EFFECT OF 1-MCP ON THE COTTON FLOWER UNDER WATER-DEFICIT STRESS

D.A. Loka
D.M. Oosterhuis
University of Arkansas
Fayetteville, AR

Abstract

The effect of the anti-ethylene plant regulator 1-methylcyclopropene (1-MCP) on cotton's floral buds and subtending leaves under conditions of water-deficit stress during reproductive development was evaluated in growth chamber experiments conducted at Altheimer Laboratory of the University of Arkansas. Plants were exposed to two consecutive drying cycles and 1-MCP was applied the second day after induction of stress in both cycles. Measurements of leaf stomatal conductance, photosynthesis and respiration were taken, while white flowers and their subtending leaves were collected and analyzed for their carbohydrate content. The results showed that water-deficit stress caused a significant reduction in stomatal conductance, photosynthesis and respiration rates of leaves. Additionally, leaf glucose content was significantly decreased under conditions of water-deficit while the opposite pattern was observed in sucrose concentration of the pistil. 1-MCP application had no significant effect on cotton's leaf gas exchange functions however, carbohydrate metabolism of the pistil was significantly affected.

Introduction

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. Results however, vary under conditions of water-deficit stress. 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 is 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. 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-Methylcyclopropene on cotton's floral buds and subtending leaves under conditions of limited water supply during reproductive development.

Materials

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 1L 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 12/12h photoperiod, 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 2x2 factorial with water deficit stress being the main effect and 1-MCP application the secondary effect. 1–MCP was applied with a CO_2 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) Untreated control, where optimum quantity of water was applied throughout the duration of experiment, 2) Untreated control + 1-MCP, where optimum quantity of water was applied throughout the duration of the experiment and plants were sprayed with 10g a.i./ha of 1-MCP, 3) Water deficit stress during flowering, where water was withheld during flowering and the plants were subjected in two cycles of drying for six days each and, 4) Water deficit stress during flowering + 1-MCP, where water was withheld during flowering and the plants were subjected in two cycles of drying for six days each and were sprayed with 10g a.i./ha 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. 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. 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.

Results

Water-deficit stress treatments resulted in a significant decrease in both leaf photosynthesis (Fig.4) and respiration rates (Fig.5) of water stressed plants compared to the control. Similarly, leaf stomatal conductance rates of water stressed cotton plants were significantly lower than the control (Fig. 1). Concerning leaf carbohydrate content, leaf glucose concentration was increased under conditions of water-deficit stress (Fig.2), 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.3).

