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Postharvest Quality Characteristics of Cultivars of Potted Rose in Response to Holding Conditions and Cytokinins

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Abstract. Six cultivars of potted rose (*Rosa* × *hybrida* L.) plants were evaluated for shipping stress-induced leaf chlorosis during holding at 8, 16, or 28°C for 2, 4, or 6 days. 'Meijikatar' showed more leaf chlorosis than the similar 'Meirutral' at the higher simulated shipping temperatures and longer durations. Plants of 'Meijikatar' were treated before simulated shipping with BA, TZ, or Promalin at 0, 25, 50, or 100 mg cytokinin/liter each, then paper-sleeved and stored in the dark in fiberboard boxes at 16°C for 5 days. Plant quality 5 days after removal from storage was better with BA at 50 or 100 than at 0 mg·liter⁻¹. All cytokinin-treated plants showed less leaf chlorosis than controls. Benzyladenine at 50 or 100 mg·liter⁻¹ reduced leaf chlorosis when compared to all TZ treatments. There were no differences among treatments in the number of etiolated shoots per plant. Chemical names used: *N*-(phenylmethyl)-1*H*-purin-6-amine (benzyladenine, BA); trans-zeatin (TZ); gibberellic acid (GA₄₊₇) + BA (Promalin).

Many cultivars of rose have been evaluated for pot culture. Traditionally, the Garnette types and Koster (polyantha) types have been used for forcing in 15-cm or larger containers (Hasek and Sciaroni, 1975; Reilly,

1983). Heins (1985) described these cultivars as "leggy" and discussed their high costs of production. Recently, rose cultivars have been developed as nongrafted pot-forcing selections. These cultivars are well suited for production in 10- (378 cm³) to 15-cm (1250 cm³) containers. A serious limitation in developing the full market potential for these potted roses is the loss of quality during postharvest shipping and handling. During shipping, the plants receive no light and often experience extreme temperatures. Shipping stress can result in chlorosis of the lower leaves, bud malformation and abscission, and etiolated shoot growth (Halevy and Kofranek, 1976; Maxie et al., 1974).

Cytokinins have been reported to slow chlorophyll degradation in barley and oat (Sabater and Rodriguez, 1978; Schistad and Nissen, 1984) and stimulate chlorophyll synthesis in dark-grown cucumber cotyledons (Dei, 1984; Fletcher and McCullagh, 1971; Fletcher et al., 1973). BA applied before dark treatment of growing rice leaves has been shown to reverse dark-induced decreases in

chlorophyll content (Reddy et al., 1985). BA treatment on dark-grown corn leaf segments with etioplasts stimulated chlorophyll accumulation during the earliest stage of development in light (Caers and Vendrig, 1986).

Foliar applications of α -naphthaleneacetic acid (NAA) plus BA halted leaf yellowing and abscission and prevented the loss of starch and nitrogen that occurs during monocarpic senescence of soybean leaves (Nooden et al., 1979). Application of 6-(benzylamino)-9-(2-tetrahydropyranyl)-9*H*-purine (PBA) before shipping reduced flower bud and leaf abscission, while NAA application prevented bud drop but promoted leaf abscission and leaf chlorosis in potted roses (Halevy and Kofranek, 1976).

The objectives of our studies were to determine rose cultivar susceptibility to leaf chlorosis during simulated shipping at various temperatures and for several durations and to determine the effectiveness of chemical applications in preventing leaf chlorosis.

Cultivar evaluation. In mid-Sept. 1988, *Rosa* × *hybrida* 'Meijikatar', 'Meirutral', 'Meilargo', 'Ruired' (marketed under trademark names Orange Sunblaze, Red Sunblaze, Lady Sunblaze, and Red Minimo, respectively), 'Confection', and 'Shy Girl' plants were received as rooted liners (two to three rooted cuttings) and grown in 10-cm pots (472 cm³) in a commercial potting mix (3B; Fafard, Anderson, S.C.) in glasshouses at Clemson Univ. Plants were allowed to grow until their roots reached the container bottom ($\approx$ 2 weeks), then were pinched to 10 cm above the soil line, and subsequently forced ($\approx$ 6 weeks). This procedure constituted a standard short-cycle forcing schedule (J. Ferare, personal communication). Plants were irrigated once daily with a solution containing 250N-116P-235K (mg·liter⁻¹) from Peter's 15-16-17 (W.R. Grace & Co., Fogelsville, Pa.), except that no fertilizer was included on weekends. Average minimum night temperature during production was 18°C ($\pm$ 2.5°C) and greenhouses were vented at $\approx$ 20°C during the day. At harvest, plants were selected for uniform shape and size within each cultivar and all had about half of the flower buds showing color. Plants were irrigated with tap water before placement under simulated shipping conditions.

