Production Factors Affecting Postproduction Quality of Flowering Potted Plants

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Floriculture crops represent 11% of crop agriculture in the United States, with a wholesale value exceeding \$2.8 billion. Over the last 14 years, floriculture sales have increased 8% each year and they have been the most rapidly expanding segment of crop agriculture in the United States. Flower marketing is changing rapidly, as flowering potted plants are transported longer distances and stored for longer periods during distribution and sales than in the past two to three decades. Often, plants are handled improperly during distribution and sales, especially with increased sales through mass market outlets. Production practices have a significant influence on crop quality and longevity, thus production conditions must be optimal if plants are to last for consumers.

Flowering plants are in direct competition with a multitude of other discretionary purchase items, and if floral sales are to continue increasing, consumers must be satisfied with the flowers they buy. In today's market, florists and mass market buyers are demanding flowering plants that keep well and have attractive physical characteristics. Repeat consumer purchases are discouraged by plants that fade, wither, and die under ordinary interior conditions.

The potential for flowering potted plant quality and maximum longevity are determined during production. Crop quality must be at the highest level when the plant leaves the production facility. Conditions during distribution and retail display will only maintain plant quality—it will not increase during distribution and retail marketing. Quality often declines and longevity is decreased during transport, storage, and retail handling as plants are exposed to adverse transport conditions, such as exclusion of light in closed containers and sleeves, exposure to harmful gases and temperature extremes, poor air movement, high humidity, and vibration. Specific recommendations for cultural, transportation, and interior conditions have been published for a wide variety of flowering potted plants (Nell, 1993). Production of the highest quality plants can minimize the harmful effects under postproduction conditions. Postproduction factors must be viewed as providing the mechanism to maintain the potential quality from production, rather than improving the quality or longevity.

PRODUCTION FACTORS AND LONGEVITY

All segments of production, handling, and marketing influence the longevity of flowering potted plants. The importance of production factors becomes evident as each of the following factors on longevity are reviewed: genetic influence (cultivar), nutrition, irrigation practices, growing medium, and production environment.

Genetic Influence

The importance of genetics in flowering potted plant longevity and quality is evident with many plants. Differences range from delayed senescence (increased longevity) to increased tolerance to low irradiance levels and ethylene exposure.

Longevity of chrysanthemum [*Dendranthema grandiflorum* (Rumet.) Kitamura] cultivars having the same flower color and form varied by as much as 2 weeks when produced and maintained similarly (Table 1). Longevity ranged from 28 days in 'Iridon' and 'Bright Golden Anne' to 13 days in 'Tip' and 'Mountain Peak'. Similarly, leaf drop in poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch) culti-

vars ranges from 15% in 'Eckespoint Lilo' to 58% in 'Gross Supjibi' (Fig. 1).

Cultivar quality and longevity differences are often associated with interactions between cultivar, production environment, plant nutrition, or other production-related factors. Cyclamen (*Cyclamen persicum* Mill) cultivars 'Rose of Aalsmeer', 'White Caramel Eye', 'Cattleya', 'Rose of Marienthal', and 'Pearl of Zehlendorf' lasted longer when produced at 17 °C compared to 13 °C (Molinar and Williams, 1977). Termination of fertilizer 3 weeks before flowering increased longevity in 'Mountain Peak' chrysanthemum, a short-lasting cultivar, by 7–11 days, but longevity of 'Iridon', a long-lasting cultivar, increased only 3–5 days (Fig. 2).

Nutrition

Nutrition programs may have more impact on flowering potted plant longevity and quality than any production factor, other than cultivar. The effect is similar to responses observed with potted foliage plants (Conover and Poole, 1984) and cut flowers (Halevy and Mayak,

Table 1. Postproduction longevity of chrysanthemum cultivars.

