Production and Postharvest Characteristics of *Rosa hybrida* L. 'Meijikatar' Grown in Pots under Carbon Dioxide Enrichment

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Abstract. The effects of carbon dioxide enrichment on growth, photosynthesis, and postharvest characteristics of 'Meijikatar' potted roses were determined. Plants were grown in 350, 700, or 1050 $\mu\text{L CO}_2/\text{liter}$ until they reached 50% flower bud coloration and then were placed into dark storage for 5 days at 4 or 16C. Plants grown in 700 or 1050 $\mu\text{L CO}_2/\text{liter}$ reached the harvest stage earlier and were taller at harvest than plants produced in 350 $\mu\text{L CO}_2/\text{liter}$, but there were no differences in the number of flowers and flower buds per plant among CO_2 treatments. Plants grown in early spring were taller and had more flowers and flower buds than plants grown in late winter. Shoot and root growth of plants grown in 700 or 1050 $\mu\text{L CO}_2/\text{liter}$ were higher than in plants produced in 350 $\mu\text{L CO}_2/\text{liter}$, with plants grown in early spring showing greater increases than plants grown in late winter. Immediately after storage, plants grown in 350 $\mu\text{L CO}_2/\text{liter}$ and stored at 4C had the fewest etiolated shoots, while plants grown in 1050 $\mu\text{L CO}_2/\text{liter}$ and stored at 16C had the most. Five days after removal from storage, chlorophyll concentration of upper and lower leaves had been reduced by $\approx 50\%$ from the day of harvest. Carbon dioxide enrichment had no effect on postharvest leaf chlorosis, but plants grown in early spring and stored at 16C had the most leaf chlorosis while plants grown in late winter and stored at 4C had the least leaf chlorosis.

Carbon dioxide enrichment is practiced commercially to increase yield and quality of greenhouse crops. Carbon dioxide enrichment has been shown to increase shoot dry weight of several floricultural crops, including cut roses (Mortensen and Moe, 1983a; Zeislin et al., 1986), begonias (*Begonia* $\times$ *heimalis* Fotsch.) (Mortensen and Ulsaker, 1985), African violets (*Saintpaulia ionantha* H. Wendl.), and chrysanthemums (*Dendranthema* $\times$ *grandiflorum* Ramat.) (Mortensen, 1986). Optimal levels of CO_2 for plant growth range from 700 to 1000 $\mu\text{L CO}_2/\text{liter}$, and these serve as the recommended levels for commercial greenhouse production (Hand and Cockshull, 1975; Mortensen and Moe, 1983b; Mortensen, 1987).

The photosynthetic rates of three cut-flower rose cultivars increased with CO_2 enrichment, with $\approx 1000 \mu\text{L CO}_2/\text{liter}$ being sufficient to saturate photosynthetic capacity (Hand and Cockshull, 1975; Mortensen and Moe, 1983b). When CO_2 concentrations were raised from 330 to 1000 $\mu\text{L CO}_2/\text{liter}$, chrysanthemum plant net photosynthesis increased, but further increases in CO_2 concentration were not beneficial (Mortensen and Moe, 1983b).

Goldsberry (1963) found no difference in postharvest longevity of 'Red Gayety' cut carnations (*Dianthus caryophyllus* L.) produced at 200, 350, and 500 $\mu\text{L CO}_2/\text{liter}$. When 'Red Bird' cut roses were produced in CO_2 -enriched atmospheres ranging from 650 to 1100 $\mu\text{L CO}_2/\text{liter}$, vase life was reduced by one-half day (Shaw and Rogers, 1964). Mattson and Widmer (1971a) found that 'Red Garnett' cut roses produced at 1000 and 2000 $\mu\text{L CO}_2/\text{liter}$ had

longer vase life than flowers of plants grown in normal atmospheres, while three other cut rose cultivars showed no differences at the same concentrations.

Potted roses are gaining popularity. Growers try to meet the demand for roses on Valentine's Day and Mother's Day. Many cultivars that are relatively easy to grow and that can be used in landscape containers and borders after their interior use has expired have been developed for pot-forcing. Most of the pot rose breeding efforts have been focused on developing cultivars that are compact and have more and/or larger flowers than older cultivars, but less attention has been given to addressing the postharvest problems.

