Photoperiod and Temperature Affect Flowering in German Primrose

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SUMMARY. The potential photoperiodic effects and interactions with temperature were identified for flowering of german primrose (*Primula obconica*). The german primrose 'Libre Light Salmon' was grown at long days (LD, 16 hours) or short days (SD, 8 hours) and 61 or 68 °F (16 or 20 °C). Visible bud (VB, 2-mm flower buds) averaged 90 days from seeding for plants grown at 61 °F independent of photoperiod or at 68 °F under LD. At 68 °F and SD, VB was delayed and flowering (horizontal petals) had not been observed at termination of the study (146 days from seeding). Flowering averaged 111 days at LD and 68 °F, 122 days at LD and 61 °F, and 133 days at SD and 61 °F. When plants within each temperature were shifted at weekly intervals from one photoperiod to the other, increasing duration of initial SD resulted in slower VB and at 68 °F more than 8 weeks resulted in no flowering. Changing to SD from initial LD did not affect VB or flowering at either 61 °F or 68 °F. These results suggest flowering of german primrose is faster under LD than SD at the recommended production temperatures of 65 to 68 °F (18 to 20 °C).

The german primrose has soft pastel colored flowers in shades of white, pink, orange, purple or lilac and is attractive as a flowering potted plant or in color bowls. Unfortunately, the allergen primin present in the leaves may cause skin rash and dermatitis (Armitage, 1986; Nau, 1999; Perry, 1981). The recently

developed primin-free cultivars have reduced the risk for skin rash and renewed the interest in german primrose.

Since german primrose has been considered day neutral, no specific photoperiodic requirement is suggested to promote flowering (Hartnett, 1993; Karlsson, 1997, 2001). A light integral of at least 10 mol·m⁻²·d⁻¹ may shorten the production time although during the summer, shading is required to control temperature and avoid burning of the foliage. The recommended production temperature is 65 to 68 °F (Armitage, 1986; Hartnett, 1993; Karlsson, 1997). There is no evidence to suggest that a temperature reduction promotes german primrose flower formation as occurs with english primrose (*Primula vulgaris*) and polyanthus (*Primula × polyantha*) (Hartnett, 1993; Karlsson, 2001; Linwick, 1992; 1996; Mureaoka, 2000; Perry, 1981; Salamati, 1988; Wandås, 1991). Dropping the temperature to 65 °F or lower during the final development of german primrose improves plant quality, flower color and size (Hartnett, 1993; Karlsson, 2001). This study was initiated to identify potential photoperiodic effects and temperature interactions for flowering of german primrose.

Materials and methods

The primin-free 'Libre Light Salmon' (Goldsmith Seeds, Inc., Gilroy, Calif.) was selected for the study. Seeds were germinated at 68 °F, 16 h photoperiod and about 5.8 mol·m⁻²·d⁻¹ (100 ± 20 μmol·m⁻²·s⁻¹) in a growth chamber (Conviron, Controlled Environments, Pembina, N. Dak.). The seedlings were transplanted into 4-inch (10-cm) pots filled with Premier Pro-Mix BX (Premier Horticulture, Premier Brands, Red Hill, Pa.) 28 d from seeding. After transplanting, plants were placed in a polycarbonate covered greenhouse maintained at 68 ± 4 °F (20 ± 2 °C). High-pressure sodium (HPS) lamps provided irradiance for 16 h at 10 mol·m⁻²·d⁻¹ (about 175 ± 20 μmol·m⁻²·s⁻¹). The plants were watered with fertilizer solutions of 50 ppm (mg·L⁻¹) nitrogen from the cotyledon stage and 100 ppm (mg·L⁻¹) nitrogen from transplanting using Peters' 15-16-17 (15N-7P-14.1K; The Scotts Co., Marysville, Ohio).

