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Forcing Irradiance, Temperature, and Fertilization Affect Quality of 'Gloria' Azalea

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Abstract. **Dormant-budded 'Gloria' azaleas *(Rhododendron* sp.) were used to observe the effect of forcing irradiance, temperature, and fertilization on postproduction performance after flower bud dormancy had been broken. Four experiments were conducted during forcing, the treatments for each experiment were: Expt. 1, three forcing irradiances (200,460, and 900 μmol·m^{-2}·s^{-1}) and three postproduction irradiances (4, 8, and 16 μmol·m^{-2}·s^{-1}); Expt. 2, three forcing irradiances (320, 560, and 1110 μmol·m^{-2}s^{-1}); Expt. 3, three controlled day/night temperatures (18/16C, 23/21C, and 29/27C); Expt. 4, fertilizer applied for 7, 14, or 28 days at either 150 or 300 mg N/liter (12% nitrate, 8% ammoniacal) 20N-4.8P-16K soluble fertilizer at every watering, control plants did not receive fertilizer. Days to harvest (time until plants had eight individual open flowers) was less at the high forcing irradiances and temperatures and when fertilizer was applied during forcing. Flower color was less intense at the low forcing irradiance levels, high temperatures, and when duration of fertilization was prolonged and concentration was high. There were more open flower inflorescences at week 2 of postproduction at high forcing irradiance levels, but their number was not affected by forcing temperature or fertilization. Postproduction longevity was shorter when forcing was at 29/27C (day/night) and when plants were fertilized for 28 days at 300 mg N/liter, but was not affected by forcing or postproduction irradiance.**

Irradiance levels, temperature, and fertilization have direct effects on development and postproduction performance of floriculture crops. High irradiance levels have been observed to shorten time to flowering in 'Reinhold Ambrosius' and 'Knut Erwén' azaleas (Bodson, 1983). Kraszewski and Ormrod (1986) observed larger flower diameter for *Browallia* and *Oxalis,* but smaller floret size for *Crossandra* when plants were grown under high production irradiances. Postproduction longevity was higher when production irradiance was relatively high for begonia (Fjeld, 1986) and *Crossandra* (Kraszewski and Ormrod, 1986).

High production temperatures shorten the forcing period and affect bud development on several azalea cultivars (Pettersen, 1973; Wilkins, 1980). However, we found no information on the effects of forcing temperature on postproduction performance and

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Table 1, Effect of irradiance during forcing on Hunter 'L' (100 = white, 0 = black) and 'a' (positive = red, negative = green) values of 'Gloria' azalea flower color at harvest and week 2 of postproduction.

Forcing irradiance ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	At harvest 'L'	At harvest 'a'	At week 2 of postproduction 'L'	At week 2 of postproduction 'a'
1110	61.8	18.7	63.0	15.0
560	61.7	18.4	62.6	14.4
320	62.5	16.6	62.0	13.7
Linear	*	**	**	*
Quadratic	*	**	NS	NS
$HSD_{0.05}$	NS	1.13	0.86	NS
$HSD_{0.01}$	NS	1.40	NS	NS

NS,*,**Nonsignificant or significant at P = 0.05 or 0.01, respectively.

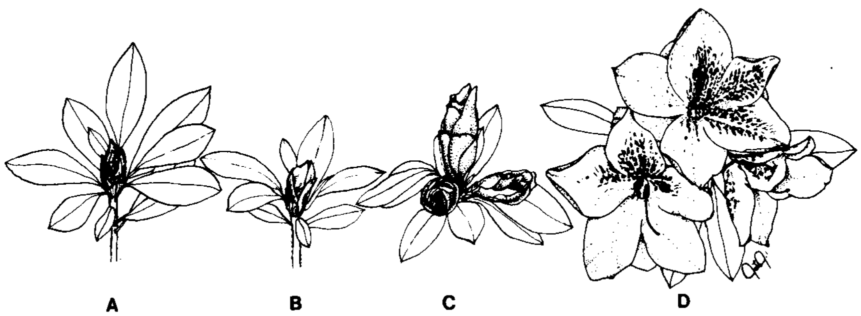

Fig. 1. The four inflorescence categories chosen to evaluate postproduction performance of 'Gloria' azalea. **(A)** Tight-inflorescenee buds with no flower color showing; **(B)** showing color-inflorescence buds exhibiting 52.5 cm of flower color; **(C)** candle-inflorescence buds with >2.5 cm of flower color; and **(D)** open flower-inflorescence flowers with a diameter 23 cm.