Chlorosis and abscission of the lower leaves are major postharvest problems of potted roses. Flower and flower bud abscission, flower malformation, flower discoloration, and shoot etiolation are also commonly observed after shipping. Because pot roses may be shipped long distances, plants are often packaged in light-tight boxes and may be subjected to adversely high temperatures. Dark and high temperature storage conditions have been shown to promote flower bud and leaf abscission in potted roses (Chen, 1990; Clark et al., 1991; Halevy and Kofranek, 1976). There has been no research published that addresses the postharvest characteristics of potted roses produced at various CO_2 levels to the best of our knowledge. The objectives of this study were to determine if CO_2 enrichment during production would increase growth of potted roses, and what effects it would have on postharvest leaf chlorosis and shoot etiolation of *Rosa hybrida* 'Meijikatar'.

Materials and Methods

Rooted liners of *Rosa hybrida* 'Meijikatar' (two to three rooted cuttings) were potted into 10-cm pots (472 cm^3) in a commercial potting mix (3B, Fafard Inc., Anderson, S.C.) and placed into CO_2 treatment chambers (described below). Plants were grown for 14 days, pinched to 10 cm above the medium, and subsequently forced, constituting a standard short-cycle forcing schedule (J. Ferrare, personal communication). Plants were sub-irrigated with fertilizer solution once daily with 250N-116P-235K ($\text{mg}\cdot\text{liter}^{-1}$)

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from Peter's 15-16-17 (W.R. Grace & Co., Fogelsville, Pa.). Nights and days averaged $18 \pm 0.2^\circ\text{C}$ and $22 \pm 0.2^\circ\text{C}$, respectively.

Growth chambers at the Soil-Plant-Atmosphere research facility (SPAR) in the Dept. of Agricultural and Biological Engineering, Clemson Univ., were used throughout the experiments. These chambers were described by Phene et al. (1978), with some key component changes (Dunlap et al., 1988). To avoid opening CO_2 chambers for irrigation, an automatic ebb and flow subirrigation system was constructed. The three treatment chambers were maintained at CO_2 concentrations of $350 (\pm 70)$, $700 (\pm 20)$, or $1050 (\pm 30)$ $\mu\text{l CO}_2/\text{liter}$ during the day, and received natural photoperiods from 18 Dec. 1990 through 10 Feb. 1991 (late winter). The experiment was repeated from 3 Mar. to 21 Apr. 1991 (early spring). During these two production periods, plants received an average light energy of 7.8 MJ/m^2 per day ($\text{SD} = 4.2$) in late winter, and 14.5 MJ/m^2 per day ($\text{SD} = 7.7$) in early spring.

Forty-three single-pot plants were assigned randomly to each treatment. When plants reached market stage, i.e., when 50% of flower buds exposed their eventual color, height and total counts of open flowers and flower buds were recorded. Total shoot and root dry weights, chlorophyll concentration in upper and lower leaves, leaf area, and total N concentration (percent) for the shoots were taken for five plants per treatment after 14 and 35 days and on the day of final harvest. Chlorophyll (total) was extracted on five leaf discs (0.28 cm^2) taken from five distal leaflets on the upper and lower one-half of the plants, as described by Moran and Porath (1980) and Moran (1982). Leaf area was measured with an area meter (LI 3100, LI-COR, Inc., Lincoln, Neb.) and total N was determined by the micro-Kjeldahl method (Eastin, 1978).

Photosynthetic measurements were taken after 14, 28, 35, and 42 days of treatment. Five plants were removed from each treatment chamber and placed under high-intensity discharge (HID) light at $1050 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ photosynthetic photon flux (PPF) for 15 min. Measurements for CO_2 consumption were then taken on the most-recent, fully expanded distal leaflet of each plant with a portable infrared gas analyzer (Model LCA 2, Analytical Development Co., Hoddesdon, England), and net photosynthesis was calculated. Following these measurements, plants were placed back in the treatment chambers.

When plants reached market stage, they were paper-sleeved and placed into fiberboard boxes. In a preliminary study, we observed that 'Meijikatar' plants produced at ambient CO_2 levels exhibited leaf chlorosis and etiolated growth if stored for more than 4 days at 16°C , but little leaf chlorosis was observed when plants were stored for 4 days or less at 4°C (Clark et al., 1991). Boxes were placed in simulated shipping incubators (Model 815 Low Temperature Incubators, Precision Scientific, Inc., Chicago) in darkness for 5 days at $4 \pm 0.5^\circ\text{C}$ and $16 \pm 0.5^\circ\text{C}$ to simulate shipping.