Cultivars	Longevity ^a (days)
White	
Power House	14
Free Spirit	17
Paragon	17
Surf	18
Puritan	19
Spirit	20
Mountain Snow	21
Yellow	
Dark Yellow Paragon	13
Sunburst Spirit	13
Tip	13
Yellow Mandalay	17
Sunny Mandalay	18
Mountain Peak	13
Bright Golden Anne	28
Iridon	28

^aEvaluated at 21±1 °C at 12 μmol·m⁻²·s⁻¹ for 12 h daily.

Fig. 1. Leaf abscission differences in poinsettia cultivars after being maintained 30 days at 21±1 °C at 12 μmol·m⁻²·s⁻¹ (12 h daily) and 50±5% relative humidity.

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1979). Fertilizer type, source, and concentration influence plant performance indoors. However, fertilizer type (slow release, liquid, or granular) does not have a significant effect on longevity or quality, provided the elemental source and balance and concentration applied to the crop are provided at optimum levels.

In most flowering potted plants, there is a direct relationship between fertilizer concentration and longevity—high fertilizer levels result in decreased longevity. Scott et al. (1984), demonstrated that application of Osmocote 14N–6.1P–11.6K (Grace Sierra, Milpitas, Calif.) at 3 g/15-cm container decreased leaf drop in poinsettia compared to plants receiving 6 g/15-cm pot. Liquid fertilizer applications providing $\approx 2.6 \text{ kg}\cdot\text{m}^{-3}$ per crop are recommended for poinsettias to achieve minimal leaf drop. In chrysanthemums, Roude et al. (1991a) showed that longevity averaged 21 days using N at $5.2 \text{ kg}\cdot\text{m}^{-3}$ per crop from a soluble fertilizer compared to 34 days using $1.3 \text{ kg}\cdot\text{m}^{-3}$. These differences were associated with growing medium soluble salt concentration (Table 2). Nell et al. (1989) have shown that terminating fertilization 3 weeks before flowering reduced leaf browning and increased longevity of potted chrysanthemums by as much as 7 days.

Poor nutrition management has been a major factor in the development of bract edge burn in poinsettias. Bract edge burn appears as a marginal browning or necrosis as the bracts expand. Necrosis may spread to the center of the bracts and render the plants unmarketable. High fertilizer concentrations and high ammoniacal-N levels increase the incidence of bract edge burn. Termination of fertilization 2 to 4 weeks before anthesis did not reduce leaf drop, but bract edge burn was reduced significantly (Nell and Barrett, 1986). Woltz and Harbaugh (1986) demonstrated that calcium deficiency is the causal factor in bract edge burn. Also, a reduced Ca : K ratio and low calcium levels in the bract margins are related to the incidence of bract edge burn (Stromme et al., 1994). They found cultivars sensitive to bract edge burn had low calcium levels in the bract margins while less sensitive cultivars had high Ca levels.

Apparently, continued fertilization, high nutrient concentrations, and high ammoniacal-N limit Ca uptake, which is necessary for cell development in the bracts. However, incorporation of supplemental calcium in the growing medium has not reduced the occurrence of bract edge burn. In contrast, spray applications of Ca at $400 \text{ mg}\cdot\text{L}^{-1}$ to the bracts weekly, beginning at bract color, can eliminate or greatly reduce bract edge burn (Nell and Barrett, unpublished data).

As with bract edge burn, nutrient balance is important in the production of high quality, long-lasting flowering potted plants. The ammoniacal-N and nitrate-N levels must be properly balanced. Chrysanthemums fertilized with 50% or more nitrate-N lasted longer than plants having higher levels of ammoniacal-N (Roude et al., 1991b). Changing the N : K ratio from 1 : 1 to 0.5 : 1 during the final 4 weeks of production has been emphasized in chrysanthemum nutrition in the past. Results by Roude et al. (1991b) suggest that the N : K ratio may not be as important as switching to a nitrate based fertilizer near the end of the crop. The responses to fertilization may be either a direct result of high medium soluble salts or elemental toxicity in the plant. Work in Germany by ter Hell and Hendricks (1995), has demonstrated a direct relationship between leaf and cyathia loss in poinsettia and bud drop in miniature roses (*Rosa* hybrids) and impatiens (*Impatiens*, New Guinea hybrids) with increased levels of nitrogen. They related these results to high soluble salts and fewer and/or damaged roots. T. Reyes (personal communication, 1996) has demonstrated that soluble salt levels in the medium may be responsible for premature leaf yellowing in chrysanthemum, rather than the amount of nitrogen applied to the plants.

