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# Mepiquat Chloride Seed Treatment and Germination Temperature Effects on Cotton Growth, Nutrient Partitioning, and Water Use Efficiency

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**Abstract.** Cotton seed (*Gossypium hirsutum* L. cv. "Stoneville 825"), treated with 0, 0.2, 1.0, and 2.0 g active ingredient (a.i.) mepiquat chloride (MC) $kg^{-1}$, was evaluated for the effect of MC on early plant growth. Emergence rate and total emergence of MC-treated seed and control were similar regardless of germination temperature. However, the number of leaves and squares and the dry weight of leaves, stems, and roots for hydroponically grown cotton plants were significantly lower at lower germination temperatures (15°C for 3 day/30°C for 1 day and 15°C for 4 days) than at higher germination temperatures (30°C for 4 days and 30°C for 3 days/15°C for 1 day). All MC treatments significantly decreased the number of nodes, leaves, and squares, as well as dry weight of leaves, stems, and roots, as compared to control plants at 28 days after emergence. MC seed treatments also significantly reduced plant height and total leaf area compared to controls. Water-use efficiency (WUE) was significantly lower for the 1.0 g a.i. MC treatment than for control plants. In general, the highest rate of MC seed treatment resulted in greater concentrations of calcium, phosphorus, and nitrogen in plant leaves and stems and also in greater concentrations of magnesium, phosphorus, and nitrogen in roots than in controls.

The foliar application of mepiquat chloride (MC) under field conditions to reduce excessive vegetative growth of cotton plants is an accepted cultural practice. It decreases plant height, leaf area, and main stem node number (Stuart et al. 1984) and increases calcium and magnesium concentration in leaves (Heilman 1985). However, in the latter study, MC did not affect the nitrogen level in leaves (Heilman 1985). Also, MC-treated plants mature earlier than nontreated plants (Gowgani and Noel 1982). Foliar application of MC on cotton plants grown in hydroponic solution altered nutrient distribution in plant tissues (Cothren et al. 1977, Nester 1978). Treatment of cotton seed with MC also reduced plant height, leaf area, and total fresh and dry weights, and increased levels of calcium, potassium, and magnesium in leaves (Cothren et al. 1983). MC-treated plants had higher leaf water potential and solute potential during mid-morning and at daily minimum leaf water potential. MC-treated plants also showed increased abaxial transpiration and decreased diffusive resistance (Stuart et al. 1984) and increased cold tolerance (Huang et al. 1981).

The objectives of this study were (1) to determine the effects of MC seed treatment and low germination temperature on the growth of cotton; (2) to evaluate the effect of MC seed treatment on water-use efficiency (WUE); and (3) to determine the effect of MC seed treatment on nutrient partitioning.

## Materials and Methods

Cotton (*Gossypium hirsutum* L.) cultivar "Stoneville 825" was chosen for this study. Random samples were obtained from a commercial source of certified, acid-delinted seed; seeds had been treated with fungicide. MC seed treatments were as follows: (1) control (0 MC); (2) 0.2 g active ingredient (a.i.) of liquid MC/kg seed; (3) 1.0 g a.i. of liquid MC/kg seed; and (4) 2.0 g a.i. of liquid MC/kg seed. For each treatment, 1 kg of seed was placed in a revolving stainless-steel drum designed for small-batch seed treatments. An equivalent volume (20 ml) of distilled water containing each MC rate was sprayed in a fine mist over the seed as they revolved. Control seeds were sprayed with 20 ml distilled water. After application of MC, each lot of treated seed was air dried at room temperature for at least 4 days prior to use.

