

# Temperature and Photoperiod Regulate Flowering of Potted *Miltoniopsis* Orchids

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**Abstract.** *Miltoniopsis* orchids have appealing potted-plant characteristics, including large, fragrant, and showy pansylike flowers that range from white and yellow to shades of red and purple. Scheduling orchid hybrids to flower on specific dates requires knowledge of how light and temperature regulate the flowering process. We performed experiments to determine whether a 9- or 16-h photoperiod [short day (SD) or long day (LD)] before vernalization and vernalization temperatures of 8, 11, 14, 17, 20, or 23 °C under SD or LD regulate flowering of potted *Miltoniopsis* orchids. Flowering of *Miltoniopsis* Augres ‘Trinity’ was promoted most when plants were exposed to SD and then vernalized at 11 or 14 °C. Additional experiments were performed to determine how durations of prevernalization SD and vernalization at 14 °C influenced flowering of *Miltoniopsis* Augres ‘Trinity’ and Eastern Bay ‘Russian’. Plants were placed under SD or LD at 20 °C for 0, 4, 8, 12, or 16 weeks and then transferred to 14 °C under SD for 8 weeks. Another set of plants was placed under SD or LD at 20 °C for 8 weeks and then transferred to 14 °C with SD for 0, 3, 6, 9, or 12 weeks. After treatments, plants were grown in a common environment at 20 °C with LD. Flowering of *Miltoniopsis* Augres ‘Trinity’ was most complete and uniform (≥90%) when plants were exposed to SD for 4 or 8 weeks before 8 weeks of vernalization at 14 °C. Flowering percentage of *Miltoniopsis* Eastern Bay ‘Russian’ was ≥80 regardless of prevernalization photoperiod or duration. This information could be used by greenhouse growers and orchid hobbyists to more reliably induce flowering of potted *Miltoniopsis* orchids.

Flowering potted orchids have become one of the largest segments of floriculture worldwide. In the United States, orchids are the second most valuable flowering potted crop, with a reported wholesale value of \$128 million in 2004 (U.S. Department of Agriculture, 2005). It is estimated that 85% to 90% of all orchids sold in the United States are *Phalaenopsis*, or the moth orchid (Nash, 2003). As the commercial market becomes saturated with *Phalaenopsis* because of the widespread knowledge of its flower-induction requirements, the sales price will likely decrease and it may become a commodity. Consequently, commercial growers and retailers are seeking other potted flowering orchids that have consumer appeal and can be programmed to flower for specific markets dates.

*Miltoniopsis*, or the pansy orchid, produces inflorescences with three to seven flat and large (7 to 8 cm), fragrant and showy flowers, which range from white and yellow to shades of red and purple. The flowers can last on the plant

for 4 to 8 weeks at 14 to 20 °C (Baker and Baker, 1993; Robinson, 2002).

In its native habitat, *Miltoniopsis* is an epiphytic and lithophytic genus of six species distributed from humid lowlands to relatively cool and wet cloud forest regions (50 to 2,100 m) of Colombia, Costa Rica, Ecuador, Panama, Peru, and Venezuela (Baker and Baker, 1993; Morrison, 2000; Lopez and Runkle, 2005). The day temperature in their native forest canopies rarely exceeds 27 °C, and the night temperature may drop to 10 °C or lower (Sweet, 1978). The sympodial growth habit of this compact plant is distinguished from *Miltonia* by the presence of a single leaf at the apex of the pseudobulb, which is surrounded by distinct leaflike sheaths. Several outstanding *Miltoniopsis* hybrids have been developed in recent years and are primarily grown by orchid hobbyists.

