Medium and Fertilizer Affect the Performance of *Phalaenopsis* Orchids during Two Flowering Cycles

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Abstract. **Bare-root seedling plants of a white-flowered *Phalaenopsis* hybrid [*P. arnabilis* (L.) Blume x *P.* Mount Kaala 'Elegance'] were grown in five potting media under three fertility levels (0.25, 0.5, and 1.0 g·liter^{-1}) from a 20N-8.6P-16.6K soluble fertilizer applied at every irrigation. The five media included 1) 1 perlite :1 Metro Mix 250:1 charcoal (by volume); 2)2 perlite :2 composted pine bark :1 vermiculite; 3) composted pine bark; 4) 3 perlite :3 Metro Mix 250:1 charcoal; and 5) 1 perlite :1 rockwool. During the first flowering season, plants in the 1 perlite: 1 Metro Mix 250:1 charcoal medium had slightly fewer but larger flowers and thicker stalks (section of the inflorescence between the base and oldest flower) than those in the 1 perlite :1 rockwool medium. Medium had no effect on stalk length. Two media (3 perlite : 3 Metro Mix 250 : 1 charcoal and 1 perlite : 1 rockwool) resulted in root systems that were inferior to those in the others. Fertilizer level had no effect on bloom date or flower size. Regardless of medium, increasing the fertility from 0.25 to 1.0 g·liter^{-1} increased flower count, stalk diameter and length, and leaf production following flowering. During the second flowering season, media had limited effect on plant performance. Increased fertility promoted earlier inflorescence emergence and blooming. Higher fertilizer rates also caused a linear increase in the number of flowers and inflorescences per plant, and in stalk diameter, total leaf count, and leaf size.**

Phalaenopsis is an epiphytic, monopodial orchid native to southeastern Asia. As a result of extensive hybridization, this orchid is available in various flower sizes and diverse colors (Takasaki, 1989; Vasquez and Frier, 1991) and is easier to grow than most other orchids (Freed, 1976). Although *Phalaenopsis* was grown primarily for cut flowers in the past, the demand for this orchid as a potted flowering plant is rapidly increasing in Asia, Europe, and the United States (Post, 1987; Takasaki, 1989; Thomas, 1992; Vasquez and Frier, 1991).

Traditionally, *Phalaenopsis* is grown commercially in orchid bark, e.g., coarse fir or redwood bark chips (Freed, 1976), Because of this orchid's succulent roots and the bark chips' large size, potting large bare-root*Phalaenopsis* plants with bark is labor intensive, which increases production cost. Also, bark does not hold much water, resulting in frequent watering and plants recover slowly after being in transit for many days. Additionally, orchid bark decomposes quickly, resulting in nutrient deficiency, poor aeration, low pH, pest infestation, and frequent repotting. Potting plants in other recommended media, such as sphagnum moss or shredded tree fern, requires even higher labor costs on a commercial scale. Therefore, media with smaller particle sizes need to be developed to provide better root contact and evaluated for mass production of this orchid. Also, fertilizer requirements for this orchid must be determined for these media on a short- (commercial forcing) and long-term (consumer use) basis. Therefore, a study was conducted to assess the effects of several media and fertility levels on flowering and growth of *Phalaenopsis* during two flowering cycles.

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Materials and Methods

Bare-root seedling plants of a white-flowered *Phalaenopsis* hybrid with five to seven leaves spreading 30 to 35 cm were potted in 1.75-liter pots immediately upon arrival on 14 Oct. 1991. They were purchased from an overseas supplier (Taiwan Sugar Corp., Taipei, Republic of China) and were in transit for 9 days. Plants were potted using five media, including 1) 1 perlite :1 Metro Mix 250: 1 charcoal (P1M1C1) (by volume); 2) 2 perlite :2 pine bark :1 vermiculite (PBV); 3) 100% pine bark (B); 4)3 perlite :3 Metro Mix 250: 1 charcoal (P3M3C1); and 5) 1 perlite : 1 rockwool (PR). The P3M3C1 medium was included for its lower cost than the P1M1C1 medium, which consisted of one-third charcoal. Small-grade perlite (#3; Grace-Sierra Horticultural Products, Foglesville, Pa.) and fine-grade rockwool (Partek North America, Englewood, Colo.) were used. Metro Mix 250 (Grace-Sierra) is a commercial medium containing peatmoss, perlite, vermiculite, groundcharred bark, and granite sand with a balanced pH and nutrient charge. The charcoal particle size distribution was 35% >8 mm, 21% between 8 and 6.3 mm, 32% between 6.3 and 4 mm, and 14% < 4 mm. The pine bark (Lousiana-Pacific, New Haverly, Texas) was fully composted with particle size < 0.75 cm. To each medium, superphosphate (45% P_2O_5) and Micromax (a micronutrient source; Grace-Sierra, Milpitas, Calif.) were added at 1.14 and 0.14 kg·m^{-3}, respectively. Each medium was mixed for 5 min in a rotary mixer, except that in charcoal-containing media, the charcoal was added and mixed briefly after the other ingredients were thoroughly mixed.