MC-treated and control seeds were planted in white plastic tubes that contained potting soil. A single seed was planted in each tube, with a total of six tubes representing each treatment

replicate. The experimental design was a 4 × 8 factorial; four MC treatments and eight germination temperatures were arranged in a randomized complete block design with four replications. Eight germination temperature regimes were used: (1) 15°C-4d (i.e., 4 days at 15°C); (2) 15°C-3d/30°C-1d; (3) 15°C-2d/30°C-2d; (4) 15°C-1d/30°C-3d; (5) 30°C-1d/15°C-3d; (6) 30°C-2d/15°C-2d; (7) 30°C-3d/15°C-1d; and (8) 30°C-4d. Each temperature regime was followed by an additional 4 days at 30°C. The experiment was conducted in a controlled environmental chamber with a 14-h day and 10-h night period. A light intensity of 600 $\mu E\ m^{-2}\ s^{-1}$ was supplied by cool-white fluorescent and incandescent bulbs. Seedling emergence rate and total percent emergence were analyzed by analysis of variance (ANOVA).

At day 9 following planting, a representative seedling from each treatment replicate was removed from the potting soil and transferred to half-strength Hoagland's solution (Hoagland and Arnon 1950) in a 1-L container for the remainder of the study. Aeration to each hydroponic plant solution was continuously supplied via a network of tubing attached to a small diaphragm pump. One week after initial transfer of seedlings, the solution was replaced with full-strength Hoagland's solution. The experimental design and environmental conditions in the controlled environmental chambers were the same as in the germination experiment, except that one temperature regime (30°C day/25°C night) was maintained.

At 3-day intervals, the amount of hydroponic solution added to maintain each jar at a constant level was recorded in order to calculate WUE. WUE is defined as milligrams of dry plant tissue produced per milliliter of water used (derived from the consumptive use of the hydroponic solution). Twenty-two days after transplanting, leaf number and main stem node number were counted and plant height measured. Total leaf area of each plant was determined with a Li-Cor 3100 area meter. Harvested plants were then divided into leaf blade, stem plus leaf petiole, and root and were oven-dried at 80°C for 48 h. Dried plant samples were weighed, ground to pass through a 40-mesh screen, and digested in preparation for nutrient analyses. An atomic absorption spectrophotometer was used to measure the levels of calcium, magnesium, and potassium. Nitrogen and phosphorus were determined with a Technicon Autoanalyzer (Technicon 1977).

## Results

### *Germination Study*

The emergence rate did not differ between MC-treated and control seeds. Final emergence percentage was not influenced by germination temperature, and the interaction term for germination temperature and MC seed treatment was not significant. However, germination temperature affected plant morphology and fruiting at 22 days following transplant as discussed in the following section.

### *Hydroponics Study*

The MC rate by germination temperature interaction was not significant for number of nodes, leaves, and squares; hence, data were pooled over MC treatments to evaluate the effect of temperature (Table 1). The 30°C-4d and 30°C-3d/15°C-1d treatments had significantly ($\alpha = 0.05$) more leaves and squares per plant than did the 15°C-3d/30°C-1d and 15°C-4d treatments (Table 1). The same trend occurred for number of nodes, although the difference between 30°C-4d and lower temperatures was not significant. Pooled analyses over temperature showed that all MC seed treatments had significantly ($\alpha = 0.05$) reduced number of nodes, leaves, and squares versus control. The number of leaves was significantly greater for 0.2 g a.i. MC than for 2.0 g a.i. MC; otherwise, the 0.2, 1.0, and 2.0 g a.i. MC rates did not differ in numbers of nodes, leaves, and squares (Fig. 1).

**Table 1.** Effect of germination temperature and duration on number of nodes, leaves, and squares for hydroponically grown cotton at 28 days after emergence.

| Germination temperature and duration | Nodes (no./plant) | Leaves (no./plant) | Squares (no./plant) |
|---|---|---|---|
| 15°C-4d | 7.7 b[a] | 9.7 d | 1.0 b |
| 15°C-3d, 30°C-1d | 7.8 b | 10.7 cd | 0.9 b |
| 15°C-2d, 30°C-2d | 7.9 ab | 12.5 abc | 1.5 ab |
| 15°C-1d, 30°C-3d | 8.1 ab | 12.6 abc | 1.4 b |
| 30°C-1d, 15°C-3d | 8.1 ab | 11.9 bcd | 1.7 ab |
| 30°C-2d, 15°C-2d | 7.8 b | 11.6 bcd | 1.0 b |
| 30°C-3d, 15°C-1d | 8.6 a | 15.2 a | 1.9 a |
| 30°C-4d | 8.4 ab | 14.0 ab | 2.1 a |

Data is pooled over MC treatments.

