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Photoperiodic Response and Vase Life of Ornamental Sunflower Cultivars

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ADDITIONAL INDEX WORDS. **daylength, *Helianthus annuus*, photoperiod, postharvest**

SUMMARY. **Photoperiodic response and vase life of 28 cultivars of ornamental sunflower (*Helianthus annuus*) were evaluated. Plants were grown in a glasshouse under 16-hour long-day (LD) or 11.5-hour short-day (SD) conditions. Most cultivars (82%) reached visible flower bud stage earlier under SD than LD. All cultivars flowered under both SD and LD conditions, but in 26 cultivars (92.9%) flowering was significantly delayed under LD, demonstrating them to be quantitative SD plants. The delay was variable among the cultivars. A 14-day or greater hastening of flowering was found under SD in 18 cultivars. Photoperiod had no effect on flowering of 'Lemon Eclair' and 'Moonshadow'; these cultivars are day-neutral (DN) plants. For some cultivars the LD photoperiod increased plant height and the number of nodes and leaves. Vase life varied from 6.8 to 11.2 days depending on the cultivar, but no photoperiodic effect was found.**

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The popularity of sunflower as an ornamental crop has increased dramatically worldwide in the last decade (Blacquière et al., 2002; Hayata and Imaizumi, 2000). Historically, sunflower was first used as a garden plant, then as a flowering potted plant, and more recently as a cut flower. Development of new cultivars has provided a wide range of flower colors and plant forms to meet the needs of the flower industry. However, further knowledge is needed about how to control flowering of the new sunflower cultivars and to facilitate crop scheduling and space planning by flower growers. Photoperiod has been shown to affect sunflower flowering, but there seems to be more than one type of photoperiodic response. Some authors have classified sunflower as a short-day (SD) plant, but others have classified it as a day-neutral (DN) plant (Schuster, 1985; Thomas and Vince-Prue, 1997). There is also some evidence for differences in photoperiodic response among sunflower cultivars (Hayata and Imaizumi, 2000; Pallez et al., 2002; Robinson et al., 1967). This study was conducted to evaluate the photoperiodic response and vase life of various cultivars of ornamental sunflower.

Materials and methods

Glasshouse experiments were conducted in Shizuoka, Japan (lat. 34°58′N, long. 138°24′E). The venting set point was at 22 °C (71.6 °F). Temperature during the experimental period was recorded with a thermo-recorder (Hybrid recorder model 3081; Yokogawa Hokushin Electric, Tokyo), and average temperatures are shown in Fig. 1. Seeds from 28 sunflower cultivars were directly sown in commercial granulated compost (Kureha, Japanese Agricultural Corp. JA, Shizuoka, Japan) in 15-cm-diameter (5.9 inches) plastic pots on 17 July 2002. Four seeds were sown in each pot. Seedlings were thinned after emergence to two uniform plants per pot, and then at the visible flower bud stage to only one plant per pot. At sowing, a slow-release fertilizer 14N–5.2P–11.6K (Long 70; Asahi Chemical Corp., Fuji, Japan)

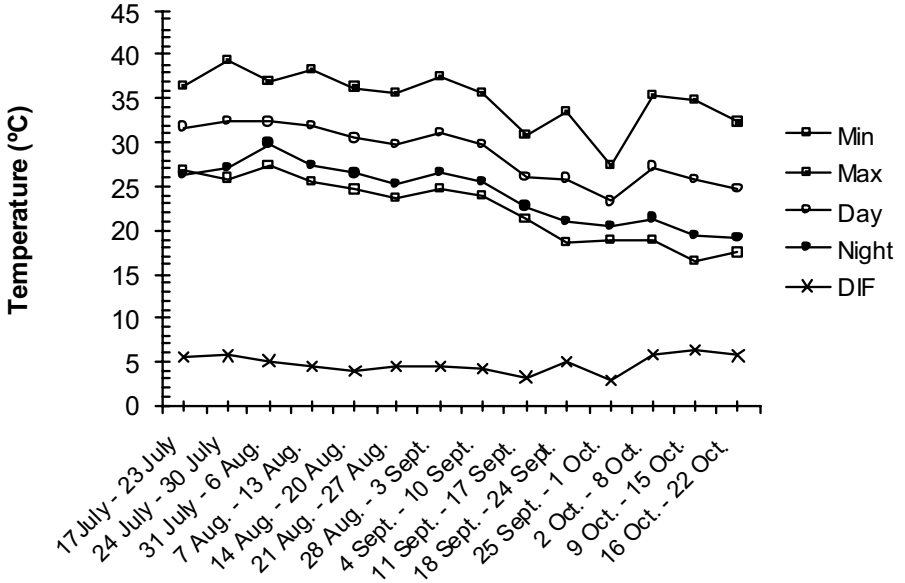

Fig. 1. Glasshouse weekly average minimum (Min), maximum (Max), day (Day), and night (Night) temperatures (°C), and the difference between day and night temperatures (DIF) during the experimental period from 17 July to 21 Oct. 2002. °F = 1.8 (°C) + 32.

