Photoperiodic Control of Growth and Development in 'Nonstop' Cultivar Series of *Begonia* x *Tuberhybrida*

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Abstract

Plants of *Begonia* x *tuberhybrida* 'Nonstop', 'Clips', and 'Musical' were exposed to 1, 2, 3, or 4 weeks of short days (SD, 9 hours day length) initiated at 3 stages of plant development (immediately upon germination, 4 or 8 weeks after germination). Prior to and succeeding short days, plants were exposed to long days (LD, 16 hours day length). Musical flowered on average 68 days, Clips 78 days and Nonstop 83 days after germination under continuous LD conditions. In Nonstop, SD for 1, 2, 3, or 4 weeks delayed plant development by an average 12 days compared to LD grown plants. One, 2, or 3 weeks of SD resulted in 1 week slower flowering and 4 weeks of SD resulted in 2 weeks later flowering in Clips. The sensitivity to SD varied with plant stage in Musical. Three or 4 weeks of SD initiated at germination or 4 weeks after germination resulted in an average delayed flowering of 13 days compared to LD plants. SD initiated 8 weeks after germination had no effect on rate of development in Musical.

Introduction

The 'Nonstop' series of *Begonia* x *tuberhybrida* Voss. was introduced during the 1970s by Benary Seeds of Germany (Ewart, 1985). These Nonstop cultivars are propagated by seed, have uniform growth over a wide range of environmental conditions and have semi-double flowers in many colors. In addition to the Nonstop series, many other seed propagated cultivar series have been introduced and are produced commercially today.

Tuberous begonias (*B.* x *tuberhybrida*) produce tubers under short days (SD) and low temperatures (Peter, 1974; Fonteno and Larson, 1982; Oloomi and Payne, 1982; Fonteno and Larson, 1983; Djurhuus, 1985; Ewart, 1985; Tonecki, 1986). In contrast to *B.* x *hiemalis* (hiemalis begonia, elatior begonia, Rieger begonia), continuous long days (LD) and temperatures above 17 °C are required for proper plant development and flowering of tuberous begonia. Once tuber formation has started, tuberous begonia plants will not easily revert back to vegetative growth and flower formation (Ewart, 1985).

Cultural recommendations for the seed propagated tuberous begonias are primarily based on experiences with cultivars propagated by tubers. One example of such a recommendation is never to allow SD exposure of seed propagated tuberous begonia after germination. SD conditions are expected to result in plant dormancy and tuber formation although the cultivars used today may respond differently to photoperiod than the traditionally grown tuberous begonias. This study was initiated to determine the sensitivity of seed propagated tuberous begonia to SD exposure during different stages of plant development.

Table 1. *Days to flower in Begonia x tuberhybrida 'Nonstop' and 'Clips' after exposure to short days (SD, 9 hours day length) for different durations during plant development. The remaining development occurred under a 16–hour photoperiod.*

Duration of SD (weeks)	Days to Flower	
	Nonstop	Clips
0	83	78
1	94	85
2	95	89
3	95	89
4	97	97
Significance		
Control vs. SD treatments	***	***
Control vs. 1 week of SD	***	*
Control vs. 2 weeks of SD	***	**
Control vs. 3 weeks of SD	***	**
Control vs. 4 weeks of SD	***	***
Duration, linear	***	***
Duration, quadratic	**	ns
Duration, cubic	*	ns
Duration, quartic	ns	ns

ns, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01 or 0.001, respectively.

Table 2. *Days to flower in Begonia x tuberhybrida 'Musical' after exposure to different durations of short days (SD, 9 hours day length) initiated at the growth stages of germination (early), intermediate (4 weeks after germination) or late stage (8 weeks after germination). The remaining development occurred under a 16–hour photoperiod.*

Duration of SD (weeks)	Stage of SD Exposure		
	Early	Intermediate	Late
		Days to Flower	
0	68	68	70
1	72	70	72
2	74	68	69
3	77	79	73
4	83	85	68
Significance			
Control vs. SD treatments	**	**	ns
Control vs. 1 week of SD	ns	ns	ns
Control vs. 2 weeks of SD	*	ns	ns
Control vs. 3 weeks of SD	**	**	ns
Control vs. 4 weeks of SD	***	***	ns
Duration, linear	***	***	ns
Duration, quadratic	ns	*	ns
Duration, cubic	ns	ns	ns
Duration, quartic	ns	ns	ns

ns, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01 or 0.001, respectively.

