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peratures were high enough to have influenced plant production similarly to extended curing.

Average daily temperatures are ≤10C for January and February, when most sweetpotatoes are presprouted for early bedding at Tifton, Ga. (U.S. Dept. of Agriculture, 1983). Average daily temperatures are relatively high during the early part of the harvest period in most areas where sweetpotatoes are grown commercially. These differences in average daily temperatures at harvest and during the time of presprouting indicate potentially lower energy costs associated with plant propagation of responsive cultivars if the duration of curing can be extended and the duration of presprouting can be reduced. Further refinements in techniques for using short extensions of curing alone or in combination with brief presprouting may avoid problems such as shrinkage and reduced storage life reported by Steinbauer and Kushman (1971) from longer durations of curing.

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Photoperiod and Gibberellic Acid Modify Growth and Flowering of *Craspedia globosa*

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Additional index words. Australian drumstick flower, GA_3, long-day plant, photoperiodism, specialty cut flower

Abstract. **The objective of this study was to investigate the influence of photoperiod and 0, 1, 5, or 10 applications at weekly intervals of GA_3 foliar sprays at 500 mg·liter^{-1} on growth and flowering of *Craspedia globosa* 'Drumstick' Benth. Long days (LD) hastened flowering and increased the number of flowers per plant. Short days (SD) increased foliage height and foliage fresh and dry weights. Foliage and total plant heights increased and days to bud and secondary inflorescence width decreased linearly as GA_3 application frequency increased. Chemical name used: (1α,2β,4aα,4bβ,10β)-2,4a,7-trihydroxy-1-methyl-8-methylenegibb-3-ene-1,10-dicarboxylic acid 1,4a-lactone (gibberellic acid, GA_3).**

Craspedia globosa (Australian drumstick flower), Family Asteraceae, is an herbaceous perennial native to Australia. The inflorescence is a compound head consisting of a golden-yellow globular secondary inflorescence containing groups of three to 10 individual flowers in primary inflorescences that open acropetally. The plant has basal rosette leaves and 60-cm scapes. This species was introduced in the United States for garden cultivation in 1988 (Park Seed Co., Greenwood S.C., personal communication).

There has been increased interest in the U.S. floriculture industry in producing garden plants as specialty cut flowers to supply florists with a greater variety of materials. Production of specialty cut flowers increased by ≈28% between 1987 and 1989, whereas the production of major cut flowers declined slightly during this time (Armitage, 1991). The Australian drumstick flower has the potential as a specialty cut flower because it has an acceptable vase life, long sturdy scapes, flowers that are suitable for drying, and a unique flower shape because the individual flowers form a globular head. The successful introduction of Australian native species as specialty cut flower crops depends on the development of techniques to extend the natural flowering season (Sharman et al., 1989).

Research with chrysanthemum [*Dendranthema ×grandiflorum* (Ramat.) Kitamura] and other Asteraceae species has shown that manipulation of photoperiod (PP) may be used as a method for year-round production. Long-day (LD) treatment decreased days to flower of shasta daisy (*Chrysanthemum ×superbum* Bergmans) (Griffin and Carpenter, 1964) and gloriosa daisy (*Rudbeckia hirta* L.) (Orvos and Lyons, 1989) and decreased days to floral initiation of two species of Australian strawflower [*Helipterum roseum* (Hook.) Benth. and *Helichrysum bracteatum* (Venten.) Andr.] (Sharman et al., 1989). Long-day PP increased the number of flowers of shasta daisy and strawflowers (Griffin and Carpenter, 1964; Sharman et al., 1989), flower diameter of shasta daisy (Griffin and Carpenter, 1964), and flower spike length of liatris [*Liatris spicata* (L.) Willd.] (Zieslin and Geller, 1983).

Gibberellin treatments induced flowering of Asteraceae species when grown under

Table 1. Effect of GA_3 application frequency and photoperiod on bud count per plant of *Craspedia globosa*.

No. weeks GA_3 applied (500 mg·liter^{-1})	Photoperiod	
	Short day	Long day
	Buds/plant	
0	2.2	12.9
1	4.0	9.1
5	4.5	11.7
10	3.5	13.1
Comparison		
Treatment effect	**	*
Linear	*	NS
Quadratic	**	NS
Cubic	*	*

NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01, respectively, with 3 and 6 df.