[a] Means in columns followed by the same letter are not significantly ($\alpha = 0.05$) different according to Duncan's multiple range test.

Germination temperature and the MC by temperature interaction were not significant for plant height and leaf area. Seed treatment with MC significantly ($\alpha = 0.05$) decreased plant height and leaf area with increasing rate of MC (Fig. 2). Data were pooled over temperature to determine the effect of MC on plant dry weight. Stem, leaf, and root dry weights of all MC treatments were significantly ($\alpha = 0.05$) less than those of the nontreated control (Fig. 3). As MC rates increased, dry weight decreased consistently. Germination temperature also affected leaf, stem, and root dry weights. The 30°C-4d and 30°C-3d/15°C-1d treatments had significantly ($\alpha = 0.05$) higher leaf, stem, and root dry weights than did the 15°C-4d and 15°C-3d/30°C-1d treatments (Table 2).

### *WUE*

Temperature and the MC by temperature interaction on WUE were not significant; thus, data were

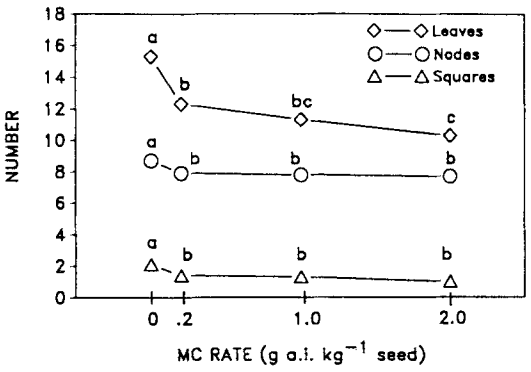


**Fig. 1.** Effect of MC seed treatment on number of leaves, nodes, and squares of cotton at 28 days after emergence. Means for each plant part followed by the same letter are not significantly ($\alpha$ = 0.05) different according to Duncan's multiple range test.

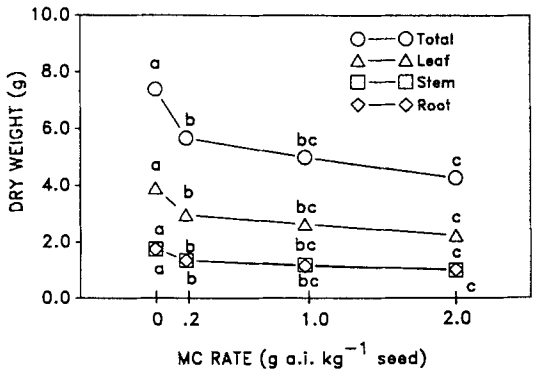


**Fig. 3.** Effect of MC seed treatment on plant, leaf, stem, and root dry weight of cotton at 28 days after emergence. Dry weight for each plant part followed by the same letter are not significantly ($\alpha$ = 0.05) different according to Duncan's multiple range test.

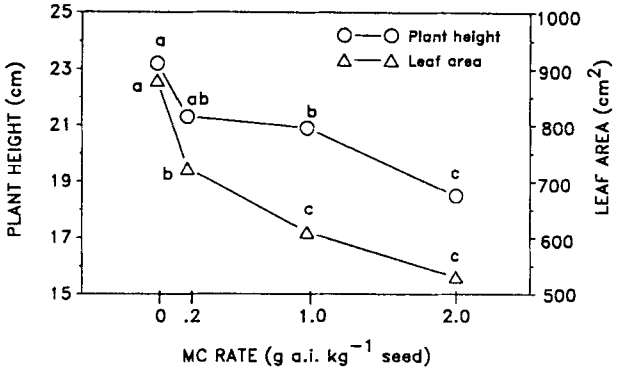


**Fig. 2.** Effect of MC seed treatment on plant height and total leaf area for cotton at 28 days after emergence. Similar symbols followed by the same letter are not significantly ($\alpha$ = 0.05) different according to Duncan's multiple range test.

