Spectral Filters Influence Transpirational Water Loss in Chrysanthemum

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Additional index words. Dendranthema ×grandiflorum, light quality, water loss, growth regulation

Abstract. Transpiration rates of chrysanthemum [Dendranthema ×grandiflorum (Ramat.) Kitamura] plants grown under spectral filters were evaluated as part of an investigation on using light quality to regulate plant growth. The 6% \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) spectral filter reduced photosynthetic photon flux density in red (R) and far red (FR) wavelengths and increased the R : FR and blue (B) : R ratios (R = 400 to 700 nm; R = 600 to 700 nm; FR = 700 to 800 nm) of transmitted light relative to the water (control) filter. After 28 days, cumulative water use of plants grown under \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) filters was \( \approx 37\% \) less than that of control plants. Transpiration rates were similar among plants grown under \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) and control filters when expressed as leaf area, a result suggesting that the reduced cumulative water loss was a result of smaller plant size. Plants grown under \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) filters had slightly lower (10%) stomatal density than control plants. Light transmitted through \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) filters did not alter the size of individual stomata; however, total number of stomata and total stomatal pore area per plant was \( \approx 50\% \) less in plants grown under \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) filters than in those grown under control filters due to less leaf area. The results suggest that altering light quality may help reduce water use and fertilizer demands while controlling growth during greenhouse production.

Chemical growth regulators commonly are used in horticulture to reduce plant height and maintain high-quality plants during marketing. Chemical growth regulators also have increased leaf chlorophyll content (Sturman et al., 1990), reduced leaf area (Wang and Gregg, 1989), reduced plant water use (Steinberg et al., 1991a, 1991b), and improved plant establishment in the field (Latimer, 1991). However, recent restrictions on using certain growth-regulating chemicals on horticultural crops and increasing environmental awareness have stimulated interest in using non-chemical alternatives to regulate plant growth.

Various nonchemical methods, such as manipulating greenhouse temperature and light quality have been investigated (Heins and Erwin, 1990; McMahon and Kelly, 1990; Mortensen and Stromme, 1987). Our experiments with spectral filters to alter light quality indicated that light transmitted through \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \) filters reduced plant height and internode length in a manner similar to chemical growth regulators in various horticultural plants (Benson and Kelly, 1991; McMahon and Kelly, 1990; Rajapakse and Kelly, 1992). Rigid or flexible plastic greenhouse covers with specific spectral qualities would enable growers to use light quality to regulate the growth of greenhouse crops.

Received for publication 15 Mar. 1993. Accepted for publication 18 May 1993. Technical contribution no. 3415 of the South Carolina Agricultural Experiment Station. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.
Total leaf area was measured at the end of the experiment (28 days) using an area meter (model LI-3100; LI-COR). Water-use efficiency (estimated as units of water used to produce one unit of dry matter) at the end of the second dry-down cycle was calculated as the average units of water consumed for production of a unit of dry matter (Kramer, 1983).

Leaf epicuticular wax development and stomatal characteristics were determined by scanning electron microscopy. At harvest (between 1100 and 1200 hr), the third leaf from the apex on each plant was frozen immediately in liquid N and freeze-dried. A leaf sample (16 mm²) from the middle of each leaf (avoiding the midrib) was mounted on aluminum stubs and coated with 0.02 µm gold palladium and observed under a scanning electron microscope (model IC 848; JEOL, Tokyo) with an accelerating voltage of 15 kV. Stomata on the abaxial and adaxial surfaces were counted on three fields from each leaf sample (total of 15 fields per treatment). Stomatal length and width were measured on five stomata from each field (total of 75 stomata per treatment). Stomatal density per square millimeter, total number of stomata, and total pore area per plant were estimated using leaf area and stomatal measurements.

Control and CuSO₄ filters were assigned randomly to four growth chambers in two replications. Five single plants were used in each treatment in replicate. Data were subjected to analysis of variance.