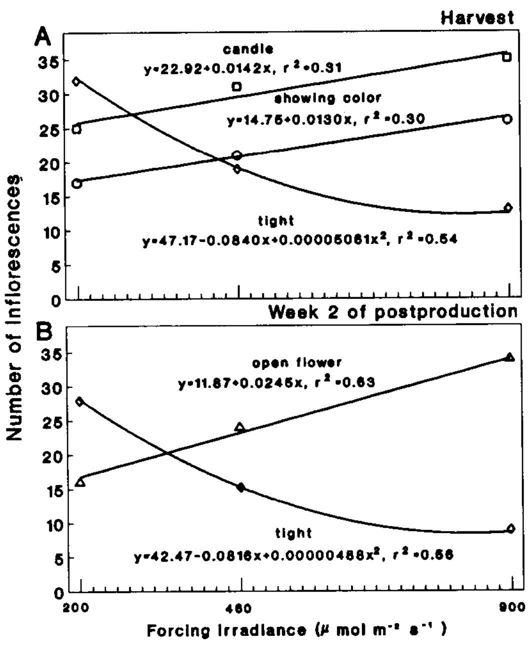

Fig. 2. Effect of forcing irradiance on the number of tight, showing-color, and candle inflorescences at harvest **(A)** and the number of tight and open flower inflorescences at week 2 of postproduction **(B)** on 'Gloria' azalea. Points are means of 36 plants at each level. Regression analysis used values for each plant.

longevity of florist azaleas.

Termination of fertilizer application and decreased fertilization during production has been observed to increase postproduction longevity of chrysanthemum *[Dendrathema grandiflorum* (Ramat.) Kitamura] (Joiner and Smith, 1962; Nell et al., 1989). High production-fertilizer concentrations have also been observed to lower a subjective rating of floral display, time to anthesis, and flower color on various herbaceous floriculture crops (Harbaugh and Waters, 1982; Joiner and Smith, 1962). However, we found no information on the effects of fertilizer during forcing on the postproduction performance of florist azaleas, a woody floriculture crop.

This research was conducted to determine the effects of forcing irradiance, temperature, and fertilization on postproduction performance of 'Gloria' azalea.

Cultural practices. Dormant-budded 'Gloria' azaleas with an 18- to 23-cm crown diameter planted in 15cm pots (1.6 liters) were obtained from a commercial grower (Yoder Brothers, Alva, Fla.) and placed for 6 weeks at 2 ± 0.5C with 15 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of irradiance from 40-W cool-white fluorescent lamps, 12 h daily. After the cold treatment, plants were moved into a fiberglass greenhouse with fan and pad cooling. Plants were watered daily with tap water, and no fertilizer was applied unless stated otherwise. Postproduction evaluations were conducted in three rooms that were maintained at 21 ± lC, 50% ± 5% relative humidity, and 12 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of irradiance (unless stated otherwise) 12 h daily, from cool-white fluorescent lamps to simulate conditions at the consumer level. Each postproduction room represented a replication in the experimental design.