was surface-applied at 5 g/pot (0.18 oz/pot). During the growing period, a 200 mg·L^{-1} (ppm) nitrogen fertilizer solution using a 20N–17.5P–25K fertilizer (Hyponex; Hyponex Japan Inc., Osaka, Japan) was applied weekly. Plants were watered as required.

Photoperiod. Plants were grown under a 16-h LD or an 11.5-h SD. The LD treatment was achieved by natural daylength plus night interruption (NI) provided by 75-W incandescent lamps at 1 to 4 μmol·m^{-2}·s^{-1}, as measured at pot level with a LI-COR quantum sensor (model LI-190 SB; LI-COR, Lincoln, Nebr.). For the SD treatment an opaque cover was automatically closed at 1700 HR and opened at 0530 HR every day. Six pots of each cultivar were grown under each photoperiod treatment.

Vase life. When the ray flowers opened to approximately 45°, flower stems were harvested before 1000 HR, and immediately placed into water. After the various measurements, stems were recut to 75 cm (29.5 inches) or as long as possible [in only three cultivars, minimum length was 45 cm (17.7 inches)]. All of the leaves, except on the upper 15 cm of each stem, were also removed. Stems were placed in a beaker with 500 mL (16.9 fl oz) of distilled water (pH 6.45) and held in a controlled-environment room at 20 ± 2 °C (68.0 ± 3.6 °F) under continuous light provided by cool white fluorescent tubes at 10–14 μmol·m^{-2}·s^{-1} at bench level. The holding water was replaced every other day. The end of vase life was defined as the time when 50% or more of the ray flowers became wilted or abscised.

Data collection and analysis. Dates of visible flower bud (VFB) and of flowering were recorded. At VFB, plant height was measured. At flowering, plant height, stem diameter halfway up the stem, and floral head diameter (from tip to tip of ray flowers) were measured. The number of leaves and nodes below the main flower head were also counted. Six single plant replicates were used and arranged in a completely randomized design. All data were subjected to analysis of variance using the one-way analysis of variance (ANOVA) procedure of the Statgraphics Plus software (Manugistics Inc., Rockville, Md.); least significant difference (LSD) test was also conducted.

Results and discussion

Photoperiodic responses. In 23 cultivars (82%), VFB occurred earlier under the SD condition than the LD condition (Table 1). The differences in days to VFB between the SD and LD treatments ranged from 0.5 to 27.5 d. Similarly, there were fewer days between VFB and flowering under SD than LD in 26 cultivars (92.9%). Only in 'Pacino' and 'Moon Shadow' were the days between VFB and flowering

Table 1. Effect of photoperiod on days to visible flower bud (VFB), days from VFB to flowering, and days to flowering (total period from sowing to flowering) in 28 cultivars of ornamental sunflower grown under 11.5-h short-day (SD) or 16-h long-day (LD) conditions.