*Miltoniopsis* has become the fourth most valuable potted orchid produced commercially in the Netherlands, with 797,000 pots sold in 2001 (Barendse, 2002). The demand for *Miltoniopsis* orchids in the United States is greatest during December and February for the Christmas and Valentine’s Day holidays. In an online survey of potted orchid buyers in the midwestern U.S., participants between the ages of 20 and 62 years selected *Miltoniopsis* as their most preferred species among *Brassia*, *Degarmoara*, and *Phalaenopsis* (Behe et al., 2003). Participants had the highest average purchase intention (5.5) on a scale of 1 to 7 (1 = very unlikely and 7 = very likely to purchase) for *Miltoniopsis* in a green plastic pot for \$19.95. *Miltoniopsis* in a bamboo pot for \$29.95 (5.0)

and *Phalaenopsis* in a black ceramic pot for \$19.95 (5.0) were the second and third most popular choices, respectively.

To our knowledge, only published research exists on environmental control of flowering of hybrids in the genus *Miltonia*, and preliminary data exists for *Miltoniopsis*. Matsui and Yoneda (1997) reported that growth and flowering of *Miltonia* cultivars were accelerated by artificially chilling plants at 15 °C under a 16-h photoperiod for 40 d in growth chambers. Preliminary results reported by Lopez et al. (2005) suggest that flowering of *Miltoniopsis* Augres ‘Trinity’ is promoted by cool temperatures, short photoperiods, or a combination of both.

To validate preliminary studies with *Miltoniopsis* Augres ‘Trinity’ (Lopez et al., 2005; Robinson, 2002), we performed experiments to determine how photoperiod and temperature influence flowering of two vegetatively propagated hybrids of *Miltoniopsis*. Our objectives were to determine 1) whether photoperiod before cooling at a range of temperatures enhances a vernalization response and 2) how durations of SD before vernalization and vernalization influence flowering of *Miltoniopsis* Augres ‘Trinity’ and Eastern Bay ‘Russian’.

## Materials and Methods

**Plant material.** Plants of the vegetatively propagated ‘Trinity’ clone of the hybrid *Miltoniopsis* Augres (*Miltonia* Pam-pam × *Miltonia* Alger) were transplanted into 8- and 10-cm pots with a medium containing 80% fine-grade douglas fir bark and 20% medium-grade perlite (by volume) on 1 June 2001 and 22 May 2002 in a commercial greenhouse (Nurserymen’s Exchange, Inc., Half Moon Bay, Calif.), respectively. Plants of the ‘Russian’ clone of the hybrid *Miltoniopsis* Eastern Bay (*Miltonia* Andy Easton × *Miltonia* Le Nez Point) were transplanted directly into 10-cm pots on 16 June 2003. Plants were grown at about 25/14 °C day/night under natural photoperiods (lat. 37°N) with an average photosynthetic photon flux (PPF) of 160 to 240 μmol·m<sup>-2</sup>·s<sup>-1</sup>. Three hundred fifty of these ‘Trinity’ and ‘Russian’ plants were received in East Lansing, Mich., on 22 July 2002 and 22 Sept. 2003, respectively, and were subsequently grown in a glass-glazed greenhouse at a constant temperature of ≈20 to 23 °C until experiments began. The photoperiod was a constant 16 h (0600 to 2200 HR), consisting of natural daylengths (lat. 42°N), with day-extension lighting from high-pressure sodium (HPS) lamps that delivered a supplemental PPF of ≈50 μmol·m<sup>-2</sup>·s<sup>-1</sup> at plant height [long day (LD) HPS]. Light transmission through the greenhouses was reduced by using a permanent woven shade curtain that reduced light by about 55% (OLS 50; Ludvig Svensson, Charlotte, N.C.) and by applying whitewash to the glass so that the maximum PPF was 300 μmol·m<sup>-2</sup>·s<sup>-1</sup>.

**Prevernalization photoperiod and vernalization experiment (Expt. 1).** The experiment was replicated in time, and experimental treatments were identical between years unless otherwise noted. Two hundred plants of

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Table 1. Average daily temperature and light integral during prevernalization, vernalization, and forcing of *Miltoniopsis* Augres 'Trinity' and *Miltoniopsis* Eastern Bay 'Russian' (Expts. 2 and 3).