Treatments consisted of the $3 \times 2 \times 2$ factorial combination of three production CO_2 regimes (350, 700, and $1050 \mu\text{l CO}_2/\text{liter}$), two production seasons (late winter and early spring), and the two shipping temperatures (4 and 16°C). Treatment combinations were arranged as a completely randomized design with three boxes of 12 single pots of each CO_2 treatment in each shipping chamber.

At the end of simulated shipping, the number of etiolated shoots per plant was recorded. Plants were then placed in an interior environment (IE) at $21 \pm 2.5^\circ\text{C}$ with $30 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF from a cool-white fluorescent source. Plants were sub-irrigated daily with tap water. The percentage of chlorotic leaves was estimated visually on the day following removal from storage and every other day for 7 days. After 5 days in the IE, six plants per treatment were selected at random and the total number of leaflets per plant, number of chlorotic leaflets per plant, shoot and root dry weights,

and chlorophyll concentration in the upper and lower leaves were recorded. The percentages for chlorotic leaves were arcsin-transformed before analysis. All production and postharvest data were subjected to analysis of variance procedure. Significant main effect means were separated by LSD at $\alpha \leq 0.05$. When significant two-way interactions were observed, means were calculated for both sources of variation.

Results and Discussion

Production characteristics-crop scheduling and yield. Plants produced in 700 or $1050 \mu\text{l CO}_2/\text{liter}$ were harvested after 45 days in both experiments; however, plants grown in $350 \mu\text{l CO}_2/\text{liter}$ did not reach the harvest stage until 6 or 3 days later when grown in late winter or early spring, respectively (data not shown). These results are similar to those reported for cut carnations grown in $550 \mu\text{l CO}_2/\text{liter}$, which required shorter intervals between crops than those grown in $200 \mu\text{l CO}_2/\text{liter}$ (Goldsberry, 1963), and African violets, which flowered earlier in 900 and $1500 \mu\text{l CO}_2/\text{liter}$ than in $330 \mu\text{l CO}_2/\text{liter}$ (Mortensen, 1983b). Regardless of production time, plants grown in 700 and $1050 \mu\text{l CO}_2/\text{liter}$ were 9% to 13% taller than plants grown in $350 \mu\text{l CO}_2/\text{liter}$ (Table 1). Similar effects of CO_2 enrichment on shoot length have been shown with cut roses (Mattson and Widmer, 1971b; Mortensen and Moe, 1983a), chrysanthemums (Hughes and Cockshull, 1971b; Mortensen and Moe, 1983b), and poinsettias (*Euphorbia pulcherrima* Willd.) (Mortensen, 1985). There were no differences in the total number of flowers and flower buds among CO_2 treatments in plants produced at either production time (Table 1). These data contradict those of others (Lindstrom, 1965; Mattson and Widmer, 1971b; Mortensen and Moe, 1983a; Zeislin et al., 1972) that showed an increased number of flowering shoots per cut rose plant due to CO_2 enrichment. However, Mortensen and Moe (1983a) found that cut 'Mercedes' roses had a similar number of flowering shoots per plant and number of flowers per shoot at 290 and $950 \mu\text{l CO}_2/\text{liter}$. Because we tested only 'Meijikatar', we concluded that flower production of 'Meijikatar' is less responsive to CO_2 enrichment than some other cut-flower rose cultivars.

Plants were 19% taller and had $\approx 16\%$ more flowers when produced in early spring than in late winter (Table 1). Higher light intensity, in combination with increased CO_2 concentration, increased shoot length of chrysanthemums (Hughes and Cockshull, 1971a, 1971b; Mortensen and Moe, 1983c). Early spring had longer photoperiods and higher average light intensities, which was likely responsible for the increased plant height and total number of flowers and flower buds per plant.

Table 1. Height of plants and total number of flowers and flower buds at harvest of potted *R. hybrida* 'Meijikatar' plants grown at three CO_2 concentrations during two seasons.

CO_2 concn. ($\mu\text{l}\cdot\text{liter}^{-1}$)	Height (cm)		Total no. of flowers and flower buds	
	Late winter	Early spring	Late winter	Early spring
350	21.7	28.2	6.1	7.0
700	24.9	31.1	6.6	7.6
1050	24.0	31.5	7.0	8.2
ANOVA				
Season	*** (0.78)		** (0.84)	
CO_2	*** (0.73)		NS	
Season $\times$ CO_2	NS		NS	

ns, *, **, *** Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

Table 2. Influence of CO₂ enrichment and growing season on leaf area of potted *R. hybrida* 'Meijikatar' plants.

