Phalaenopsis Orchid Light Requirement during the Induction of Spiking

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Abstract. **Potted mature *Phalaenopsis* 'Joseph Hampton' orchid (clone Diane) plants were placed in each of four growth chambers with 0, 8, 60, or 160 μmol·m^{-2}·s^{-1} photosynthetic photon flux (PPF) for 12 hours daily and at 20C day/15C night air. Plants under 160 or 60 μmol·m^{-2}·s^{-1} PPF began spiking (an elongating reproductive bud protruding through the base of its subtending leaf) in an average of 28 or 34 days, respectively. None of the plants placed under 0 or 8 μmol·m^{-2}·s^{-1} PPF started spiking within 6 weeks. These plants, following return to a greenhouse, spiked and flowered 8 weeks later than those receiving 160 μmol·m^{-2}·s^{-1}. In a second experiment, plants were placed in each of three growth chambers and kept in complete darkness at 20C day/15C night for 2, 4, or 6 weeks before exposure to 160 μmol·m^{-2}·s^{-1} PPF. Air was maintained at 20C day/15C night for an additional 6 weeks and then raised to 25C day/20C night to accelerate flowering. Plants exposed to 2, 4, or 6 weeks of darkness required 45, 60, or 77 days, respectively, to reach spiking. However, all plants spiked at similar times (31 to 35 days) after lighting began. Anthesis occurred at progressively later dates for plants placed in darkness for increasing durations, but plants in all treatments required 123 days to reach anthesis following their exposure to light. Flower count and size were not affected in both experiments.**

In recent years, potted blooming *Phalaenopsis* orchids (the moth orchids) have rapidly gained worldwide popularity (Thomas, 1992; Wang and Lee, 1994a, 1994b). Domestic production and import of this orchid are increasing rapidly. In the past, *Phalaenopsis* was mainly grown by nurseries specializing in orchids. With the increasing supply of less expensive materials and the growing market demand, this orchid now is being grown alongside traditional floral crops. Development of advanced cultural techniques to grow high-quality *Phalaenopsis* profitably is urgently needed.

In *Phalaenopsis*, one large potentially reproductive bud and a small vegetative bud are produced in the axil of the subtending leaf. When all the physiological and environmental requirements are met, the large upper reproductive bud elongates, which can lead to flowering. Many studies (Lee and Lin, 1984, 1987; Sakanishi et al., 1980; Yoneda et al., 1992) have investigated the requirement of relatively low temperatures for inducing the elongation of the reproductive bud (spiking). Flower bud initiation occurs after the reproductive stem (spike) has reached a certain length under the required environmental conditions (Lin, 1994).

Although mature plants of this orchid can be forced to bloom year-round in cool areas or in air-conditioned greenhouses, most bloom in spring following their exposure to the natural cool weather in fall and winter. As a consequence, blooming *Phalaenopsis* orchids are in short supply in late spring and summer. Many growers remove the first inflorescence, in anticipation that a second one will develop in time for Mother's Day. However, this practice does not always offer satisfactory results.

Keeping greenhouse air temperatures at ≥28C prevents the elongation of the reproductive bud (Chen et al., 1994; Yoneda et al., 1991), thereby inhibiting flowering. However, maintaining greenhouse air at such high temperatures during fall and winter is cost prohibitive. Kubota and Yoneda (1993a, 1993b) reported that *Phalaenopsis* grown under continuous low photosynthetic photon flux (PPF) responded less favorably to temperatures needed for spiking than those produced under a higher PPF. My objectives were to develop techniques to delay flower opening by determining the effects of decreasing light level and of duration of darkness during exposure of *Phalaenopsis* plants to cool conditions on spiking and flowering.

Materials and Methods

Light intensity. Thirty-two, tissue-culture-propagated 'Joseph Hampton' orchids (clone Diane), with six to nine leaves spreading 55 to 65 cm across, in 1.75-liter pots (15 cm) were selected. All plants had bloomed once in Spring 1993. Four growth chambers were maintained at spike-inducing temperatures (20C day/15C night) (Lee and Lin, 1984). Eight plants were placed in each of three growth chambers (model GC–15; Environmental Growth Chambers, Chagrin Falls, Ohio) with 160, 60, or 8 μmol·m^{-2}·s^{-1} PPF at plant level on 24 Aug. 1993 to induce spiking. Ninety percent of the light energy at the two higher PPFs was provided by cool-white fluorescent tubes, whereas incandescent bulbs supplied 100% of the energy in the 8-μmol·m^{-2}·s^{-1} PPF chamber. The photoperiod was 12 h daily. Another eight plants were placed in a dark growth chamber (Revco Scientific, Ashville, N.C.). Pots were watered with 0.5 g 20N–8.6P–16.6K soluble fertilizer/liter (Grace-Sierra, Fogelsville, Pa.) as needed. Plants were checked daily, and the