	Days to VFB			Days from VFB to flowering			Days to flowering		
Cultivar	SD	LD	Significance	SD	LD	Significance	SD	LD	Significance
Big Smile	22.3	31.0	**	16.7	30.8	**	39.0	61.8	**
Claret	26.3	36.5	*	20.2	30.3	*	46.5	66.8	**
Cocoa	25.3	41.0	**	18.2	25.5	*	43.5	66.5	**
Double Shine	30.3	48.5	**	22.0	40.8	**	52.3	89.3	**
F_1 Premier Light Yellow[z]	22.3	31.8	**	15.7	25.5	**	38.0	57.3	**
Floristan	26.5	31.0	**	19.3	27.8	**	45.8	58.8	**
Full Sun	27.0	38.3	**	23.8	30.7	**	50.8	69.0	**
Hikari	26.3	39.8	**	26.0	37.5	**	52.3	77.3	**
Kagayaki	25.3	38.8	**	25.7	34.7	**	51.0	73.5	**
Kirameki	24.8	39.3	**	20.7	31.5	**	45.5	70.8	**
Lemon Eclair	25.0	26.0	NS	19.0	23.3	*	44.0	49.3	NS
Monet's Sunflower	22.8	34.5	**	17.2	29.8	**	40.0	64.3	**
Moon Light	23.3	50.8	**	16.2	37.2	**	39.5	88.0	**
Moonshadow	28.5	23.3	NS	20.5	23.5	NS	49.0	46.8	NS
Moulin Rouge	24.5	28.3	**	16.8	21.8	**	41.3	50.0	*
Munchkin	35.3	34.6	NS	19.3	23.9	**	54.6	58.5	**
Nozomi	25.5	38.8	**	20.3	27.7	**	45.8	66.5	**
Pacino	25.5	29.3	**	20.0	23.0	NS	45.5	52.3	**
Prado Red	25.3	25.8	NS	19.0	24.7	**	44.3	50.5	**
Ruby Eclipse	26.3	27.0	NS	17.0	28.8	**	43.3	55.8	**
Sonja	23.0	26.8	*	21.3	28.0	**	44.3	54.8	**
Soraya	25.3	34.3	**	21.5	42.2	**	46.8	76.5	**
Sunbeam	26.5	44.3	**	24.3	33.0	**	50.8	77.3	**
Sunrich Lemon	25.8	35.3	**	20.0	28.7	**	45.8	64.0	**
Sunrich Orange	26.0	32.8	**	18.8	25.9	**	44.8	58.7	**
Taiyo	25.2	39.0	**	25.1	40.0	**	50.3	79.0	**
Tiffany	26.3	33.5	**	21.5	29.5	**	47.8	63.0	**
Valentine	23.8	32.5	**	16.5	34.0	**	40.3	66.5	**

[z]This cultivar is marketed by Takii & Co. Ltd. (Kyoto, Japan) as 'F_1 Summer Sunrich Pine 45' in Japan
NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

similar in both treatments. In 'Soraya', 'Big Smile', and 'Ruby Eclipse', the delay under LD was more from VFB to flowering than from sowing to VFB. Other environmental factors, such as temperature, could affect the response of these cultivars. Interactions between photoperiod and temperature have been described in various plant species (Thomas and Vince-Prue, 1997).

All cultivars flowered under both SD and LD conditions. However, flowering of 26 cultivars (92.9%) was delayed when grown under LD (Table 1). Therefore, these cultivars are considered to be quantitative SD plants. In 18 of these cultivars, the delay was especially long, more than 14 d (2 weeks). In contrast, there was no effect of photoperiod on days to VFB or days to flowering in 'Lemon Eclair' and 'Moonshadow'. Therefore, these two cultivars are DN plants.

Photoperiodism is a complex phenomenon, but is clearly an important component of the interaction between plants and their environment (Thomas and Vince-Prue, 1997). The native habitat of sunflower extends throughout the U.S., and includes southern Canada and northern Mexico (Liberty Hyde Bailey Hortorium, 1976). Roberts and Summerfield (1987) have stated that, although the environmental conditions in the native habitat of sunflower are more variable than in the case of other SD plants, the sunflower SD response is the result of adaptation to this environment. The other photoperiodic responses found in sunflower seem to be the products of selection for special agricultural purposes.

The response levels were variable among the cultivars showing a SD response. Varietal differences in quantitative response to SD treatments were also reported by Robinson et al. (1967) for agricultural cultivars of sunflower. From a practical horticultural point of view, the response level is more important than the response type. For example, from the results of this study, a photoperiodic management program to accelerate flowering could be designed for cultivars showing a strong quantitative SD reaction.

At VFB, 19 cultivars (67.9%) were shorter when grown under SD than under LD; however, for some of these cultivars this height difference disappeared by the time of flowering (Table 2). Interestingly, all cultivars whose flowering was delayed less than 2 weeks under LD compared with SD showed little or no effect of photoperiod on height or number of nodes and leaves. At flowering, 15 cultivars (53.6%) showed similar plant height in both treatments and 13 cultivars (46.4%) were taller under LD (Table 2). The number of nodes was similar between the two treatments for 13 cultivars and higher under LD for 12 cultivars. The number of leaves

Table 2. Effect of photoperiod on plant height at visible flower bud (VFB) and on plant height and number of nodes and leaves at flowering in 28 cultivars of ornamental sunflower grown under 11.5-h short-day (SD) or 16-h long-day (LD) conditions.

