Average Daily Temperature and Reversed Day/Night Temperature Regulate Vegetative and Reproductive Responses of a *Doritis pulcherrima* Lindley Hybrid

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Abstract. It was unknown how prolonged periods of cool days and warm nights affect *Phalaenopsis* Blume hybrids, which perform crassulacean acid metabolism and absorb CO₂ primarily at night. The ‘Lava Glow’ plants vegetatively propagated from a hybrid *Doritaenopsis* (*Phalaenopsis* Buddha’s Treasure × *Doritis pulcherrima* Lindley*), 15 cm in leaf span, were grown at day/night (12 hours each daily) temperatures of 30/25, 25/30, 25/20, or 20/25 °C under 170 μmol·m⁻²·s⁻¹PPF. After 37 weeks, plants at the higher average daily temperature of 27.5 °C (ADT, 30/25 and 25/30 °C) produced more leaves than the lower 22.5 °C ADT. Those grown at 30/25 °C had the largest leaf span and combined length of the new leaves. Plants at 30/25, 25/30, 25/20, or 20/25 °C had 5.0, 4.7, 3.6, and 2.8 new leaves that were 72, 61, 44, and 29 cm in total length, respectively. Warmer nights than days resulted in a small leaf span, reduced leaf growth, and shorter leaves that were particularly noticeable at the 22.5 °C compared with 27.5 °C ADT. Leaves that emerged and grew at the lower ADT had a reduced length to width ratio and a more oval shape. The most striking effect of the 20/25 °C treatment was that 14 of 15 plants bloomed, whereas only five plants at 25/20 °C and none at 30/25 or 25/30 °C produced flowers. Similar results were obtained in a second experiment using 30/20, 20/30, 25/15, or 15/25 °C. After 29 weeks, all plants at 15/25 °C bloomed, whereas none in the other treatments had flowers. Long-term exposure to 15/25 °C resulted in slow leaf production and undesirable small leaves. These results suggest that day and night temperature may both affect growth and flowering of this orchid.

Potted orchids have become one of the most important potted floral crop in the United States with a wholesale value of \$144 million in 2005 (USDA, 2006) and worldwide (Wang, 2004), particularly the hybrid *Phalaenopsis*. Young plants of *Phalaenopsis* and *Doritaenopsis* (intergeneric hybrids between *Phalaenopsis* species and *Doritis pulcherrima* Lindley and between their hybrids or species) require a relatively warm environment to grow quickly (Krizek and Lawson, 1974; Lee, 1991; Lee and Lin, 1984; Lin and Lee, 1988; Wang, 2005). However, once plants have reached maturity, a relatively cool environment (15 to 25 °C) is needed to promote the emergence of flowering stems (spiking) (Lee and Lin, 1984; Sakanishi et al., 1980). *Phalaenopsis* and *Doritaenopsis* perform crassulacean acid metabolism to fix CO₂ primarily during the dark period of the day (Guo, 1999; Ota et al.,

1991). Ota et al. (1991) reported that at a common 20 °C nighttime temperature, increasing daytime temperatures from 10 °C to 30 °C caused progressively decreased CO₂ uptake during the light period, whereas CO₂ uptake during the dark period increased on a short-term basis. However, none of these studies determined the long-term effects of temperature on plant growth. Extended exposure to nights warmer than the days may alter CO₂ uptake and that may result in modified growth and flowering. The objective of this study was to determine how prolonged periods of nights warmer than days and average daily temperature would affect vegetative and reproductive response of a *Doritaenopsis* hybrid.

Materials and Methods

Expt. 1. On 3 Mar., plants of the ‘Lava Glow’ clone of *Doritaenopsis* (*Phal.* Buddha’s Treasure × *Doritis pulcherrima*), ≈15 cm in leaf spread (Twyford Laboratories, Apopka, Fla.) were planted in 11.4-cm standard pots (650-mL vol). The root substrate consisted of 70% small grade Douglas fir bark [*Pseudotsuga menziesii* (Mirb.) Franco]

and 10% each of Canadian sphagnum peat, large grade perlite, and dust sphagnum moss. The substrate was amended with 6 g·L⁻¹ powdered dolomitic limestone and 1 g·L⁻¹ of Micromax (a micronutrient source; Scotts, Inc., Marysville, Ohio). Plants were selected for their uniformity in overall size and distributed evenly to four blocks by the size of the newest, growing leaf, which was marked. Plants were moved to and remained in four growth chambers (Model EGC15; Environmental Growth Chambers, Chagrin Falls, Ohio) at 170 μmol·m⁻²·s⁻¹PPF with a 12-h photoperiod. Ninety percent of the irradiance was provided by cool-white fluorescent tubes and 10% was from incandescent bulbs. There was no barrier between the light source and plants.