CO ₂ concn. (μl-liter ⁻¹)	Leaf area (cm ²)		
	Day of measurement ²		
	14	35	Harvest
<i>Late winter</i>			
350	570	480	970
700	643	578	1149
1050	648	875	1112
<i>Early spring</i>			
350	570	532	1065
700	660	624	1233
1050	724	875	1268
ANOVA			
CO ₂	NS	*** (133)	NS
Season	NS	NS	NS
CO ₂ × Season	NS	NS	NS

²Refers to duration of exposure to CO₂ concentrations given.

ns,*,***Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

Leaf area. Total leaf area was similar after 14 days of production, but, after 35 days, plants grown in 1050 μl CO₂/liter had larger leaves than plants grown in 350 μl CO₂/liter in late winter, or in 350 or 700 μl CO₂/liter in early spring (Table 2). The lack of difference in leaf area among CO₂ treatments after 14 days was due most likely to insufficient time allowed for these differences to develop. There were no significant differences in leaf area at harvest (Table 2), likely because plants had longer production times at low CO₂ concentrations.

Shoot and root dry weight. No significant differences in shoot dry weight were found after 14 days of exposure to CO₂ (Table 3). After 35 days, shoot dry weight was higher for plants grown in 1050 than in 350 μl CO₂/liter in late winter and, in early spring, shoot dry weight increased as CO₂ concentration increased. Similar results have been shown with chrysanthemums (Hughes and Cockshull, 1971b; Mortensen and Moe, 1983b) and cut roses (Mortensen and Moe, 1983a). Lack of differences in shoot dry

Table 3. Influence of CO₂ enrichment and growing season on shoot and root dry weights of potted *R. hybrida* 'Meijikatar' plants.

CO ₂ concn. (μl-liter ⁻¹)	Shoot dry wt (g)			Root dry wt (g)		
	Day of measurement ²			Day of measurement ²		
	14	35	Harvest	14	35	Harvest
<i>Late winter</i>						
350	2.9	2.5	5.9	0.5	0.5	0.9
700	3.3	3.2	6.8	0.5	0.7	1.3
1050	3.5	3.7	7.0	0.8	0.8	1.7
<i>Early spring</i>						
350	2.8	2.5	7.6	0.5	0.5	1.3
700	3.4	3.5	8.4	0.5	0.7	2.0
1050	3.6	5.2	9.4	0.9	0.9	2.5
ANOVA						
CO ₂	NS	*** (0.75)	NS	*** (0.15)	*** (0.14)	*** (0.45)
Season	NS	NS	*** (1.50)	NS	NS	*** (0.36)
CO ₂ × Season	NS	NS	NS	NS	NS	NS

²Refers to duration of exposure to CO₂ concentrations given.

ns,*,***Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

weight at harvest may be attributed to the longer production time having been given to plants grown in 350 μl CO₂/liter.

Plants grown in 1050 μl CO₂/liter had higher root dry weights than plants grown in 350 or 700 μl CO₂/liter after 14 days of production at both production times (Table 3). In early spring, increased root dry weight was observed for both elevated CO₂ concentrations after 35 days of production and at harvest (Table 3). Plants produced in early spring had ≈49% higher root dry weight at harvest than plants produced in late winter (Table 3), which may be attributed to increased dry matter accumulation due to increased light intensity and duration in early spring. Increases in root dry weight of soybeans grown in 450 to 800 μl CO₂/liter compared with 330 μl CO₂/liter were attributed to increases in root length (Del Castillo et al., 1989).

Leaf chlorophyll concentration. After 35 days of production in both seasons, chlorophyll concentration in upper leaves was lower with 700 μl CO₂/liter than with 350 μl CO₂/liter (Table 4). Similar differences in chlorophyll concentration of such leaves were observed at harvest in late winter, but, at harvest in early spring, chlorophyll concentration was lower with 1050 μl CO₂/liter than with 700 μl CO₂/liter (Table 4). Chlorophyll concentration measured in the lower leaves of plants followed no pattern (Table 4). Chlorophyll concentration at harvest was higher in the lower leaves of plants produced in early spring than in late winter (Table 4). Because the magnitude of this difference was rather small (<4 μg/cm² per plant), we considered it negligible.