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Table 2. Effect of photoperiod on flowering and vegetative development of *Craspedia globosa*.

Photoperiod[y]		Days to[z] Bud	Days to[z] Anthesis	Flower count/plant	Total bud and flower dry wt (g)	Foliage Ht (cm)	Foliage Dry wt (g)
Short day		113	128	0.3	13	67	64
Long day		93	117	7.5	34	49	29
Source[x]	df	Mean square ($\times 10^{-2}$)					
B	2	3.2^{NS}	0.0^{NS}	0.4^{NS}	7.5^{NS}	0.9^{NS}	30.8^{NS}
PP	1	197.8*	10.9*	24.7*	182.5*	148.7*	601.8*
Main plot error	2	2.3^{NS}	0.2^{NS}	0.4^{NS}	2.0^{NS}	2.9^{NS}	6.9^{NS}
GAF	3	4.8**	0.1^{NS}	0.3^{NS}	5.9^{NS}	58.2***	9.9^{NS}
PP × GAF	3	1.5^{NS}	0.1^{NS}	0.2^{NS}	1.7^{NS}	2.0^{NS}	29.0^{NS}
Subplot error	12	0.7^{NS}	0.4^{NS}	0.3**	1.7^{NS}	3.3**	9.1^{NS}
Error	174	0.6	0.3	0.1	2.3	1.4	5.6

[z]Measured from sowing.
[y]B = block; PP = photoperiod; GAF = GA_3 application frequency.
[x]Error degrees of freedom ranged from 103 to 174 depending on variable.
NS,*,**,***Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively, with 1 and 2 df.

Table 3. Effect of GA_3 application frequency on flowering and vegetative development of *Craspedia globosa*.

No. weeks GA_3 applied (500 mg·liter^{-1})	Days to bud[y]	Foliage ht (cm)	Total plant ht (cm)	Secondary inflorescence[z] Width (mm)	Secondary inflorescence[z] Length (mm)
0	106	49	95	24	22
1	103	50	100	23	22
5	101	60	108	21	23
10	100	73	122	19	23
Comparison					
Treatment effect	**	***	**	**	NS
Linear	**	***	***	**	---

[z]Scape and secondary inflorescence measurements taken on long-day plants only.
[y]Measured from sowing.
NS,**,***Nonsignificant or significant at P = 0.01 or 0.001, respectively, with 12 or 6 (long-day only measurements) error df.

noninductive PP. Blanket flower (*Gaillardia ×grandiflora* Van Houtte), a quantitative LD plant, flowered under short day (SD) after multiple applications of GA_{4+7} (Evans and Lyons, 1988). In contrast, cosmos (*Cosmos bipinnatus* Cav.), a quantitative SD plant, was induced to flower under LD after treatment with GA_3 (Molder and Owens, 1974). Objectives of this study were to identify the response of *C. globosa* 'Drumstick' to PP and to describe the effect of exogenously applied GA_3 on floral and vegetative development under LD and SD.

Seeds of 'Drumstick' were sown 22 Jan. 1990 in rows in plastic 52.5 × 26 × 7-cm flats containing Jiffy-Mix (Jiffy Products, West Chicago, Ill.) and placed under intermittent mist until emergence. On 16 Feb., seedlings were transplanted into 165-cm^3 cells containing ProMix BX (Premier Brands, New Rochelle, N.Y.). Fertilization with each irrigation was begun on 2 Mar. using 20N–4.4P–16.6K with N at 200 mg·liter^{-1}. Plants were placed on 35-cm centers in ground beds in an inflated, double-layer polyethylene greenhouse on 12 Mar. The medium consisted of 2 peatmoss : 1 vermiculite : 1 perlite (by volume) mixture amended with 7.5 kg ground dolomite lime; 1.4 kg superphosphate; 698 g calcium nitrate; 351 g potassium nitrate; 175 g fritted trace elements; 116 g chelated iron; and 291 g wetting agent per cubic meter. Venting/night temperature set points were 21/16C.

