# Flowering of the Orchid *Miltoniopsis* Augres ‘Trinity’ is Influenced by Photoperiod and Temperature

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**Abstract**

**The production of flowering potted orchids has increased dramatically throughout the world in the past decade. For example, production value in the United States has increased 147% in the past six years, and in 2002 the estimated wholesale value was $105 million. Scheduling orchid species to flower on specific dates requires knowledge of how environmental parameters regulate plant development from propagation to flowering. In a preliminary experiment, we observed that flowering of *Miltoniopsis* Augres ‘Trinity’ was promoted by cool temperatures (14 to 20 ºC), short photoperiods (9 hours), or a combination of both. We performed additional experiments to determine the minimum durations of short photoperiods and cool temperatures (vernalization at 14 ºC) required for rapid and uniform flowering. To quantify the effect of photoperiod before exposure to cool temperature, *Miltoniopsis* were placed under 9- or 16-h photoperiods at 20 ºC for 0, 4, 8, 12, or 16 weeks, then were transferred to growth chambers at 14 °C with a 9-h photoperiod for 8 weeks. To determine the optimal cooling duration, a separate experiment was performed in which plants were placed under 9- or 16-h photoperiods at 20 ºC for 8 weeks and then transferred to 14 °C with a 9-h photoperiod for 0, 3, 6, 9, or 12 weeks. Following treatments, plants were grown in a common environment at 20 °C with a 16-h photoperiod. The flowering percentage of plants that were not exposed to short days was only 40%. Flowering percentage was greatest when exposed to short days for 4 to 8 weeks before cooling. The optimum vernalization treatment was for eight weeks under short days.**

## INTRODUCTION

Orchids have become the second most valuable flowering potted crop in the United States (USDA, 2003). According to the American Orchid Society, over 75% of all orchids sold in the United States are *Phalaenopsis*, commonly known as the moth orchid (Griesbach, 2002). Currently, the wholesale price of flowering *Phalaenopsis* in a 15-cm pot in the U.S. is $8 to $12, with a retail price of $15 to $25 on the mass market (Wang, 2003). As the market becomes saturated with *Phalaenopsis* due to the widespread knowledge of its flower induction requirements, the price will likely decrease and the plant may become a commodity. Consequently, commercial growers and retailers are already seeking other orchids that have consumer appeal and can be programmed into flower for specific markets dates.

*Miltoniopsis,* or the pansy orchid, produces inflorescences that are adorned with three to six flat, and large (7 cm) fragrant and showy flowers, which range in color from cream to pink, magenta, scarlet, or yellow. The flowers often last on the plant for four to eight weeks at temperatures from 14 to 20 ºC (Robinson, 2002). Due to these attributes, *Miltoniopsis* has become the fifth most valuable potted orchid produced commercially in the Netherlands, with 797,000 pots sold in 2001 (Barendse, 2002).

In its native habitat, *Miltoniopsis* is an epiphytic and lithophytic genus of six species distributed throughout the wet cloud forest regions (610 to 2,100 m) from Costa Rica to Peru (Baker and Baker, 1993; Morrison, 2000). The sympodial growth habit of this compact plant is distinguished from *Miltonia* by the presence of a single leaf at the

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pseudobulb apex, which is surrounded by distinct leaf-like sheaths.

Several outstanding hybrids have been developed in recent years, which are mainly enjoyed by hobbyists. However, little information is currently available on flowering induction of *Miltoniopsis*. In a previous study, we found that flower initiation of *Miltoniopsis* Augres 'Trinity' was uniform and complete only when plants were exposed to 9-h photoperiods before and during vernalization at 11 to 14 ºC (unpublished data). A similar response was observed in *Cattleya warscewiczii, C. gaskelliana,* and C. *mossiae;* flower induction occurred under continuous 9-h photoperiods at 13 ºC, and flowering was inhibited when the photoperiod was 16 h (Rotor, 1952; Rotor, 1959). Like *Miltoniopsis, Cattleya* are epiphytes native to the humid and wet forests of Central and South America.

Further investigation is necessary to minimize the production time of *Miltoniopsis.* This information will assist greenhouse growers with developing a production schedule for complete, rapid and uniform flowering of *Miltoniopsis* Augres 'Trinity' for specific market dates. We performed experiments to determine how the duration of pre-vernalization photoperiods and vernalization duration influence flowering of *Miltoniopsis*. Another objective of this study was to determine if short days are indeed critical for flowering prior to vernalization.