Experiment	Year	Prevernalization duration (weeks)	Vernalization duration (weeks)	Set point temp (°C)			Avg daily light integral (mol·m <sup>-2</sup> ·d <sup>-1</sup> )			
				Avg temp (°C)			Prevernalization	Vernalization	Forcing	
				Prevernalization	Vernalization	Forcing				
2	1	0	8	NU <sup>z</sup>	13.8	21.0	NU	ND <sup>y</sup>	4.3	
	2	0	8	NU	12.4	20.0	NU	ND	3.2	
	1	4	8	22.8	13.8	21.0	5.8	ND	3.4	
	2	4	8	19.9	12.6	20.6	4.9	ND	3.6	
	1	8	8	22.8	14.1	21.1	4.3	ND	2.9	
	2	8	8	20.2	12.5	20.8	3.8	ND	4.0	
	1	12	8	22.5	14.0	21.0	3.4	ND	3.0	
	2	12	8	20.1	12.5	20.8	3.4	ND	4.2	
	1	16	8	21.8	14.0	21.1	3.4	ND	3.9	
	2	16	8	20.1	12.5	20.6	3.3	ND	4.1	
	3	1	8	0	20.8	NU	21.1	6.7	NU	4.4
		2	8	0	20.1	NU	20.5	6.1	NU	3.6
1		8	3	20.8	14.4	20.9	6.7	2.0	4.4	
2		8	3	20.1	14.8	20.5	6.1	2.9	3.6	
1		8	6	20.8	14.1	21.0	6.7	2.1	4.6	
2		8	6	20.1	14.7	20.6	6.1	2.9	3.8	
1		8	9	20.8	14.1	21.0	6.7	2.5	4.8	
2		8	9	20.1	14.6	20.8	6.1	2.9	4.2	
1		8	12	20.8	14.1	21.1	6.7	2.5	5.1	
2		8	12	20.1	14.4	20.8	6.1	3.0	4.2	

<sup>z</sup>NU = treatment not used.

<sup>y</sup>ND = no data collected.

*Miltoniopsis* Augres 'Trinity' were placed at 23 °C for 8 weeks under 9-h short days (SD) or 16-h LD (prevernalization photoperiods) beginning on 28 Aug. 2002 (Year 1) and 8 Dec. 2003 (Year 2). Photoperiods were created by retracting blackout cloth over plants from 1700 to 0800 HR. The 16-h photoperiod was created by light from incandescent lamps (delivering about 3 μmol·m<sup>-2</sup>·s<sup>-1</sup>) from 1655 to 2400 HR (LD INC).

On 23 Oct. 2002 (Year 1) and 2 Feb. 2004 (Year 2), 20 plants of *Miltoniopsis* Augres 'Trinity' were transferred to greenhouse sections with temperature set points of 11, 14, 17, 20, and 23 °C (8 °C was also used in Year 1). At each temperature, 10 plants were placed under SD and LD INC photoperiods for 8 weeks. Vapor pressure deficit during the temperature treatments was maintained at about 0.7 kPa by the injection of water vapor as needed. After 8 weeks at the temperature treatments, plants were forced in a common greenhouse at 23 °C (Year 1) or 20 °C (Year 2) under LD HPS.

**Prevernalization photoperiod experiment (Expt. 2).** *Miltoniopsis* Augres 'Trinity' (Year 1) and Eastern Bay 'Russian' (Year 2) were grown at 20 °C under SD or LD INC beginning on 26 July 2002 and 25 Sept. 2003, respectively, for 0, 4, 8, 12, or 16 weeks in a glass-glazed greenhouse. From 0800 to 1700 HR, HPS lamps provided a supplemental PPF of ≈40 μmol·m<sup>-2</sup>·s<sup>-1</sup> at plant level when the outdoor PPF was <140 μmol·m<sup>-2</sup>·s<sup>-1</sup>. The plants were then cooled for 8 weeks at 14 °C under SD in a refrigerated growth chamber. The photoperiod during cooling was provided by a combination of cool-white fluorescent (VHOF96T12, Philips, Bloomfield, N.J.) and incandescent lamps from 0800 to 1700 HR at 150 μmol·m<sup>-2</sup>·s<sup>-1</sup>. After the cooling treatment, plants were grown in the greenhouse at 20 °C under LD HPS.

