

Temperature and Pseudobulb Size Influence Flowering of *Odontioda* Orchids

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Additional index words. base temperature, degree days, *Odontoglossum* alliance

Abstract. *Odontioda* is a cool-growing, sympodial epiphytic genus of orchids originating from the Andes Mountains of South America. Several hybrids are commercially grown as potted flowering plants for their brightly colored flowers and compact growth habit. We quantified how constant and fluctuating day/night temperatures influenced inflorescence initiation, time from visible inflorescence (VI) to flower, and pseudobulb development. *Odontioda* George McMahon 'Fortuna' and Lovely Penguin 'Emperor' were grown at constant temperature set points of 14, 17, 20, 23, 26, or 29 °C and day/night (12 h/12 h) temperatures of 20/14, 23/17, 26/14, 26/20, 29/23, or 29/17 °C. Plants were grown in glass greenhouses under a 12-h photoperiod and a maximum irradiance of 500 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Within 6 weeks, heat stress symptoms such as leaf necrosis were observed on plants grown at a day temperature of 26 °C or greater regardless of the night temperature. After 20 weeks, 90% or greater of both clones had a VI when grown at a constant temperature of 14 or 17 °C. Plants grown at a constant temperature of 17 °C had the greatest pseudobulb diameter with a mean increase of 3.5 to 4.0 cm. In all treatments, a minimum pseudobulb diameter was required for uniform inflorescence initiation; pseudobulbs with a diameter of 5.5 cm or greater developed a VI in 93% of plants. Data for time from VI to open flower were converted to a rate, and a thermal-time model relating temperature with inflorescence development was developed. The base temperature and thermal time for VI to flower in George McMahon 'Fortuna' and Lovely Penguin 'Emperor' were estimated at -0.1 °C and 1429 °C $\cdot\text{d}^{-1}$ and 0.8 °C and 1250 °C $\cdot\text{d}^{-1}$, respectively. This information could be used by commercial orchid growers to assist in producing potted flowering *Odontioda* orchids for specific market dates.

Orchids are the second most valuable potted flowering plant in the United States with a reported wholesale value of \$123 million in 2006, an increase of 162% in the past decade (U.S. Department of Agriculture, 2007). In 2006, 14.7 million potted orchids were sold with a mean wholesale unit value of \$8.32 (U.S. Department of Agriculture, 2007). Among all the orchid genera sold within the United States, *Phalaenopsis* and related genera compose an estimated 85% to 90% of the potted orchid sales (Nash, 2003). However, as the production of *Phalaenopsis* orchids increases, commercial producers are looking for additional orchid genera that can be grown and sold at mass markets.

The ability for commercial greenhouse growers to schedule potted plants into flower during periods of high demand (e.g., holidays) requires knowledge of environmental characteristics that regulate flowering. Temperature has been reported to control flowering in several orchid genera such as *Dendrobium* (Rotor, 1952), *Miltoniopsis* (Lopez and Runkle, 2006b), *Phalaenopsis* (Blanchard and Runkle, 2006; Sakanishi et al., 1980), and *Zygopetalum* (Lopez et al., 2003). For example, in *Dendrobium nobile* Lindley, plants grown at 18 °C remained vegetative, whereas those grown at 13 °C flowered regardless of photoperiod (Rotor, 1952). Similarly, plants of *Zygopetalum* Redvale 'Fire Kiss' had the highest flowering percentages when grown under a 9-h photoperiod followed by 8 weeks of cooling at 11 or 14 °C (Lopez et al., 2003). The promotion of flowering in these orchid genera by exposure to low temperature suggests that flowering in other orchid species could also be regulated by temperature.

Odontioda orchids are intergeneric hybrids that are classified into the *Odontoglossum* alliance (Rittershausen and Rittershausen, 2003). These intergeneric hybrids were first created in the early 1800s by breeders in Europe who crossed two genera, *Odontoglossum* H.B.K. and *Cochlioda* Lindl. (Carpenter, 2000). The genus *Odontoglossum* is composed of 54 species that are native

to humid mountainous regions (1500 to 3200 m) of South America, whereas the genus *Cochlioda* is composed of only seven species that are native to humid forests of the Andes Mountains (1700 to 3350 m) of Bolivia, Columbia, Ecuador, and Peru (Baker and Baker, 2006).

Odontioda are sympodial epiphytic orchids and produce green pseudobulbs that have an apical pair of long narrow leaves and a shorter pair of leaves that arise from the base of the pseudobulb (Rittershausen and Rittershausen, 2003). Similar to other sympodial orchid genera, inflorescence primordia are initiated in the axils' leaf sheaths at the base of pseudobulbs (Goh et al., 1982). *Odontioda* hybrids have been selected by breeders for their bright and showy flowers and are available in many color combinations and patterns (Rittershausen and Rittershausen, 2003). They can be appealing potted plants because of their compact growth habit (30 to 45 cm), erect to arching colorful inflorescences, and long-lasting flowers (up to 30 d) (Carpenter, 2000; Rittershausen and Rittershausen, 2003).

