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Influence of End-of-day Red and Far-red Light on Potted Roses¹

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Abstract -

The effects of end-of-day red and far-red light on postharvest leaf chlorosis of potted roses were investigated. Rosa \times hybrida L. 'Meijikatar' (Tradename: Orange Sunblaze) and 'Confection' plants were treated with 30 minutes of red light (600–700 nm) or farred light (700–780 nm) at the end of each daily photoperiod throughout production. At harvest, plants were placed in storage for 5 days at 16°C (61°F). 'Meijikatar' plants treated with end-of-day far-red light had more leaf chlorosis than plants treated with endof-day red light or those which served as controls. 'Confection' plants treated with end-of-day far-red light had more leaf chlorosis than plants treated with end-of-day red light. 'Meijikatar' plants were treated in the greenhouse at the end of each photoperiod with 1 hour of incandescent or fluorescent light, with control plants receiving natural greenhouse end-of-day light, and then placed into storage. Plants treated with end-of-day incandescent light were taller than plants treated with end-of-day fluorescent light or controls. After simulated storage, plants treated with end-of-day incandescent light had the most etiolated shoots. Light treatments had no significant effect on the amount of leaf chlorosis 5 days after removal from simulated storage.

Key Words: chlorosis, phytochrome, postharvest, Rosa \times hybrida, storage.

Significance in the Nursery Industry

The manipulation of light quality during production shows promise as an inexpensive, non-chemical means of regulation of growth responses of plants which are presently controlled by use of chemical growth regulators. In this study, end-of-day red and far-red light treatments given to Rosa \times hybrida 'Meijikatar' and 'Confection' plants in the laboratory had significant effects on postharvest leaf chlorosis. However, when standard light sources with a high amount of red or far-red light (fluorescent and incandescent light) were irradiated on plants at the end of a natural greenhouse photoperiod, there were no effects on postharvest leaf chlorosis. These results indicate that precise alterations of end-of-day light quality must be used to influence leaf chlorosis. These alterations could most easily be obtained with selective light filters such as liquid spectral filters, or lightselective shading materials.

Introduction

Potted roses are a relatively new greenhouse crop for U.S. growers. Recent breeding efforts have resulted in improved pot-forcing cultivars which are easier to grow and have the

¹Received for publication October 18, 1990: In revised form April 5, 1991. ²Graduate Student, Professor, and Associate Professor, resp. potential for being mass-marketed to fill consumer demands for roses at Valentine's and Mother's Day. Although potted roses have a promising future, their commercial development is limited by losses encountered during postharvest handling. Because the crop is often shipped in small numbers, it is not always feasible for growers to ship under refrigeration. Adverse storage temperatures and darkness inside storage boxes can lead to crop deterioration. A common postharvest problem with potted roses is leaf chlorosis developing in the lower leaves of plants 3 to 5 days after removal from storage which, subsequently, leads to leaf abscission. Leaf abscission of pot roses was reduced when the cytokinin 6-(benzylamino)-9-(2-tetrahydropyranyl)-9Hpurine was sprayed onto plants prior to simulated transport (4). Foliar application of benzyladenine and transzeatin 1 hr prior to storage at 16°C (61°F) reduced lower leaf chlorosis of 'Meijikatar' potted roses 3 and 5 days after removal from storage (1). Presently, there are no chemicals labeled to control leaf chlorosis in potted roses.

Brief end-of-day (EOD) irradiations of tobacco plants with red (R) or far-red (FR) light have been shown to have dramatic morphological effects (6). Plants treated with EOD FR light were more elongated with fewer lateral branches, and had chloroplasts with fewer, smaller starch grains, while plants treated with R light were more compact with more lateral branches and had chloroplasts with more, and larger starch grains (7). Tomato plants treated with FR light showed suppression of side shoot growth (11, 12). It has also been shown that R light inhibits abscission and FR light promotes abscission in *Coleus* (2). Dark-induced leaf abscission of mung bean was inhibited with low intensity R light treatments, and the amount of this inhibition depended on the intensity and length of treatment (3). Our experiments were conducted to determine the effects of EOD R and EOD FR light treatments on plant growth and shipping stress-related leaf chlorosis in potted roses, and to determine if these techniques could be used in a greenhouse production situation.

Materials and Methods

Experiment 1. Rooted liners (2-3 rooted cuttings) of Rosa × hybrida 'Meijikatar' and 'Confection' were potted into 10-cm (4 in) pots (472 cm³) (28.8 in³) in a commercial potting mix and spaced on 20 cm (8 in) centers in an unshaded glass greenhouse. Plants were grown until roots reached the container bottom, then shoots were mechanically pinched to 12 cm (4.7 in) above the media surface. Plants were irrigated once daily and fertilized with 250N-116P-235K mg/liter from Peter's 15-16-17 fertilizer through irrigation on weekdays, with a no fertilizer irrigation once daily on weekends. The greenhouse was vented at 21°C (70°F) during the day.