**Vernalization duration experiment (Expt. 3).** *Miltoniopsis* Augres 'Trinity' (Year 1) and Eastern Bay 'Russian' (Year 2) were grown for 8 weeks at 20 °C under SD or LD INC beginning on 28 Aug. 2002 and 25 Sept. 2003, respectively. The plants were then cooled for 0, 3, 6, 9, or 12 weeks at 14 °C under SD in a glass-glazed greenhouse. After the vernalization treatments, plants were grown at 20 °C under LD HPS in the greenhouse. Light intensity was controlled as previously described.

**Greenhouse temperature and irradiance control.** Greenhouse temperature set points were monitored and maintained by an environmental computer (Priva CD 750 Computer System, Vineland Station, Ontario) which controlled roof vents, exhaust fans, evaporative cooling pads, and heating as needed. Temperature on each bench was measured by a thermocouple (0.127-mm type E) in an aspirated chamber every 10 s. Light intensity was measured by line quantum sensors (Apogee Instruments, Logan, Utah) located at plant height. Hourly averages were recorded by a CR-10 datalogger (Campbell Scientific, Logan, Utah). The average daily air temperature (± standard deviation) and daily light integral (DLI) were 23.7 ± 2.4 °C and 3.2 mol·m<sup>-2</sup>·d<sup>-1</sup> during the prevernalization treatment of Expt. 1. The actual average temperatures during vernalization were 8.9 ± 1.8, 11.6 ± 1.9, 14.2 ± 0.8, 17.2 ± 1.0, 19.9 ± 0.6, and 24.1 ± 1.4 °C, and the average DLI was 3.2 mol·m<sup>-2</sup>·d<sup>-1</sup>. During forcing, the averages were 22.5 ± 2.8 °C and 3.8 mol·m<sup>-2</sup>·d<sup>-1</sup>. Average daily air temperature and DLI were calculated for Expts. 2 and 3 from the beginning of the prevernalization photoperiod until the end of forcing (Table 1).

**Plant culture.** Plants in all three experiments were irrigated as necessary with reverse osmosis water supplemented with water-soluble fertilizer to provide the following (mg·L<sup>-1</sup>): 125 N, 12 P, 100 K, 65 Ca, 1.0 Fe and Cu, 0.5

Mn and Zn, 0.3 B, and 0.1 Mo (MSU Special, Greencare Fertilizers, Chicago, Ill.). In Year 2, *Miltoniopsis* Augres 'Trinity' plants were transplanted into 10-cm pots containing 66% medium-grade fir bark, 17% long-fiber Canadian sphagnum peat, and 17% medium-grade perlite (by volume).

**Data collection and analysis.** The date at which the first inflorescence was visible without dissection (visible inflorescence, or VI) and the date that the first flower opened were recorded for each plant. Days to VI, days from VI to flower, days to flower, the percentage of plants that initiated or aborted an inflorescence, and flowering percentage were calculated for each treatment. The total number of VIs and the number of flower buds and flowers on the first VI were recorded for each plant. On the date of flowering, inflorescence length from emergence to the tip of the inflorescence was measured on the first VI. Each year, a completely randomized block design was used with ten plants randomly assigned to each treatment. Data were pooled for Year 1 and 2 of Expt. 1 for all measured characteristics. Data in Expt. 2 and 3 represent 1 year of data for each hybrid. Data were analyzed with SAS (SAS Institute, Cary, N.C.) mixed model procedure (PROC MIXED), and pairwise comparisons between treatments were performed using Tukey's honest significant difference test (HSD).

