

Production and Postproduction Irradiance Affects Acclimatization and Longevity of Potted Chrysanthemum and Poinsettia

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Abstract. Production irradiance levels on growth, light compensation point (LCP), dark respiration (DR), and interior longevity of potted chrysanthemum (*Demfranthema grandiflora* Tzvelev. cvs. Iridon and Mountain Peak) and poinsettia (*Euphorbia pulcherrima* Wind. cvs. Annette Hegg Dark Red and Gutbier V-10 Amy) were determined. LCP and DR were measured at anthesis and during acclimatization to interior conditions ($10 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$). Days to flowering, inflorescence diameter, total chlorophyll, and interior longevity of chrysanthemum increased when maintained at a mean maximum photosynthetic photon flux density (PPFD) of $500 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ compared to plants shifted to 300 or $100 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ 8 weeks after planting. LCP and DR were highest at anthesis and were reduced 38% and 49%, respectively, for chrysanthemum and 19% and 42%, respectively, for poinsettia within 3 days in interior conditions. Chrysanthemum plants shifted to $300 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ during production had lower LCP and DR rates at anthesis and throughout time in interior conditions compared to plants maintained at $500 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$. The acclimatization of chrysanthemum to reduced production PPFD is of little significance because interior longevity is reduced. No differences were found in the LCP or DR of poinsettia or chrysanthemum cultivars that differ in interior performance, demonstrating that these physiological characteristics are not good indicators of interior longevity for chrysanthemum and poinsettia.

Foliage plants produced under reduced light or fertilizer levels lose fewer leaves once plants are moved indoors (Conover and Poole, 1975, 1981, 1984; Fails et al., 1982; Pass and Hartley, 1979). This process is referred to as acclimatization and can be accomplished by growing plants under specific light intensities (Conover and Poole, 1975) or providing an acclimatization period during the final 6 to 8 weeks of production. Conover and Poole (1984) have emphasized that the use of acclimatized foliage plants increases the potential for continued plant growth and aesthetic quality indoors.

Acclimatization of foliage plants has been associated with a low LCP and DR rate, and increased photosynthetic efficiency at low irradiances (Fonteno and McWilliams, 1978; Mbah et al., 1983; Pass and Hartley, 1979). Fonteno and McWilliams (1978) observed that dark respiration was reduced 50% to 70% in four foliage plant species during acclimatization and concluded that respiration rate must be a major factor in acclimatization. Pass and Hartley (1979) suggested that the reduction in LCP and DR during acclimatization may result from the change in the relative importance of the two components of respiration—maintenance and growth respiration. Lower maintenance respiration may be responsible for greater efficiency at lower irradiance levels, as observed in three foliage plant species (Pass and Hartley, 1979).

Little information has been developed regarding the factors affecting longevity of flowering potted plants. Staby and Kofranek (1979) showed that termination of fertilizer 2 weeks before anthesis of 'Annette Hegg Supreme' poinsettia decreased leaf drop under interior conditions. Scott et al. (1984) demonstrated that poinsettia leaf drop was reduced when plants were produced with low levels of slow-release fertilizer. Micronutri-

ent source has also been found to influence the postharvest performance of poinsettias (Scott et al., 1982). Reductions in production light levels have been found to decrease LCP in chrysanthemum (Nell et al., 1981), but production light effects on longevity have not been evaluated. Our objectives were to determine production irradiance effects on growth, LCP, DR, and interior longevity of flowering potted chrysanthemum and poinsettia and to determine the changes in LCP and DR following transfer to interior conditions. Within each crop, a long-lasting cultivar was tested against a short-lasting one for differences in LCP and DR rates. Light acclimatization of chrysanthemum was also evaluated.