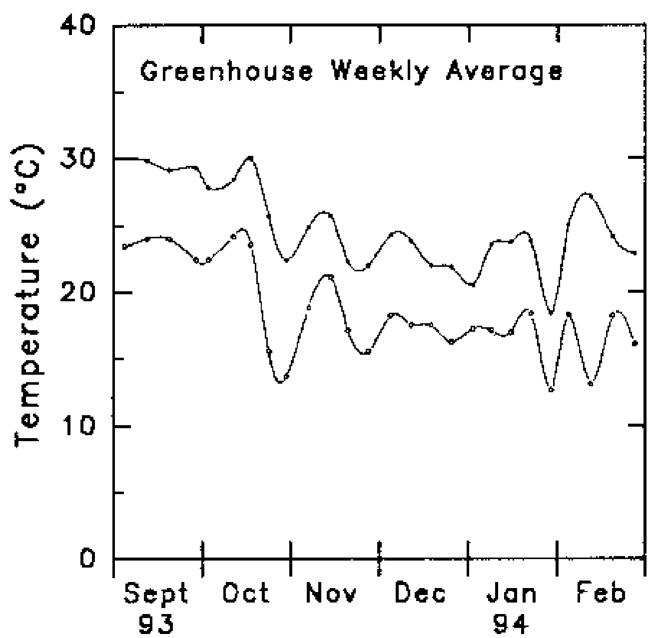

Fig. 1. Weekly average maximum and minimum greenhouse temperatures at plant level from Sept. 1993 to the end of Feb. 1994.

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date when spiking began was recorded for each plant.

After 6 weeks, all plants were moved back to a greenhouse and arranged in a randomized complete-block design, replicated eight times, including control plants that had experienced only greenhouse temperatures (Fig. 1) during the period that the other plants were in growth chambers. The maximum PPF in the greenhouse was ≈270 μmol·m^{-2}·s^{-1}. Each plant was an experimental unit and checked daily for spiking. The date when the first flower on each plant had become flat open was recorded. Flower count per inflorescence and size of the first flower were recorded for each plant. Tukey's multiple range test was used for mean separation.

Duration in darkness. On 14 Oct. 1993, 10 mature 'Joseph Hampton' orchid (clone Diane) plants in 2.6-liter pots (but otherwise similar to plants described previously) were selected and placed in each of three growth chambers. All treatments were initiated on the same day to simulate the arrival of spike-inducing temperatures in a greenhouse. The plants were kept in complete darkness at 20C day/15C night for 2, 4, or 6 weeks before exposure to 160 μmol·m^{-2}·s^{-1} PPF at plant level for 12 h daily. Ninety percent of the light energy was provided by cool-white fluorescent tubes and the rest by incandescent bulbs. Air temperature was maintained at 20C day/15C night for an additional 6 weeks after the light was turned on in each chamber to ensure sufficient exposure to cool air for spiking. Then the air temperature was raised to 25C day/20C night. After the last 10 plants received 6 weeks of 20C day/15C night cycles, all plants were redistributed among the three growth chambers in a randomized complete-block design until the end of the experiment. One plant represented an experimental unit. All plants were kept in a greenhouse between 17 and 28 Feb. 1994 because of growth chamber malfunction. The average greenhouse maximum and minimum during this period were 23.6 and 17.5C, respectively. Spiking and flowering dates, flower count on an inflorescence, and diameter of the first flower were recorded for each plant. Regression analysis was performed on the data using weeks in darkness as the independent variable.

Results and Discussion

Light intensity. An adequate light intensity was required for rapid response to low temperatures to induce spiking. Plants under 160 or 60 μmol·m^{-2}·s^{-1} PPF spiked in ≈1 month (Table 1). Spiking was absent on plants placed under 8 μmol·m^{-2}·s^{-1} PPF or in complete darkness during the 6 weeks in a growth chamber at the 20C day/15C night cycle, which induces spiking in mature plants (Lin and Lee, 1984). There was slow leaf and root extension and no leaf drop during the 6 weeks in darkness. However, subsequent leaf drop in the greenhouse was more severe in plants kept in darkness than those receiving light. The control plants in the greenhouse did not spike by the time the treated plants were returned, indicating that spiking in plants maintained at the two higher PPFs was induced by the low temperatures in the growth chambers. Those exposed to 8 μmol·m^{-2}·s^{-1} PPF or darkness required a similar time (88 to 95 days) to spike as greenhouse control plants, suggesting that they did not perceive low-temperature stimulation for spiking while they were in growth chambers. Low greenhouse temperatures during October and November (Fig. 1) induced spiking in these control plants.

Plants exposed to 160 or 60 μmol·m^{-2}·s^{-1} PPF during induction of spiking bloomed at about the same time (Table 1). Those exposed to 8 μmol·m^{-2}·s^{-1} PPF or complete darkness and greenhouse control plants bloomed much later, but almost simultaneously. Neither flower count nor flower size (data not shown) was affected by light intensities.

Aharoni and Halevy (1977) reported that *Phalaenopsis* plants kept in darkness at 20C day/14C night did not spike. These plants spiked only after being moved to light, and they flowered 25 days later than those exposed to high light intensity while being cooled, apparently responding to the low temperature following their exposure to light (Halperin and Halevy, 1975).