Fiberboard shipping boxes were sealed with tape to exclude light and were placed into dark incubators (Model 815 Low Tempera-

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Table 1. Average incidence (%) of leaf chlorosis in six cultivars of potted rose placed in all combinations of three simulated shipping temperatures and three shipping durations. Data were taken 7 days after removal from simulated shipping.*

Cultivar	Shipping duration (days)								
	2			4			6		
	Shipping temp (°C)								
	8	16	28	8	16	28	8	16	28
	(%)								
Meijikatar	4.5	4.5	7.5	5.0	3.5	14.5*	9.0*	19.0*	25.5*
Meirutral	1.5	1.5	2.0	2.0	3.5	5.0	6.0	4.0	6.0
Meilarco	8.5	5.5	5.0	5.0	5.0	9.5*	7.5	12.0*	14.0*
Confection	6.5	10.0*	8.0	9.0*	12.0*	16.0*	13.0*	19.0*	33.0*
Shy Girl	1.5	4.0	2.5	3.0	5.0	3.5	6.0	6.5	11.5*
Ruired	5.5	3.0	3.5	3.5	3.5	7.0	7.5	7.5	19.0*

*Leaf chlorosis means transformed by arcsin transformation before statistical analysis; the transformed data are presented.

*Mean leaf chlorosis percentages significantly greater than the standard of 5% by a z test ($\alpha = 0.05$). The test formula for computing significance was: $x > 0.05 + (1.65)(0.0218405)$.

Table 2. Average quality rating (1 = lowest quality; 5 = highest quality) of six cultivars of potted rose placed in all combinations of three simulated shipping temperatures and three shipping durations. Data were taken 7 days after removal from simulated shipping.

Cultivar	Shipping duration (days)								
	2			4			6		
	Shipping temp (°C)								
	8	16	28	8	16	28	8	16	28
Meijikatar	4.0	3.5	3.0*	3.5*	3.5*	3.0*	3.0*	3.0*	3.0*
Meirutral	4.5	5.0	4.5	4.0	4.0	4.0	3.5*	4.0	3.5*
Meilarco	4.0	4.0	4.0	3.5*	4.0	4.0	3.5*	3.0*	3.0*
Confection	3.5*	3.5*	4.0	4.0	3.5*	3.5*	3.5*	3.5*	3.0*
Shy Girl	4.5	4.0	4.0	4.0	4.0	4.0	4.0	3.5*	3.0*
Ruired	4.0	4.0	4.0	4.0	4.0	3.0*	3.5*	3.0*	3.0*

*Mean visual quality ratings significantly greater than the standard of 4.0 by a z test ($\alpha = 0.05$). The test formula for computing significance was: $x < 4 - (1.65)(0.21821789)$.

ture Incubators; Precision Scientific, Chicago). Treatments were arranged as a $6 \times 3 \times 3$ factorial combination of the six cultivars, three shipping temperatures (8, 16, and 24°C), and three durations (2, 4, and 6 days), with four single-plant replications of each treatment. The experimental design was a split-plot, with shipping temperatures as nonreplicated main plots.

