Spectral Filters Affect Growth, Flowering, and Postharvest Quality of Easter Lilies

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Abstract. The role of light quality on growth, flowering, and postharvest characteristics of 'Nellie White' Easter lilies (*Lilium longiflorum* Thunb.) was evaluated in two growing seasons using 4% CuSO₄ and water (control) as spectral filters. The CuSO₄ filter significantly reduced plant height and internode length. However, the height reduction was smaller in the 1994–95 season (9%) than in the 1995–96 growing season (32%). The number of days to flower bud appearance and flower opening, and the number and diameter of flowers were not significantly affected by the spectral filters in either season. The CuSO₄ filters reduced flower longevity by 3 days in nonstored plants, and by 5 days when plants were subjected to 1 week storage at 4 °C prior to placing in the postharvest room. Results suggest that spectral filters are effective in controlling height and producing compact Easter lily plants without causing a delay in flowering or reducing number of flowers per plant but flower longevity can be adversely affected.

Height control of greenhouse crops is an important practice in producing high-quality plants. Many techniques are available for height control, but chemical control has been the standard practice in commercial operations. Although chemicals are being widely used, interest in using nonchemical (or less chemical) alternatives is increasing because of health hazards to humans and nontargeted animals and the concern over environmental pollution by growth-regulating chemicals.

The growth of plants can be altered by manipulating the red (R) to far-red (FR) ratio. Eliminating far-red light from the greenhouse environment by liquid copper sulfate spectral filters is effective in reducing height and producing compact plants of a wide range of dicotyledonous plants (Benson, 1992; Mortensen and Stromme, 1987; Rajapakse and Kelly, 1992). Our previous work on spectral filters was focused mainly on dicotyledonous plants and, to our knowledge, spectral filter effects on bulb crops have not been investigated. The objective of this study was to investigate the effects of CuSO₄ spectral filters on growth, flowering, and postharvest quality of Easter lilies.

Materials and Methods

Two separate experiments were conducted during the 1994–95 and 1995–96 growing seasons (December to April). Easter lily (*Lilium longiflorum* Thunb.) 'Nellie White' bulbs were vernalized at 4 °C for 6 weeks before planting into 1.75-L round plastic pots containing commercial potting mixture (Mix 3B; Fafard, Anderson, S.C.). The plants were grown in a glass greenhouse for 4 (1995–96 season) or 6 weeks (1994–95 season) before transferring them to the spectral filter chambers. At the time of transfer, plants were 6 cm (1995) and

10 cm (1994) tall. The plants were fertilized at irrigation with N at 200 mg·L⁻¹ from calcium nitrate and potassium nitrate. The plants were grown according to cultural practices recommended by Miller (1992).

After the establishment period, plants were transferred to growth chambers with 4% CuSO₄·5H₂O (w:v) or water (control) "fluid roof" spectral filters. All chambers were placed inside a nonshaded glass greenhouse. Two fans located at opposite sides circulated air inside the chambers. The spectral photon flux (330 to 1100 nm) of light transmitted through CuSO₄ and control filters was measured between 1200 and 1400 HR at the beginning and end of each experiment with a LI-1800 spectroradiometer fitted with a LI-1800-10 remote cosine sensor (LI-COR, Lincoln, Nebr.). The photon distribution, ratios of photons between 600–700 nm and 700–800 nm (R : FR) and of photons between 400–500 nm and 600–700 nm (B : R), and phytochrome photoequilibrium (ø, estimated as described by Sager et al., 1988) of light transmitted through the filters are presented in Fig. 1. Photosynthetic photon flux (PPF) inside the chambers was determined biweekly on clear days between 1200 and 1300 HR with a LI-185 quantum meter fitted with a LI-190SA quantum sensor. The PPF was reduced ≈30% by the CuSO₄ spectral filter and a neutral density filter was used to adjust the PPF in all chambers to an average of 750 ± 75 µmol·m⁻²·s⁻¹. Natural photoperiods at the beginning and at the end of the growing period were 10 and 12 h, respectively. Spectral filters did not affect minimum or maximum air temperatures, which were 25 ± 3 °C and 17 ± 3 °C in the 1994–95 season, and 21 ± 2 °C and 16 ± 2 °C in the 1995–96 season, respectively.

Light treatments (control and CuSO₄ filters) were randomly allocated to each of two growth chambers giving two replicates per

Fig. 1. Photon flux distribution, ratios of photon flux between 600–700 nm and 700–800 nm (R : FR) and between 400–500 nm and 600–700 nm (B : R), and phytochrome photoequilibrium (ø) of light transmitted through 4% CuSO₄·5H₂O or unshaded control (water) filter.

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treatment. Twenty plants were grown in each chamber until marketable stage (at least one fully open flower). Plant height from soil level to plant apex and number of leaves were recorded weekly until flower bud appearance on 10 plants in each treatment chamber. The average internode length was calculated as height divided by number of leaves. The numbers of days from placing in the chamber to flower bud appearance and to flower opening, number of flowers and flower buds, and the diameter of flowers (when flowers were fully open) were recorded.