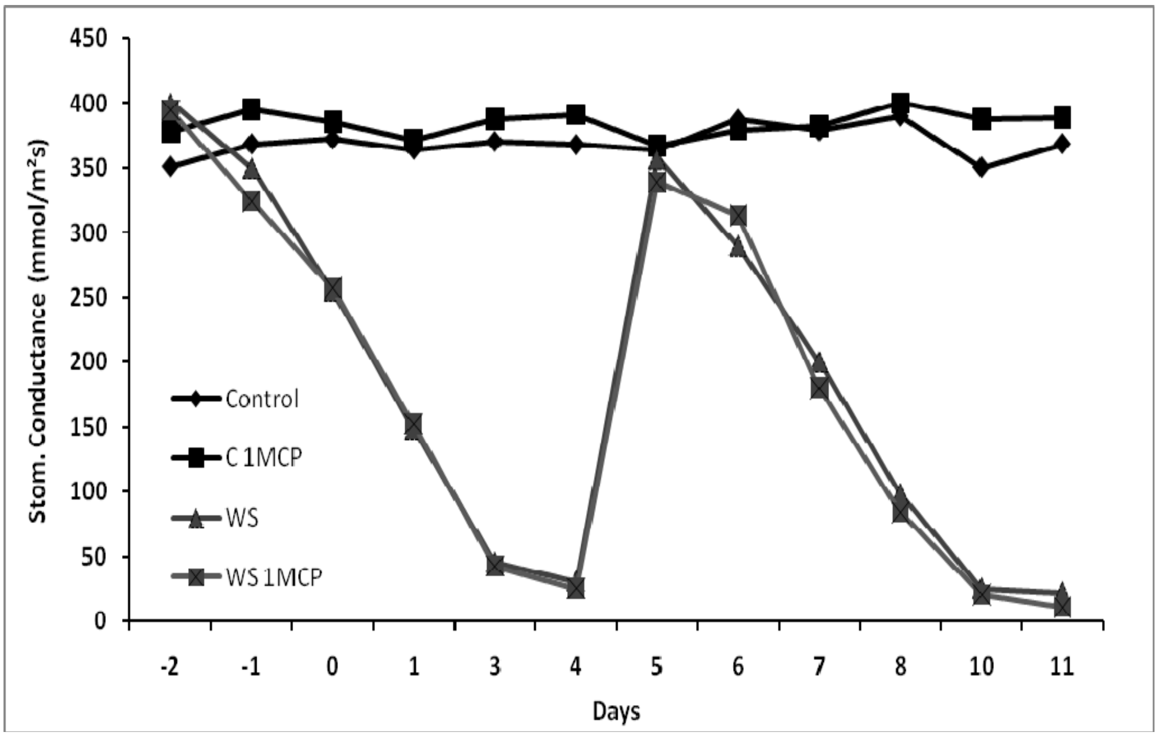

Figure 1. Effect of water-deficit stress and 1-MCP application on leaf stomatal conductance (1-MCP was applied on days 0 and 7).

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.

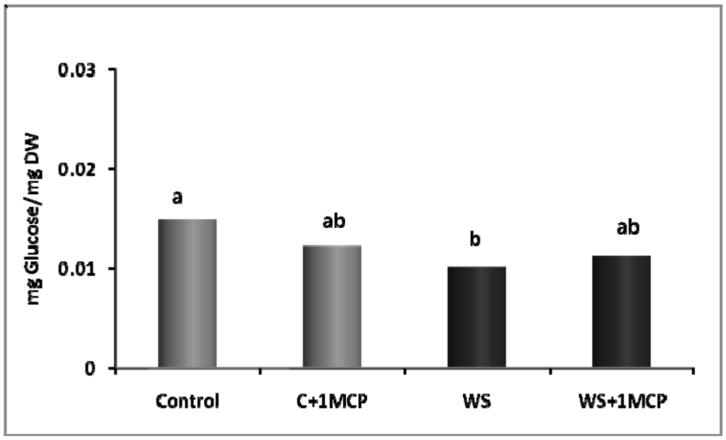

Figure 2. Effect of water-deficit stress and 1-MCP application on leaf glucose content (Columns with the same letter are not significantly different, P=0.05).

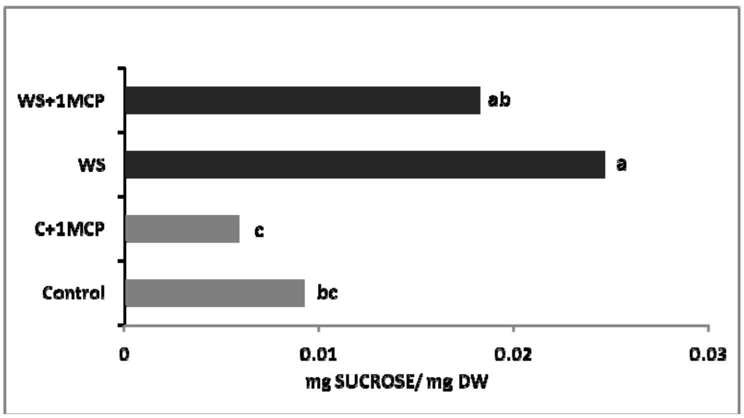

Figure 3. Effect of water-deficit stress and 1-MCP application on pistil sucrose content (Bars with the same letter are not significantly different, P=0.05).

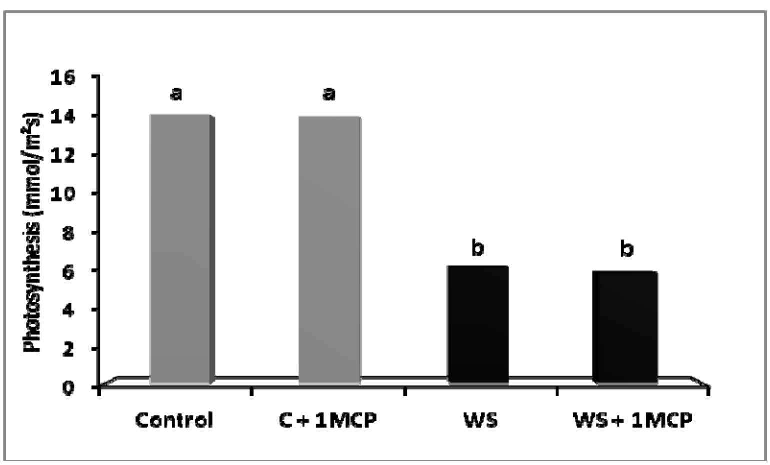

Figure 4. Effect of water-deficit stress and 1-MCP application on leaf photosynthesis four days after the induction of stress (Columns with the same letter are not significantly different, P=0.05).