Materials and Methods

Chrysanthemum plant culture. Rooted cuttings of 'Iridon' (good interior longevity) and 'Mountain Peak' (poor interior longevity) chrysanthemums were planted one per 12.5-cm-diameter \times 12.5-cm-deep (1.2-liter) plastic container in a soilless medium (Metro Mix 300, W.R. Grace Co., Cambridge, Mass). Plants were placed in a fiberglass, fan-and-pad cooled greenhouse in Gainesville, Fla., at maximums of 24C and minimums of 18C.

Mean maximum PPFD of $500 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ was provided for 9 hr/day. Plants received a 4-hr/day non-inductive night interruption (2200 to 0200 HR) for 10 days. Short-day photoinductive periods were provided by covering the greenhouse bench with a black, light-opaque woven cloth from 1700 to 0800 HR. Plants were pinched 1 week after planting and fertilized at every watering with N at $300 \text{ mg}\cdot\text{liter}^{-1}$ from a 20N-4.8P-16K soluble fertilizer. Butanedioic acid mono(2,2-dimethylhydrazide) (daminozide) was applied as a foliar spray at $5000 \text{ mg}\cdot\text{liter}^{-1}$ when lateral shoots were 4.5 cm long and again 10 days later.

'Mountain Peak' chrysanthemum grown at three PPFD levels (Expt. 1). 'Mountain Peak' chrysanthemums were grown at a mean maximum PPFD of $500 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ until anthesis or shifted to a mean maximum PPFD of 300 or $100 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ 8 weeks after planting and held there until anthesis. A randomized complete-block design was used with three replicates of

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eight plants each. At anthesis, which was determined when the outer rows of florets were perpendicular to the stem, flower diameter and total chlorophyll were measured. Total chlorophyll was determined by placing two 6-mm² leaf disks in 5 ml of acidified (10% HCl) methanol for 48 hr at OC in the dark (Arnon, 1949). Optical density was measured at 652 nm using a Bausch and Lomb Spectronic 710 Spectrophotometer.

'Mountain Peak' and 'Iridon' chrysanthemum grown at two PPFd levels (Expt. 2). 'Iridon' and 'Mountain Peak' chrysanthemums were grown at a mean maximum PPFd of 500 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ until anthesis or shifted 8 weeks after planting to a mean maximum PPFd of 300 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$. A factorial experiment with two production light levels and two cultivars arranged in a randomized complete-block design was used with three replicates of eight plants each.

Plants from both experiments were moved at anthesis to interior rooms maintained at 21 \pm 2C. Interior lighting from cool-white fluorescent lamps supplied 10 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ for 12 hr/day. Relative humidity was 55% \pm 5%. LCP and DR of both cultivars were measured at anthesis and every 3 days for 'Iridon' grown at 500 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ and weekly on 'Iridon' shifted to 300 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ once in interior conditions. The termination date for plant longevity was determined when discoloration was observed on a minimum of four rows of florets. Plant interior longevity was based on this criterion because plant aesthetic quality degraded to the point where the plant was no longer useful in an interior setting.

Poinsettia plant culture (Expt. 3). Rooted cuttings of 'Annette Hegg Dark Red' (good interior performance) and 'Gutbier V-10 Amy' (poor interior performance) poinsettia were planted one cutting per 15-cm-diameter \times 11.9-cm-deep (1.6-liter) plastic container in a soilless medium (Metro Mix 500, W. R. Grace). Plants were placed in a fiberglass, fan-and-pad cooled greenhouse in Gainesville, Fla., at maximum of 32C and minimum of 18C. Plants were grown at a mean maximum PPFd of 500 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ until anthesis. Plants received non-inductive photoperiod conditions for 5 weeks until photoinductive conditions were provided as described above. Plants were pinched to five nodes 3 weeks after planting and fertilized at every watering with N at 300 mg-liter⁻¹ from 20N-4.8P-16K soluble fertilizer. Plants were moved at anthesis to interior rooms described above and maintained for 30 days. LCP and DR were determined at anthesis for both cultivars and after 3, 6, 9, 18, and 30 days in the interior for 'Annette Hegg Dark Red'.