Treatments commenced on 24 Mar. after the plants had 15 leaves. SD was effected by pulling black sateen cloth at 1800 HR and removing it at 0700 HR; LD was effected by incandescent night interruption from 2200 to 0200 HR. Two 60-W incandescent bulbs spaced 90 cm apart and placed 1 m above the medium surface supplied 5.1 μmol·m^{-2}·s^{-1} measured at plant canopy level.

GA_3 treatments included 0 and 500 mg·liter^{-1} foliar spray to runoff. A commercial formulation of GA_3 (Pro-Gibb 4%, Abbott Labs, North Chicago, Ill.) was used. Plants were divided into the following four groups: no GA_3; one application of GA_3 at week 1; five or 10 applications of GA_3 at weekly intervals beginning with week 1. Spray drift was controlled by separation of treatments by border rows and by placing a polyethylene screen between treatments during application.

The experiment was a split-plot design with three replications of nine plants, each containing PP as main plots and GA_3 application frequency (GAF) as subplots. Statistical analysis of flower (secondary inflorescence) measurements were completed for LD plants only, because SD substantially reduced the percentage of plants that flowered. Plants were harvested on 6–8 June by cutting at the medium surface.

Days to bud and days to anthesis were checked every 2 days and determined as the number of days from sowing until the first macroscopically visible bud appeared and the first individual flower reached anthesis on a plant, respectively. Secondary inflorescences were considered buds when fewer than one-third of the primary inflorescences were open and flowers when one-third or more of all primary inflorescences were open.

Foliage height was measured from the base of the plant to the top of the foliage. Total plant height was measured from the base to the top of the foliage or secondary inflorescence, whichever was more distal, since the scapes of many SD plants had not elongated at harvest. Fresh weight was measured immediately after harvest and dry weight after 72 h at 80C.

Flower data for LD plants included scape length and caliper and secondary inflorescence length and width. Scape length was from the point of attachment at the crown to the base of the receptacle. Scape caliper was measured 15 cm below the base of the receptacle. Secondary inflorescence length was measured from the receptacle to the apex vertically and width was across the widest point horizontally.

The General Linear Model (SAS Inst., Cary, N.C.) was used as the analysis of variance procedure. F tests were used in determining significant differences between treatment means. When appropriate, trend fits were calculated using the same error term used for the corresponding F test. Due to a PP × GAF interaction, number of buds per plant was analyzed by PP and the interaction term was used as the mean square error for trend fits involving GAF.

Only the number of buds per plant had a PP × GAF interaction (Table 1). Under SD, increasing GAF increased the number of buds per plant compared with controls, whereas under LD, there was generally no difference among treatments.

Under LD, days to bud was decreased by 20 days and days to anthesis by 11 days relative to SD (Table 2). Compared with SD, LD caused an increase in the number of flowers and an increase in total bud and flower weights. At termination of the experiment,

19.5 weeks after sowing, only 17% of all SD plants flowered, whereas 100% of the LD plants flowered, suggesting that *Craspedia* is a quantitative LD plant.

There was a concurrent reduction in vegetative growth when *Craspedia* was grown under LD. LD plants had rosette foliage with scapes produced from the middle of the crown. SD plants were bushy, with foliage growing to the same height as the secondary inflorescence grew on the LD plants. Thus, PP had no effect on total plant height (data not shown).

As GAF increased, days to bud decreased and foliage and total plant heights increased linearly (Table 3). Quadratic and cubic trends were nonsignificant. GAF did not affect days to anthesis, number of flowers, total flower and bud or foliage fresh or dry weight (data not shown). Therefore, GA_3 did not substitute for LD.

LD scape caliper averaged 2.0 ± 0.08 mm SE, and scape length averaged 87 ± 3.3 cm SE and were not affected by GAF (data not shown). Gibberellin application did not increase secondary inflorescence size of *Craspedia* and caused malformed inflorescences by decreasing secondary inflorescence width (Table 3).