**Table 2.** Effect of germination temperature and duration on leaf, stem, and root dry weight for hydroponically grown cotton at 28 days after emergence.

| Germination temperature and duration | Leaves (g/plant dry wt) | Stems (g/plant dry wt) | Roots (g/plant dry wt) |
|---|---|---|---|
| 15°C-4d | 2.4 c[a] | 1.1 c | 1.1 c |
| 15°C-3d, 30°C-1d | 2.4 c | 1.1 c | 1.1 c |
| 15°C-2d, 30°C-2d | 3.0 abc | 1.4 abc | 1.3 abc |
| 15°C-1d, 30°C-3d | 2.9 abc | 1.3 bc | 1.3 abc |
| 30°C-1d, 15°C-3d | 3.0 abc | 1.3 abc | 1.3 abc |
| 30°C-2d, 15°C-2d | 2.8 bc | 1.2 c | 1.3 bc |
| 30°C-3d, 15°C-1d | 3.6 a | 1.7 a | 1.6 ab |
| 30°C-4d | 3.5 ab | 1.6 ab | 1.6 a |

Data is pooled over MC treatments.

[a] Means in columns followed by the same letter are not significantly ($\alpha$ = 0.05) different according to Duncan's multiple range test.

pooled over temperature. WUE was numerically greater for the control than for any of the MC treatments (Fig. 4) and was significantly greater in the control than in the 1.0 g a.i. rate of MC-treated plants. However, WUE did not differ significantly among MC-treated plants (Fig. 4).

### *Nutrient Composition*

Germination temperature did not affect the concentration of nutrients in leaves, stems, or roots. The temperature by MC treatment interaction was not significant; thus, data were pooled over temperature for analysis of MC treatments. The concentrations of magnesium and potassium in leaf and stem tissue, and calcium in root tissue, did not differ between MC treatment and the control (Table 3).

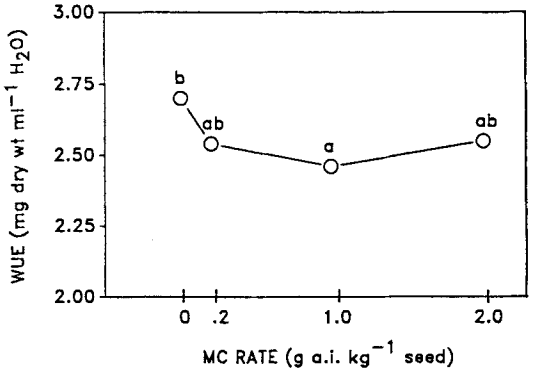


**Fig. 4.** Effect of MC seed treatment on WUE of cotton. Means for WUE followed by the same letter are not significantly ($\alpha$ = 0.05) different according to Duncan's multiple range test.

**Table 3.** Effect of MC on nutrient concentration of leaves, stems, and roots from hydroponically grown cotton plants at 28 days after emergence.

| Plant part | MC rate[a] | Mg (mg/g dry wt) | K (mg/g dry wt) | Ca (mg/g dry wt) | N (mg/g dry wt) | P (mg/g dry wt) |
|---|---|---|---|---|---|---|
| Leaves | 0 | 7.0 a[b] | 34.5 a | 44.8 b | 39.3 c | 7.5 b |
| | 0.2 | 6.5 a | 34.7 a | 47.0 ab | 40.8 bc | 8.2 b |
| | 1 | 6.9 a | 33.7 a | 51.3 ab | 42.5 ab | 9.8 a |
| | 2 | 6.8 a | 35.6 a | 53.8 a | 43.9 a | 9.9 a |
| Stems | 0 | 3.1 a | 52.6 a | 10.2 b | 28.5 b | 4.7 b |
| | 0.2 | 3.1 a | 53.8 a | 10.3 b | 28.2 b | 4.5 b |
| | 1 | 3.5 a | 56.6 a | 12.0 ab | 29.6 ab | 5.0 a |
| | 2 | 3.6 a | 55.1 a | 12.3 a | 31.3 a | 5.2 a |
| Roots | 0 | 2.8 b | 46.8 ab | 19.5 a | 27.9 b | 4.7 b |
| | 0.2 | 3.2 ab | 44.1 b | 18.7 a | 28.0 b | 4.5 b |
| | 1 | 3.4 a | 47.6 a | 17.0 a | 29.5 b | 5.0 a |
| | 2 | 3.5 a | 46.7 ab | 18.2 a | 31.5 a | 5.2 a |