When plants had at least one open flower, 10 plants from each treatment chamber were transferred to an interior environment (IE) lighted continuously with cool-white fluorescent bulbs ($30\text{--}35\ \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF at bench level). Temperature in IE ranged from 18 to 22 °C (average 20 °C) during the evaluation period. The other 10 plants from each treatment chamber were placed in cardboard boxes and were subjected to dark storage at 4 ± 1 °C for 7 d before transfer to IE. Longevity of individual flowers (days from opening to wilting) was recorded. Overall plant quality after 3 weeks in IE was evaluated on a 1 to 5 scale (1 = unacceptable; 5 = excellent). The data were analyzed by analysis of variance and the means were compared by Duncan's multiple range procedure at the 5% level of significance (SAS Institute, Cary, N.C.).

Results and Discussion

Light transmitted through the CuSO_4 filter reduced height and internode length of 'Nellie White' plants in both seasons (Table 1). However, the magnitude of the response varied between seasons. For example, plants grown under the CuSO_4 filter were 9% shorter than the controls (40 cm in control vs. 36.5 cm in CuSO_4) in 1994–95 vs. 32% shorter (33 cm in control vs. 22.5 cm in CuSO_4) in 1995–96. The number of leaves per plant was not significantly affected by the spectral filters in either season (data not shown). Therefore, the height reduction was caused by the reduction in internode length. The differential response in the two seasons could be partly due to the difference in maturity level when the study was initiated. In the 1994–95 season, plants were 10 cm tall and had been grown for 6 weeks when the study was initiated, whereas they were 6 cm tall and had been grown for 4 weeks in 1995–96. Temperature also varied between the two seasons. In 1994–95, the average greenhouse temperature maxima and minima were ≈ 4 and 1 °C, respectively, higher than in the 1995–96 season.

Table 1. Influence of spectral filters on plant height and internode length at anthesis of 'Nellie White' Easter lily grown in two seasons. Average initial plant heights at the beginning of the experiment in 1994–95 and 1995–96 seasons were 10 ± 1 cm and 6 ± 1 cm, respectively.

Spectral filter	Plant height ^a (cm)		Internode length ^a (cm)	
	1994–95	1995–96	1994–95	1995–96
Control	40.0 a	33.0 a	0.56 a	0.54 a
CuSO_4	36.5 b	22.5 b	0.49 b	0.40 b

^aMean of 10 plants. Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

Table 2. Influence of spectral filters and dark storage at 4 °C on flower longevity and overall plant quality of 'Nellie White' Easter lily grown in two seasons. Overall plant quality was evaluated after 3 weeks in a postharvest evaluation room maintained at 20 ± 2 °C with continuous light at $30\text{--}35\ \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF at bench levels from a cool-white fluorescent source.

Spectral filter	Storage	Flower longevity (d)		Quality rating	
		1994–95	1995–96	1994–95	1995–96
Control	–	14	15	4.0	4.1
	+	13	13	3.8	3.7
CuSO_4	–	11	12	3.4	3.7
	+	8	8	2.5	2.7
ANOVA					
Spectral filter		**	**	**	**
Storage		**	**	**	**
Spectral filter $\times$ storage		**	*	*	*

*, ** Significant at $P = 0.05$ and 0.01, respectively.

The numbers of days to flower bud appearance and flower opening, and the number and diameter of flowers were not significantly affected by the CuSO_4 spectral filters in either season (data not shown). In our previous work, the CuSO_4 filter delayed flowering of 'Bright Golden Anne' chrysanthemum by 7–13 d and produced smaller flowers than control plants in 'Meijikatar' miniature roses and chrysanthemums (Rajapakse and Kelly, 1995).

Use of CuSO_4 filters reduced flower longevity in nonstored plants by 3 d in both seasons (Table 2). Dark storage at 4 °C reduced the flower longevity in control plants by 1–2 d and in CuSO_4 filter-grown plants by 3–4 d. The overall quality after 3 weeks in the postharvest evaluation room was reduced by CuSO_4 filters (Table 2). Dark storage did not significantly affect the quality of control filter-grown plants, but reduced that of plants grown under the CuSO_4 filter. The poor postharvest performance of the latter could be partly a result of reduced carbohydrate reserves. Use of CuSO_4 filters reduced leaf and stem soluble sugars and starch concentrations in miniature roses (Rajapakse and Kelly, 1994) and chrysanthemums (Rajapakse and Kelly, 1995). A preliminary study with chrysanthemum flowers indicated that flower carbohydrate levels were reduced under CuSO_4 filters (unpublished data). The apparent relationship between flower carbohydrate levels and the postharvest performance under spectral filters will be investigated in future research.

We conclude that spectral filters are effective in controlling height and producing compact Easter lily plants in the greenhouse without causing a delay in flowering or reducing the number of flowers per plant. However, the filters reduced postharvest longevity and quality. Currently, we are evaluating alternative ways of using spectral filters to maximize the carbohydrate supply while attaining the desired height control.

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