Odontioda hybrids are generally considered among orchid hobbyists to perform best at night temperatures ranging from 7 to 13 °C and day temperatures between 24 and 27 °C (Miller, 1992; Rohrl, 2005). Kubota et al., (2005) reported that plants grown at 18/8 °C or 23/13 °C (12-h day/12-h night) for 54 weeks had visible inflorescence (VI) percentages of 7% and 50%, respectively. A diurnal temperature fluctuation has also been suggested to improve vigor and plant performance (Miller, 1992; Rohrl, 2005), although to our knowledge, there is no scientific literature to support these observations. The growth of *Odontioda* orchids at cool temperatures suggests that they could be an appealing crop to produce in temperate climates where energy for heating is a significant greenhouse production cost (Bartok, 2001). However, to our knowledge, no scientific information has been published on the environmental flowering requirements for *Odontioda*.

The objectives of this study were 1) to determine how constant and fluctuating day and night temperatures influence flower initiation and pseudobulb development, and 2) to quantify how temperature controls time from VI to flowering in two *Odontioda* hybrids.

Materials and Methods

Plant material. In June 2003, mericlone plants of *Odontioda* George McMahon 'Fortuna' (*Odontoglossum* Parade \times *Odontioda* Golden Rialto) and *Odontioda* Lovely Penguin 'Emperor' (*Odontioda* Lovely Morning \times *Odontioda* Strawberry) were transplanted into 11-cm round pots (0.6-L volume) in medium containing 75% fine-grade composted Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] bark, 15% medium-grade perlite, and 10% sphagnum peat (by volume) and grown in a commercial greenhouse in

Received for publication 11 Feb. 2008. Accepted for publication 18 Mar. 2008.

We gratefully acknowledge funding by Michigan's plant agriculture initiative at Michigan State University (Project GREEN), the Fred C. Gloeckner Foundation, the Michigan Agricultural Experiment Station, and greenhouse growers providing support for Michigan State University floriculture research. We also thank Dr. Donald Garling for his contributions to the manuscript and Mike Olrich for his greenhouse assistance.

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California. Plants were grown at 24/18 °C (day/night) under a natural photoperiod (lat. 37° N) and a maximum photosynthetic photon flux (*PPF*) of 500 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. On 22 Sept. 2003, 240 plants were received in East Lansing, MI, and were subsequently grown for 10 weeks in a glass-glazed greenhouse at a mean daily temperature (MDT) of 22.3 °C. The photoperiod was a constant 16 h (0600 to 2200 HR) consisting of natural photoperiods (lat. 43° N) with day-extension lighting provided by high-pressure sodium (HPS) lamps delivering a *PPF* of 20 to 25 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at plant height [as measured with a line quantum sensor (Apogee Instruments, Logan, UT)]. Light transmission was reduced with woven shade curtains (OLS 50; Ludvig Svensson, Charlotte, NC) and whitewash applied to the greenhouse glazing so that the maximum *PPF* at plant height was 300 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

Plant culture. Plants were irrigated as necessary with reverse osmosis water supplemented with a water-soluble fertilizer providing ($\text{mg}\cdot\text{L}^{-1}$): 125 N, 12 P, 100 K, 65 Ca, 12 Mg, 1.0 Fe and Cu, 0.5 Mn and Zn, 0.3 B, and 0.1 Mo (MSU Special; Greencare Fertilizers, Chicago, IL). In Year 2, all plants were transplanted into the same size pot in a medium consisting of 80% medium-grade composted Douglas fir bark (Rexius Forest By-Products, Eugene, OR), 10% long-fiber Canadian sphagnum moss (Mosser Lee Co., Millston, WI), and 10% medium-grade perlite (Therm-O-Rock, Inc., New Eagle, PA) (by volume).

Temperature treatments. Ten plants of each *Odontioda* clone were placed in each of 12 glass greenhouse sections with constant temperature set points of 14, 17, 20, 23, 26,

or 29 °C or fluctuating day/night (12 h/12 h) temperature set points of 20/14, 23/17, 26/14, 26/20, 29/17, or 29/23 °C. In Year 2, constant temperature set points of 26 and 29 °C and day/night temperature set points of 26/14, 26/20, 29/17, and 29/23 °C were not used because heat stress symptoms were observed on plants grown at these temperatures in Year 1. Temperature set points were maintained by an environmental computer (Priva CD750; Vineland Station, Ontario, Canada) that controlled roof vents, exhaust fans, evaporative cooling, and heating as needed. The photoperiod was maintained at 12 h for 20 weeks

by pulling opaque black cloth from 1700 to 0800 HR and was extended with light from incandescent lamps (3 to 4 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at plant height). The photoperiod and skotoperiod paralleled the day and night temperature set points, respectively. After 20 weeks and until the end of each replication, plants remained in the temperature treatments, but the photoperiod was a constant 16 h (0600 to 2200 HR) consisting of natural daylength, with day-extension lighting provided by HPS lamps delivering a *PPF* of 50 to 75 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at plant height. A vapor-pressure deficit of 0.9 kPa was maintained at each

Table 1. Mean daily light integral ($\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) at plant level per 4-week period during experiment for Year 1 (1 Dec. 2003 to 7 May 2004) and Year 2 (26 Oct. 2004 to 12 June 2005).