## MATERIALS AND METHODS

### Plant Material and Culture

*Miltoniopsis* Augres 'Trinity' were grown by a commercial greenhouse (Calif.) at 16 to 26 ºC under natural photoperiods (37 ºN lat.) with a maximum photosynthetic photon flux (*PPF*) of ≈350 $\mu mol \cdot m^{-2} \cdot s^{-1}$. They were planted in a bark and perlite-based media in June 2002 (10-cm pots) and were received in East Lansing, Mich. on 22 July 2002. Plants were maintained at ≈23 ºC in a glass-glazed greenhouse until experiments began. The photoperiod was a constant 16 h, consisting of natural daylengths (42 ºN lat.) with day-extension lighting from high-pressure sodium (HPS) lamps, which delivered a supplemental *PPF* of ≈50 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at plant height [as measured with a line quantum sensor (Apogee Instruments, Inc., Logan, Utah)]. Light transmission through the greenhouses was reduced using a permanent woven shade curtain that reduced light by ≈55% (OLS 50; Ludvig Svensson, Charlotte, N.C.) and by applying whitewash (up to 50%) to the glass as needed so that the maximum *PPF* was ≈350 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Plants were irrigated as necessary with reverse osmosis water supplemented with water-soluble fertilizer to provide the following ($mg \cdot L^{-1}$): 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, IL).

### Pre-vernalization Duration Experiment (Expt. 1*)*

Plants were grown at 20 ºC under 9-h short days (SD) or 16-h long days (LD) beginning on 26 July 2002 for 0, 4, 8, 12, or 16 weeks in a glass-glazed greenhouse. Photoperiods were created by pulling opaque blackout cloth over plants between 1700 and 0800 HR, and for the 16-h photoperiod, light from incandescent lamps (delivering ≈2 $\mu mol \cdot m^{-2} \cdot s^{-1}$) was provided between 1700 and 2400 HR. From 0800 to 1700 HR, HPS lamps provided a supplemental *PPF* of ≈40 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at plant level when the ambient greenhouse *PPF* was <120 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The plants were then cooled for eight weeks at 14 ºC under SD in a controlled-environment chamber. The photoperiod was provided by a combination of cool-white fluorescent (VHOF96T12, Philips, Bloomfield, NJ.) and incandescent lamps from 0800 to 1700 HR at 150 $\mu mol \cdot m^{-2} \cdot s^{-1}$. After the cooling treatment, plants were grown at 20 ºC under a 16-h LD in the greenhouse.

### Vernalization Duration Experiment (Expt. 2)

Plants were grown at 20 ºC under SD or LD (as described above) beginning on 26 August 2002 for eight weeks. The plants were then cooled for 0, 3, 6, 9 or 12 weeks at 14 ºC under SD in a glass-glazed greenhouse. After the cooling treatment, plants were grown at 20 ºC under LD in the greenhouse. Light conditions were controlled as described above.

## Greenhouse Temperature and Irradiance Control

Temperature on each bench was measured by a thermocouple in an aspirated chamber every 10 s, and hourly averages were recorded by a CR-10 datalogger (Campbell Scientific, Logan, Utah). Average daily air temperature and light integral (DLI) were determined for each experiment from the beginning of the pre-vernalization photoperiod until the end of forcing. The actual temperatures during pre-vernalization, vernalization, and forcing were 20.8 to 22.8 ºC, 13.8 to 14.4 ºC, and 20.9 to 21.1 ºC, respectively. The average DLI during these periods was 4.0 to 8.2 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, 2.0 to 2.5 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, and 5.2 to 7.0 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, respectively.

## Data Collection and Analysis

Ten plants were randomly assigned to each treatment. The date at which the first inflorescence was visible (visible inflorescence, or VI) without dissection and the number of VI were recorded for each plant. The percentage of plants that initiated flowers and days to VI were calculated. The few plants that died during the experiments were discarded and not included in the results. A complete randomized design was used and data were analyzed using SAS (SAS Institute, Cary, N.C.) mixed model procedure (PROC MIXED).

# RESULTS

## Pre-Vernalization Photoperiod Experiment (Expt. 1)

Flower initiation was most complete and uniform when plants were exposed to four or eight weeks of SD prior to vernalization (Table 1). Flower initiation never increased above 60% when plants were placed under LD prior to vernalization for any duration. Half of the plants placed directly into the 14 ºC chamber for eight weeks initiated flowers. Under short days before vernalization, days to VI from the end of vernalization increased as pre-vernalization photoperiod duration increased. Inflorescence count was not influenced by any treatment provided.

## Vernalization Duration Experiment (Expt. 2)

Increasing the duration of cooling up to nine weeks increased flower initiation percentage (Table 2). Flower initiation was greatest (≥ 80%) when plants were placed under SDs prior to vernalization and vernalized for ≥ 9 weeks at 14 ºC. Flower initiation was ≤ 40% when plants were not exposed to a 14 ºC temperature treatment. Time to VI was not influenced by pre-vernalization photoperiod. As vernalization duration increased from 0 to 12 weeks, time to VI decreased from 165 to 67 d if SD were provided before cold. Inflorescence count was not influenced by photoperiod prior to vernalization or vernalization duration.