Three weeks after transplanting (51 d from seeding), 400 plants with five to six expanded leaves were selected. The

plants were grown in two greenhouse sections of similar size and dimensions at 61 ± 4 °F or 68 ± 4 °F. The photoperiod was 8 h (short days, SD) or 16 h (long days, LD). Black cloth was manually pulled at 1600 HR and retracted at 0800 HR for SD treatments. Electric fans provided adequate air circulation to maintain the temperature consistent with the greenhouse environment without compromising the photoperiodic growing area. HPS lamps were turned on at 0800 HR and off at midnight except over SD benches where they were turned off at 1600 HR. Irradiance was about 10 mol·m⁻²·d⁻¹ with 175 ± 20 μmol·m⁻²·s⁻¹ for 16 h or 350 ± 20 μmol·m⁻²·s⁻¹ for 8 h. The natural day length from sunrise to sunset during the study (early November through February) varied from 3 h 43 min to 10 h 1 min (lat. 64°49'N). At the time the plants were placed in the greenhouse the natural day length was 7 h 36 min, at initiation of treatments 5 h 8 min, and at termination 10 h 1 min. The influence of natural light was due to the short duration and very low sun angle, limited during the experiment.

Ten plants were randomly assigned to each of the 40 treatments and placed at SD or LD. Within each temperature, plants in treatments were moved to the second photoperiod at weekly intervals for 9 weeks and left until termination as illustrated in Fig. 1. The treatments were arranged in a split plot design with temperature as the main plot and photoperiod as subplots. The study was terminated 146 d from seeding. Time to visible bud (VB, 2-mm flower bud) and flowering (first horizontal petals) was recorded for each plant. Data were analyzed using analysis of variance (ANOVA), single degree of freedom polynomial and LSD tests (SPSS, 1999). Rates of development are reported from start of treatments (51 d from seeding).

Results and discussion

Results of ANOVA indicated temperature ($P \leq 0.05$) and photoperiod ($P \leq 0.001$) to significantly affect VB and flowering. The interaction between temperature and photoperiod was also significant ($P \leq 0.001$) for the time required to VB and flower. Plants grown continuously under LD had similar VB at the two temperatures averaging 37 d at 61 °F and 39 d at 68 °F (Table 1). Flowering at LD was however, significantly faster (11 d) at the higher temperature. Continuous SD at 68 °F slowed VB and flowering was not observed for

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Fig. 1. Treatment combinations included in the study. The illustrated treatments were maintained at 61 °F (16 °C) and repeated at 68 °F (20 °C) for a total of 40 treatments. Plants were placed at short day (SD, 8 h) or long day (LD, 16 h), moved to the second photoperiod at weekly intervals for 9 weeks and left until termination (146 d from seeding). Open portions of the bars illustrate LD and the crosshatched portions SD. The speckled segments of the bars illustrate the 4 weeks between seeding and transplanting and the shaded segments the 23 d between transplanting and initiation of treatments.

these plants at the time of termination. At 61 °F, the average difference in flowering was 11 d between LD and SD.

A change in photoperiod during the experiment did not significantly affect VB or flowering at 61 °F (Fig. 2A). Time to VB averaged 41 d at 61 °F. In addition, VB was not statistically different for plants kept at 61 °F or those moved from LD to SD at 68 °F (Fig. 2B). As the duration of SD increased, VB was delayed at 68 °F from 44 d with 2 or 3 weeks of SD to 52 d with more than 8 weeks of SD. Polynomial analysis showed linear and quadratic effects of SD exposure on time to VB at 68 °F. One, 2 or 3 initial weeks of SD at 68 °F did not slow flower initiation as plants

grown at 61 °F or those shifted to LD at 68 °F had similar VB.

There was a trend for later flower-

ing with increasing duration of SD at 61 °F (Fig. 2A). However, differences in flowering among plants moved from SD to LD or from LD to SD were not significant. Average time to flower at 61 °F was 74 d for plants starting at LD and 77 d for plants starting at SD. At 68 °F, shifting plants from LD to SD did not affect flowering compared to continuous LD (Fig. 2B). Flowering averaged 58 d at 68 °F and initial or continuous LD. Increasing duration of SD delayed flowering and with more than 8 weeks of SD, the initiated buds failed to develop into flowers within the 95 d of the experiment. Polynomial tests showed significant linear and cubic effects on flowering at 68 °F with increasing exposure from 1 to 8 weeks of SD.