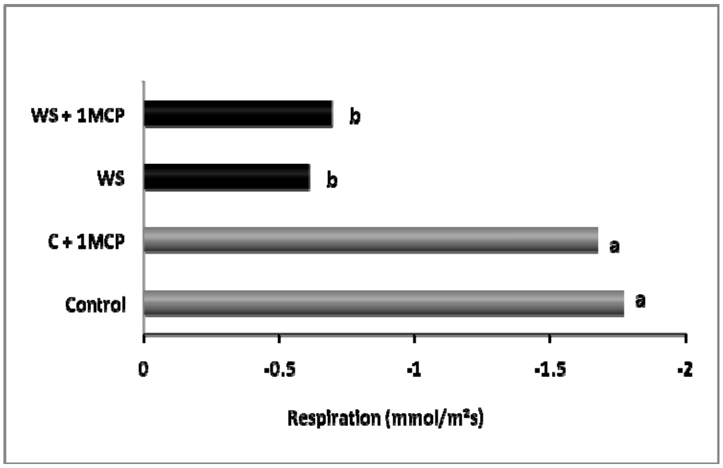

Figure 5. Effect of water-deficit stress and 1-MCP application on leaf respiration four days after the induction of stress (Bars with the same letter are not significantly different, P=0.05).

Summary

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 of application of 1-MCP however, carbohydrate metabolism of the pistil appeared to be more responsive.

References

Basal H., C.W. Smith, P.S. Thaxton, and J.K. Hemphill. 2005. Seedling Drought Tolerance in Upland Cotton. Crop Sci. 45: 766-771.

Blankenship, S.M., and J.M. Dole. 2003. 1-Methylcyclopropene:a review. Postharvest Biol. Technol.28:1-25.

Bugbee, B. 2011. Water stress, ethylene synthesis and cotton: are our textbooks correct? In: D.M. Oosterhuis (ed.) Stress Physiology in Cotton. Publ. Cotton Foundation, Memphis TN. (in press).

Guinn, G. 1976. Water deficit and ethylene evolution by young cotton bolls. Plant Physiol. 57: 403-405.

Kawakami, E.M., D.M. Oosterhuis, and J.L. Snider. 2010. Physiological effects of 1-Methylcyclopropene on well-watered and water-stressed cotton plants. J. Plant Growth Regul.

Kramer, P.J. 1983. Water deficits and plant growth. pp: 342-389. In: P.J. Kramer (Ed.). Water relations of plants. Academic Press, New York.

Morgan, P.W., C. He, J.A. De Greef, and M.P. De Proft. 1990.Does water-deficit stress promote ethylene synthesis by intact plants? Plant Physiol. 94:1616-1624.

McMichael, B.L., W.R. Jordan, and R.D. Powell. 1972. An effect of water stress on ethylene production by intact cotton petioles. Plant Physiol. 49:658-660.

Nepomuceno, A. L., D.M. Oosterhuis, and J.M. Stewart. 1998. Physiological responses of cotton leaves and roots to water deficit induced by polythelene glycol. Environ. Exp. Bot. 40: 29-41.

Oosterhuis, D.M., and S.D. Wullschleger. 1987. Osmotic adjustment in cotton (*Gossypium hisrsutum* L.) leaves and roots in response to water stress. Plant Physiol. 84: 1154-1157.

Sisler, E.C., and M. Serek. 1997. Inhibitors of ethylene responses in plants at the receptor level: Recent developments. Physiol. Plant. 100:577-582.

Zhao, D., C.T. MacKown, P.J. Starks, and B.K. Kindiger. 2008. Interspecies variation of Forage Nutritive Value and Nonstructural Carbohydrates in Perennial Cool-Season Grasses. Agron. J. 100:837-844.