Light compensation point and dark respiration measurements. Light compensation point and dark respiration were determined in an open system with an infrared gas analyzer (Anarad Model AR-600R, Anarad, Inc., Santa Barbara, Calif.). Whole plants were enclosed in a 34.5 \times 30.0 \times 48.5 cm (L \times W \times H) plexiglass (6-mm-thick) chamber and illuminated with a 400-W metal halide lamp (Sylvania Lumalux Lu400). Roots were sealed in an airtight plastic bag to eliminate root and media respiration input during measurements. High-density polyethylene tubing was used throughout the system due to its low water absorption and CO₂ permeability (Bloom et al., 1980). Incoming ambient air was saturated with water vapor using an air-stone submerged in deionized water and continually circulated with a 60-Hz boxer fan (IMC Magnetics Corp., Rochester, N.H.). Relative humidity, measured with a hygrometer (Bacharach Instrument Co., Pittsburgh, Pa.), ranged from 63% to 68%. Flow meters (Dwyer Instruments Inc., Michigan City, Ind.) were used to regulate flow from 5 to 10 liters-min⁻¹ to maintain a CO₂ differential of 30 mg-liter⁻¹ or less throughout the measurement period.

Chamber, leaf, and soil temperatures were monitored using copper-constantan thermocouples and a digital thermometer (Cole-Parmer Instrument Co., Chicago). The chamber and leaves were maintained at 26 \pm 2C and the soil at 21 \pm 2C, using a water-filled heat sink below the light source and a temperature-regulating water bath (Laude K-21R, Brinkman Instruments, Westbury, N.Y.). Air pressure was determined using a barometer (Airguide Instrument Co., Chicago). Total leaf area was determined for each plant after each measurement with a portable area meter (LI-COR Model LI-3000, LI-COR, Lincoln, Neb.).

Light compensation point was determined by reducing light intensity, which was measured at the top of plant leaf canopy, from a maximum of 400 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ using layers of cheese-cloth until the net CO₂ flux was zero. At this point, the lamp was extinguished and the chamber draped with an opaque cloth to obtain complete darkness. Dark respiration was measured when the CO₂ concentration stabilized. Carbon exchange rate was computed by the equation used by Pass and Hartley (1979), modified for an open system.

Regression analysis and analysis of variance were performed using the General Linear Model procedure of the Statistical Analysis System program (SAS Institute, Cary, N.C.), Tukey's HSD mean separation was used to determine significant differences ($P \leq 0.05$) among means when significant F values were found.

Results and Discussion

Experiment 1. Flowering was delayed 5 days and inflorescence diameter, total chlorophyll, and interior longevity were reduced when 'Mountain Peak' plants were shifted to 100 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ compared to plants maintained at 500 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ throughout production (Table 1). No differences in these characteristics were observed between plants maintained at 500 and 300 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ except for a 2-day difference in flowering. Cockshull and Hughes (1972) demonstrated that flower initiation and development in chrysanthemum are dependent on irradiance level, but an effect on interior longevity has not been shown previously.

Experiments 2 and 3. LCP at anthesis of 'Mountain Peak' and 'Iridon' chrysanthemums grown at 500 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ throughout production averaged 167 (\pm 26) and 162 (\pm 13) $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$, respectively, while poinsettia LCP at anthesis averaged 21 (\pm 2.5) $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ for 'Dark Red Annette Hegg' and 17 (\pm 3.0) $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ for 'Gutbier V-10 Amy' (\pm SE).

Table 1. Effect of production PPFd on growth and interior longevity of 'Mountain Peak' chrysanthemum.

Production PPFd ^z ($\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$)	Days to anthesis ^y	Flower diam (cm)	Total chlorophyll (mg-liter ⁻¹)	Interior longevity* (days)
500	61	16.7	11.05	24
300	63	16.4	11.10	22
100	66	12.6	9.79	18
HSD				
0.05	1.39	1.25	1.01	4.15
0.01	1.82	1.57	1.38	5.35

^zPlants grown at a mean maximum PPFd of 500 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ until anthesis or shifted to 300 or 100 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ 8 weeks after planting.

