PHYSIOLOGICAL EFFECTS OF 1-METHYLCYCLOPROPENE ON WELL-WATERED AND WATER-STRESSED COTTON PLANTS

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Abstract

Among all abiotic stress factors, drought is the major environmental constraint to crop productivity worldwide (Sharp et al., 2004). Even in irrigated or high rainfall areas, short periods of interruption of the water supply can increase fruit shed and decrease yield. Alleviation plant stress during dry periods could prevent yield loss and increase profits. The current study was designed to test the effect of 1-Methylcyclopropene (1-MCP) on alleviating the detrimental effect of drought in cotton plants. The experiment was carried in a growth chamber in 2006 and 2007. The treatments consisted of: (T1) Untreated control well-watered, (T2) 1-MCP @ 10 g ai/ha well-watered, (T3) Untreated Control water-stressed, and (T4) 1-MCP @ 10 g ai/ha water-stressed. Results indicated that water-stressed plants treated with 1-MCP had a higher stomatal resistance, higher maximum quantum efficiency of Photosystem II and better maintenance of membrane integrity. The effect of 1-MCP on water-stressed plants lasted for about 5 days. There was no significant effect of 1-MCP on water-use efficiency and dry matter production. These results indicated that application of 1-MCP to water-stressed cotton may be beneficial, due to lower levels of stress in treated plants, however the study needs to be continued to determine the effect on yield.

Introduction

In many regions of the U.S. Cotton Belt, cotton yields are limited by inadequate amounts, or inadequate distribution, of rainfall (Basal et al., 2005). The main physiological effect of water deficit in cotton and other plants is the reduction in photosynthetic carbon assimilation which results in low dry matter accumulation. Many processes are associated with this effect such as increased ethylene synthesis, stomatal closure, low radiation use efficiency and decreased plant metabolism. The scarcity of water resources and the high costs of irrigation management have significantly increased the need for solutions for cotton farmers to overcome problems of water deficit. Since 1-Methylcyclopropene (1-MCP) acts as a inhibitor of the hormone ethylene, the use of 1-MCP could be a possible short term solution to situations of water deficit.

1-Methylcyclopropene (1-MCP) is a biopesticide approved for use in fruit and vegetable by the EPA. The product works by decreasing or delaying the effect of ethylene which normally acts as an endogenous stress and senescence phytohormone. In essence, 1-MCP occupies ethylene receptors such that ethylene cannot bind and elicit action (Blankenship and Dole, 2003). The objective of our study was to investigate the effect of the plant growth regulator 1-MCP on the physiology and growth of cotton plants under water-stressed and well-watered conditions.

Materials and Methods

The study was conducted in the Altheimer laboratory, Arkansas Agricultural Research and Extension Center. In June 2007, cotton (*Gossypium hirsutum* L.) cultivar DP 444 BG/RR was planted in one liter pots filled with Sunshine potting mix (Sun Gro Horticultural Distribution Inc., Bellevue, WA). Pots were arranged in a large growth chamber with a day/night temperature regime of 30/20^{o}C, 12 hour photoperiods and a relative humidity of 60%. After four weeks, 1-MCP was sprayed according to the treatments. The pots were wrapped with plastic bags to avoid water evaporation from the soil and to confine water loss to transpiration only. Half of the pots (10 pots) were carried through a water-deficit stress regime. The stress regime was established for five days; after which, the stressed plants were rewatered. This process was repeated three times, giving a total of three water-stress cycles at the end of the experiment. The experiment was arranged in a completely randomized design with two factors that consisted of 1-MCP treatment and water regime. A two factor factorial statistical analysis with six replications was utilized to evaluate the results. The treatments consisted of : (T1) Untreated control well-watered, (T2) 1-MCP @

10 g ai/ha well-watered, (T3) Untreated Control water-stressed, and (T4) 1-MCP @ 10 g ai/ha water-stressed. The 1-MCP was applied with a CO_2 backpack sprayer calibrated to deliver 20 gal/acre. All 1-MCP treatments were applied with the adjuvant AF-400 at 0.375% v/v.