## Results

**Photoperiod and vernalization experiment (Expt. 1).** The photoperiod before vernalization and vernalization temperature both significantly ( $P \leq 0.05$  and  $P \leq 0.001$ , respectively) influenced the VI percentage of *Miltoniopsis* Augres 'Trinity' (Fig. 1). Plants exposed to 8 weeks of SD followed by 8 weeks of vernalization at 11 to 14 °C had the highest flowering percentage (≥75%). Flower initiation was vari-

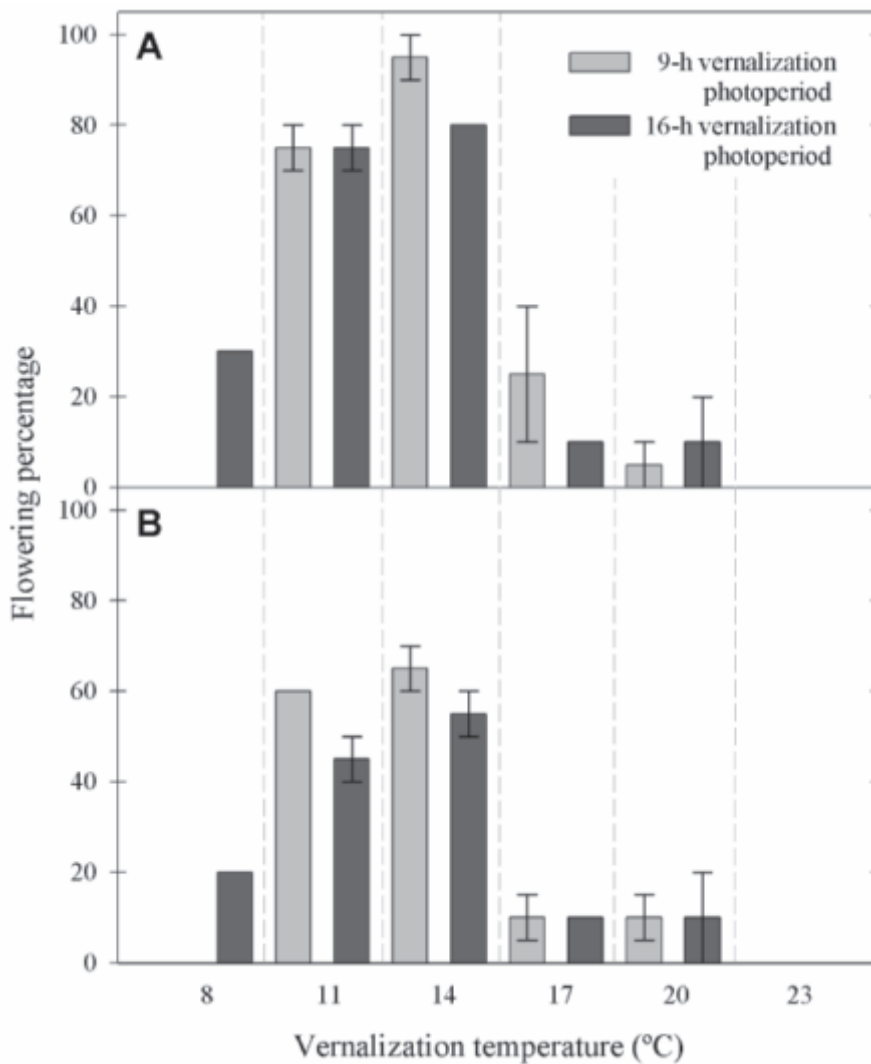


Fig. 1. Flowering percentage of *Miltoniopsis* Augres 'Trinity' after a prevernalization photoperiod of 9 h (A) or 16 h (B) for 8 weeks at 23 °C followed by 8 weeks at 8, 11, 14, 17, 20, or 23 °C under a 9- or 16-h photoperiod. Plants were subsequently grown at 23 °C under a 16-h photoperiod. Data were pooled for Years 1 and 2 (n = 20). The effects of prevernalization photoperiod and vernalization photoperiod and temperature on flowering percentages were analyzed using a binomial distribution with logit transformation. Vertical bars represent the standard error of the mean.

able when vernalization temperatures were  $\geq 17$  °C, and inflorescence abortion was observed. In general, flower induction was greatest when plants were exposed to SD before vernalization treatments. Average time to VI from the start of the prevernalization photoperiod was  $166 \pm 36$  d ( $\pm$  standard deviation), and time to flower from VI was  $73 \pm 5$  d across all treatments (data not presented). Flowering plants had a similar inflorescence count, flower number, and inflorescence height, and the means were 1.6, 4.6, and 27.9 cm, respectively (data not presented).