	Plant ht at VFB (cm)[z]			Plant ht at flowering (cm)			No. of nodes			No. of leaves		
Cultivar	SD	LD	Sig.[y]	SD	LD	Sig.	SD	LD	Sig.	SD	LD	Sig.
Big Smile	15.8	17.7	NS	48.0	48.1	NS	15	23	**	23	33	**
Claret	46.0	90.6	**	136.0	161.3	*	24	27	NS	33	31	NS
Cocoa	34.8	82.1	**	98.9	154.4	**	20	25	NS	24	29	NS
F_1 Premier L.Yellow	27.6	51.7	**	83.1	102.2	NS	18	19	NS	24	24	NS
Double Shine	44.5	80.4	**	109.5	122.9	NS	26	32	*	34	36	NS
Floristan	38.1	46.8	NS	83.8	91.1	NS	18	17	NS	23	23	NS
Full Sun	54.0	107.3	**	144.1	192.7	**	27	29	NS	31	33	NS
Hikari	46.1	99.2	**	148.0	174.3	**	24	29	*	29	32	NS
Kagayaki	41.4	99.3	**	140.6	172.1	*	23	27	*	27	32	**
Kirameki	41.8	88.8	**	129.5	159.9	**	23	31	**	29	34	*
Lemon Eclair	38.2	46.9	*	101.6	94.7	NS	19	18	NS	27	23	NS
Monet's Sunflower	26.2	46.2	**	69.8	99.3	*	17	24	*	26	30	*
Moon Light	34.0	104.9	**	100.0	141.8	*	18	25	**	21	30	**
Moonshadow	33.0	37.9	NS	101.2	102.3	NS	19	15	NS	24	19	NS
Moulin Rouge	43.1	65.0	NS	119.5	142.6	NS	23	19	*	26	25	NS
Munchkin	22.5	20.7	NS	49.0	48.0	NS	25	21	*	30	27	**
Nozomi	38.8	87.5	**	128.1	171.5	**	23	28	**	27	31	*
Pacino	13.2	18.4	**	49.9	48.1	NS	24	23	NS	28	28	NS
Prado Red	44.6	44.4	NS	115.6	117.6	NS	23	16	*	25	22	NS
Ruby Eclipse	48.8	57.0	NS	121.6	126.2	NS	21	19	NS	24	23	NS
Sonja	20.4	25.5	NS	83.2	79.3	NS	12	15	NS	24	23	NS
Soraya	22.0	30.5	NS	90.4	114.2	NS	15	20	*	21	23	NS
Sunbeam	40.8	96.1	**	120.5	144.8	*	24	29	*	28	32	*
Sunrich Lemon	44.6	70.5	**	120.4	111.6	NS	25	23	NS	31	29	NS
Sunrich Orange	41.0	72.8	**	114.4	121.0	NS	22	26	NS	29	30	NS
Taiyo	43.2	92.6	**	141.5	157.5	*	21	26	**	25	30	**
Tiffany	44.2	77.7	**	129.4	159.1	*	25	29	**	30	32	NS
Valentine	34.5	55.3	**	93.5	124.8	*	19	22	NS	23	27	NS

[z]1.0 cm = 0.39 inch.
[y]Significance.
NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Effect of photoperiod on flower and stem diameter in 28 cultivars of ornamental sunflower grown under 11.5-h short-day (SD) or 16-h long-day (LD) conditions.

Cultivar	Flower diam (cm)[z]			Stem diam (cm)		
	SD	LD	Sig.[y]	SD	LD	Sig.
Big Smile	8.1	8.5	NS	0.94	0.82	**
Claret	12.0	10.2	NS	1.06	1.06	NS
Cocoa	8.6	8.2	NS	0.82	0.80	NS
Double Shine	11.7	10.9	NS	1.10	1.00	*
F_1 Premier L.Yellow	7.3	8.1	NS	0.94	0.74	NS
Floristan	8.5	7.1	NS	0.98	0.73	**
Full Sun	13.4	12.9	NS	1.09	1.10	NS
Hikari	13.1	12.2	NS	1.11	0.89	NS
Kagayaki	12.6	11.1	NS	1.14	0.98	*
Kirameki	11.5	10.2	NS	1.10	0.93	*
Lemon Eclair	10.2	8.0	*	0.94	0.89	NS
Monet's Sunflower	8.6	8.6	NS	0.80	0.74	NS
Moon Light	9.4	8.4	NS	1.06	0.70	*
Moonshadow	9.5	9.4	NS	0.98	0.83	NS
Moulin Rouge	10.9	9.4	NS	0.92	0.97	NS
Munchkin	10.1	8.6	**	0.80	0.74	NS
Nozomi	13.8	11.1	*	1.10	0.96	NS
Pacino	10.7	8.2	*	0.73	0.65	NS
Prado Red	11.7	8.4	NS	0.82	0.82	NS
Ruby Eclipse	10.1	9.5	NS	0.92	0.87	NS
Sonja	7.6	5.4	NS	0.91	0.69	NS
Soraya	7.7	8.0	NS	0.91	0.77	*
Sunbeam	12.8	10.5	**	1.00	0.98	NS
Sunrich Lemon	10.5	7.7	NS	1.07	0.75	*
Sunrich Orange	11.7	8.7	*	0.96	0.76	NS
Taiyo	13.0	9.1	**	1.09	0.91	NS
Tiffany	13.5	12.8	NS	0.96	1.14	*
Valentine	7.8	8.3	NS	0.95	1.02	NS