Stomatal resistance was recorded daily using a LICOR 6200 porometer and measurements of fluorescence were made using a Modulate Fluorometer (OS1-FL). Membrane integrity was measured with a conductivity meter using leaf discs. All the measurements were recorded between 12:00 p.m. and 2:00 p.m. on the upper fully-expanded main-stem leaf at four nodes below the terminal of the plant. In order to calculate water use efficiency (g/ml), pots were weighed daily to estimate water use and at the end of the experiment values of total dry matter (g) were divided by the total amount of water used (ml). Total dry matter production was recorded at the end of the experiment.

Results and Discussion

Under water-deficit stress 1-MCP treated plants exhibited a higher stomatal resistance (Fig. 1). Significant differences (P=0.05) were observed at day 5 and 10; at day 5 the magnitude of the dissimilarity was much greater than at day 10. On the other hand, under well-watered conditions there were no differences between treated and untreated plants. The explanation of this occurrence could be related to the findings of Tanaka et. al.(2005), in which they observed that ethylene inhibits ABA-induced stomatal closure in Arabidopsis. Since 1-MCP acts as a anti-ethylene compound it is expected that the stomates of treated plants will behave differently than untreated plants.

Membrane integrity measurements showed that water-stressed plants treated with 1-MCP exhibited lower values of electrical conductivity than untreated plants (Fig. 2). This difference, at day 5, was statistically significant (P=0.05). The maintenance of membrane integrity is extremely important to protect the functioning of vital physiological processes in the plant. Damaged cell membranes in the leaf tissues could become leaky and result in impaired physiological functions.

Chlorophyll fluorescence in water-stressed plants measured at day 5 showed a higher yield values in the 1-MCP treated plants, significantly different compared to the untreated plants (Table 1). This implies that at day 5, the Photosystem II of 1-MCP treated plants exhibited higher quantum use efficiency than the untreated plants.

Measurements of total dry matter and water-use-efficiency (Table 1) indicated no significant effect of 1-MCP in either water regime. However, 1-MCP resulted in numerically higher dry matter production and a slightly lower value of water-use-efficiency in the water-stress treatment.

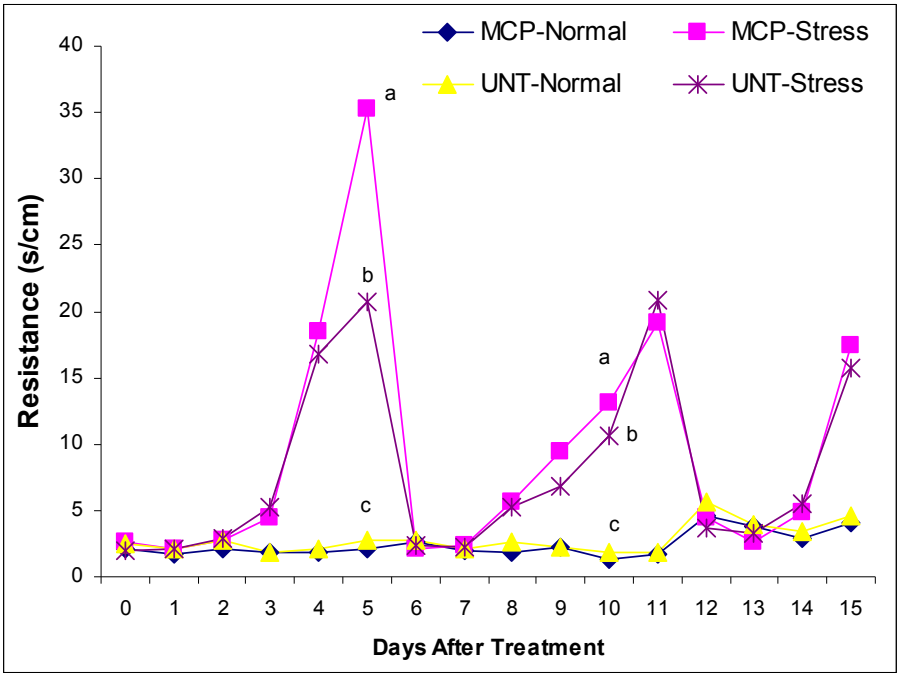

Fig. 1. Effect of 1-MCP on stomatal resistance, with and without water deficit. 1-MCP was applied at day 0 and measurements were made at midday. Days with the same letters are not significantly different (P=0.05).