Procedures

'Nonstop Orange', 'Clips Orange', and 'Musical Orange' were the cultivars selected for this study. Seed was germinated at 21–24 °C media temperature and 24 hours of light. The experiment was initiated 2 weeks after seeding. Plants at different stages of development were placed under SD for variable duration and then returned to LD. The photoperiod during SD was 9 hours at a photosynthetic photon flux (PPF) of 180 ± 20 μmol • m^{-2} s^{-1}. PPF level during the 16–hour LD period was 100 ± 10 μmol • m^{-2} s^{-1}. The instantaneous PPF levels from high-pressure sodium lamps were selected to provide similar total daily PPF of 5.8 mol m^{-2} day^{-1} for both the 9– and the 16–hour day length. The day temperature was maintained at 21 ± 2°C and the night temperature at 18 ± 2 °C. The day and night periods for the temperatures followed the 9–hour photoperiod to give an average daily temperature close to 19 °C. Stages of plant development for SD exposure were at germination (2 weeks after seeding), 4 or 8 weeks after germination. The plant stages for initiation of SD will be referred to as early, intermediate and late. The duration of SD exposure was 0, 1, 2, 3, or 4 weeks. The treatments were arranged in a factorial experiment and plants were randomized within each cultivar and rerandomized as SD treatments were initiated or completed. There were 10 plants in each treatment. Flowering was recorded when the first bud on the plant showed color. Data on time to flower, shoot, leaf and flower number, leaf area, and dry weight were collected 105 days after germination to allow most plants to flower. The results in the text are given as the mean of the plants in a treatment ± SE (standard error).

Results and Discussion

The time required for plants to flower under continuous LD conditions throughout the development was significantly different for the three cultivars (Figure 1). Flowering in Musical was observed 68 ± 1.7 days from germination. Clips flowered on average 10 days later or 78 ± 1.3 days from germination and Nonstop was the slowest developing cultivar requiring 83 ± 1.7 days for flowering. The least significant difference (P=0.05) for average number of LD to flowering among cultivars was 4.1 days.

Statistical analyses of the photoperiodic effects on rate of plant development within each cultivar showed highly significant effects of SD duration. However