[z]1.0 cm = 0.39 inch.
[y]Significance.
NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 4. Effect of photoperiod on vase life in 28 cultivars of ornamental sunflower grown under 11.5-h short-day (SD) or 16-h long-day (LD) conditions. Means ± standard deviation.

Cultivar	Vase life (d)		
	SD	LD	P^z
Big Smile	7.0 ± 0.6	6.5 ± 0.6	0.4680
Claret	8.3 ± 1.0	9.5 ± 2.4	0.3675
Cocoa	7.0 ± 0.8	7.5 ± 0.7	0.1778
Double Shine	9.8 ± 1.3	7.8 ± 1.3	0.0656
F_1 Premier Light Yellow	11.0 ± 0.8	10.0 ± 2.2	0.4197
Floristan	8.0 ± 0.6	7.8 ± 0.5	0.0972
Full Sun	7.8 ± 2.2	7.5 ± 1.9	0.8701
Hikari	10.5 ± 1.3	9.3 ± 4.6	0.6177
Kagayaki	10.0 ± 2.0	8.8 ± 1.3	0.3524
Kirameki	9.0 ± 1.4	11.8 ± 3.2	0.1671
Lemon Eclair	10.0 ± 0.8	9.0 ± 1.6	0.3153
Monet's Sunflower	10.5 ± 1.0	9.7 ± 4.6	0.7328
Moon Light	10.8 ± 1.0	11.5 ± 0.7	0.3911
Moonshadow	8.0 ± 0.8	6.8 ± 2.1	0.3026
Moulin Rouge	7.8 ± 0.5	7.0 ± 0.8	0.1682
Munchkin	11.0 ± 1.9	10.8 ± 1.5	0.7758
Nozomi	9.0 ± 0.8	8.5 ± 0.6	0.3559
Pacino	7.5 ± 1.0	7.8 ± 0.5	0.6704
Prado Red	7.5 ± 0.6	6.0 ± 1.4	0.1161
Ruby Eclipse	7.5 ± 0.6	8.3 ± 1.0	0.2283
Sonja	8.8 ± 1.0	6.8 ± 2.1	0.1289
Soraya	9.3 ± 1.5	7.3 ± 1.0	0.0656
Sunbeam	8.3 ± 1.0	10.0 ± 1.0	0.1087
Sunrich Lemon	9.0 ± 0.8	8.0 ± 1.2	0.2070
Sunrich Orange	7.8 ± 0.5	8.0 ± 0.8	0.6202
Taiyo	8.8 ± 0.5	9.5 ± 1.0	0.2283
Tiffany	9.5 ± 1.0	9.3 ± 1.0	0.7304
Valentine	10.0 ± 0.8	9.0 ± 0.8	0.1340

[z]Probability value obtained from the analysis of variance for vase life under the two photoperiodic treatments (SD and LD).

was similar in both treatments for 19 cultivars, and eight cultivars had more leaves under LD. Similar results, showing increases in plant height and number of nodes and leaves for some sunflower cultivars under LD conditions, have been reported previously (Blacquière et al., 2002; Pallez et al., 2002). In addition, an effect of photoperiod on stem elongation and the number of nodes has been described in many plant species. However, the incandescent lamps used for the LD treatment in this study could have had some additional effect on plant height. Specifically, incandescent lamps produce a high amount of far-red light, which itself promotes stem elongation (Runkle and Heins, 2002; Thomas and Vince-Prue, 1997).