Yr	4-week period						
	1	2	3	4	5	6	7
1	3.8	3.9	5.2	5.9	6.3	8.8	— ^z
2	4.1	3.6	3.9	4.8	7.1	9.0	8.0

^zData not collected.

Table 2. Actual mean air temperatures of each temperature treatment in Years 1 and 2.^z

Day/night temp set point (°C)	Actual day/night temp (°C)	
	Yr 1	Yr 2
14/14	15.1/14.4	14.2/13.7
17/17	17.6/17.3	17.6/16.9
20/20	20.0/20.0	20.5/20.0
23/23	24.4/22.4	23.1/22.4
26/26	25.8/26.1	— ^y
29/29	29.1/29.4	—
20/14	20.0/13.8	19.4/14.1
23/17	21.4/16.2	22.3/17.1
26/14	25.2/14.3	—
26/20	25.7/19.4	—
29/17	27.4/17.0	—
29/23	28.4/22.8	—

^zThe duration of the day and night temperature set points was 12 h.

^yTreatment not used in Year 2.

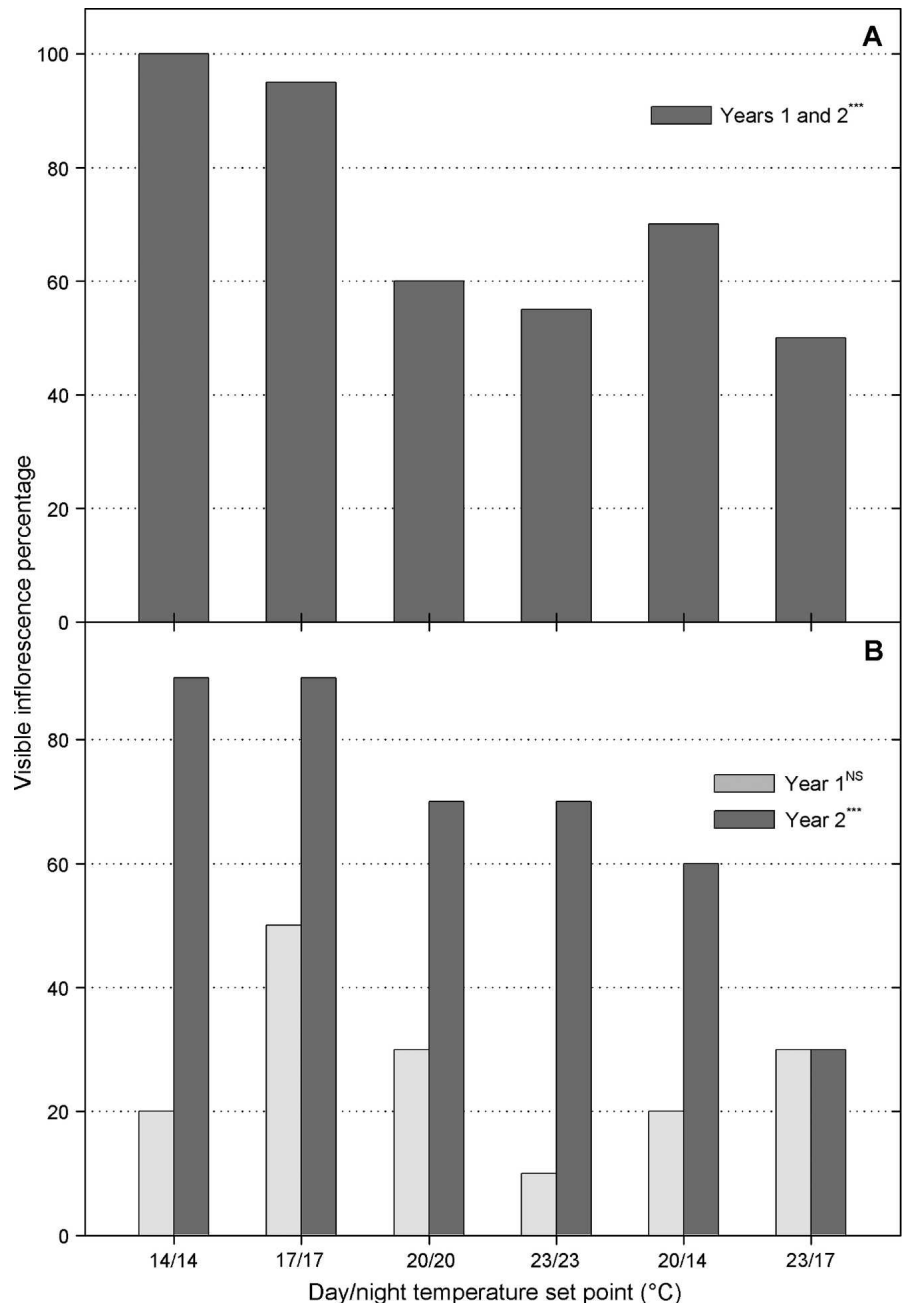


Fig. 1. Visible inflorescence (VI) percentages for (A) *Odontioda* George McMahon 'Fortuna' and (B) *Odontioda* Lovely Penguin 'Emperor' after 20 weeks at constant temperature set points of 14, 17, 20, or 23 °C and fluctuating day/night temperature set points of 20/14 or 23/17 °C. The day and night were 12 h each. VI percentages were analyzed using a binomial distribution with logit transformation. Data for George McMahon 'Fortuna' were pooled for Years 1 and 2 because there was no significant difference between years. ^{ns}, ^{***}Nonsignificant or significant at $P \leq 0.001$.