Beginning the day of pinch, plants received an 8-hr photoperiod of natural light. At the end of each photoperiod, plants were placed in either R or FR light treatment chamber and were exposed for 30 minutes, with control plants being placed in darkness. In the R light treatment chamber, light from 6 cool-white, 40-W fluorescent lamps was passed through a Roscolux #19 acetate filter (Rosco, Port Chester, NY 10573) allowing transmission of R light (2.8 W \cdot m⁻² in the 600 to 700 nm wavelength band) into the chamber. In the other chamber, light from two 150-W internal reflector, incandescent-filament lamps was passed through a cast acrylic (#2711, dark red, Rohm and Haas, Bristol, PA 19007), allowing transmission of FR light (10.2 W \cdot m⁻² in the 700 to 780 nm wavelength band) into the chamber. Treatments were arranged as a completely randomized design with 5 single plant replications per treatment. Following the light treatments, chamber doors were opened in darkness to allow proper air circulation, and plants remained in darkness until the beginning of the next photoperiod. Average night temperature during treatments was $21 \pm 2^{\circ}C$, (70 \pm 4°F) but during the 30-minute light treatments, plants in the FR treatment chamber briefly experienced 25°C (77°F) temperatures toward the end of the light treatments, due to heat energy given off by the incandescent bulbs. Treatments were given to plants from March 28, 1989 until April 19, 1989.

Experiment 2. In the second study, the above experiment was repeated with cultural practices performed as described, except plants received a 12-hr photoperiod each day and were treated from July 1, 1989 until July 22, 1989. Only the cultivar 'Meijikatar' was used because it was most responsive to light treatments for leaf chlorosis measurements in the first experiment. Two additional treatments were added to the R, FR, and control groups. In these 2 groups, plants were treated with 30 minutes of R followed by 30 minutes of FR or 30 minutes of FR followed by 30 minutes of R. Treatments were arranged in a completely randomized design with 5 single plant replications per treatment.

At the end of the treatment cycle, plants were sleeved in newspaper, boxed, and placed into simulated dark storage incubators (Model 815 low temperature incubators, Precision Scientific, Inc., Chicago, IL 60647) at $16 \pm 0.5^{\circ}$ C ($61 \pm 1^{\circ}$ F) for 5 days. This combination of storage temperature and duration was shown to induce postharvest leaf chlorosis in these cultivars (1). Following simulated storage, plants were placed into an interior environment (IE) for postharvest evaluation. The IE was lit by cool-white fluorescent light ($30 \mu \text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$) with a 24 hour photoperiod and held at $21 \pm 2^{\circ}$ C ($70 \pm 4^{\circ}$ F). Plants remained in the IE for 5 days.

Number of lateral breaks per shoot was determined after 1 week of light treatments. Percent leaf chlorosis and visual quality were evaluated after 1, 3, and 5 days in the IE. Visual quality was rated by a 1 to 5 scale where 1 was poor quality (unsalable) and 5 was excellent quality. Plants which had no leaf chlorosis or abscission and no flower malformation, discoloration, or abscission were rated 5. A quality rating of 4 was given to plants which had less than 5% leaf chlorosis and/or less than 10% flower malformation, discoloration, and abscission. Plants which had less than 10% leaf chlorosis, and/or less than 25% flower malformation, discoloration, and abscission were given a quality rating of 3. A quality rating of 2 was given to plants which had less than 25% leaf chlorosis and/or less than 50% flower malformation, discoloration, and abscission. Plants which had more than 25% leaf chlorosis and more than 50% flower malformation, discoloration, and abscission were rated 1. The data were analyzed by analysis of variance procedure and mean separation was performed using least significant difference (LSD) at the 5% level.