Stem and flower diameters were similar between treatments in most cultivars (67.9% and 75%, respectively), but in some cultivars (28.6% and 25%, respectively) the diameters were larger in plants grown under SD conditions (Table 3). Hayata and Imaizumi (2000) reported that photoperiod has little or no effect on sunflower flower diameter. Blacquière et al. (2002), using the cultivars Sunrich Orange and Sunbright, found differences in flower diameter between SD and LD, but these differences gradually disappeared in successive cultivations from spring to summer. They associated the reduced flower diameter with a reduction in the number of disc and ray florets.

Vase life. Photoperiod had no effect on vase life of any of the cultivars (Table 4). Regardless of the photoperiodic treatment, the longest average vase life of cut sunflowers was observed for 'Moon Light' (11.2 d), and the shortest for 'Big Smile' and 'Prado Red' (6.8 d). Similar values were reported by Gast (1995) in an evaluation of cut sunflowers. She also stated that a postharvest life of at least 10 d is desirable in the wholesale fresh cut flower market. In our experiments only eight cultivars had an average vase life of 9.5 d or more. However, different results might be obtained with the use of flower preservative pulsing or preservatives in the holding water, which were not used in our study. Jones et al. (1993) demonstrated that pulsing with the nonionic detergent Triton X-100 (Union Carbide Chemicals & Plastics Technology Corp., Houston) at 0.01% or 0.02% resulted in increased sunflower vase life. Devecchi (2003) also reported that preservative solutions increased 'Sunrich Orange' vase life by 30% compared with deionized water alone. Therefore, the postharvest life of the cultivars evaluated in this study

would be expected to be improved by using these or other similar postharvest treatments.

In summary, only two cultivars behaved as DN plants. The others were shown to be quantitative SD plants. The delay in flowering under LD was also variable among the cultivars, and ranged from a few days to about 1 month. In some cultivars the LD photoperiod increased plant height and the number of nodes and leaves. Although the vase life of cut flowers varied from 6.8 to 11.2 d depending on the cultivar, no effect of photoperiod was found.

Literature cited

Blacquière, T., N. Straver, and D. van den Berg. 2002. Possibilities for using photoperiodism to program flowering of sunflowers (*Helianthus annuus*) in the greenhouse and in the open. Proc. 4th Intl. Symp. Artificial Light. Acta Hort. 580:101–109.

Devecchi, M. 2003. Post-harvest physiology of cut flowers of sunflowers (*Helianthus annuus*): First experimental results. 8th Intl. Symp. Postharvest Physiol. Ornamental Plants, The Netherlands, 10–14 Aug. 2003. (Abstr.)

Gast, K.L.B. 1995. Production and postharvest evaluation of fresh-cut sunflowers. Rpt. Prog. 751, Agr. Expt. Sta., Kansas State Univ., Manhattan.

Hayata, Y. and Y. Imaizumi. 2000. Effect of photoperiod on flower bud development of ornamental sunflowers (*Helianthus annuus* L.). J. Jpn. Soc. Hort. Sci. 69:708–710.

Jones, R.B., M. Serek, and M.S. Reid. 1993. Pulsing with Triton X-100 improves hydration and vase life of cut sunflowers (*Helianthus annuus* L.). HortScience 28:1178–1179.

Liberty Hyde Bailey Hortorium. 1976. Hortus third: A concise dictionary of plants cultivated in the United States and Canada. Macmillan, New York.

Pallez, L.C., J.M. Dole, and B.E. Whipker. 2002. Production and postproduction studies with potted sunflowers. HortTechnology 12:206–210.

Roberts, E.H. and R.J. Summerfield. 1987. Measurement and prediction of flowering in annual crops, p.17–50. In: J.G. Atherton (ed.). Manipulation of flowering. Butterworths, London.

Robinson, R.A., L.A. Bernat, H.A. Geise, F.K. Johnson, M.L. Kinman, E.L. Mader, P.M. Oswald, E.D. Putt, C.M. Swallers, and J.H. Williams. 1967. Sunflower development at latitudes ranging from 31 to 49 degrees. Crop Sci. 7:134–136.

Runkle, E.S. and R.D. Heins. 2002. Stem extension and subsequent flowering of seedlings grown under a film creating a far-red deficient environment. Scientia Hort. 96:257–265.

Schuster, W.H. 1985. *Helianthus annuus*, p. 98–121. In: A.H. Halevy (ed.). Handbook of flowering. Vol. 5. CRC Press, Boca Raton, Fla.

Thomas, B. and D. Vince-Prue. 1997. Photoperiodism in plants. 2nd ed. Academic, San Diego.