Experimental procedures. Harvest was defined as the time when plants had eight individual open flowers; this was the end of the forcing period. Days to harvest was recorded in each experiment. For postproduction evaluations, inflorescences were categorized into four groups: 1) tight-inflorescence buds with no flower color showing; 2) showing color-inflorescence buds exhibiting ≤ 2.5 cm of flower color; 3) candle-inflorescence buds with >2.5 cm of flower color; and 4) open flower-inflorescence flowers with a diameter 13 cm (Fig. 1). Inflorescences contained an average of three flowers each. The number of inflorescences was counted as a means of determining flowering uniformity and overall plant development. Tight and showing-color inflorescences were seen as one bud (Fig. 1). When inflorescences developed to the candle and open-flower stage, each individual flower was visible. In all experiments, the number of tight, showing-color, candle, and open-flower inflorescences was determined at harvest and week 2 of postproduction. All treatments were applied after flower buds were initiated: therefore, the sum of the number of tight, showing-color, candle, and open-flower inflorescences (total number of inflorescences) was not affected by treatments. Four open flowers per plant were used to determine flower diameter at harvest and week 2 of postproduction. Postproduction longevity was determined as the number of days from placement in postproduction rooms (harvest) to when 90% to 95% of all flowers showed signs of necrosis.

At harvest and week 2 of postproduction, flower color of the adaxial petal surface, void of red spots, was determined with a HunterLAB colorquest sphere spectrocolorimeter (Hunter Assocs.., Reston, Va.) using 'L' and 'a' modes. The instrument was calibrated according to manufacturer's instructions using standard white (X = 81.70, Y = 86.53, Z = 93.98) and gray (X = 51.37, Y = 54.64, Z = 59.20) reference plates.

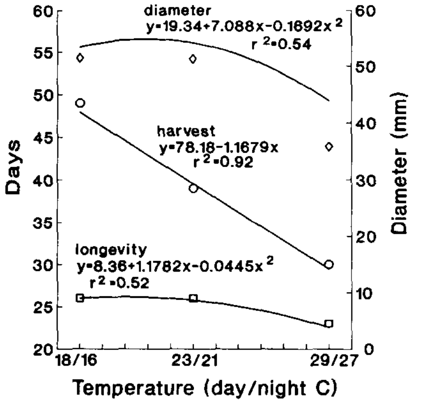

Fig. 3. Effect of forcing temperature on days to harvest, flower diameter of buds showing color at harvest (measured at week 2 of postproduction) and postproduction longevity of 'Gloria' azalea. Regression equations were calculated with three day/night temperatures and values for each plant (x value was calculated using day temperature). Points are means of 15 plants at each level.

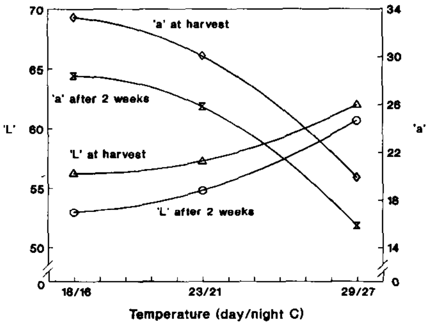

Fig. 4. Effect of forcing temperature at harvest and week 2 of postproduction on Hunter 'L (100 = white, 0 = black) and 'a' values (positive = red, negative = green). Regression equations were calculated using three day/night temperatures and values for each plant (x value was calculated using day temperature). Points are means of 15 plants (60 measurements) at each level. Regression equations are: 'a' at harvest, $y = 5.32 + 3.2765x - 0.0956x^2$, $r^2 = 0.87$; 'a' at week 2, $y = -6.00 + 3.8117x - 0.1055x^2$, $r^2 = 0.78$; 'L' at harvest, $y = 68.87 - 1.8701x + 0.0548x^2$, $r^2 = 0.82$; 'L' at week 2, $y = 74.66 - 1.9808x + 0.0533x^2$, $r^2 = 0.65$.

The 'L' value represents black at 0 and white at 100. The 'a' value represents increasing degree of redness as the value increases toward the positive and increasing degree of greenness as the value becomes more negative. A 'Gloria' azalea flower petal with an intense pink color would have a low 'L' value and a high positive 'a' value. Data were analyzed by analysis of variance, Tukey's honestly significant difference test and regression analysis.