Experiment 3. Rooted liners of 'Meijikatar' were potted and grown as described previously. Greenhouse night temperatures were held at $20 \pm 1^{\circ}C$ (68 $\pm 2^{\circ}F$), and at the pinch date, plants were pinched to 8 cm (3.15 in) above the soil line. Beginning the day of pinch, plants received natural light until 30 minutes before sunset daily. At this time, plants were treated with a light source high in FR (FR:R = 1.2) or R (FR:R = 0.2), with control plants receiving natural greenhouse light. For the R light source, two four foot coolwhite fluorescent bulbs (Sylvania workshop F40, GTE, Manchester, NH 03103) (15 \pm 1 µmol \cdot m⁻² \cdot s⁻¹ PPF) irradiated on plants from approximately 1 meter above the shoot tips. For the FR light source, light from two 60-W incandescent filament bulbs (Miser, General Electric, Cleveland, OH 44114) (12 \pm 1 µmol \cdot m⁻² \cdot s⁻¹ PPF) was irradiated onto plants from approximately 1 meter above the shoot tips. Light from each source was measured at the shoot tips using a LI-COR 1800 spectroradiometer with a remote cosine sensor on a 1.5 m (59 in) fiber optic probe (LI-COR, Lincoln, NE 68504). Treatments continued from March 19, 1990 to April 16, 1990. Light treatments were arranged in a randomized complete block design with 2 replications of 12 plants per replication.

After 2, 3, and 4 weeks of treatment, plant height was measured. Plants were harvested when flower buds showed 50% coloration (after 4 weeks of treatment), and leaf area, total shoot dry weight, and total number of flowers and buds per plant were measured. Leaf area was measured using a LI-COR 3100 leaf area meter (LI-COR, Lincoln, NE 68504).

Plants were then placed into simulated storage incubators for 5 days at $16 \pm 0.5^{\circ}$ C ($61 \pm 1^{\circ}$ F) as described above.

Cultivar Treatment	Lateral breaks per shoot		Percent leaf chlorosis			
	'Confection'	'Meijikatar'	'Confection'		'Meijikatar'	
			3 days	5 days	3 days	5 days
Far-red (FR)	2.05 b ^z	1.80 a	7.6 a ^{yz}	20.0 a	8.2 a	
Red (R)	2.88 a	2.30 a	4.8 ab	16.7 ab	4.0 b	22.6 b
Control	2.47 ab	1.70 a	3.4 b	12.7 b	3.2 b	17.8 b

Table 1.	Number of lateral breaks per shoot after one week of end-of-day light treatments, and percent leaf chlorosis after 3 and 5 days in the
	IE of Rosa × hybrida 'Confection' and 'Meijikatar' in Experiment 1.

^yMeans transformed by arcsin transformation.

^zMean separation in columns by LSD at the 5% significance level.

On the day of removal from simulated storage, data were taken for the number of etiolated shoots per plant for all plants. After 5 days in the IE, percent leaf chlorosis was determined for 6 plants per treatment. All production and postharvest data were analyzed by analysis of variance procedure with means separated by LSD at the 5% level.

Results and Discussion

Experiment 1. 'Confection' plants treated with EOD FR had fewer lateral bud breaks per shoot than plants treated with EOD R, but neither light treatment induced differences in lateral bud break production compared to controls (Table 1). Data were collected only once because the rose cultivars began branching heavily, and further data collection would have damaged treated plants. End-of-day FR treatments have been shown to inhibit lateral branching in tomato (11), tobacco (5), and cut roses (9). Lack of difference between light treated plants and controls was likely due to control light having more R and FR light present, while the other light treatments had primarily only one source. After 3 and 5 days in the IE, 'Confection' plants treated with EOD FR light had more leaf chlorosis than control plants, but no differences in leaf chlorosis were found between EOD R and FR treatments after storage (Table 1). 'Meijikatar' plants treated with EOD FR light had more leaf chlorosis than plants treated with EOD R light or control plants (Table 1). Exposure of plants to low levels of FR light has been shown to promote abscission in Coleus (2) and mung bean (3).

Experiment 2. 'Meijikatar' plants treated with EOD FR and EOD R followed by FR (R/FR) had fewer lateral breaks per shoot than plants treated with EOD R or EOD FR fol-

Table 2. Number of lateral breaks per shoot after one week of endof-day light treatments, and percent leaf chlorosis after 3 and 5 days in the IE of *Rosa* × *hybrida* 'Meijikatar' in Experiment 2.

	Lateral breaks	Percent leaf chlorosis		
Treatment	per shoot	3 days	5 days	
Far-red (FR)	1.12 c ^z	24.0 a ^{yz}	26.0 a	
Red (R)	1.51 a	8.2 c	14.6 b	
Control	1.21 bc	17.0 ab	24.0 a	
Red/Far-red (R/FR)	1.05 c	16.0 b	21.0 a	
Far-red/Red (FR/R)	1.39 ab	14.2 b	20.0 ab	

^yMeans transformed by arcsin transformation.