Craspedia cut-flower production can be maximized with LD exposure. The number of flowers was increased and vegetative growth was minimized. Growing *Craspedia* under night-interruption lighting would allow closer spacing of the plants in the bed, improving efficiency. Relative daylength has influenced morphological development of other species of the Asteraceae. SD-treated shasta daisies had different growth habits than LD-treated plants (Griffin and Carpenter, 1964), and gloriosa daisies had more leaves (Orvos and Lyons, 1989).

In this study, GA_3 application did not improve *C. globosa* 'Drumstick' cut-flower production by reducing time to harvest or increasing flower yield, although days to bud was decreased by ≈6 days and the number of buds was increased under SD. These results may be due to GA inducing flower initiation but not flower development, as was shown with other Asteraceae species (Evans and Lyons, 1988; Molder and Owens, 1974; Sharman et al., 1989).

Applications of GA_3 did not affect *Craspedia* LD scape length and caliper. This differs from findings for blanket flower that gibberellin (GA_{4+7}) increased scape length and decreased scape caliper (Evans and Lyons, 1988), and GA_3 increased plant height and produced spindly stems in cosmos (Molder and Owens, 1974). Similar to our study, flower deformities were also evidenced when GA_3 application to cosmos produced a smaller receptacle, crowding ray flowers (Molder and Owens, 1974), and GA_{4+7} reduced flower diameter of blanket flower (Evans and Lyons, 1988). This response was thought to be due to GA_3 inducing vegetative growth elsewhere on the plant, resulting in a deficiency in the supply of substrate or other necessary hormones at the floral apex (Molder and Owens, 1974).

In this study, gibberellin application did not alleviate the LD photoperiod requirement for flowering of SD-treated *C. globosa* plants. Gibberellin-induced bolting of LD plants under noninductive SD depends on many factors, including plant species, maturity status, the specific GA applied, and the GA concentration (Evans and Lyons, 1988). Additional rates or other gibberellins would need to be tested to fully determine their effect on *Craspedia* flowering.

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Florists' Hydrangea Blueing with Aluminum Sulfate Applications during Forcing

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Abstract. **The Al content was determined in roots, buds, and stems of dormant florists' hydrangeas [*Hydrangea macrophylla* subsp. *macrophylla* var. *macrophylla* (Thunb.) 'Mathilda Gutges' and 'Brestenburg'] that were or were not treated in the field with aluminum sulfate. During the greenhouse forcing stage, previously nontreated plants were subjected to four successive weekly subirrigated applications of aluminum sulfate totalling 4, 8, 12, or 16 g/pot. Applications were early (weeks 2, 3, 4, 5) or late (weeks 6, 7, 8, 9), using the start of forcing as week = 0. The Al contents in stems and buds of dormant plants were about five to six times higher in field-treated than in nontreated plants. Roots were the primary location of Al accumulation (≈70%). Aluminum sulfate applications of 12 to 16 g/pot during greenhouse forcing provided commercially acceptable blue plants. Maximum foliar Al concentration was 50% higher in early than in late-treated plants and calculated to occur with 14.5 and 12.2 g aluminum sulfate/pot for early and late-treated plants, respectively. There was a positive correlation (r = 0.74) between blueness ranking and the Al foliar concentration of the two uppermost expanded leaves taken from flowering plants.**

Chenery (1937) and Allen (1943) showed that availability of Al in soil and/or application of Al ions to the sepals strongly influenced the blueing of florists' hydrangeas. Robinson and Robinson (1932) showed that both Al and anthocyanin (delphinidin-3-monoglucoside) were involved in blueing of hydrangea sepals. Takeda et al. (1985) reported that the blueing of hydrangea sepals was mainly due to the delphinidin-3-glucoside-aluminum-3-caffeoylquinic acid complex, with Al serving as the stabilizer.

Florists' hydrangeas are normally grown from spring-rooted cuttings in pots placed outside during the summer (Bailey, 1989). At the end of summer (August–September), Al is applied to plants scheduled to be forced with blue sepals. This is normally done by manual drenching the substrate two to four times with aluminum sulfate (AS) at 12 to 20 g·liter^{-1}. Besides the additional labor of applying the drenches, this decision commits the field producer to the number of plants to be forced as blue, since AS-treated plants are

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