At the end of storage, plants were removed from the boxes, unsleeved, and placed in an interior environment (IE) for evaluation. The IE was a room held at 21°C ($\pm 2.5^\circ\text{C}$) with continuous $30 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ photosynthetic photon flux (PPF) from cool-white fluorescent light. Although many researchers have used 8 or 16-h photoperiods for interior evaluation, continuous lighting was used to simulate a common supermarket or office situation. The plants were subirrigated daily for 7 days. Measurements were made on the day following removal from storage and every other day until day 7 for percentage of chlorotic leaves and visual quality. Leaf chlorosis was visually estimated due to the need for a nondestructive means for evaluating its progression. Since decreases in quality are also attributed to poor flower color and form, failure of flowers to open, and generally poor appearance of the plant, visual quality was rated on a 1 to 5 scale, where 1 = poor and 5 = excellent quality. Plants without chlorotic leaves and no flower malformation, discoloration, or

abscission (flower distortion) were rated 5; 4 = plants with <5% chlorotic leaves and/or <10% distorted flowers; 3 = plants with <10% chlorotic leaves and/or <25% distorted flowers; 2 = plants with <25% chlorotic leaves and/or <50% distorted flowers; 1 = plants with >25% chlorotic leaves and/or >50% distorted flowers.

The cultivar screening study served to find a cultivar with sufficient leaf chlorosis to be used in the cytokinin experiment. Instead of using a traditional statistical analysis to determine significant main effects and interactions, we compared the percentage of leaves with chlorosis to a chosen standard of 5% and visual quality to a rating of 4 to show which cultivar(s) performed poorly at each treatment combination. Plants with leaf chlorosis ratings significantly greater than 5% were deemed unacceptable, and plants that received a visual quality rating significantly less than 4.0 were deemed unacceptable. These standards were equivalent to 10% of the maximum loss that normally is encountered after shipping. Analysis of variance (ANOVA) revealed significant main effects and various interactions (data not shown). For this reason, we believe that the treatment combinations were sufficient to show any useful differences. Arcsin transformations were used for means of percent leaf chlorosis before data analysis.

Chemical treatments. Plant production practices and harvest stage of development

were the same as described above. *Rosa* $\times$ *hybrida* 'Meijikatar' was chosen because it developed excessive leaf chlorosis in the cultivar screening study.

BA, TZ, and Promalin (Abbott Laboratories, Chicago) were tested for their ability to reduce shipping-stress-related symptoms. Foliar sprays were applied at midday and plants were allowed to dry for 1 h before placement into storage. Treatments included a water control, two solvent-blank controls corresponding to commercial formulations (ABG 3070, the solvent blank for BA and TZ; ABG 7008, the solvent blank for Promalin), BA, and TZ (each at 25, 50, and 100 mg·liter⁻¹). Promalin was applied at the BA concentrations noted, with GA concentrations also increasing correspondingly. The treatments were arranged as a completely randomized design with two replications (six plants constituted a replication). The data were analyzed by ANOVA. If the ANOVA indicated significant differences among the treatment means, then an LSD at $\alpha = 0.05$ was used to compare the means. Means for percentage of leaves with chlorosis were transformed by arcsin transformation before their statistical analysis, but no comparisons were made among concentrations of a given compound. After chemical treatment, plants received simulated shipping as described earlier, except that plants were stored only at 16°C ($\pm 0.5^\circ\text{C}$) in darkness for 5 days to induce leaf chlorosis and shoot etiolation.

Upon removal from simulated shipping, plants were initially observed for shipping-stress-related symptoms and placed in the IE. The number of etiolated shoots per plant was counted. The following day, leaf chlorosis and visual quality were assessed. The percentage of chlorotic leaves and visual quality ratings were then determined every other day for 5 days, as described above.

Cultivar comparisons. There was wide variation in leaf chlorosis among the six cultivars after simulated shipping. Leaf chlorosis appeared soon after plants were removed from storage and continued to develop. All cultivars, except 'Meirutral', showed more leaf chlorosis with a combination of higher storage temperatures and longer storage (Table 1). Only 'Confection' was unacceptable after 2 days of storage at 16°C; it also was unacceptable after 4 or 6 days at any temperature. 'Shy Girl' and 'Ruired' were unacceptable when stored for 6 days at 28°C. 'Meirutral' and 'Meijikatar' are two cultivars with very similar appearance in foliage and flower form, and 'Confection' and 'Shy Girl' also have similar foliage and flower characteristics. However, they displayed different levels of shipping-stress-induced leaf chlorosis in pairwise comparisons (Table 1). A similar phenomenon was observed by Halvey and Kofranek (1976), who also showed that potted roses 'Pink Margo Koster' and 'Orange Margo Koster' displayed different amounts of leaf and bud abscission following simulated shipping.