**Prevernalization duration experiment (Expt. 2).** Flowering of *Miltoniopsis* Augres 'Trinity' was most complete ( $\geq 90\%$ ) and uniform when plants were exposed to 4 or 8 weeks of a prevernalization SD photoperiod at 20 °C before vernalization at 14 °C (Table 2). At least 80% of *Miltoniopsis* Eastern Bay 'Russian' plants flowered in all prevernalization treatments. There was a linear or quadratic increase in time to VI as the prevernalization

duration increased for both Augres 'Trinity' and Eastern Bay 'Russian' (Table 2). The appearance of VI from the start of forcing decreased as the prevernalization duration increased for Eastern Bay 'Russian', but there were no clear trends for Augres 'Trinity'. Time from VI to flower at 20 °C was similar for all treatments and took  $76 \pm 5$  and  $53 \pm 6$  d, respectively, for Augres 'Trinity' and Eastern Bay 'Russian' (data not presented). The number of inflorescences per plant, the number of flower buds, and inflorescence height were not influenced by prevernalization photoperiod or duration, and the means were 1.4, 3.2, and 21.3 cm and 1.6, 3.6, and 18.4 cm for Augres 'Trinity' and Eastern Bay 'Russian', respectively (data not presented).

**Vernalization duration experiment (Expt. 3).** Flowering percentage of Eastern Bay 'Russian' was  $\geq 70\%$  regardless of the duration of vernalization treatment (Table 3). In Augres 'Trinity', flowering percentage generally increased as vernalization duration increased

to 9 weeks. However, time to flower from the start of forcing decreased as vernalization duration increased for both hybrids. For example, Augres 'Trinity' and Eastern Bay 'Russian' vernalized for 9 weeks reached VI an average of 99 or 48 d earlier than plants not vernalized. Time to flower from VI at 20 °C was similar for all treatments and averaged  $76 \pm 5$  and  $56 \pm 7$  d, respectively, for Augres 'Trinity' and Eastern Bay 'Russian' (data not presented). Flowering plants of Eastern Bay 'Russian' had a similar flower bud number among all vernalization treatments, but flower number of Augres 'Trinity' increased as vernalization duration increased to approximately 9 weeks (Table 3). The number of inflorescences per plant and the height of the first VI were not influenced by prevernalization photoperiod or vernalization duration, and the means were 1.5 and 20.8 cm and 1.8 and 21.6 cm for Augres 'Trinity' and Eastern Bay 'Russian', respectively (data not presented).

## Discussion

In Expt. 1, the most complete, rapid, and uniform flowering of *Miltoniopsis* Augres 'Trinity' occurred when plants were placed under SD for 8 weeks and then vernalized under SD at 11 to 14 °C for 8 weeks. The duration of SD before cooling that was required for most rapid flowering was determined in Expt. 2, in which 4 to 8 weeks of SD elicited the highest flowering percentage and most rapid flowering. Results from Expt. 3 showed that 9 to 12 weeks of cooling at 14 °C was required and that plants exposed to LD before cooling often had a lower flowering percentage. These results are supported by Robinson (2002), in which 90% to 100% of *Miltoniopsis* Augres 'Trinity' flowered when placed in environmental chambers with constant temperatures of 14 °C under a 9-h SD. However, a moderate percentage of Augres 'Trinity' plants flowered in nearly all treatments, indicating that flowering is not highly controlled by environmental conditions.