# DISCUSSION

The most complete, rapid and uniform flowering of *Miltoniopsis* Augres 'Trinity' occurred when plants were placed under SD for four to eight weeks then cooled at 14 ºC for eight to twelve weeks under SD. These results are in agreement with results from a previous experiment in which plants had the highest flower initiation percentage (100%) when placed under SD for eight weeks and then cooled for eight weeks. In a separate study, 90 to 100% of *Miltoniopsis* Augres 'Trinity' placed in environmental chambers with constant temperatures of 14, 17 or 20 ºC under 9-h SD eventually flowered (Robinson, 2002). Robinson (2002) also found that time from VI to flower at 14, 17 and 20 ºC under a 9-h photoperiod was 71, 70 and 61 days, respectively. Our results indicate that production time can be reduced by four weeks, since four weeks of SD prior to cooling is adequate for relatively rapid flowering of *Miltoniopsis*.

These results also illustrate the importance of providing plants with SD before cold and SD during vernalization. Unfortunately, neither photoperiod nor cooling can be substituted or eliminated. Sixty percent or less of plants initiated flowers when not exposed to SD before cooling (Table 1), and only 30% flowered when not provided with a cool temperature treatment (Table 2). The importance of SD before cooling has also been observed in *Hatiora*, where plants exposed to LD before cooling (7.5 to 12.5 ºC for four weeks) flowered poorly (58-73% flowering). *Hatiora* plants exposed to SD prior to cooling had 93 to 100% flowering (Rohwer, 2002). Similar to *Miltoniopsis*, *Hatiora* is native to tropical regions of South America.

The numerous positive attributes of *Miltoniopsis* Augres 'Trinity' merit its consideration as a potted flowering plant for winter and spring holidays in North America and Europe (Christmas, Valentine's Day, Easter and Mother's Day), when temperatures are not excessive for shipping and storage to preserve flower quality. Sales at these times would also facilitate production schedules for greenhouse growers in northern latitudes as growers could utilize the natural short days and cool temperatures of autumn and winter for flower induction.

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## Tables

Table 1. The effect of pre-vernalization photoperiod and duration on flowering of *Miltoniopsis* Augres 'Trinity' (Expt. 1). The pre-vernalization photoperiod was delivered at 20 ºC. Plants were then cooled for eight weeks at 14 ºC under a 9-h photoperiod and subsequently forced at 20 ºC under a 16-h photoperiod.

| Pre-vernalization | | | | |
|---|---|---|---|---|
| Photoperiod (h) | Duration (weeks) | Flower initiation (%) | Days to visible inflorescence | Inflorescence count |
| -[z] | 0 | 50 | 84 | 1.0 |
| 9 | 4 | 90 | 39 | 1.2 |
| | 8 | 100 | 65 | 1.3 |
| | 12 | 60 | 88 | 1.5 |
| | 16 | 60 | 89 | 1.5 |
| 16 | 4 | 40 | 61 | 1.3 |
| | 8 | 60 | 90 | 1.0 |
| | 12 | 60 | 64 | 1.3 |
| | 16 | 60 | 136 | 1.5 |
| Significance | | | | |
| Pre-vernalization photoperiod (PVP) | | | NS | NS |
| Pre-vernalization photoperiod duration (PVPD) | | | * | NS |
| PVP x PVPD | | | NS | NS |

[z]Plants did not receive a photoperiod treatment prior to vernalization.

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

Table 2. The effect of pre-vernalization photoperiod and vernalization duration on flowering of *Miltoniopsis* Augres 'Trinity' (Expt. 2). Pre-vernalization photoperiods were provided at 20 ºC for eight weeks. Plants were then cooled at 14 ºC under a 9-h photoperiod and subsequently forced at 20 ºC under a 16-h photoperiod.

| Pre-vernalization photoperiod (h) | Vernalization duration (weeks) | Flower initiation (%) | Days to visible inflorescence | Inflorescence count |
|---|---|---|---|---|
| 9 | 0 | 30 | 165 | 1.7 |
| | 3 | 30 | 184 | 1.3 |
| | 6 | 60 | 111 | 1.2 |
| | 9 | 90 | 82 | 1.4 |
| | 12 | 80 | 67 | 1.6 |
| 16 | 0 | 40 | 182 | 1.3 |
| | 3 | 30 | 169 | 1.3 |
| | 6 | 60 | 143 | 1.2 |
| | 9 | 60 | 154 | 1.3 |
| | 12 | 60 | 97 | 2.1 |
| Significance | | | | |
| Pre-vernalization photoperiod (PVP) | | | NS | NS |
| Vernalization duration (VD) | | | *** | NS |
| PVP x VD | | | NS | NS |

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