The three levels of fertility included adding 0.25, 0.5, or 1.0 g of Peters 20N–8.6P-16.6K (Grace-Sierra) per liter of water at each irrigation. The lowest fertility level was included due to the high soluble salt levels (between 0.9 and 1.2 dS·m^{-1}, pH ≈7.4) in the irrigation water. Pots were examined daily, and each medium was irrigated to leaching separately, as needed.

Plants were placed on a greenhouse bench receiving a maximum photosynthetic photon flux ranging between 230 (winter) and 410 (summer) µmol·m^{-2}·s^{-1} at noon. The factorial experiment had a split-plot design of five media (the main plot) and three fertility levels (the subplot) replicated 20 times.

Data collection included air temperatures during the experiment (Fig. 1), the date on which the first (the oldest) flower became fully open, width of the first flower, flower count, and stalk length (the portion of the inflorescence between the base and oldest flower), and its diameter at the middle of the fourth internode. Leachate was collected from pots in mid-April for determining pH and electrical conductivity (EC) by using the pour-through technique (Wang and Boogher, 1987). Plants were taken out of pots for root examination and then immediately repotted in the same medium. On 31 Aug. 1992, the number of leaves produced after planting, including any expanding leaf that was longer than half the length of the youngest fully expanded leaf, was recorded for each plant.

To determine how these cultural factors affected the performance during the second flowering season, plants were checked daily from 1 Sept. 1992 for inflorescence emergence. Dates were recorded when an inflores-

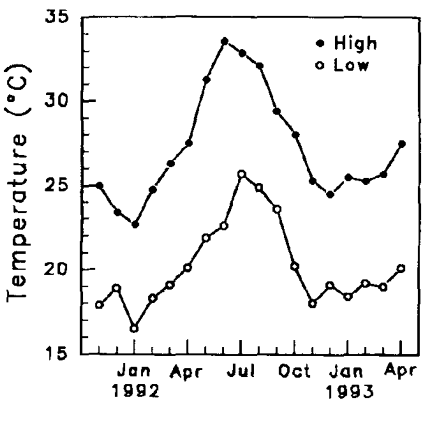

Fig. 1. Monthly average of the high and low temperatures for the duration of this study.

Table 1. The effect of medium and fertility on flowering and growth of *Phalaenopsis* and on pH and electrical conductivity (EC) of the medium leachate. There was no significant media × fertilizer rate interaction; therefore, only the main effect means are presented.[z]

	First flower			Stalk[y]		Medium leachate		Root	
Treatment	Bloom (days)	Width (cm)	Flower no.	Diam (mm)	Length (cm)	pH	EC (dS·m^{-1})	grade (1–5)[x]	New leaves
Medium[w]									
1 (P1M1C1)	123 bc	10.2 a	6.8 b	4.70 a	66.3 a	7.46 a	1.91 b	4.1 a	2.8 a
2 (PBV)	124 ab	10.4 a	7.4 ab	4.75 a	68.6 a	6.42 c	1.64 c	4.3 a	2.9 a
3 (B)	122 bc	10.4 a	7.1 ab	4.72 a	68.5 a	6.17 d	1.72 c	4.3 a	2.9 a
4 (P3M3C1)	127 a	10.3 a	7.2 ab	4.78 a	67.8 a	7.43 a	2.16 a	3.4 b	2.2 b
5 (PR)	119 c	9.8 b	7.5 a	4.49 b	66.7 a	7.00 b	1.87 b	2.9 b	2.8 a
Fertilizer (g·liter^{-1})[v]									
0.25	124	10.3	6.7	4.62	65.2	7.29	1.66	3.9	2.2
0.50	123	10.1	7.0	4.61	66.5	7.00	1.78	3.7	2.6
1.00	123	10.2	8.0	4.82	71.0	6.41	2.15	3.8	3.4
Significance	NS	NS	L***	L**	L***	L***	L***	NS	L**

