four treatments. Carbohydrate extraction was done according to Zhao et al. (2008) and the supernatants were analyzed with a Multiscan Microplate Reader (Diversified Equipment Co., Lorton, Va.).
RESULTS AND DISCUSSION

Water-deficit stress treatments resulted in a significant decrease in both leaf photosynthesis (Fig. 1A) and respiration rates (Fig. 1B) of water stressed plants compared to the control. Similarly, leaf stomatal conductance rates of water stressed cotton plants were significantly lower than the control. Concerning leaf carbohydrate content, leaf glucose concentration was increased under conditions of water-deficit stress (Fig. 2A), whereas leaf fructose and sucrose concentration remained unaffected. On the other hand, pistil glucose and fructose concentrations remained similar to the control levels, while pistil sucrose concentration of water stressed plants was significantly increased compared to the control (Fig. 2B).

1-MCP application had no significant effect on cotton’s gas exchange functions and failed to ameliorate the effects of water-deficit stress on leaf photosynthesis, respiration and stomatal conductance. However, application of 1-MCP resulted in a decrease in sucrose of the pistil. We speculate that this decrease was due to more efficient cleavage of sucrose into glucose and fructose and ultimately a better utilization of the carbohydrates.

PRACTICAL APPLICATION

Application of 1-MCP had no alleviating effect on leaf photosynthesis, respiration and stomatal conductance under conditions of water-deficit stress. Leaf and pistil total soluble carbohydrate content remained unaffected, with the exception of pistil sucrose content. 1-MCP decreased sucrose accumulation resulting in more efficient utilization. In conclusion, leaf gas exchange functions of cotton remained unaffected from application of 1-MCP, however, carbohydrate metabolism of the pistil appeared to be more responsive. Further research is required in order to elucidate the implications of ethylene in the biochemistry of the cotton flower and the potential alleviating effect of anti-ethylene plant growth regulators.

LITERATURE CITED


Fig. 1. Effect of water-deficit stress and 1-MCP application on leaf photosynthesis (A) and respiration (B) four days after induction of stress. Bars with the same letter are not significantly different ($P = 0.05$).
Fig. 2. Effect of water-deficit stress and 1-MCP application on leaf glucose content (A) and pistil sucrose content (B). Columns with the same letter are not significantly different ($P = 0.05$).