^yDetermined from the beginning of photoinduction until the outer rows of florets were perpendicular to the stem.

^{*}Number of days elapsed from when plants placed in interior rooms until discoloration on a minimum of four rows of florets observed.

LCP was reached more rapidly for chrysanthemum than poinsettia, indicating that poinsettia has a greater ability to use CO₂ under low irradiance levels. DR rate at anthesis of plants grown continually at 500 μmol·s⁻¹·m⁻² averaged 1.6 mg CO₂/dm² per hr for chrysanthemum and 2.6 mg CO₂/dm² per hr for poinsettia. No differences were observed in DR or LCP between the two chrysanthemum cultivars or between the two poinsettia cultivars.

Changes in LCP and DR over time in interior conditions of both plant species are compared in Fig. 1. LCP and DR of chrysanthemums and poinsettias were highest at anthesis (day 0) and declined rapidly once plants were moved to interior con-

ditions. LCP was reduced 38% and DR 49% in 'Iridon' chrysanthemum grown at 500 μmol·s⁻¹·m⁻² after only 3 days in interior conditions. Reductions of 19% and 42% of LCP and DR, respectively, were observed in 'Annette Hegg Dark Red' poinsettia after 3 days. LCP continued to decline until day 7 for chrysanthemum and day 9 for poinsettia, after which no changes were observed. LCP reached a minimum of 5 μmol·s⁻¹·m⁻² in poinsettia compared to 71 μmol·s⁻¹·m⁻² for chrysanthemum grown at 500 μmol·s⁻¹·m⁻². The minimum LCP in poinsettia is similar to levels observed in *Brassica actinophylla* after a 7-week acclimatization period, while minimum levels for chrysanthemum were higher than found in *Nephrolepis exaltata* 'Bostoniensis' (Pass and Hartley, 1979). Fonteno and McWilliams (1978) showed that changes in LCP of four foliar species occur within the first 4 to 6 weeks of acclimatization. Our results demonstrate that similar changes are occurring in flowering potted plants during acclimatization, but initial changes are more rapid than with foliage plants.

Pass and Hartley (1979) noted that the minimum PAR level a plant reaches depends on plant species and production history. 'Iridon' plants shifted to 300 μmol·s⁻¹·m⁻² had lower LCP and DR rates at anthesis and throughout time in interior conditions compared to plants maintained at 500 μmol·s⁻¹·m⁻² throughout production (Fig. 1), demonstrating that reduced production PPFD is sufficient to alter the acclimatization processes in chrysanthemum. However, the changes in LCP and DR maybe of little significance, since longevity is reduced at low PPFD. In addition, there were no significant differences found in LCP between the two chrysanthemum cultivars or between the two poinsettia cultivars at anthesis, even though their interior performance differs.

It is important to note that there are limitations associated with using LCP to define the minimum PPFD required for plant maintenance, since it uses an instantaneous CO₂ exchange rate and does not account for respiratory losses or consider the whole plant (roots and shoots). Mbah et al. (1983) found that the PPFD at which a plant can maintain itself is underestimated by LCP and concluded that a more reliable method for determining PPFD required for plant maintenance is by using a carbon balance analysis, which follows plant growth by the analysis of carbon gains and losses in a whole plant using 24-hr carbon exchange rate measurements. This method is limited, however, by the assumption that the substrate produced in photosynthesis is completely used in 1 day without any storage. Although there is no exact method for defining the minimum PPFD requirements for plant maintenance, the LCP reported in this study indicates that flowering potted plants, influenced by production PPFD, are acclimatizing very rapidly to interior conditions.