[z]Mean separation within columns by Duncan's multiple range test, α = 0.05.
[y]Diameter was measured at the middle of the fourth basal internode. Length was the distance between the base and the oldest flower.
[x]1 = all roots dead; 2 = poor roots; 3 = some dead roots, good old roots overall; 4 = few dead roots, some new roots; 5 = very few dead roots, abundant new roots.
[w]1 = 1 perlite : 1 Metro Mix 250 : 1 charcoal (P1M1C1); 2 = 2 perlite : 2 pine bark : 1 vermiculite (PBV); 3 = 100% pine bark (B); 4 = 3 perlite : 3 Metro Mix 250 :1 charcoal (P3M3C1); 5 = 1 perlite : 1 rockwool (PR).
[v]Peters (20N–8.6P–16.6K) water-soluble fertilizer.
NS,**,***Nonsignificant or linear (L) and significant at α = 0.01 or 0.001, respectively.

cence first broke the base of its subtending leaf and when the first flower opened on each plant. In the case of two or more inflorescences on the same plant, data were taken only from the first one emerged. Irrigation water was switched to that from a reverse osmosis device (EC ≤0.03dS·m^{-1}) in early Jan. 1993. Number of inflorescences on each plant, of flowers on the main inflorescence, and the total flower count (including those on the lateral inflorescences), size of the first flower, stalk length, and internode length between the first two flowers were recorded. Total leaf count and width and length of the distal second fully matured leaf were determined. Leachate samples were collected in mid-April for determining pH and EC.

Results and Discussion

First season. There was no significant medium × fertility interaction for any of the characteristics recorded. Plants in the PR medium bloomed sooner but had thinner stalks and smaller flowers than the two containing charcoal (Table 1). The P1M1C1 medium resulted in slightly fewer flowers than the PR. Stalk length was unaffected by medium. Fertilizer level had no influence on bloom date or flower size. Increasing fertility from 0.25 to 1.0 g·liter^{-1} increased flower count, stalk diameter and length, and leaf production.

Both pH and EC of the medium leachate were affected by medium composition and fertility level. Media containing bark had the lowest pH and EC (Table 1). The P3M3C1 medium had high pH and EC. As expected, increasing fertility level resulted in lower pH and higher EC.

Roots in the P3M3C1 and PR media were inferior to those in the others (Table 1). Increasing fertility increased leaf count but had no effect on root gade. Plants in P3M3C1 did not produce as many leaves as those in other media.

Second season. Medium composition had little effect on plant growth and flowering (Tables 2 and 3). Plants grown in 100% composted pine bark had more leaves than those in any other medium, except PBV (Table 3). Although leaves of all plants were similar in length, those grown in P1M1C1 had significantly wider leaves than any others, except those in 100% pine bark.

Nearly all of the characteristics recorded responded linearly to increasing fertility from 0.25 to 1.0 g·liter^{-1}. Flower spikes emerged and bloomed earlier as fertilizer level increased (Table 2). Plants receiving fertilizer at 1.0 g·liter^{-1} bloomed 16 days earlier than those fertilized with 0.25 g·liter^{-1}. However, once the inflorescence had emerged, plants receiving the lower fertility levels required fewer days to reach flower opening than those fertilized at 1.0 g·liter^{-1}. As fertility level increased, total flower count also increased as a result of more flowers on the main inflorescence and the increasing number of lateral inflorescences. Higher fertility also brought about more inflorescences on a plant (Table 2). As in the previous season, flower size was unaffected by fertilizer rates.

Stalk length increased as fertility increased (Table 3). The length of the portion bearing flowers also increased with increased fertility. Length of the internode between the first two flowers, however, did not change in response to increasing fertility. Therefore, plants given fertilizer at 1.0 g·liter^{-1} had the longest inflorescences due to the longer length of both portions.