Shoot nitrogen concentration. The percentage of N in the shoots was higher with 700 μl CO₂/liter than with 1050 μl CO₂/liter at 14 days and at harvest in both seasons (Table 5). Kuehny (1988) showed that increased CO₂ concentration, in combination with increased irradiance levels, led to decreased accumulation of shoot N in chrysanthemums. Overall, N concentration decreased over time in late winter but changed little in early spring (Table 5).

Photosynthesis. After 42 days of growth in both seasons, the rate of photosynthesis was lower at 700 and 1050 μl CO₂/liter than at 350 μl CO₂/liter (data not shown). Because plants were removed

Table 4. Influence of CO₂ enrichment and growing season on chlorophyll concentration in upper and lower leaves of potted *R. hybrida* 'Meijikatar' plants.

CO ₂ concn. (μl·liter ⁻¹)	Leaves					
	Upper			Lower		
	Day of measurement ²					
	14	35	Harvest	14	35	Harvest
<i>Chlorophyll (μg·cm⁻²)</i>						
<i>Late winter</i>						
350	23.0	19.1	22.7	23.0	23.0	24.9
700	22.9	16.0	18.1	23.3	22.4	25.1
1050	25.2	16.6	18.7	23.0	24.5	24.2
<i>Early spring</i>						
350	23.3	19.6	20.8	23.0	23.1	28.5
700	22.6	16.9	19.1	23.1	22.3	30.6
1050	24.9	16.8	16.2	23.2	24.7	26.9
ANOVA						
CO ₂	*** (1.40)	*** (1.16)	*** (2.05)	NS	** (1.30)	* (1.68)
Season	NS	NS	NS	NS	NS	*** (1.37)
CO ₂ × Season	NS	NS	NS	NS	NS	NS

²Refers to duration of exposure to CO₂ concentrations given.

ns,*,***Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

Table 5. Influence of CO₂ enrichment and growing season on shoot nitrogen concentration of potted *R. hybrida* 'Meijikata' plants.

CO ₂ concn. (μl·liter ⁻¹)	Shoot N (%)		
	Day of measurement ²		
	14	35	Harvest
<i>Late winter</i>			
350	4.1	3.5	3.2
700	4.0	3.4	3.3
1050	3.8	3.6	3.1
<i>Early spring</i>			
350	3.4	3.3	3.4
700	3.3	3.4	3.3
1050	3.1	2.8	3.0
ANOVA			
CO ₂	*(0.15)	NS	*(0.18)
Season	*** (0.16)	*** (0.18)	*** (0.16)
CO ₂ × Season	NS	**	NS

²Refers to duration of exposure to CO₂ concentrations given.

NS,*,**,* Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

from the treatment chambers and placed in ambient air, these measurements are comparisons of photosynthetic activity at the same CO₂ level. Wong (1979) suggested that, for soybeans grown in high CO₂ levels, ribulose biphosphate carboxylase and available nitrogen were spread over more cells or "diluted," thus resulting in reduced photosynthesis per unit of leaf area. N.C. Rajapakse (unpublished data) found that 'Meijikatar' potted roses produced under the same conditions as in the present study had lower stomatal apertures at higher CO₂ concentrations, thus resulting in higher stomatal resistance to water vapor diffusion.

Table 6. Influence of CO₂ enrichment, growing season, and storage temperature on total chlorophyll concentration in upper and lower leaves of potted *R. hybrida* 'Meijikatar' plants. Plants were stored for 5 days at each temperature. Chlorophyll concentration was measured after 5 days in an interior environment.

		Leaves			
		Upper		Lower	
		Season			
CO ₂ concn. (μl·liter ⁻¹)	Temp. (C)	Late winter	Early spring	Late winter	Early spring
<i>Chlorophyll (μg·cm⁻²)</i>					
350	4	11.0	12.3	8.9	10.4
	16	10.5	12.6	8.7	8.5
700	4	10.7	11.9	8.8	10.8
	16	10.6	10.7	7.1	7.8
1050	4	10.2	11.6	9.1	11.4
	16	10.3	11.2	7.0	8.2
ANOVA					
CO ₂		**(0.56)		NS	
Season		NS		*** (0.48)	
Temp.		*** (0.46)		*** (0.48)	
CO ₂ × Temp.		NS		*	
CO ₂ × Season		NS		NS	
Temp. × Season		NS		*	
CO ₂ × Temp. × Season		NS		NS	

NS,*,**,* Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

Table 7. Influence of CO₂ enrichment, growing season, and storage temperature on the number of etiolated shoots after removal from storage and the percentage of chlorotic leaves of potted *R. hybrida* 'Meijikatar' plants after 5 days in an interior environment.