Treatments were day/night temperatures being maintained at 30/25, 25/30, 25/20, or 20/25 °C at 12 h each. In addition to a growth chamber’s own temperature control system, temperatures were monitored with a hygrothermograph and a mercury thermometer in each chamber. PPF in each chamber was monitored with a light meter frequently. Temperature and irradiance were adjusted when necessary.

Plants were fertigated when needed with a 15N–2.3P–12.9K soluble fertilizer (Scotts Inc.) at 0.67 g·L⁻¹ with 33 mg·L⁻¹ Ca and 13 mg·L⁻¹. After 37 weeks, leaf span (the distance between the tips of the two top leaves) was measured and the number of new leaves and their combined length were recorded. The length and width of the uppermost mature leaf were measured and their ratio was calculated. Plants were also observed for flowering. There were 15 plants per treatment.

Expt. 2. A second experiment was initiated on 21 May using the same clone, except they were in 14-cm standard pots. Plants 18 to 22 cm in leaf span were selected as previously stated and subjected to a wider day/night temperature differential, including 30/20, 20/30, 25/15, and 15/25 °C. Other environmental factors remained the same as in Expt. 1. Data were collected similar to this experiment after 29 weeks. There were 22 plants per temperature regimen. Analysis of variance was performed on the data in both experiments, except for number of plants flowered.

Results

Expt. 1. Plants at the higher average daily temperature (ADT, 27.5 °C, 30/25 °C, or 25/30 °C) produced more leaves than the ones at the lower ADT (22.5 °C, 25/20 °C, or 20/25 °C) regardless of the day and night temperatures (Table 1). Those grown at 30/25 °C had the widest leaf span and the largest total length of new leaves. For any given ADT, cooler days resulted in shorter total leaf length. At the higher ADT (27.5 °C), day and night temperatures did not affect the number of new leaves being produced. However, at the lower ADT (22.5 °C), fewer leaves (2.8 versus 3.6) were produced when days were cooler than the nights (20/25 °C).

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**Doritis pulcherrima* Lindley has been reclassified as *Phalaenopsis pulcherrima* (Lindl.) J. J. Sm. (Christenson, 2001).

At any given ADT, cooler days resulted in shorter and narrower leaves, but the length and width ratio remained similar to that when the days were warmer (Table 2). Leaves that emerged and grew at the lower ADT had reduced length to width ratios than those at the higher ADT, giving more oval-shaped leaves. Although leaves produced at 25/30 °C or 25/20 °C had similar lengths, those grown at 25/20 °C had a reduced length to width ratio.

Fourteen of 15 plants maintained at 20/25 °C flowered by the end of December, whereas only five plants in the 25/20 °C treatment and none at the higher ADT (27.5 °C) bloomed (Table 2).

Expt. 2. Results from the second experiment were similar to the first one despite that the day/night differential was increased from 5 °C to 10 °C. Although 30/20 °C and 20/30 °C resulted in similar numbers of new leaves being produced, those produced at 20/30 °C were shorter (Table 3). The small leaf span and lesser combined leaf length were dramatic at 15/25 °C (Table 3). Despite the same ADT, new leaves produced at 15/25 °C were very small

and only 50% the length of those at 25/15 °C (Table 4; Fig. 1), giving a length to width ratio of 1.4, and a round appearance. These leaves were deeper green than leaves in other temperature regimen (Fig. 1). All 22 plants at 15/25 °C bloomed, whereas none in the other three day/night temperature regimen had flowers.

Discussion

Phalaenopsis performs crassulacean acid metabolism to assimilate CO₂ primarily during the dark period of the day (Guo and Lee, 2006; Ota et al., 1991). Growing them at constant temperatures, Ota et al. (1991) determined that the net CO₂ uptake by *Phalaenopsis* leaves during the 12-h light period decreased as temperature increased from 10 °C and declined to a very low level when temperatures reached or exceeded 25 °C. CO₂ uptake during the 12 h in darkness increased as temperature rose from 10 °C, reaching its plateau at 20 °C and then declined as temperature increased further to 30 °C. However, when grown at different day/night temperatures, the daily cumulative CO₂ up-

take at 10/20 °C was much lower than that at 30/20, 25/20, or 25/15 °C (Ota et al., 1991).