Duration in darkness. Plants in darkness for 2, 4, or 6 weeks required 45 to 77 days from the start or 31 to 35 days following the onset of lighting to reach spiking (Table 2). No plant started spiking while in darkness. Data from this and the light intensity experiment suggest that plants could not respond to low temperature stimulation for spiking while under a low PPF or in darkness. Thus, light exceeding a certain threshold level would be required for the plants to perceive low-temperature stimulation for inducing the elongation of the reproductive buds.

Plants placed in darkness for more time bloomed at progressively later dates (Table 2). However, all plants required 123 days to reach anthesis following the exposure to light accompanied by inductive temperatures. All plants used in this study were mature and would spike under favorable conditions. Had additional plants been placed in a chamber without dark treatment, they would have all bloomed in 123 days. Because darkness prevented plants from responding to spike-inducing cool air, spiking and bloom dates were delayed by subjecting plants to darkness for 2 to 6 weeks without detrimental effects. There was no unusual leaf drop in any plant for the duration of this experiment. As in the first experiment, darkness duration did not adversely affect flower quality (e.g., flower count or flower size) (data not presented).

Kubota and Yoneda (1992a, 1992b) reported that tissues of *Phalaenopsis* plants under a low PPF had lower sugar and higher nitrogen levels than those under a higher PPF, which resulted in reduced spiking or no spiking at all. A continuous sugar supply to the apex of a reproductive bud is essential for continued floral development, whether induced by high light, low temperature, or gibberellin (Chen et al., 1994). Although *Phalaenopsis* leaves perform crassulacean acid metabolism and take up CO_2 in darkness, increasing PPF from 0 to 300 μmol·m^{-2}·s^{-1} increased daily CO_2 uptake and possibly sugar production (Endo and Ikusima, 1989; Ota et al., 1991). When plants were placed in darkness during the day, respirational carbon loss occurred and no net CO_2 uptake was observed. As a consequence, a *Phalaenopsis* plant exposed to low PPF or in darkness, without a constant supply of a certain threshold level of sugars, may not respond to spike-inducing temperatures.

My data clearly show that *Phalaenopsis* plants must be exposed to light above a certain level to respond to cool air to activate the reproductive bud. Spiking and flowering are delayed but without adverse effects when plants are exposed to low PPF or complete darkness

Table 1. Effect of various levels of photosynthetic photon flux (PPF) during 6 weeks of 20C day/15C night cycles on spiking of the *Phalaenopsis* orchid. All plants were moved to a greenhouse following treatment in growth chambers.[z]

PPF (μmol·m^{-2}·s^{-1})	Days to spiking[y]	Days to anthesis[y]	Days from spiking to anthesis	Flower count	Leaf drop
160	28 b	156 b	128 a	10.4 a	0.2 b
60	34 b	167 b	134 a	14.0 a	0.2 b
8	88 a	211 a	123 a	10.8 a	0.4 b
0	95 a	216 a	123 a	11.1 a	1.3 a
Natural[x]	89 a	213 a	124 a	10.0 a	0 b

[z]Mean separation by Tukey's honest range test at $\alpha = 0.05$.
[y]Day 0 = 23 Aug. 1993.
[x]Plants continuously in greenhouse.

Table 2. Effect of 2, 4, or 6 weeks in complete darkness while being subjected to 20C day/15C night spike-inducing temperatures on spiking and flowering of *Phalaenopsis* orchid.

Weeks in darkness	Days to spiking: From the beginning	Days to spiking: After light on	Days to anthesis: From the beginning	Days to anthesis: After light on	Flower count
2	45	31	137	123	10.9
4	60	32	151	123	10.0
6	77	35	165	123	10.5
Significance[z]	L***	NS	L***	NS	NS

[z]L = linear response.
NS, ***Nonsignificant at $\alpha \leq 0.05$ or significant at $\alpha \geq 0.001$, respectively.

under otherwise cool inductive conditions. Bloom date could have been delayed further in this study had plants been subjected to lower temperatures than the 25C day/20C night following spiking (Lee and Lin, 1984).

Although light quality has been shown to affect flowering (Roh and Wilkins, 1977) and leaf growth (Reid et al., 1968), in this study, late-blooming plants in the 8-$\mu mol \cdot m^{-2} \cdot s^{-1}$ chamber likely responded only to the light quantity. According to Kubota and Yoneda (1993a), plants grown continuously under <50 $\mu mol \cdot m^{-2} \cdot s^{-1}$ do not spike.

Given similar results on delaying flowering by 0 and 8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPF, providing a dim light to plants while being exposed to relatively low temperatures will have the benefit of preventing leaf abscission or severe weakening of plants while discouraging spiking. The threshold PPF above which *Phalaenopsis* plants will respond to spike-inducing temperatures is not known, but the information from this study could be used to develop techniques for staggering flowering to help extend the availability of potted, blooming *Phalaenopsis* orchid under commercial conditions.

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