temperature treatment during the skotoperiod by the injection of water vapor. Light transmission through the greenhouse was reduced as previously described. The mean daily light integral per 4-week period during the experiment was between 3.6 and 9.0 mol·m⁻²·d⁻¹ (Table 1).

Air temperature was measured in each greenhouse section by aspirated thermocouples (0.127-mm type E) every 10 s and hourly means were recorded by a data logger (CR10; Campbell Scientific, Logan, UT). Temperature control during the experiment was within ± 1.6 °C of the greenhouse temperature set points for all treatments in both years (Table 2).

The experiment was replicated in time beginning on 1 Dec. 2003 (Year 1) and on 26 Oct. 2004 (Year 2). In each year, plants were assigned randomly to each of the temperature treatments. After completion of the first replication and until the beginning of the second replication, plants were transferred to a common glass-glazed greenhouse with an MDT of 21.9 °C and a constant 16-h (0600 to 2200 HR) photoperiod consisting of natural daylengths with day-extension lighting provided by HPS lamps delivering a PPF of 25 to 50 μmol·m⁻²·s⁻¹ at plant height. Between the first and second replication, the maximum PPF at plant height was maintained at 300 μmol·m⁻²·s⁻¹ as previously described. Plants that displayed symptoms of heat stress in Year 1 were not used in Year 2.

Data collection. The date of first VI without dissection (less than 0.3 cm) and the date that the first flower opened were recorded for each plant. Days to VI, days from VI to open flower, days to open flower, VI percentage, and inflorescence abortion 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, total inflorescence length from emergence to the tip of the inflorescence was measured. In both years, plants that did not have a VI after 20 weeks of the onset of treatments were considered not reproductive.

In Year 2 at the beginning of the experiment, one pseudobulb on each plant was selected and the leaf length and pseudobulb diameter were measured. Pseudobulbs were selected if they had no VI, had not previously initiated an inflorescence, and if the epidermis was not shriveled. In general, only one pseudobulb per plant met these criteria. Leaf length was measured from the base of the pseudobulb to the tip of the longest extended leaf. Pseudobulb diameter was measured at the widest point of the pseudobulb from the outer edge of a basal leaf to the outer edge of the opposing leaf by using a digital caliper. Leaf length and pseudobulb diameter were measured again when each plant flowered or after 31 weeks of temperature treatments for plants that did not have a VI. The increase in pseudobulb diameter and the leaf length was calculated.

Statistical analysis. A completely randomized block design was used in each year.