At a common 25 °C day temperature, *Phalaenopsis* leaves had higher level of CO₂ absorption at 15 °C than at 25 °C during the dark period (Ota et al., 1991). At a common night temperature of 15 °C, daytime temperature of 25 °C resulted in much higher total nighttime CO₂ absorption than 15 °C. Lootens and Heursel (1998) reported that young *Phalaenopsis* plants had higher daily cumulative CO₂ uptake at 20/15 °C than at 25/20 °C or 25/25 °C, measured over a 24-h period. However, Guo and Lee (2006) determined that *Phalaenopsis* leaves incorporated much higher quantities of CO₂ at 32/28 °C or 29/25 °C than at 25/20 °C or 21/16 °C day/night temperatures. Guo and Lee (2006) and Lee and Lin (1984) clearly established that higher daily net CO₂ uptake at higher temperatures (15 °C to 32 °C) resulted in increased leaf growth in *Phalaenopsis*.

Maturation of the slow-growing *Phalaenopsis* is directly related to the rate of increase in cumulative leaf area (Lee, 1991). The current data support the findings of Lin and Lee (1988) that *Phalaenopsis* hybrids require high temperatures to grow quickly and produce more total leaf area at 30/25 °C compared with 25/20 °C or 20/15 °C. It is very clear that, for slow-growing plant species such as orchids, results from short-term experiments may not be a reliable tool for predicting the long-term growth response to certain environmental conditions.

The cool day/warm night temperature regimens of 20/25 °C and 15/25 °C markedly restricted vegetative growth. Because increased levels of soluble sugars in leaves have been associated with spiking (Lee and Lee, 1996), the current data suggest that there might have been increased sugar levels in leaves at the 20/25 °C and 15/25 °C conditions, which contributed to spiking and flowering. The photosynthetic response and levels of soluble sugars in the leaf at cool day/warm night conditions need to be studied in more detail to fully understand what contributed to flowering at these conditions.

Day/night air temperatures of 25/20 °C and 20/15 °C are capable of triggering spiking in *Phalaenopsis* and its hybrids

Table 1. Effects of various day/night temperatures on vegetative growth (Expt. 1)².

Treatment (day/night, °C)	Leaf span (cm)	New leaves	
		Number	Linear length (cm)
30/25	31.0 a	5.0 a	71.6 a
25/30	26.4 b	4.7 a	60.9 b
25/20	25.4 b	3.6 b	44.4 c
20/25	19.8 c	2.8 c	28.8 d

²Means within columns followed by different letters are different by Duncan's multiple range test at $P \leq 0.05$ (n = 15).

Table 2. Effects of various day/night temperatures on leaf and flowering (Expt. 1)².

Treatment (day/night, °C)	Uppermost mature leaf			No. of plants bloomed among 15
	Length (cm)	Width (cm)	L:W ratio	
30/25	17.2 a	8.4 b	2.04 a	0
25/30	14.8 b	7.6 c	1.95 a	0
25/20	14.7 b	9.0 a	1.63 b	5
20/25	11.1 c	7.3 c	1.52 b	14

²Means within columns followed by different letters are different by Duncan's multiple range test at $P \leq 0.05$ (n = 15).

Table 3. Effects of 30/20, 20/30, 25/15, and 15/25 °C day/night temperatures on vegetative growth (Expt. 2)².

Treatment (day/night, °C)	Leaf span (cm)	New leaves	
		Number	Linear length (cm)
30/20	32.6 a	4.2 a	64.0 a
20/30	26.4 b	4.3 a	57.6 b
25/15	28.1 b	3.4 b	48.3 c
15/25	16.7 c	2.1 c	19.5 d

²Means within columns followed by different letters are different by Duncan's multiple range test at $P \leq 0.05$ (n = 22).

Table 4. Effects of 30/20, 20/30, 25/15, and 15/25 °C day/night temperatures on leaf and flowering (Expt. 2)².

Treatment (day/night, °C)	Uppermost mature leaf			No. of plants bloomed among 22
	Length (cm)	Width (cm)	L:W ratio	
30/20	18.3 a	8.7 b	2.10 a	0
20/30	14.7 c	7.9 c	1.86 b	0
25/15	16.4 b	9.2 a	1.79 b	0
15/25	8.2 d	7.1 d	1.39 c	22

²Means within columns followed by different letters are different by Duncan's multiple range test at $P \leq 0.05$ (n = 22).