Overall postharvest quality was not a direct result of the amount of leaf chlorosis a cultivar displays. 'Ruired', a cultivar that

Table 3. Incidence (%) of leaf chlorosis of *Rosa × hybrida* 'Meijikatar' 3 and 5 days after removal from 5 days of simulated shipping at 16C.^z

Compound ^x	Concn (mg·liter ⁻¹)	Time in interior environment (days) ^y	
		3	5
		(%)	
BA	100	0.8 a	5.1 a
	50	0.8 a	5.8 a
	25	1.2 a	9.6 abc
Promalin	100	2.0 a	7.1 ab
	50	1.4 a	9.6 abc
	25	1.6 a	14.0 abc
TZ	100	2.5 a	18.5 c
	50	2.6 a	17.8 bc
	25	2.8 a	18.4 bc
Control, distilled water		12.5 b	43.1 d
ABG 3070		13.8 b	38.8 d
ABG 7008		14.4 b	38.8 d

^xLeaf chlorosis means transformed by arcsin transformation before statistical analysis; the transformed data are presented.

^yMean separation in columns by LSD at $\alpha = 0.05$.

^zABG 3070 and ABG 7008 are the solvent blanks for BA and TZ, and Promalin, respectively.

Table 4. Quality rating (1 = lowest quality; 5 = highest quality) of *Rosa × hybrida* 'Meijikatar' 3 and 5 days after removal from 5 days of simulated shipping at 16C.

Compound ^y	Concn (mg·liter ⁻¹)	Time in interior environment (days) ^z	
		3	5
BA	100	3.5 a	3.1 ab
	50	3.4 ab	3.3 a
	25	2.9 abc	2.3 abc
Promalin	100	3.0 abc	2.4 abc
	50	3.0 abc	2.4 abc
	25	2.5 bc	2.0 c
TZ	100	3.4 ab	2.4 abc
	50	2.8 abc	2.1 bc
	25	3.0 abc	2.1 bc
Control, distilled water		2.4 bc	1.4 c
ABG 3070		2.4 c	1.8 c
ABG 7008		2.5 bc	1.9 c

^yMean separation in columns by LSD at $P = 0.05$.

^zABG 3070 and ABG 7008 are the solvent blanks for BA and TZ, and Promalin, respectively.

showed little postharvest leaf chlorosis (Table 1), was judged low for overall quality after 6 days of simulated shipping at any

temperature tested (Table 2). Decreases in quality were attributed to poor flower color and form, failure of flowers to open, and, generally, poor appearance of the plant.

Effects of chemicals. There were no differences for 'Meijikatar' for the number of etiolated shoots per plant for any treatment combination (data not shown). Leaf chlorosis was observed after 3 days in the IE, but all cytokinin-treated plants had reduced leaf chlorosis over the controls after 3 and 5 days in the IE (Table 3). BA at 50 or 100 mg·liter⁻¹ was more effective than TZ in retarding leaf chlorosis. BA has also been shown to be more effective than TZ in retarding senescence in soybean (Garrison et al., 1984) and broccoli florets (Rushing, 1990). This phenomenon has been suggested as a result of TZ being metabolized faster in plants than BA (Garrison et al., 1984). There were no differences in leaf chlorosis between Promalin- and BA-treated plants, indicating that the gibberellic acid in the Promalin formulation had no effect on leaf chlorosis. Plants treated with BA at 100 mg·liter⁻¹ were of better quality than any control after 3 days in the IE, and plants treated with 50 or 100 mg BA/liter were of superior quality than any control after 5 days in the IE (Table 4).

We have shown that significant differences exist in response to various simulated shipping temperatures and durations in the postharvest characteristics of rose cultivars that have been developed for pot culture. Also, shipping temperature/duration combinations that induce unacceptable levels of postharvest leaf chlorosis and overall quality for the cultivars tested are given. Spray applications of BA at 50 or 100 mg·liter⁻¹ just before 5 days of simulated shipping at 16C decrease postharvest leaf chlorosis and result in higher quality plants after storage.

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