*Miltoniopsis* Eastern Bay 'Russian' flowered under a wider range of environmental conditions than Augres 'Trinity', but both hybrids flowered earliest when exposed to a similar sequence of SD followed by exposure to a cool temperature (i.e., 14 °C). Flowering in response to low temperature alone or in combination with SD has been reported in other orchid genera native to Central and South America. For example, flowering of *Zygopetalum* Redvale 'Fire Kiss' was most complete when plants were grown under SD and then cooled at 11 to 14 °C for approximately 8 weeks (Lopez et al., 2003). In *Odontioda* George McMahon 'Fortuna' and *Odontioda* Lovely Penguin 'Emperor', the percentage of plants that initiated an inflorescence was greatest ( $\geq 90\%$ ) when plants were grown at 14 and 17 °C (Blanchard, 2005). The importance of SD before cooling has also been observed in other epiphytes such as *Hattoria*, in which plants exposed to LD before vernalization (7.5 to 12.5 °C for 4 weeks) flowered poorly. However, when *Hattoria* was provided with SD before vernalization, the flowering percentage

Table 2. The effect of prevernalization photoperiod and duration on inflorescence initiation percentage (including aborted inflorescences), and days to visible inflorescence (VI) from start of prevernalization (PV) treatment and the start of forcing of *Miltoniopsis* Augres 'Trinity' and Eastern Bay 'Russian' (Expt. 2). The PV photoperiod was 9 or 16 h and was delivered at 20 °C for the indicated durations. Plants were then vernalized for 8 weeks at 14 °C under a 9-h photoperiod and subsequently forced at 20 °C under a 16-h photoperiod.

PV photoperiod (h)	PV duration (weeks)	Inflorescence initiation (%)		Days to VI from start of PV		Days to VI from start of forcing	
		Augres 'Trinity'	Eastern Bay 'Russian'	Augres 'Trinity'	Eastern Bay 'Russian'	Augres 'Trinity'	Eastern Bay 'Russian'
No photoperiod <sup>z</sup>	0	60	100	154 bc <sup>y</sup>	103 c	98	47 a
9	4	90	100	123 c	113 bc	39	29 ab
	8	100	90	177 bc	127 bc	65	15 bc <sup>d</sup>
	12	80	100	203 abc	130 b	63	-10 <sup>x</sup> d
	16	60	90	257 ab	193 a	89	25 abc
16	4	40	90	145 bc	118 bc	61	34 ab
	8	60	90	194 abc	130 bc	82	18 bc
	12	60	90	216 abc	140 b	76	0 cd
	16	60	80	304 a	190 a	136	22 abc
Significance							
Prevernalization photoperiod (PVP)				NS	NS	NS	NS
Prevernalization duration (PVD)				***	***	NS	***
P <sub>Linear</sub>				***	***	NS	***
P <sub>Quadratic</sub>				*	***	*	***
PVP × PVD				NS	NS	NS	NS

<sup>z</sup>Plants did not receive a photoperiod treatment before vernalization.

<sup>y</sup>Values within columns with the same letter are not significantly by Tukey's honest significant difference test at  $P \leq 0.05$ .

<sup>x</sup>VI occurred during the vernalization treatment.

NS,\*,\*\*\*Nonsignificant or significant at  $P \leq 0.05$  or 0.001, respectively.

Table 3. The effect of vernalization duration on inflorescence initiation percentage (including aborted inflorescences), days to visible inflorescence (VI) from start of prevernalization (PV) treatment and the start of forcing, and flower count on the first VI of *Miltoniopsis* Augres 'Trinity' and Eastern Bay 'Russian' (Expt. 3). The PV photoperiod was 9- or 16-h and was delivered at 20 °C for 8 weeks. Plants were then vernalized for the indicated durations at 14 °C under a 9-h photoperiod and subsequently forced at 20 °C under a 16-h photoperiod.