Table 2. The effect of medium and fertility on flowering of *Phalaenopsis* during the second season.[z]

Treatment	Inflorescence emergence (Oct. 1993)	Bloom date (Jan. 1993)	Inflorescence emergence to bloom (days)	Flower no. on inflorescence: Main	Lateral	Total	No. lateral inflorescence	Inflo-rescence no./plant
Medium[y]								
1 (P1M1C1)	10 a	14 a	97 a	11.5 a	3.4 a	14.9 a	0.76 b	1.72 a
2 (PBV)	12 a	17 a	98 a	11.0 a	3.4 a	14.4 a	0.75 b	1.89 a
3 (B)	16 a	20 a	96 a	10.4 a	4.9 a	15.3 a	1.26 a	1.69 a
4 (P3M3C1)	14 a	18 a	97 a	10.6 a	2.8 a	13.4 a	0.57 b	1.85 a
5 (PR)	7 a	9 a	95 a	11.7 a	2.9 a	14.6 a	0.69 b	1.85 a
Fertilizer (g·liter^{-1})[x]								
0.25	21	25	96	10.2	0.5	10.7	0.13	1.53
0.50	13	15	95	10.8	2.3	13.1	0.60	1.73
1.00	2	8	99	12.0	7.8	19.8	1.72	2.12
Significance	L***	L***	L*	L***	L***	L***	L***	L***

[z]Mean separation within columns by Duncan's multiple range test α = 0.05.
[y]1 = 1 perlite : 1 Metro Mix 250 : 1 charcoal (P1M1C1); 2 = 2 perlite : 2 pine bark : 1 vermiculite (PBV); 3 = 100% pine bark (B); 4 = 3 perlite : 3 Metro Mix 250 : 1 charcoal (P3M3C1); 5 = 1 perlite : 1 rockwool (PR).
[x]Peters 20N–8.6P–16.6K water-soluble fertilizer.
*,***Linear (L) and significant at α = 0.05 or 0.001, respectively.

Table 3, The effect of medium and fertilizer amount on inflorescence stalk size and leaf growth of *Phalaenopsis* and on leachate pH and electrical conductivity (EC) during the second season.[z]

Treatment	Stalk Diam (mm)	Stalk Length (cm)	Total leaf no.	Second uppermost mature leaf Length (cm)	Second uppermost mature leaf Width (cm)	Soil leachate pH	Soil leachate EC ($dS \cdot m^{-1}$)
Medium[y]							
1 (P1M1C1)	6.39 a	60.8 a	6.7 bc	20.2 a	9.2 a	5.51 a	1.00 ab
2 (PBV)	6.39 a	59.3 a	7.2 ab	20.1 a	8.7 b	4.40 c	0.83 c
3 (B)	6.51 a	60.3 a	7.4 a	19.7 a	8.8 ab	4.43 c	0.71 d
4 (P3M3C1)	6.30 a	58.1 a	6.7 bc	20.3 a	8.6 b	5.52 a	1.08 a
5 (PR)	6.35 a	60.0 a	6.2 c	20.8 a	8.6 b	5.12 b	0.93 bc
Fertilizer ($g \cdot liter^{-1}$)[x]							
0.25	5.89	54.4	5.7	18.2	8.2	5.28	0.63
0.50	6.25	57.5	6.5	19.9	8.8	5.01	0.90
1.00	7.02	67.1	8.2	22.5	9.3	4.70	1.21
Significance	L***	L***	L***	L***	L***	L**	L***

[z]Mean separation within columns by Duncan's multiple range test, $\alpha = 0.05$.
[y]1 = 1 perlite : 1 Metro Mix 250 : 1 charcoal; 2 = 2 perlite (P1M1C1) : 2 pine bark : 1 vermiculite (PBV); 3 = 100% pine bark (B); 4 = 3 perlite : 3 Metro Mix 250 : 1 charcoal (P3M3C1); 5 = 1 perlite : 1 rockwool (PR).
[x]Peters (20N–8.6P–16.6K) water-soluble fertilizer.
**, ***Linear (L) and significant at $\alpha = 0.01$ or 0.001, respectively.