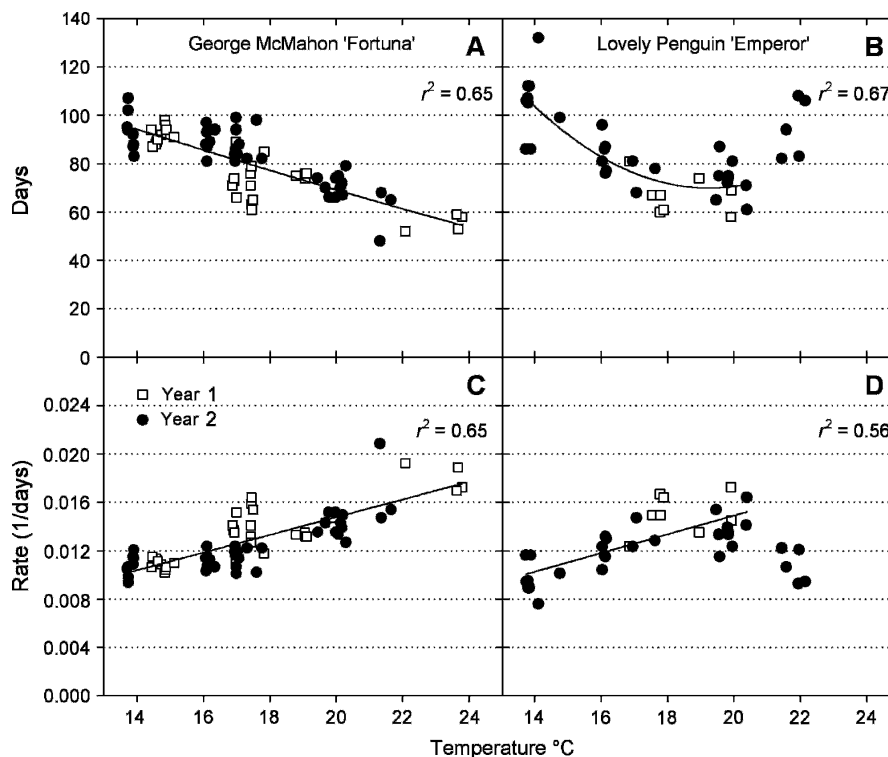


Fig. 2. Effect of temperature on time from visible inflorescence to flower (A and B) and rate of progress to flower (C and D) in two *Odontioda* clones. Each symbol represents an individual plant. The solid lines represent the regression equation using pooled data for Years 1 and 2. Data points greater than 20.4 °C for Lovely Penguin 'Emperor' were judged to be supraoptimal and were not included in the regression analysis. The mean daily temperature was reported for treatments with a fluctuating day and night temperature. Parameters of linear regression analysis in C and D are presented in Table 3.

Table 3. Parameters of linear regression analysis relating temperature to rate of progress for time from visible inflorescence to flower in *Odontioda* George McMahon 'Fortuna' and *Odontioda* Lovely Penguin 'Emperor'.^z

<i>Odontioda</i> clone	Temperature (°C)	Intercept (b ₀) (1/days)	Slope (b ₁) (1/days)/°C	T _b (°C)	°C·d ⁻¹
George McMahon Fortuna	13.7 to 23.8	1.0 E-4 ± 1.1 E-3 ^y	7.0 E-4 ± 6.4 E-5	-0.1	1429
Lovely Penguin Emperor	13.7 to 20.4	-6.0 E-4 ± 2.0 E-3	8.0 E-4 ± 1.0 E-4	0.8	1250

^zThe slope (b₁) and intercept (b₀) were used to calculate the base temperature (T_b) and degree-days (°C·d⁻¹).

^ySE.

Data were analyzed using a statistical analysis software (SAS; SAS Institute, Cary, NC) mixed-model procedure (PROC MIXED), and pairwise comparisons between treatments were performed using Tukey's honestly significant difference test. VI percentages were analyzed by using the generalized model procedure (PROC GENMOD) with a binomial distribution and logit transformation. Pearson correlation coefficients were determined for the relationship between final pseudobulb diameter and the occurrence of VI for each plant using the correlation procedure (PROC CORR). For each *Odontioda* clone, rates of progress toward flowering were modeled as a function of the calculated MDT for each plant from the date of VI to the date of flowering. Data for time from VI to flower were converted to rates by calculating the reciprocal (1/days), and linear regression analysis was performed in Sigma Plot (SPSS,

Chicago, IL). The intercept (b₀) and slope (b₁) of the regression lines were used to estimate the base temperature (T_b = -b₀/b₁) and the amount of thermal time (units of degree-days) that were required from VI to flower (°C·d⁻¹ = 1/b₁) in each *Odontioda* clone (Roberts and Summerfield, 1987).

Results

During Year 1, plants of both clones displayed symptoms of heat stress (e.g., severe necrosis on leaf margins and apices) when grown at day/night temperature set points of 26/26, 29/29, 26/14, 26/20, 29/17, or 29/23 °C. The percentage of plants that had a VI and days to VI were variable among plants in these treatments (data not presented). Furthermore, a high percentage of plants that initiated inflorescences during the temperature treatments aborted before

flowering. Data from these treatments were not included in further analysis.

Visible inflorescence percentage. Temperature had a significant influence on the percentage of plants that initiated a VI and developed to flowering in George McMahon 'Fortuna' (Years 1 and 2) and Lovely Penguin 'Emperor' (Year 2) (Fig. 1). During Year 1, inflorescence initiation in Lovely Penguin 'Emperor' was variable and 50% or less of plants initiated inflorescences in all treatments. After 20 weeks, 90% or greater of plants of George McMahon 'Fortuna' and Lovely Penguin 'Emperor' (Year 2 only) had a VI when grown at 14/14 and 17/17 °C. Inflorescence abortion was not observed on any plants grown at a day temperature 23 °C or less in both years regardless of the night temperature.

Time to visible inflorescence and flower. Temperature had no influence on time to VI in both *Odontioda* clones and varied among treatments from a mean of 52 to 86 d (data not presented). Days from VI to flower in George McMahon 'Fortuna' decreased with increasing MDT until ≈ 24 °C, whereas it decreased with increasing MDT only until ≈ 20 °C in Lovely Penguin 'Emperor' (Fig. 2). For example, as MDT increased from 14 to 23 °C, time from VI to flower in George McMahon 'Fortuna' decreased from 93 to 58 d. Similarly, an increase in temperature from 14 to 20 °C reduced time from VI to flower in Lovely Penguin 'Emperor' from 105 to 72 d.

The rate of progress from VI to flower was linear for both George McMahon 'Fortuna' and Lovely Penguin 'Emperor' within the measured MDT ranges of 13.7 to 23.8 °C and 13.7 to 20.4 °C, respectively (Fig. 2). Flower development was delayed in Lovely Penguin 'Emperor' when grown at temperatures above 20.4 °C. In George McMahon 'Fortuna', the base temperature for the rate of development from VI to first open flower was calculated as -0.1 °C and thermal time for completion of the event was estimated at 1429 °C·d⁻¹ (Table 3). The base temperature and thermal time from VI to flower in Lovely Penguin 'Emperor' were calculated to be 0.8 °C and 1250 °C·d⁻¹, respectively.