Growing medium characteristics have an important role in the interior performance of flowering potted plants. Longevity increased as N concentration decreased when chrysanthemums were grown in Metro Mix 350 (Grace Sierra, Milpitas, Calif.), whereas N concentration had no significant effect on chrysanthemums grown in Vergro Klay Mix (Verlite Co., Tampa, Fla.) or a peat-perlite-sand mix (Roude et al., 1991a). Differences in response to medium type may be related to differences in conductance as affected by high cation exchange capacity of Vergro Klay Mix compared to the other media. Thus, correlating medium soluble salt levels with longevity must be conducted with each growing medium.

Irrigation Practices

Little is known about the relationships between irrigation practices and longevity, due primarily to the lack of technology that allows for the monitoring of growing medium moisture tension in containers during production. Establishing a well-developed root system is important in the production of a high quality and long-lasting plant. Thus, irrigation practices must be related directly to the nutrition program and growing medium soluble salts. Excessive irrigation will leach nutrients from the medium and could lead to root injury and poor longevity due to low O_2 concentration in the medium. Conversely, low irrigation may result in high medium salt levels and poorly developed root systems if the nutrient levels are high. Irrigation and nutrition programs must be coordinated to produce a strong, functional root system if maximum longevity is to be achieved. Similar relationships have been demonstrated for potted foliage plants (Conover and Poole, 1984).

Proper medium moisture levels for flowering potted plants becomes an issue in the retail setting and in interior locations. Increased sales of flowering potted plants through mass market retailers have led to increased problems due to poor irrigation of plants during marketing. Growing media used in commercial floriculture contain high proportions of peat moss that lose water rapidly and are difficult to rewet once dry. Drying out is a serious problem during retail sales. Chrysanthemums that were allowed to wilt before watering lasted 21 days while plants watered before wilt lasted 28 days (Nell and Barrett, unpublished data). Two approaches have been evaluated as a means of minimizing the wilting of plants following production: 1) increasing the growing medium moisture retention, and 2) reducing leaf moisture loss.

Modification of the growing medium by changing the proportion or type of components has not led to significant changes in moisture retention characteristics that have a major effect on the time to wilt under interior conditions. In many cases, improved medium moisture retention characteristics have led to production of plants with increased leaf area and higher moisture loss than plants produced in media having less desirable characteristics. The increased moisture retention of the medium is not sufficient to counter the effect of

Fig. 2. Effect of fertilizer termination on longevity of chrysanthemum cultivars. Plants received N at $300 \text{ mg}\cdot\text{L}^{-1}$ until flowering (continued) or until 3 weeks before flowering (terminated). Plants were maintained at $21\pm 1^\circ\text{C}$ at $12 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (12 h daily) and $50\pm 5\%$ relative humidity.

Table 2. Effect of N concentration on 'Iridon' chrysanthemum postharvest longevity and medium conductance.

N concentration ($\text{kg}\cdot\text{m}^{-3}$ per crop)	Flower longevity (days)	Medium conductance ($\text{dS}\cdot\text{m}^{-1}$)
1.3	34	0.5
2.6	30	1.5
5.2	21	2.3

Adapted from Roude et al., 1991a.