Cumulative water loss of plants grown under CuSO₄ filters was lower than that of control plants during both dry-down cycles (Fig. 1 A and B). The difference in water loss between plants grown under control and CuSO₄ filters was greater during the second dry-down cycle, mainly due to greater leaf area of control plants (i.e., a 37% reduction in cumulative water use at the end of the second dry-down cycle compared to a 13% reduction at the end of the first cycle).

The transpiration rate per plant during the light period was significantly higher in plants grown under control than CuSO₄ filters in both dry-down cycles (Fig. 2 A and B). However, the difference in transpiration rate per plant between plants grown under CuSO₄ and control filters was small in the first dry-down cycle (17% increase in control over CuSO₄ filters). The difference in transpiration rate per plant between plants grown under CuSO₄ and control filters was greater during the second dry-down cycle (72% increase in control over CuSO₄ filters). Transpiration rate per plant during the night was similar between plants grown under control and CuSO₄ filters, although plants grown under CuSO₄ filters had smaller leaf areas than plants grown under control filters. This result indicates that plants grown under CuSO₄ filters lost more water per unit area during the night, possibly due to higher cuticular transpiration or impaired stomatal closure. During the second dry-down cycle, the day and night extremes were greater in plants grown under control filters.

Stomatal resistance measured at 0.7, or 14 days after treatment was similar for plants grown under control and CuSO₄ filters (data not shown). However, abaxial-surface stomatal resistance was slightly but significantly lower in plants grown under control filters (1.7 s·cm⁻¹ for plants grown under control vs. 2.1 s·cm⁻¹ for plants grown under CuSO₄ filters, P ≤ 0.05) after 21 days in the chambers. Transpiration rate, calculated based on leaf area (at the end of the second dry-down cycle), indicated that the day transpiration rate was significantly (P ≤ 0.05) higher (10%) in plants grown under control filters. Night transpiration rate of plants grown under CuSO₄ filters was ≈33% higher than that of plants grown under control filters (P ≤ 0.05). These findings agree with the water-loss pattern of plants treated with chemical growth regulators. Steinberg et al. (1991a) reported that Ligustrum plants treated with the chemical growth regulator (α)-1-(p-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)-1-penten-3-ol (uniconazole) had similar transpiration rates per unit leaf area but lower cumulative water use compared with nontreated plants.

Water-use efficiency of plants grown under control filters (394) was greater than that of plants grown under CuSO₄ filters (515, P ≤ 0.05). Our previous research showed that plants grown under CuSO₄ filters had ≈38% lower dry-matter production compared to that of plants grown under control filters (Rajapakse and Kelly, 1992). Reduced water-use efficiency of plants grown under CuSO₄ filters could be due to a greater reduction of dry-matter accumulation compared to plants grown under control filters.

The difference in cumulative water loss and transpiration rate per plant between plants...
grown under control and CuSO₄ filters maybe explained by plant and stomatal characteristics. Leaf cuticular wax development was similar in plants grown under CuSO₄ and control filters (Fig. 3). Abaxial-surface stomatal density of plants grown under CuSO₄ and control filters, total pore area and total number of stomata per plant = 50% lower in plants grown under CuSO₄ filters due to reduced total leaf area, a result that explains the lower cumulative water loss under CuSO₄ filters. In contrast to present findings, the chemical growth regulators α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol (ancymidol) and uniconazole have increased stomatal density of sunflower (*Helianthus annuus* L.) (Starman et al., 1990) and *Ligustrum japonicum* Thunb. (Steinberg et al., 1991a), respectively. However, transpiration rate per unit leaf area did not increase in growth-regulator-treated plants due to reduced stomatal aperture (Orton and Mansfield, 1976) or suppressed xylem development (Wang and Gregg, 1989).

Our results suggest that the quality of light transmitted through CuSO₄ filters could reduce water loss in chrysanthemum plants and reduce plant height and leaf area. Reduced water loss was a result of reduced plant size under CuSO₄ filters. However, the postproduction quality of chrysanthemum plants grown under CuSO₄ filters remains to be determined.

**Literature Cited**