Data is pooled over germination temperatures.

[a] g a.i. MC $kg^{-1}$ seed.

[b] Means in columns followed by the same letter within each plant part are not significantly ($\alpha = 0.05$) different according to Duncan's multiple range test.

However, calcium content of leaves and stems from the 2.0 g a.i. MC treatment, as well as magnesium concentration for roots from the 1.0 and 2.0 g a.i. MC rates, were significantly ($\alpha = 0.05$) greater than the control (Table 3). The 1.0 and 2.0 g a.i. MC seed treatments resulted in significantly ($\alpha = 0.05$) greater phosphorus concentrations in all plant parts as compared to control. The 2.0 g a.i. seed treatment caused significantly ($\alpha = 0.05$) higher nitrogen concentrations in all plant parts as compared to control (Table 3).

## Discussion

Seed treatment with MC did not affect emergence of cotton seedlings under various cold temperature regimes. In an earlier report, foliar-applied MC decreased sensitivity to cold injury for cotton plants when compared to control plants (Huang et al. 1981). The method of MC application (seed versus foliage) may in part explain this difference. Also, Huang et al. (1981) used lower temperatures: 1.7°C for 10 nights followed by −2.2°C for 24 h. Although the interaction for MC and germination temperature was not significant, the number of leaves and squares decreased when seeds were subjected to 15°C for 3 continuous days during germination. Investigation of the MC effect on plant morphology showed that MC treatments reduced plant height, leaf area, and plant dry weight. These results agree with earlier work by Cothren et al. (1983) and Stuart et al. (1984).

Foliar application of MC increased solute and pressure potentials (Stuart et al. 1984). Also, improved plant water status was reflected through an increased leaf water potential. Our investigation determined that whole plant water content was increased for the 1.0 g a.i. MC rate compared to control (data not shown). However, in general, WUE was reduced for MC-treated seeds as compared to nontreated seeds.

Magnesium content for roots and calcium content of leaves and stems increased significantly due to MC treatment. Other work relating effects of MC to nutrient composition of plant tissue indicated similar findings. Cothren et al. (1983) and Heilman (1985) reported increased Ca and Mg concentrations in leaf tissue from MC treatment. Heilman (1985) also reported that leaf nitrogen was not altered by MC. In contrast, our findings show that the 2.0 g a.i. MC rate increased both nitrogen and phosphorus levels in leaves, stems, and roots compared to the control and 0.2 g a.i. MC rate.

Treatment with MC, either seed or foliar applied, has multiple effects, as is apparent from the current study and previous studies. Plant nutrient concentrations generally increase, whereas plant height, leaf area, and plant dry weight decrease. When these reductions are too severe, cotton yield may decrease. Due to variations in the above parameters, MC in field studies may increase lint yield (Cothren 1988), sometimes may not affect lint yield (Stuart et al. 1984), and sometimes shows mixed results, depending on factors such as cultivar height

(Kerby 1985) and time of planting (Cathey and Meredith 1988).

In summary, MC seed treatment altered cotton growth and development. The MC seed treatment increased the nutrient composition of leaves, stems, and roots, but failed to improve cotton germination and growth under the environmental conditions of this study. Future research efforts will include an evaluation of MC seed treatment on seedling leaf chlorophyll content and membrane integrity of cotton.

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