The plants in this study may have perceived the stimulus for flower initiation before the onset of experimental conditions. Flower initiation has been suggested to occur at six to ten leaves in english primrose (Erickson, 1986). Recent studies however, failed to establish a requirement or correlation between plant size and flower formation of english primrose (Karlsson, 1997, 2001; Salamati, 1988; Welander and Selander, 1981). It is not known if a specific morphological plant size is required before flowers are initiated in german primrose.

During flower initiation or the differentiation of flower parts, depending on stage of development at start of this experiment, continuous SD at 68 °F was not a supportive environment for flowering of the german primrose 'Libre' (Fig. 2B). More than 3 weeks of SD delayed VB compared to other environments and flowering was progressively slower with additional weeks of SD beyond VB. On the other hand, 1 or more weeks of LD in addition to the LD conditions before the study, limited the negative effect of SD on flowering at 68 °F.

Flower development after VB was

Table 1. Days from start of treatments to visible bud (VB, 2-mm flower buds) and flower (first horizontal petals) for german primrose 'Libre'. Treatments were initiated 51 d from seeding and maintained until termination 95 d later. Growing conditions were 68 °F (20 °C) and 16 h photoperiod before treatments. Daily light integral was 10 mol·m⁻²·d⁻¹.

Photoperiod (h)	Temp (d)	VB ^a (°F/°C)	Flower ^a (d)
8	61/16	42.1 a	82.2 c
8	68/20	52.0 b	---
16	61/16	37.1 a	71.2 b
16	68/20	39.0 a	59.7 a

^aMeans within columns followed by different letters are significantly different at LSD $P < 0.001$ ($n = 10$).

^bNo flowers by termination of the study.

Fig. 2. Days from start of treatments (51 d from seeding) to flower bud (VB, 2-mm flower buds) and flowering (first horizontal petals) in German primrose 'Libre' at A) 61 °F (16 °C) and B) 68 °F (20 °C). Plants were moved from short day (SD, 8 h) to long day (LD, 16 h) or from LD to SD and left until termination. Daily light integral was 10 mol·m⁻²·d⁻¹. Data points marked continuous represent treatments that were not moved. Open symbols illustrate time to VB and filled symbols time to flowering. NS, ***, **** Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively; L = linear, Q = quadratic, C = cubic.

more responsive to temperature than flower bud appearance. Under LD, flowering was 11 d faster at 68 °F compared to 61 °F, even though flower initiation and the appearance of flower buds occurred in a similar number of days (Table 1). Up to 7 weeks of SD did not delay flowering at 68 °F compared to 61 °F although more than 8 weeks of SD produced no flowers (Fig. 2). Interactions and variations in photoperiodic response have been noted in other plants with changes in production temperatures. For instance, holiday cactus (*Schlumbergera* sp.) is day neutral at temperatures of 55 °F (13 °C) or lower but at higher temperatures flowering is only induced under SD (Dole and Wilkins, 1999). Similarly German prim-

rose based on the results presented here, appears to be day neutral with respect to flower bud appearance at 61 °F but a long day plant at 68 °F.

The photoperiodic response may vary between flower initiation and subsequent development of initiated buds. The critical day length is shorter for flower bud development than initiation in chrysanthemum (*Dendranthema grandiflorum*) (Vince-Prue, 1994). In this study, days to VB at 61 °F were similar regardless of photoperiod although flowering was faster (11 d) under LD than SD (Table 1). At 68 °F, VB and flowering were faster at LD. Additional studies are required to determine flower response to photoperiod at growing temperatures other than 61 or 68

°F. At higher than 68 °F, flower initiation may not occur under any photoperiod as has been found for holiday cactus at 70 to 75 °F (21 to 24 °C) (Dole and Wilkins, 1999).

Growing conditions with LD were most suitable for German primrose in this study. The flowering response to photoperiod and temperature could alter with a daily light integral other than 10 mol·m⁻²·d⁻¹. Low light during a longer day may more efficiently support flower formation in German primrose than a similar daily light integral during a shorter day.

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