Forcing and postproduction irradiance. A 3 × 3 factorial experiment was conducted using three forcing irradiances (200, 460, and 900 $\mu mol\cdot m^{-2}\cdot s^{-1}$) and three postproduction irradiances (4,8, and 16 $\mu mol\cdot m^{-2}\cdot s^{-1}$). The experiment was a split-plot design with three replications and two plants per experimental unit. The main plot was postproduction irradiance and the subplot was forcing irradiance. Greenhouse temperatures ranged from a maximum day of 27C to a minimum night of 16C. Flower color was not determined in this experiment.

A second experiment was conducted using three forcing irradiances (320, 560, or 1110 $\mu mol\cdot m^{-2}\cdot s^{-1}$). The experimental design was a randomized complete block with five plants per experimental unit and three replications. Greenhouse temperatures ranged from a maximum day of 35C to a minimum night of 21C. One petal from each of four flowers per plant was used, for a total of 60 petals per treatment, for flower color determination. Flower diameter was not determined in this experiment.

Forcing temperature. Three forcing day/night temperatures were used (18/16 ± lC, 23/21 ± 1C, and 29/27 ± 1C). Day temperatures were provided from 0800 to 1700 HR. The design was a randomized complete block with five plants per experimental unit and three replications. One petal from each of four flowers per plant was used, for a total of 60 petals per treatment, for flower color determination. Four buds showing 2.0 to 2.5 cm of flower color per plant at harvest were tagged and flower diameter was recorded at week 2 of postproduction.

Fertilization during forcing. A 3 × 2 factorial experiment was conducted using three durations of fertilizer application (7, 14, or 28 days after removal from coolers) and two concentrations [150 or 300 mg N/liter (12% nitrate, 8% ammoniacal) from a 20N-4.8P-16K soluble fertilizer at every watering] with a control. Control plants received water daily with no fertilizer applications. The design was a randomized complete block with two plants per experimental unit and three replications. The greenhouse ranged from a maximum day of 32C to a minimum night of 18C. One petal from each of four flowers per plant was used, for a total of 24 petals per treatment, for flower color determination. Four buds showing 2.0 to 2.5 cm of flower color per plant at harvest were tagged and flower diameter was recorded at week 2 of postproduction. Dunnett's procedure was used to compare all means with the control.

Effects of forcing and postproduction irradiance. Plants were harvested at 30, 28, and 27 days when forcing irradiance was 320, 560, and 1110 $\mu mol\cdot m^{-2}\cdot s^{-1}$ respectively. Regression analysis showed a quadratic equation significant at $P = 0.06$ with an 9 = 0.41 for days to harvest, these data are in agreement with previous results on 'Reinhold Ambrosius' and 'Knut Erwén' azaleas (Bodson, 1983). At harvest, there were more candle and showing-color inflorescences and fewer tight inflorescences for plants forced at 460 and 900 $\mu mol\cdot m^{-2}\cdot s^{-1}$ than at 200 $\mu mol\cdot m^{-2}\cdot s^{-1}$ (Fig. 2A). More candle and showing-color inflorescences at harvest resulted in more open flower inflorescences at week 2 of postproduction for plants forced at 460 and 900 $\mu mol\cdot m^{-2}\cdot s^{-1}$ (Fig. 2B). Plants forced at high irradiances had the most uniform floral display. Open flower diameter and postproduction longevity were not significantly affected by forcing irradiance (data not shown).

At harvest, flower redness ('a' value) was higher at forcing irradiances of 1110 and 560 $\mu mo1\cdot m^{-2}\cdot s^{-1}$ than at 320 $\mu mo1\cdot m^{-2}\cdot s^{-1}$ (Table 1). However, at week 2 of postproduction there was little difference in 'a' value for plants forced at different irradiances. Flower petal 'L' value (100 = white, 0 = black) showed little difference at harvest and week 2 of postproduction due to forcing irradiance.

Postproduction irradiance had no significant effect on the number of tight, showing-color, candle, and open flower inflorescences or postproduction longevity of 'Gloria' azalea (data not shown).