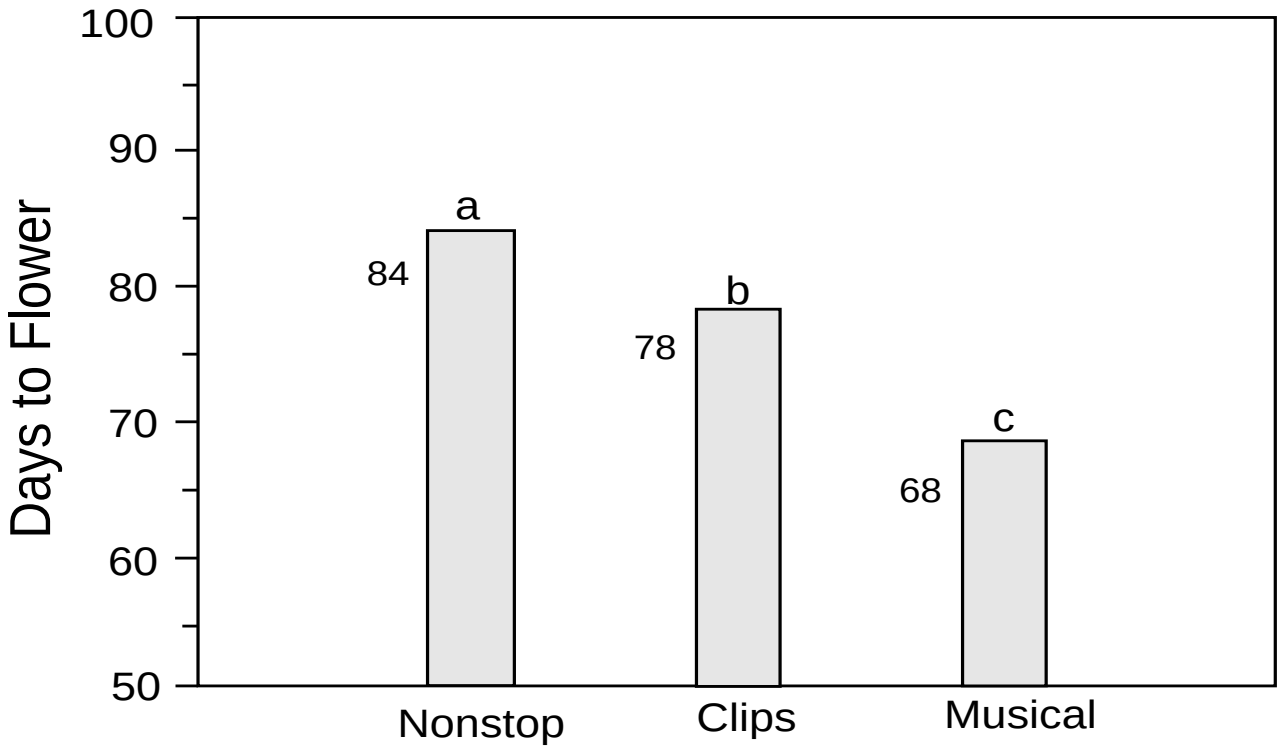

Figure 1. *Days to flower in Begonia x tuberhybrida 'Nonstop', 'Clips', and 'Musical' grown under 16-hour photoperiod. Treatments identified with the same letters are not significantly different by the least significant difference (lsd), P = 0.05.*

there were no significant effects of plant stage at SD exposure or the interaction of plant stage by SD duration in Nonstop and Clips. The data were therefore pooled over the different plant stages in Nonstop and Clips. Rate of development in Musical was significantly (P=0.05) affected by the plant stage at SD exposure and by the interaction between plant stage and SD.

Average days required for flowering in Nonstop and Clips after exposure to different durations of SD are presented in Table 1. The delay in Nonstop plants was similar for 1, 2, 3, or 4 weeks of SD exposure compared to the plants under continuous LD. On average, 95 ± 0.9 days were required for flowering in Nonstop after any SD during plant development. Nonstop plants maintained under LD conditions required an average 83 ± 1.7 days to flower. For Clips plants, there was a trend for slower development with increasing number of SD weeks (Table 1). Four weeks of SD resulted in an average 19 days slower flowering compared to the control plants of Clips.

Plant stage at initiation of SD altered the influence by short photoperiods in Musical (Table 2). During early development, longer exposure to SD resulted in progressively larger delay with an average 15 days slower flowering after 4 weeks of SD. Three weeks of SD initiated during intermediate plant stage resulted in flowering 79 ± 2.2 days after germination compared to flowering in 68 ± 1.7 days under LD. The delay for a 4–week SD period during intermediate development was 17 days. There were no significant effects on rate of development by SD initiated during late development in Musical.

Sensitivity of developmental rate to SD varied with cultivar in seed propagated tuberous begonia. Nonstop responded with delayed development even after 1 week of SD at any time during growth (Table 1). Increasing the length of SD from 1 to 2, 3, or 4 weeks did not appear to affect the amount of delay in Nonstop. SD for 1, 2, or 3 weeks resulted in 1 week and SD for 4 weeks in 2 weeks later flowering in Clips (Table 1). Independent of when the short photoperiod was initiated during development, there were no significant delay in Musical following 1 SD week (Table 2). Musical plants responded with slowed development especially after 3 or 4 weeks of SD during early or intermediate development. Plants of any cultivar kept under SD throughout their development grew very slowly, having 3 or 4 leaves 100 days after germination.

There were no significant differences among plants from SD treatments within cultivars with respect to plant size characteristics. Musical plants were the largest plants and Nonstop the smallest plants of the 3 cultivars. Musical had an average of 5 ± 0.1 shoots per plant, Clips 4 ± 0.4, and Nonstop 2 ± 0.2. Leaf and flower number on the main shoot were 12 ± 0.5 and 8 ± 0.9; 10 ± 0.4 and 4 ± 0.6; and 8 ± 0.1 and 3 ± 0.1 for Musical, Clips and Nonstop respectively. Total average leaf area per plant for Musical, Clips and Nonstop were 836 ± 55 cm^2, 659 ± 73 cm^2 and 485 ± 56 cm^2 respectively. The calculated average leaf size for the whole plant was

largest in Nonstop with 45 cm^2 followed by 27 cm^2 for Clips and 23 cm^2 for Musical. Plant height at the termination of the experiment was different among cultivars but not within cultivars. The average plant height was 19 ± 0.5 cm for Musical, 15 ± 1.1 cm for Clips and 12 ± 0.4 cm for Nonstop.

Exposure to SD was expected to result in slowed growth and higher proportion of root dry weight (Peter, 1974; Fonteno and Larson, 1982; Oloomi and Payne, 1982; Fonteno and Larson, 1983; Djurhuus, 1985; Ewart, 1985; Tonecki, 1986). Though shoot weight responded to SD, there were no significant differences in root dry weight among plants in different SD treatments. Musical plants had an average root dry weight of 2.7 ± 0.31 gram, Clips plants 2.7 ± 0.12 gram and Nonstop 2.3 ± 0.12 gram root dry weight per plant. Total plant dry weight among plants varied correspondingly among cultivars such that the percentage root dry weight in a plant was close to 50% for all 3 cultivars.

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