CO ₂ concn. (μl·liter ⁻¹)	Temp. (C)	Etiolated shoots/plant		Percent leaf chlorosis	
		Late winter	Early spring	Late winter	Early spring
350	4	1.6	2.4	8.7	12.5
	16	7.2	7.6	24.4	31.9
700	4	8.4	8.8	9.5	13.3
	16	10.0	9.6	23.9	38.7
1050	4	9.6	9.9	10.2	12.0
	16	11.8	11.6	26.0	36.0
ANOVA					
CO ₂		*** (0.74)		NS	
Production time		*** (0.73)		** (2.0)	
Temperature		NS		*** (2.0)	
CO ₂ × Temp.		***		NS	
CO ₂ × Production time		NS		NS	
Temp. × Production time		NS		***	
CO ₂ × Temp. × Production time		NS		NS	

NS,*,**,* Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. Numbers within parentheses denote LSD values ($\alpha = 0.05$).

Postharvest characteristics-leaf chlorophyll concentration. Total chlorophyll concentration measured after 5 days in the IE was ≈50% lower than that measured at harvest in all treatments, suggesting that much of the chlorophyll was degraded during storage. After 5 days in the IE, chlorophyll concentration in upper leaves was similar for both storage temperatures (Table 6). Plants produced in 700 or 1050 μl CO₂/liter in early spring and stored at 16C had lower chlorophyll concentrations in upper leaves than plants produced in 350 μl CO₂/liter (Table 6). Time of production affected plant responses to storage temperature for the amount of total chlorophyll measured in the lower leaves of plants after 5 days in the IE (Table 6). Plants stored at either temperature in early spring had more lower leaf chlorophyll than those stored in late winter, except those from the 350 μl CO₂/liter treatment stored at 16C. Regardless of CO₂ treatment, greater chlorophyll differences were observed between storage temperatures in early spring than in late winter. This result suggests that potted roses produced at higher light intensity and longer photoperiods may have more chlorophyll degradation at higher storage temperatures than plants produced at lower light intensity and shorter photoperiods.

Shoot etiolation. On the day of removal from simulated shipping, plants grown in 350 μl CO₂/liter and stored for 5 days at 4C had the fewest etiolated shoots per plant, with increased CO₂ concentration and higher storage temperature resulting in more shoot etiolation (Table 7). Increased growth and metabolism due to increased CO₂ during production and the higher storage temperature resulted apparently in more shoot expansion, which was etiolated due to a lack of light in the containers during storage.

Leaf chlorosis. Carbon dioxide enrichment had no effect on the percentage of chlorotic leaflets of plants grown at either production time and stored at either storage temperature (Table 7). Mattson and Widmer (1971a) reported that only one of four cut rose cultivars tested had increased vase life when grown at higher-than-normal CO₂ concentrations. Goldsberry (1963) found that vase life of cut 'Red Gayety' carnation did not increase in response to CO₂ enrichment. Production time and storage temperature affected the percentage of chlorotic leaflets (Table 7). At the higher storage temperature, plants grown in early spring had more leaf

chlorosis than plants grown in late winter. This is in agreement with our preliminary study, which showed that 'Mejikatar' potted roses had increased leaf chlorosis when stored at higher temperatures (Clark et al., 1991).

Our results indicate that potted 'Mejikatar' roses grown in early spring are taller and produced more flowers and flower buds than those grown in late winter. Carbon dioxide enrichment during production does appear to be beneficial for reducing time of crop production. However, it does not cause an increase in the number of flowers produced per plant, and it increases foliar growth. This combination causes the plants to have a less effective floral display. Plants grown in early spring have more leaf chlorosis if shipped at 16C than plants grown in late winter. These results suggest that higher-quality 'Mejikatar' plants can be produced for Mother's Day than for Valentine's Day, but that they will not handle adversely high storage temperatures as well. Carbon dioxide enrichment during production does not result in better postharvest quality of potted 'Mejikatar' roses. In fact, it causes more shoot etiolation during 5 days of storage at 4 or 16C, and has no effect on postharvest leaf chlorosis after storage.

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