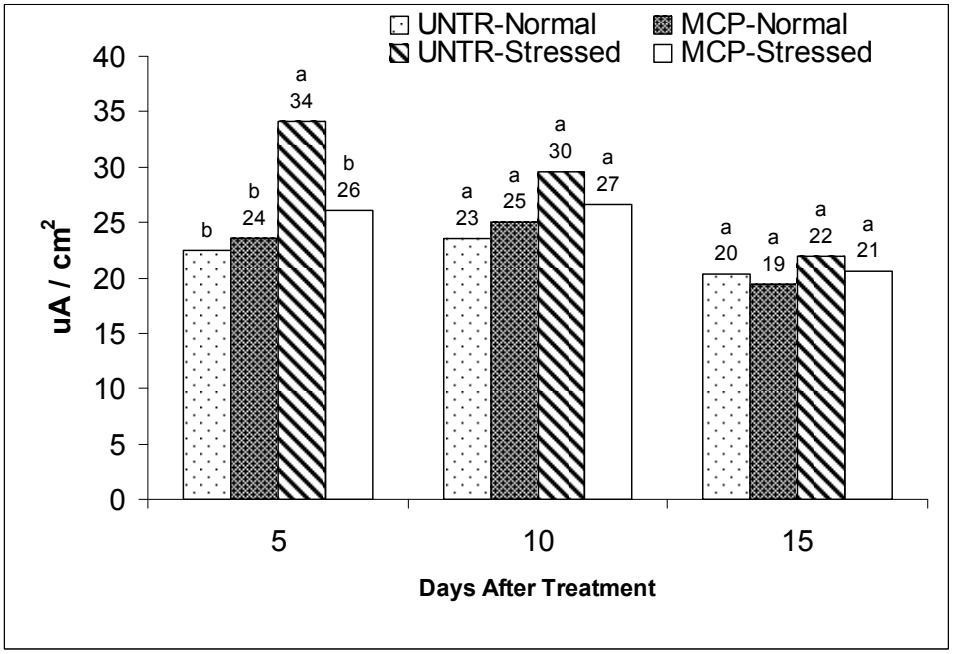

Fig. 2. Effect of 1-MCP on cotton membrane leakage, with and without water deficit. The days 5, 11, and 15 correspond to the end of each stress cycle. Columns with the same letters are not significantly different (P=0.05).

Table 1. Effect of 1-MCP on Chlorophyll Fluorescence, Water Use Efficiency, Leaf Area, Dry Matter, and Number of Squares.

TREATMENT	Chlorophyll Fluorescence* (Fv/Fm)	Water Use Efficiency g/ml	Total Dry Mater grams
T1- Untreated well-watered	0.742 a**	0.100 a	28.95 a
T2- 1-MCP well watered	0.756 ab	0.100 a	30.10 a
T3- Untreated water-stressed	0.741 b	0.150 b	19.93 b
T4- 1-MCP water-stressed	0.776 a	0.145 b	20.25 b

*Measurement recorded at day 5, which correspond to the end of the first stress cycle.
**Columns with the same letters are not significantly different (P=0.05).

Conclusions

We conclude that 1-MCP applications had positive effects on the physiological parameters measured under water deficit, and that the effects lasted for about 5 days. However, 1-MCP application did not have an effect on the production of total dry matter. It is possible that under conditions of water deficit, multiple applications of 1-MCP applied at 5-day intervals may be needed for improved productivity.

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