^zMean separation in columns by LSD at the 5% significance level.

lowed by R (FR/R) (Table 2). These results suggest that the lateral bud break response is phytochrome-mediated in potted roses. After 3 days in the IE, plants treated with EOD FR light had more leaf chlorosis than plants in all other treatments except controls (Table 2). After 5 days in the IE, plants treated with EOD R light had the least leaf chlorosis, but there were no differences among other treatments (Table 2). These results indicated that potted roses may show differences in sensitivity to the effects of EOD light at different times of year under longer photoperiods, or that longer treatment periods may be needed to fully convert phytochrome in the reversal treatments. Visual quality (% leaf chlorosis, bud malformation, and bud discoloration) was not influenced by EOD light treatments in either experiment (data not shown).

Experiment 3. No differences between replications for all data measurements were observed, so all data were pooled and analyzed. After 2 weeks of treatment, plant height was not affected by EOD light treatments, but after 3 and 4 weeks of treatment, plants treated with EOD incandescent light were approximately 10% taller than plants treated with EOD fluorescent light or control plants (Table 3). In similar studies, EOD FR light treatments increased stem length in tobacco and soybeans, respectively, compared to EOD R treatments (5, 10). Time to 50% flower coloration, leaf area, total shoot dry weight, and total number of flowers and buds per plant were not affected by EOD light treatments (data not shown). Total leaf area and number of floral primordia of soybeans were not affected by 30-minute treatments of EOD incandescent or fluorescent light, but total shoot dry weight was greater in plants treated with EOD incandescent light than those treated with EOD fluorescent light (10).

Table 3.	Plant height measured after 2, 3, and 4 weeks of end-of-
	on the day of removal from 5 days of simulated storage at
	16°C (61°F), and percent leaf chlorosis after 5 days in the
	IE of Rosa × hybrida 'Meijikatar' in Experiment 3.

	Plant height (cm) Weeks of treatment			Etiolated		
					Percent	
Treatment	2	3	4	shoots	leaf chlorosis	
Incandescent	11.2 a ^z	15.2 a	17.9 a	12.0 a	12.2 a	
Fluorescent	10.9 a	13.9 b	16.2 b	10.3 b	13.8 a	
Control	10.5 a	14.1 b	16.4 b	9.8 b	11.1 a	

^zData for both replications were pooled and analyzed.

Mean separation in columns by LSD at the 5% significance level.

Soybean plants treated with 5 minutes of EOD FR light had greater shoot dry weights than plants treated with 5 minutes of EOD R light (8). Lack of differences in the present study may be attributed to the fact that a large percentage of total shoot dry weight was produced before light treatments started.

On the day of removal from simulated storage, plants treated with EOD incandescent light had more etiolated shoots than plants treated with EOD fluorescent light or controls (Table 3). This suggests that during storage, plants treated with EOD incandescent light continue to exhibit shoot elongation responses similar to those displayed during production. After 5 days in the IE, there were no differences in percent leaf chlorosis among treatments (Table 3). When compared to differences observed in experiment 1, it can be concluded that altering the R:FR is not enough to affect postharvest leaf chlorosis. Exclusion of either FR or R light must be attained to give an effect, thus making applications of this practice impractical when trying to reduce postharvest leaf chlorosis in the greenhouse. A possible alternative could be found with using a red light source after darkness.

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Effect of Time and Application of Sodium Chloride in the Dormant Season on Selected Tree Seedlings1

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- Abstract -

Seedlings of Acer platanoides, A. rubrum, Quercus palustris, and Q. rubra were subjected to soil-applied sodium chloride (NaCl) solutions of 0.0, 1.1, and 5.0 N NaCl once every month beginning in October and ending in April. In May, the trees were evaluated for damage, harvested and dried. Growth measurements and shoot Na and Cl content were analyzed. For all four species, plants in the November through February/March salt treatments sustained little plant damage and reduction in growth. The October application of NaCl resulted in heavy plant damage and reduced growth in each species, while April NaCl applications produced similar results in A. rubrum and Q. palustris alone. Shoot Na and Cl content were greater in plants in the October, March, and April salt treatments.

In a second experiment, actively-growing, greenhouse-grown plants of the four species were subjected to either a fertilizer solution plus 0.25 N NaCl at every irrigation or a single application of 1.1 N NaCl followed by normal irrigation thereafter. A. platanoides lost its resistance to soil-applied NaCl by mid summer, while A. rubrum and Q. palustris were sensitive to a high dosage of NaCl applied at this time and Q. rubra was resistant. In both experiments, there were significant interactions between the time of NaCl application and the periodicity of plant growth, soil temperature, precipitation, and leaching of the salt from the soil as well as genetic factors, which affected the amount the salt injury sustained by trees.

Index words. NaCl, salt, salinity, Acer platanoides, Acer rubrum, Quercus palustris, Quercus rubra

Significance to the Nursery Industry

Landscape maintenance managers should not use sodium chloride (NaCl) to deice walkways and roadways during late

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