Inflorescence characteristics. There was no clear trend in the effect of temperature on inflorescence number and plants of both clones had a mean of 1.2 ± 0.3 inflorescences (data not presented). There were no differences among treatments in the number of flower buds on the first VI, and means were 8.9 and 7.4 for George McMahon 'Fortuna' and Lovely Penguin 'Emperor', respectively (data not presented). The total inflorescence length at flower was not significantly influenced by temperature in George McMahon 'Fortuna' and Lovely Penguin 'Emperor', and means were 26.8 and 35.0 cm, respectively (data not presented).

Pseudobulb diameter and leaf length. Temperature had a significant influence on the increase in pseudobulb diameter ($P \leq 0.01$) and the final pseudobulb diameter ($P \leq 0.001$) of both *Odontioda* clones (Fig. 3). As the day temperature increased from 14

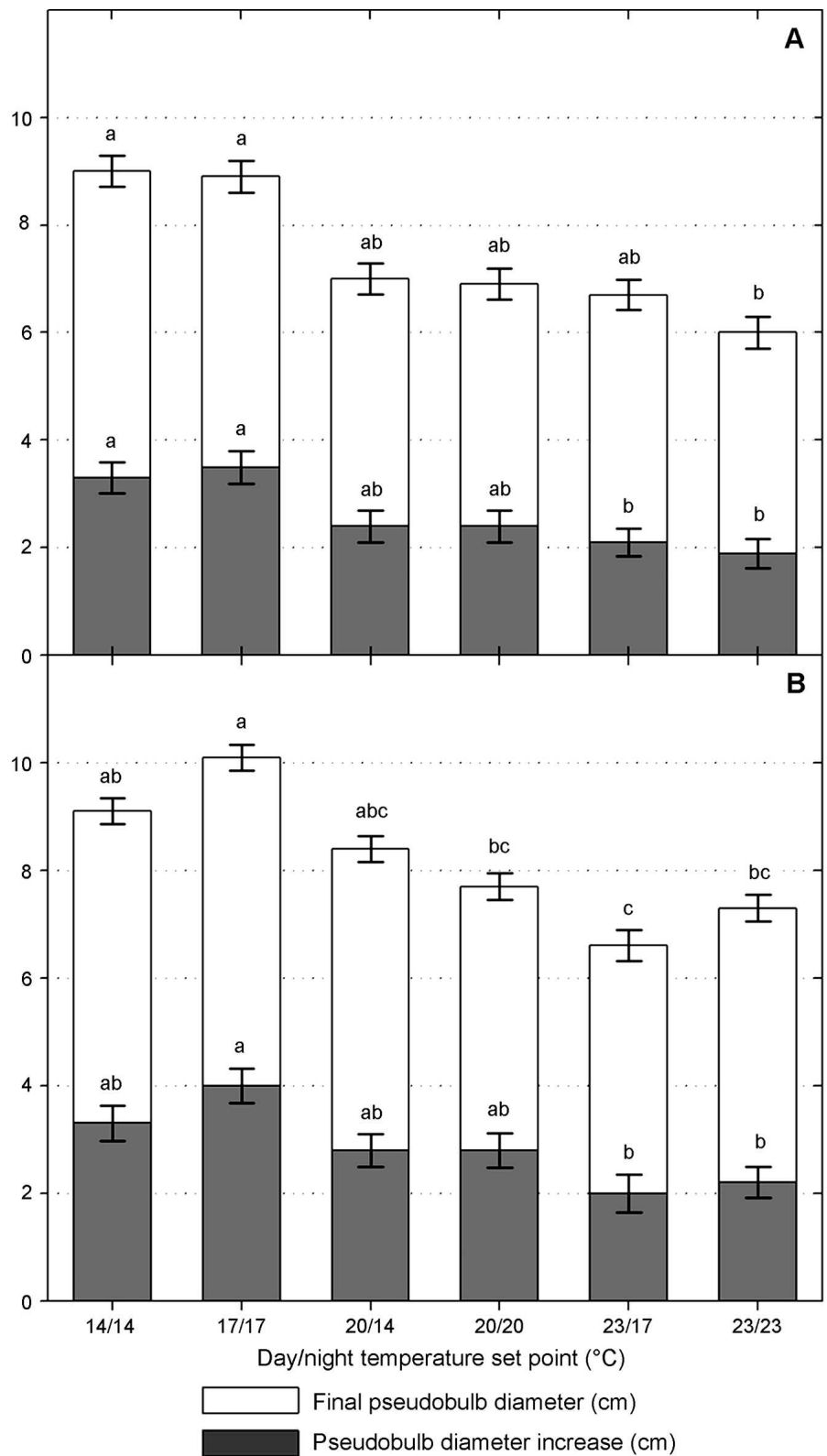


Fig. 3. Influence of temperature on final pseudobulb diameter and pseudobulb diameter increase in (A) *Odontioda* George McMahon 'Fortuna' and (B) *Odontioda* Lovely Penguin 'Emperor' at constant temperature set points of 14, 17, 20, or 23 °C and fluctuating day/night temperature set points of 20/14 or 23/17 °C. The day and night were 12 h each. Vertical bars indicate ses of treatment means. Mean separation within species and variable by Tukey's honestly significant difference test at $P \leq 0.05$.