Plants had more leaves as fertility level increased (Table 3), possibly the result of accelerated leaf production (Table 2) and slower leaf senescence. Increasing the fertilizer levels also resulted in greener, longer, and wider leaves. Lee and Lin (1987) found that full-strength Johnson's solution (0.224 g N/liter) resulted in better leaf growth of *Phalaenopsis* than half-or quarter-strength.

Leachate samples taken in Apr. 1993 from the two media containing pine bark had the lowest pH and EC (Table 3). Increasing fertility resulted in lower pH and higher EC in the medium, similar to that determined previously (Wang and Sauls, 1988). Although water with a pH between 5.5 and 6.5 is recommended for irrigating *Phalaenopsis* (Gordon, 1990), the low pH (≈4.4)in two media did not appear to have adversely affected plant growth (Table 3). Although several previous reports indicated that fertility levels affected plant growth, none had assessed the impact of fertilizer rates on the pH of potting media (de Kreji and van den Berg, 1990; Gomi et al., 1980; Lee and Lin, 1987; Poole and Seeley, 1977, 1978).

During the first season, three media (P1M1C1, PBV, and B) performed reasonably well. The P3M3C1 and the PR media may have retained too much water during the cool period, resulting in low root quality due to the death of some of the original roots. However, all these media resulted in equally good plant growth and performance during the second season (Tables 2 and 3). Perlite was previously recommended to be mixed with bark for growing *Phalaenopsis* (Griesbach, 1986).

Nitrogen at 100 $mg \cdot liter^{-1}$, among other nutrients, was determined to be proper for the growth of *Phalaenopsis* in solution culture studies (Chen et al., 1990; Poole and Seeley, 1978) where the nutrient solution was supplied several times a day. Griesbach (1986) recommends 100 ppm N for 'Toyland' *Phalaenopsis*. Lee and Lin (1987), using a mixture of peatmoss and coarse sand, determined that *Phalaenopsis* plants fertilized with a nutrient solution containing 225 mg N/liter (Johnson et al., 1957) had better growth than those receiving the solution at half strength, which is similar to the results of Gomi et al. (1980) and Poole and Seeley (1977). When planted in solid media, this orchid's roots usually do not have tight contact with the loose, porous medium particles as they do with water in a solution culture. *Phalaenopsis* has relatively few roots, making them unable to explore a large volume of the medium. Also, the porous media probably did not retain a sufficient amount of nutrients for optimum plant growth at lower fertility levels (Poole and Seeley, 1977). Therefore, a higher fertilizer level is needed for better plant performance in solid medium culture, or a fertilizer at a lower concentration can be applied more frequently to obtain good growth (Lee and Lin, 1987). Examination of roots at the termination of our study showed that both the quality and mass of roots increased dramatically as the fertility increased from 0.25 to 1.0 $g \cdot liter^{-1}$, regardless of medium.

Although *Phalaenopsis* requires heavy fertilization for best growth, under cool conditions (20C day/15C night), vegetative growth becomes extremely limited, and plants do not respond to various fertility levels (Lee and Lin, 1987). In our study, increased leaf production in response to higher fertilizer levels did not start until Apr. 1992 when the greenhouse became warmer and flowers had opened.

Plants grown in "orchid bark" tend to produce many roots that grow out of the pot, become attached to benches, and have to be removed from plants before selling, resulting in damage to the plants. The media used in this study apparently provided better root-to-medium contact than bark, which enabled the existing roots to absorb adequate water and nutrients and may have nullified the need to produce more roots to meet this demand. When plants used in this study were examined 20 months following planting, there were very few roots growing out of the pots. Although this study did not compare plant growth to that in the traditional bark medium, selling plants with their roots intact may prevent infection by pathogens and possibly result in longer display life and better quality. Plants in the current test were watered at intervals of 7 days or longer, whereas plants in bark media had to be irrigated more frequently (Poole and Seeley, 1977).

Under conditions of this study, despite the differences in plant performance among the five media during the first season, all media resulted in equally satisfactory plant growth and performance during the second season. For early blooming, high flower count, and the best plant growth, the 20N–8.6P–16.6K water-soluble fertilizer should be used at 1.0 $g \cdot liter^{-1}$ with each irrigation. The response of *Phalaenopsis* plants to medium and fertilization is different during forcing and subsequent growth. Therefore, recommendations for this orchid's production should be based on the production schedule and how long plants will be maintained in a production facility.

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