Effects of forcing temperature. More days to harvest were required at day/night cycles of 18/16C or 23/21C than 29/27C (Fig. 3), which is in agreement with previous data on azaleas (Pettersen, 1973). However, forcing temperature had no significant effect on the number of tight, showing color, candle, or

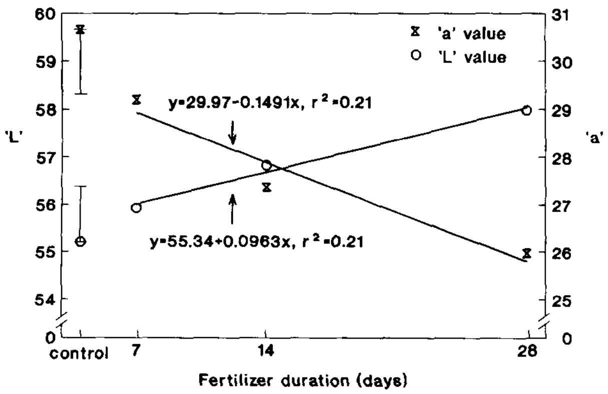

Fig. 5. Effect of duration of fertilizer application on Hunter 'L' (100 = white, 0 = black) and 'a' (positive = red, negative = green) values of 'Gloria' azalea flower petal color at harvest. Fertilizer concentration and the concentration **x** duration interaction were not significant at harvest; therefore, data were pooled over duration. Regression analysis was calculated using three durations and values for each plant. Points are means of 12 plants (48 measurements) at each level. Control (plants received no fertilizer during forcing) points are means of six plants each (24 measurements), and bars represent Dunnett's procedure at P = 0.05 used to compare all means with the control.

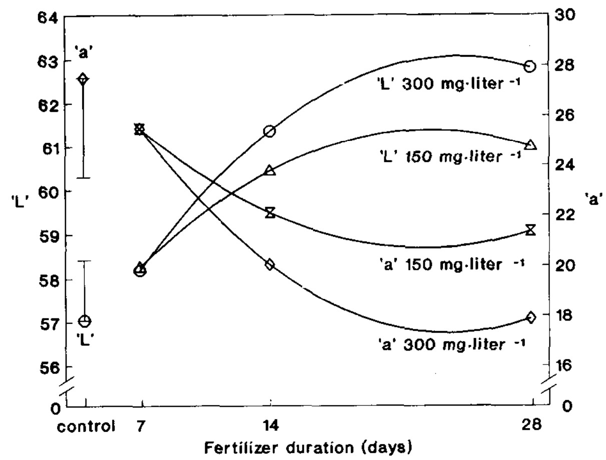

Fig. 6. Effect of duration of fertilizer application and concentration on Hunter 'L' (100 = white, 0 = black) and 'a' (positive = red, negative = green) values of 'Gloria' azalea flower petal color at week 2 of postproduction. Duration × concentration interaction was not significant. Regression analysis was calculated using three durations at two concentrations and values for each plant. Points are means of 12 plants (48 measurements) at each level. Control (plants received no fertilizer during forcing) points are means of six plants each (24 measurements), and bars represent Dunnett's procedure at P = 0.05 used to compare all means with the control. Regression equations are: 'L' at 300 mg·liter^{1}, y = 53.38 + 0.8040x - 0.0167x^2, r^2 = 0.50; 'L' at 150 mg·liter^{1}, y = 54.81 + 0.5828x − 0.0129x^2, r^2 = 0.27; 'a' at 150 mg·liter^{1}, y = 30.91 − 0.9173x + 0.0206x^2, r^2 = 0.28; 'a' at 300 mg·liter^{1}, y = 33.87 − 1.4035x + 0.0297x^2, r^2 = 0.44.