to 23 °C, pseudobulb diameter generally decreased. In both clones, plants grown at a constant temperature of 17 °C had a greater pseudobulb diameter increase than plants

grown at 23/23 or 23/17 °C with a mean of 3.5 to 4.0 cm. The occurrence of inflorescence initiation in all temperature treatments was positively correlated ($P \leq 0.01$) to final

pseudobulb diameter (Fig. 4). In George McMahon 'Fortuna' and Lovely Penguin 'Emperor', pseudobulbs with a diameter 3.5 or greater and 5.0 cm or greater, respectively, had developed a VI in 60% or more of plants. The increase in leaf length and the final leaf length were not significantly different among treatments, and final leaf lengths varied from 24.6 to 30.3 cm (data not presented).

Discussion

In this study, *Odontioda* grown at a day temperature of 26 °C or higher developed leaf necrosis, and inflorescences aborted; thus, plants were determined to be of unacceptable quality for commercial sales. Therefore, to prevent high-temperature stress during commercial production, these temperatures are not recommended. Our observations are supported by a Kubota et al. (2005) study, in which all plants of *Odontioda* Marie Noel 'Velano' grown at 28/18 °C (12-h day/12-h night) developed yellow leaves within 8 weeks and died within 24 weeks. A similar response to high temperature has been reported in the ladybird orchid, *Zygopetalum* Redvale 'Fire Kiss', in which flower buds on plants transferred to MDTs of 25.4 to 28.6 °C developed necrotic lesions and aborted within 20 d (Lopez and Runkle, 2004).

In both *Odontioda* clones, the percentage of plants that initiated an inflorescence and developed open flowers was greatest at a constant temperature of 14 or 17 °C. A similar response to low temperature has been reported in another South American orchid genus, *Miltoniopsis* (Lopez and Runkle, 2006b). Plants of *Miltoniopsis* Augres

'Trinity' had the highest flowering percentage (90% or greater) when grown under a 9-h photoperiod at 20 °C for 4 to 8 weeks and transferred to 14 °C for 8 weeks (Lopez and Runkle, 2006b). In *Phalaenopsis* orchids, which are native to tropical and subtropical habitats of northern Australia and Asia (Baker and Baker, 1991), the low temperature that elicits flower initiation is higher than for *Odontioda* and *Miltoniopsis*. Flowering of *Phalaenopsis* was inhibited in plants grown at 28 °C or greater (Sakanishi et al., 1980) and was promoted after exposure to a day temperature less than 26 °C (Blanchard and Runkle, 2006; Lee and Lin, 1987). The promotion of flowering in several orchid genera by exposure to low temperature can be considered a vernalization process, in which the flowering response to low temperature is either qualitative or quantitative.

There was no advantageous effect of a diurnal temperature fluctuation on inflorescence initiation for either *Odontioda* clone compared with constant temperature treatments with a similar MDT. For example, in George McMahon 'Fortuna' grown at 17/17 or 20/14 °C, VI percentages after 20 weeks were 95% and 70%, respectively. These results suggest that a high day temperature (20 to 23 °C) reduced the percentage of plants that flowered, even when the night temperature was low (14 to 17 °C). Blanchard and Runkle (2006) reported that flowering in *Phalaenopsis* orchids is primarily controlled by the day temperature, not the night temperature.

There was no temperature treatment included in this study that completely inhibited inflorescence initiation. During com-

mercial production, the ability to inhibit or promote flowering in a crop by manipulating the environment is desirable because it allows for precise crop scheduling and improved production efficiency. In *Odontioda*, a growing environment that promotes vegetative development and inhibits flowering would be beneficial because plants that flower prematurely require the removal of inflorescences or sorting, both of which are labor-intensive. Kubota et al. (2005) reported that no plants of *Odontioda* initiated inflorescences within 54 weeks when grown under a low light intensity (150 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ or less) and at 18/8 or 23/13 °C. These results collectively suggest that during production of *Odontioda*, flowering could be delayed or inhibited by growing plants at a day temperature of 23 °C and under a low light intensity. However, the effect of this environmental strategy on subsequent flowering in a favorable environment is unknown.

In this study, a minimum pseudobulb diameter was required for uniform inflorescence initiation; pseudobulbs with a diameter 5.5 cm or greater developed a VI in 93% of plants of both *Odontioda* clones. As with other flowering plants, a juvenility period exists in orchids in which a specific stage of maturity must be reached before plants are capable of reproductive development (Goh et al., 1982). The low VI percentages observed in *Odontioda* Lovely Penguin 'Emperor' during Year 1 could be at least partially attributed to plant immaturity.