Fig. 1. Effect of day/night temperatures of 30/20, 20/30, 25/15, and 15/25 °C on leaf growth and flowering.

(Lee and Lin, 1984). However, 25/20 °C in Expt. 1 only triggered one third of the plants to flower and 25/15 °C in Expt. 2 failed to trigger this cloned *Doritaenopsis* to start spiking. Surprisingly, with the same ADT, the reversed day/night temperatures (20/25 °C and 15/25 °C) effectively induced plants to flower under a 12-h photoperiod. *Doritis pulcherrima* naturally spikes in the spring rather than in the fall as *Phalaenopsis* or the large-flowered *Doritaenopsis* hybrids do. The *Doritaenopsis* used in this study is a first-generation hybrid of *Doritis pulcherrima*. As such, this *Doritaenopsis* clone may behave differently from *Phalaenopsis* or the more complex *Doritaenopsis* hybrids. More research is needed to fully understand the control mechanism for spiking in *Phalaenopsis* and *Doritis* species and hybrids.

The changes of leaf L:W ratio in response not only to ADT, but to day/night temperatures clearly show the diurnal thermoregulation of plant morphology. The smaller leaf L:W ratio at lower temperatures is in agreement to that observed by Lin and Lee (1988).

Results from this study clearly show the marked diurnal thermoregulation of plant growth and development. Having the day temperature in the 25 °C to 15 °C range, a prolonged period of nights being 5 °C to 10

°C warmer does not appear to enhance the accumulation of photosynthetic products and is not favorable for rapid vegetative growth. However, cool days and warm nights may be used as an effective tool for inducing spiking in certain hybrids. Additional studies are needed to learn if other *Phalaenopsis* species and hybrids respond similarly to the reversed day/night temperatures as this first generation *Doritis pulcherrima* hybrid.

Literature Cited

- Christenson, C.A. 2001. *Phalaenopsis*—A monograph. Timber Press, Portland, Ore.
- Guo, W.J. and N. Lee. 2006. Effect of leaf and plant age and day/night temperature on net CO₂ uptake in *Phalaenopsis amabilis* var. *formosa*. J. Amer. Soc. Hort. Sci. 131:320–326.
- Guo, W.J. 1999. Studies on characteristics of photosynthesis in *Phalaenopsis*. Master's thesis. Dept. of Hort; National Taiwan Univ., Taipei, Taiwan.
- Krizek, D.T. and R.H. Lawson. 1974. Accelerated growth of *Cattleya* and *Phalaenopsis* under controlled-environment conditions. Amer. Orchid Soc. Bul. 43:503–510.
- Lee, N. 1991. Juvenility in *Phalaenopsis*. Symp. on Forcing Culture of Hort. Crops II:77–86 (Taiwan).
- Lee, N. and C.H. Lee. 1996. Changes in carbohydrates in *Phalaenopsis* during flower induction and inflorescence development. J. Chinese Soc. Hort. Sci. 42:262–275.
- Lee, N. and G.M. Lin. 1984. Effect of temperature on growth and flowering of a *Phalaenopsis* white hybrid. J. Chinese Soc. Hort. Sci. 30:223–232.
- Lin, G.M. and N. Lee. 1988. Leaf area estimation and the effect of temperature on the growth of *Phalaenopsis* leaves. J. Chinese Soc. Hort. Sci. 34:73–80.
- Lootens, P. and J. Heursel. 1998. Irradiance, temperature, and carbon dioxide enrichment affect photosynthesis in *Phalaenopsis* hybrids. HortScience 33:1183–1185.
- Ota, K., K. Morioka, and Y. Yamamoto. 1991. Effects of leaf age, inflorescence, temperature, light intensity, and moisture conditions on CAM photosynthesis in *Phalaenopsis*. J. Jpn. Soc. Hort. Sci. 60:125–132.
- Sakanishi, Y., H. Imanishi, and G. Ishida. 1980. Effect of temperature and flowering on *Phalaenopsis amabilis*. Bul. Univ. Osaka Pref. Ser. B. 32:1–9.
- Wang, Y.T. 2004. Potted orchids continue to rise worldwide. Flower Tech. 7:14–17.
- Wang, Y.T. 2005. Temperature and nutrient effects on *Phalaenopsis*. Proceedings of 2005 Taiwan International Orchids (*Paphiopedilum* and *Phalaenopsis*) Symposium. p. 249–258.
- United States Department of Agriculture (USDA). 2006. Floriculture Summary. USDA Statistical Service, Washington, D.C.