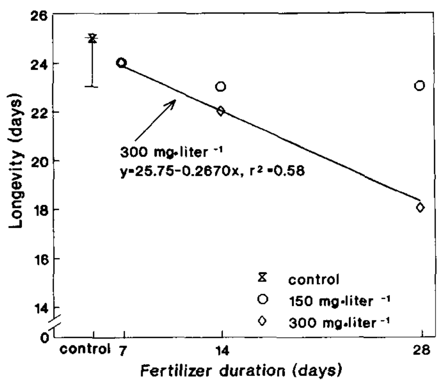

Fig. 7. Effect of duration of fertilizer application and concentration on postproduction longevity of 'Gloria' azalea. Concentration × duration interaction significant at P = 0.0015. Regression analysis was performed on values for each plant. Regression analysis for longevity of plants fertilized at 150 mg·liter^{1} was nonsignificant. Points represent means of 12 plants at each level. Control (plant received no fertilizer during forcing) points are means of six plants and bars represent Dunnett's procedure at P = 0.05 used to compare all means with the control.

open flower inflorescences at harvest or week 2 of postproduction (data not shown). Open flower diameter was not significantly affected by forcing temperature (data not shown). However, flower diameter of buds showing color at harvest was smaller for plants forced at high than at moderate temperatures at week 2 of postproduction (Fig. 3). Postproduction longevity was 3 days less when forced at a day/night cycle of 29/27C than 18/16C or 23/21C (Fig. 3). 'L' and 'a' values measured at harvest and week 2 of postproduction showed flower color was more intense at day/night cycles of 18/16C than at 23/21C or 29/27C (Fig. 4).

Effects of *fertilization during* forcing. Days to harvest was significantly longer for control plants (39 days) than those provided with a fertilizer treatment during forcing (35 to 37 days) P = 0.0013. Fertilization duration and concentration had no significant effect on the number of tight, showing-color, candle, and open flower inflorescences at harvest and week 2 of postproduction (data not shown). Flower diameter of 'Gloria' azalea was also not significantly different due to fertilizer treatment (data not shown).

At harvest, 'L' and 'a' values showed flower color was more intense for control plants and those fertilized for 7 than 14 or 28 days (Fig. 5). At week 2 of postproduction, 'L' and 'a' values showed flower color to be more intense for control plants and those fertilized at 150 than at 300 mg N/liter and for a duration of fertilizer application of 7 than of 14 or 28 days (Fig. 6). There was no interaction between fertilizer concentration and duration for 'L' and 'a' values. Joiner and Smith (1962) observed chrysanthemum flower color to increase as fertilizer concentration decreased. The most pigment (delphinidin-3-glucoside) in hydrangea *(Hydrangea arborescence* L.) sepals was in plants supplied with the lowest concentration of available N during forcing (Asen et al., 1960).

The interaction between fertilizer concentration and duration was significant for postproduction longevity (Fig. 7); longevity was shortest when plants were fertilized with a concentration of 300 mg N/liter for 28 days. Longevity was similar for plants fertilized at concentrations of 150 mg N/liter applied for 7, 14, or 28 days or 300 mg N/liter for 7 days. Control plants (no fertilizer treatment during forcing) lived the longest.

Our results demonstrate that postproduction longevity of 'Gloria' azalea was adversely affected when forced under high day/night temperatures and when plants were fertilized for 28 days at 300 mg N/liter during forcing. Postproduction longevity was unaffected by forcing or postproduction irradiance level. The number of open flower inflorescences during postproduction was enhanced by high forcing irradiance and was unaffected by forcing temperature and fertilization. Flower color was most intense at harvest when forced under high irradiance levels (900 to 1106 µmol·m^{-2}·s^{-1}), low temperatures (18/16C day/night), and when no fertilizer was applied during forcing. Flower diameter of buds that developed after harvest (buds showing color at harvest and measured at week 2 of postproduction) was largest when plants were forced at low temperatures (18/16 ± 1C to 23/21 ± 1C day/night). It must be noted that forcing conditions that produce the optimum postproduction qualities may compromise production time and cost to maintain optimum irradiance and temperature levels.

Based on these results, optimum conditions during forcing are: irradiance from 900 to 1110 µmol·m^{-2}·s^{-1}, day/night temperatures from 18/16C to 23/21C, and no use of fertilizer. This combination results in florist azaleas with high postproduction qualities.

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