Odontioda grown at the coolest constant temperatures of 14 or 17 °C had the greatest increase in pseudobulb diameter and thus the greatest final pseudobulb diameter. Therefore, pseudobulb size could be a good tool for determining when a population of *Odontioda* plants is of adequate maturity for flower induction. Ichihashi (1997) reported that flower initiation in *nobile*-type *Dendrobium* orchids occurred on mature pseudobulbs only when they were exposed to temperatures of 7.5 to 20 °C (Ichihashi, 1997). In *Miltoniopsis* Augres 'Trinity', when pseudobulb diameter was 1.5 cm or less or 3.1 cm or greater, 27% and 90% of pseudobulbs initiated inflorescences, respectively, after vernalization (Lopez and Runkle, 2006a).

The time from VI to flower in *Odontioda* grown at 17 °C was considerably longer than the estimated time for *Zygopetalum* Redvale 'Fire Kiss' (39 d) but shorter than the estimated time for several *Phalaenopsis* hybrids (139 d) (Lopez and Runkle, 2004; Robinson, 2002). The mean time from VI to flower in *Odontioda* Lovely Penguin 'Emperor' at 23 °C was 23 d greater than plants grown at 20 °C, which suggests that a constant temperature of 23 °C is supraoptimal for inflorescence development in this clone.

The calculated base temperatures of George McMahon 'Fortuna' and Lovely Penguin 'Emperor' during inflorescence development were similar: -0.1 and 0.8 °C. These base temperatures are considerably lower than the temperatures used in this study, and further experiments at lower

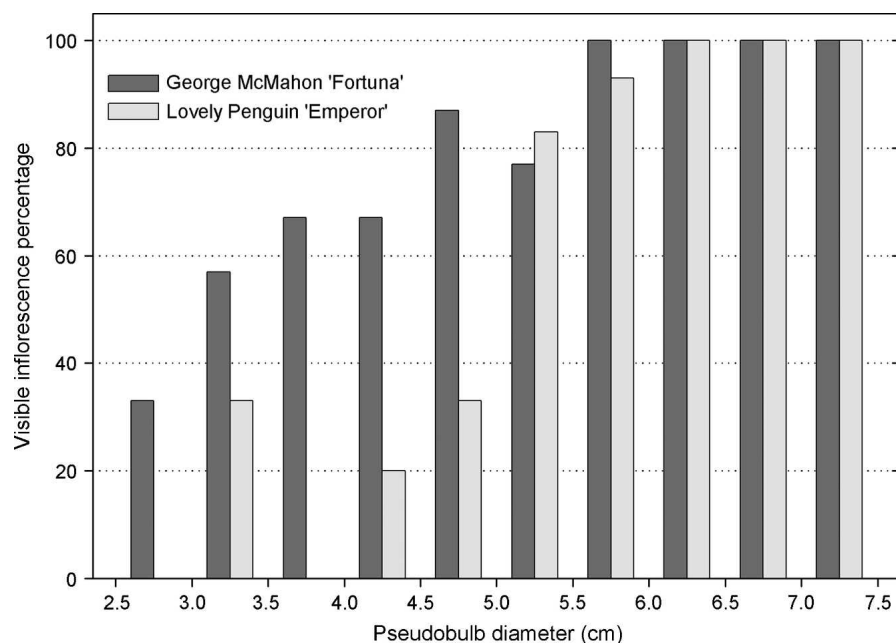


Fig. 4. Influence of pseudobulb diameter on visible inflorescence percentage in two *Odontioda* clones. Pseudobulb diameter was measured when each plant flowered or after 31 weeks of temperature treatments for plants that did not have a visible inflorescence (VI). Pearson correlation coefficients for the relationship between pseudobulb diameter and VI were 0.40 ($P \leq 0.01$) and 0.58 ($P \leq 0.001$) for George McMahon 'Fortuna' and Lovely Penguin 'Emperor', respectively. Data are for Year 2 only.

MDTs are needed to more precisely estimate their values. The estimated base temperature for *Odontioda* is 3.2 °C lower than the estimated base temperature of another native South American orchid genus, *Zygopetalum* (Lopez and Runkle, 2004). The lower base temperature in *Odontioda* could be attributed to the genetic background of these intergeneric clones. The predominant species in the background of *Odontioda* George McMahon 'Fortuna' and Lovely Penguin 'Emperor' is *Odontoglossum crispum* Lindl., which is native to high elevations (1800 to 3000 m) of the Andes Mountains in Columbia (Baker and Baker, 2006; Wildcatt Orchids, 2004). In comparison, *Zygopetalum* is native to mid-elevations of 300 to 1500 m (Pridgeon, 2000).

In conclusion, *Odontioda* orchids should be grown at temperatures 26 °C or less to avoid heat stress and inflorescence abortion. Cool constant temperatures between 14 and 17 °C can be used to promote both inflorescence initiation and development in these two *Odontioda* clones. At this temperature range, pseudobulbs will attain a minimum size required for uniform flowering. Time from inflorescence initiation to flowering is related to the MDT and can be predicted with our model. This information could be used by commercial orchid growers when producing *Odontioda* orchids in flower for specific market dates.

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