PV photoperiod (h)	Vernalization duration (weeks)	Inflorescence initiation (%)		Days to VI from start of PV		Days to VI from start of forcing		No. of flower buds on first VI	
		Augres 'Trinity'	Eastern Bay 'Russian'	Augres 'Trinity'	Eastern Bay 'Russian'	Augres 'Trinity'	Eastern Bay 'Russian'	Augres 'Trinity'	Eastern Bay 'Russian'
9	0 <sup>z</sup>	50	70	224 ab	101 b <sup>y</sup>	168 a	45 b	3.0 ab	3.6
	3	30	90	261 ab	118 b	184 a	41 b	4.3 ab	4.3
	6	60	80	209 ab	115 b	111 ab	17 bc	3.5 ab	3.3
	9	100	100	188 b	117 b	69 b	-3 <sup>x</sup> c	4.2 a	3.4
	12	90	90	199 ab	138 ab	59 b	-2 c	3.0 ab	3.2
16	0 <sup>z</sup>	40	70	238 ab	164 a	182 a	108 a	1.7 b	4.0
	3	30	90	246 ab	118 b	169 ab	41 b	3.7 ab	3.6
	6	60	90	241 ab	119 b	143 ab	21 bc	4.0 ab	5.8
	9	70	100	276 a	138 ab	157 a	19 bc	3.9 ab	4.0
	12	60	100	237 ab	162 a	97 ab	22 bc	2.7 ab	4.1
Significance									
Prevernalization photoperiod (PVP)				*	***	*	***	NS	NS
Vernalization duration (VD)				NS	***	***	***	**	NS
P <sub>Linear</sub>				NS	*	***	***	NS	NS
P <sub>Quadratic</sub>				NS	**	NS	**	***	NS
PVP × VD				NS	**	NS	**	NS	NS

<sup>z</sup>Plants did not receive a vernalization treatment.

<sup>y</sup>Values within columns with the same letter are not significantly by Tukey's honest significant difference test at  $P \leq 0.05$ .

<sup>x</sup>VI were recorded during the vernalization treatment.

NS,\*,\*\*,\*Nonsignificant or significant at  $P \leq 0.05$ , 0.01, or 0.001, respectively.

increased to 93% to 100% (Rohwer, 2002).

We postulate that, similar to that of other flowering plants, a juvenile phase exists in *Miltoniopsis* and plants must reach a certain stage of growth before attaining the capacity to flower. Thus, sexual reproduction is delayed until plants reach a size sufficient to maintain the energetic demands of flowering and seed production. Lopez (2003) reported that pseudobulb maturity can significantly influence flower initiation and time to VI. Time to VI increased by  $\approx 100$  d if the only inducible pseudobulb on a plant was immature. If an immature pseudobulb ( $\leq 6$  cm in height) was placed in an inductive treatment, it was incapable of initiating flowers. However, immature pseudobulbs  $\geq 7$  cm had the capacity to initiate flowers, which could explain the variability in time to flowering that

we observed within treatments and between experiments.

We have shown that flowering of a population of *Miltoniopsis* is promoted most by exposure to SD followed by exposure to a cool temperature (e.g., 14 °C), but some plants flowered without exposure to either or both treatments. This lack of a uniform flowering response and variability between hybrids can be problematic for greenhouse growers trying to produce flowering plants for specific holidays. *Phalaenopsis* orchids can be precisely scheduled into flower by maintaining vegetative growth at a high temperature (e.g., 28 °C) and inducing flowering at a lower temperature ( $< 25$  °C) (Sakanishi et al., 1980; Yoneda et al., 1992). However, Blanchard (2005) reported that hybrids of the same orchid genus respond

differently to temperature. *Phalaenopsis* Miva Smartissimo × Canberra were reproductive at 26/26, 26/14, and 26/20 °C (day/night), while no Brother Goldsmith '720' plants had initiated an inflorescence within 20 weeks. Conditions that inhibited flowering of *Miltoniopsis* the most (constant exposure to LD at 23 °C) elicited heat-stress symptoms in plants, and plant vigor gradually declined. Therefore, we have not identified environmental conditions that can strictly control transition from the vegetative to reproductive state. Additional research on the effects of temperature and photoperiod on plants of differing maturity is merited.

Nevertheless, the numerous positive attributes of *Miltoniopsis* merit its consideration as a potted flowering plant for winter and spring holidays (Christmas, Valentine's Day,

Easter, and Mother's Day) when temperature in temperate climates in the northern hemisphere is not excessive for shipping and storage to preserve flower quality. Sales at these times would also facilitate production schedules for greenhouse growers in northern climates, in which growers could use the natural SD and cool temperatures of autumn and winter for flower induction.

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