The primary procedure for acclimatization of foliage plants is reduction of irradiance level during production. This procedure reduces longevity of chrysanthemums, as shown with 'Mountain Peak'. Previous results indicate a slight reduction in poinsettia leaf loss following a brief period at low irradiance levels (Nell and Barrett, 1986), although premature cyathia abscission can occur if irradiance levels are too low during the final 4 weeks of poinsettia production (Miller and Heins, 1986). The present results demonstrate that LCP and DR are not related to interior longevity of chrysanthemum and that light acclimatization of chrysanthemum has no beneficial effects on its longevity.

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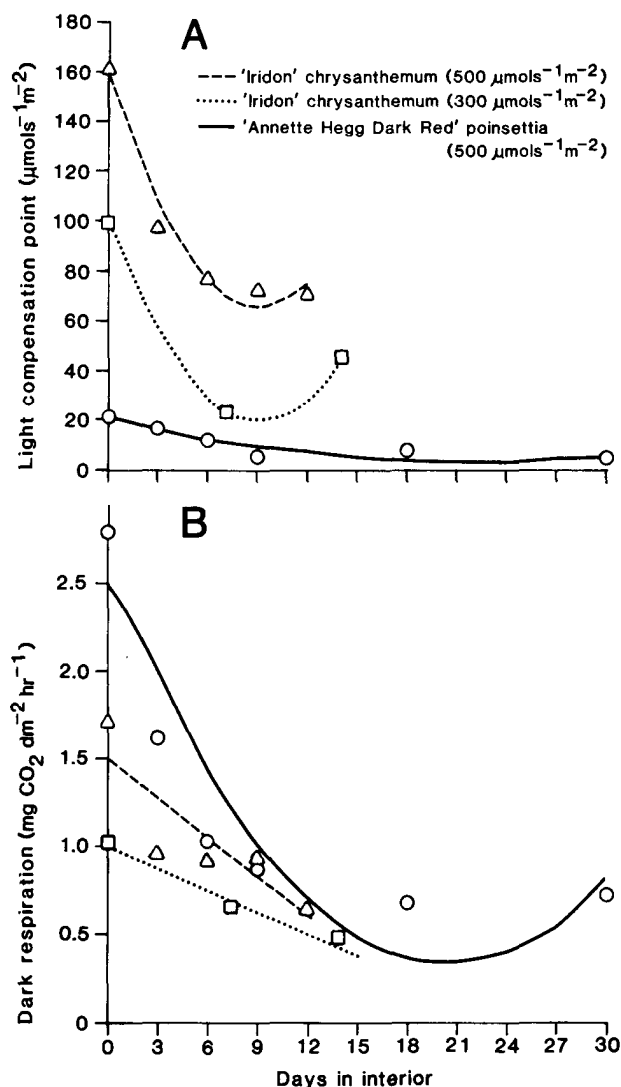


Fig. 1. (A) Relationship of light compensation point to time in interior conditions of 'Iridon' chrysanthemum grown at 500 μmol·s⁻¹·m⁻²: $Y = 158.64 - 20.36x + 1.11x^2$; $R^2 = 0.83$; and, at 300 μmol·s⁻¹·m⁻²: $Y = 100.00 - 18.07x + 1.01x^2$; $R^2 = 0.96$. 'Annette Hegg Dark Red' poinsettia grown at 500 μmol·s⁻¹·m⁻²: $Y = 19.96 - 1.49x + 0.034x^2$; $R^2 = 0.72$. (B) Relationship of dark respiration to time in interior conditions of 'Iridon' chrysanthemum grown at 500 μmol·s⁻¹·m⁻²: $Y = 1.49 - 0.077x$; $R^2 = 0.68$; and, at 300 μmol·s⁻¹·m⁻²: $Y = 1.02 - 0.042x$; $R^2 = 0.87$. 'Annette Hegg Dark Red' poinsettia grown at 500 μmol·s⁻¹·m⁻²: $Y = 2.45 - 0.201x + 0.005x^2$; $R^2 = 0.79$. Points represent treatment means (n = 4).

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