increased transpiration water loss as a result of increased leaf area. Polyacrylamide gels have been incorporated into the growing medium for poinsettias, chrysanthemums, and other flowering potted plants as a means of increasing the moisture retention of the medium and delaying the time to wilt in retail settings. Results have been inconsistent and, generally, no significant benefit has been observed with the use of gels (Table 3). However, application of a wetting agent to the medium of chrysanthemums before removal from the production area can delay the time to wilt (Table 4). The wetting agent increases the water holding capacity of the medium by allowing for its more uniform wetting at each irrigation. No research is available to show that irrigation requirements under interior conditions can be modified through osmotic adjustment of the plants during production. Application of antitranspirants have been evaluated as a means of reducing moisture loss on several flowering potted plants. Results have been inconsistent and phytotoxicity has been apparent on hydrangea (*Hydrangea macrophylla* Thunb.) and cineraria (*Senecio cruentus* DC.) flowers (McDaniel and Bresenham, 1978; Tracey and Lewis, 1981).

Production Environment

Production temperature and light levels affect plant size and flower color and may impact production quality and longevity significantly. Flower color is enhanced by lowering the temperature 1 to 2 °C during the final 1 to 2 weeks of crop production (Nell, 1990). Research has not been conducted to demonstrate an effect of production temperature on longevity. However, postproduction problems have been associated with production temperature. High night temperatures (relative to day temperatures) increase poinsettia bract size and lead to a higher incidence of bract edge burn and more rapid cyathia drop after plants are moved to interior conditions (Moe et al., 1992). Also, high night temperatures increase the level of postproduction leaf yellowing in Easter lily (*Lilium longiflorum* Thunb.). The difference in lily leaf yellowing has been related to a reduction in carbohydrate levels at high night temperatures (Miller et al., 1993).

Lowering the production light level has reduced leaf drop in *Ficus benjamina* L. and other potted foliage crops (Conover and Poole, 1984). Reduction in light compensation point has been correlated with this decreased leaf drop at low light levels. Acclimatization of chrysanthemums to reduced light levels also causes a reduction in the light compensation point, but is of little significance because longevity is reduced when the plants are grown at low light levels (Nell et al., 1990). These results suggest that the acclimatization process in flow-

ering potted plants is different from that of foliage plants and that the light compensation point is not a useful technique to predict the potential longevity of flowering potted plants. Other postproduction problems, such as premature cyathia drop in poinsettias, has been related to low production light levels (Miller and Heins, 1986).

CONCLUSION

Numerous opportunities exist to improve the longevity and quality of flowering potted plants for consumers. Scientific efforts have demonstrated the importance of plant genetics and production practices in maximizing longevity of such plants. Unfortunately, the majority of the research has been conducted on two or three of the most economically important crops and no physiological link has been made to predict the potential longevity of flowering potted plants. Thus, it is necessary to investigate the effects of production practices on longevity on a crop-by-crop basis. As genetic manipulation of crop senescence becomes more commonplace, major strides will be made toward improving the longevity of flowering potted plants for consumers.

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Table 3. Effect of Supersorb Gel on postproduction water use, time to wilt, and longevity of 'Indio' chrysanthemum.

Supersorb Gel ^z	Days to first wilt	Water use until first wilt (g) ^y	Days to second wilt	Water use until second wilt (g)	Postharvest longevity (days) ^x
yes	4	576	6	539	32
no	4	711	6	604	30

^zSupersorb Gel (Aquatrols Corp. of America, Cherry Hill, N.J.) incorporated into Metro Mix 500 at planting (3.75 L·m⁻³).

^yWater use included water loss by plant and media.

^xEvaluated at 21±1 °C at 12 µmol·m⁻²·s⁻¹ for 12 h daily.

Table 4. Effect of AquaGro wetting agent on days to wilt of 'Dark Charm' and 'Iridon' chrysanthemum.

AquaGro ^y	Days to first wilt		Days to second wilt		Longevity ^z (days)
	Cultivar				
	Iridon	Dark Charm	Iridon	Dark Charm	Iridon
yes	12	12	14	15	25
no	13	9	11	13	25

^zEvaluated at 21±1°C at 12 µmol·m⁻²·s⁻¹ for 12 h daily.

^yAquaGro (Aquatrols Corp. of America, Cherry Hill, N.J.) applied at flowering at a rate of 100 mg·L⁻¹.