

# Fertilizer Source and Medium Composition Affect Vegetative Growth and Mineral Nutrition of a Hybrid Moth Orchid

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**ABSTRACT.** Research was conducted to investigate the interaction of water-soluble fertilizer and medium composition on vegetative growth and the concentration of mineral nutrients in media and in leaves of a hybrid moth orchid (*Phalaenopsis* Blume.). The vegetatively propagated 'TSC 22' clone of the hybrid *Phalaenopsis* Atien Kaala plants 15 cm in leaf spread were potted in a medium consisting of either 100% fine grade douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] bark or a mixture of 7 fir bark : 3 sphagnum peat (by volume). Plants were fertigated at each irrigation with a soluble 10N–13.1P–16.6K, 20N–2.2P–15.8K, or 20N–8.6P–16.6K fertilizer, or a 2N–0.4P–1.7K liquid fertilizer at a common N rate of 200 mg·L<sup>-1</sup>. After 1 year in a greenhouse, plants grown in the bark–peat medium produced more leaves, greater fresh weights (FW), and larger total leaf areas than those in 100% bark. In the bark medium, the 20N–2.2P–15.8K fertilizer resulted in plants of the highest quality, despite its low P concentration (22 mg·L<sup>-1</sup>). When grown in bark–peat, the two fertilizers (20N–2.2P–15.8K and 20N–8.6P–16.6K) containing urea as part of their N source (10% and 52%, respectively) resulted in plants with 40% to 50% heavier shoot FW and 40% larger leaf area than the other fertilizers without urea. With any given fertilizer, plants had similar root FW in both media. Media and fertilizers had limited or no effect on the concentrations of mineral nutrients in the second mature acropetal leaves, except P, which nearly doubled in leaves of plants grown in 100% bark. High leaf Mg concentration was associated with low Ca. Water extracts from the bark–peat medium had lower pH, higher electrical conductivity, and much higher levels of NH<sub>4</sub>-N, Ca, Fe, Na, Cl, B, and Al than those from 100% bark. Extracts from the bark medium did not have detectable levels of NO<sub>3</sub>-N, whereas extracts from the bark–peat medium all had similar levels of NH<sub>4</sub>-N, regardless of which fertilizer was applied. Levels of P and K were not different between the two media.

The wholesale value of potted, blooming orchids was over \$100 million in 2000, an increase of 27% over 1999 (U.S. Dept. of Agr., 2001). *Phalaenopsis* sp. (moth orchids) are the most popular orchids among all orchids for pot plant use. Despite the surge in production of potted orchids during the past decade, research in the United States to develop detailed information for mass production of potted orchids has been limited. While the information on orchid media and fertility suggests that many materials are useful for growing orchids, most of this knowledge is based on personal experience and not from scientific studies. Researchers have suggested the need to study these various media scientifically (Poole and Sheehan, 1977a; Sheehan, 1960).

A 1985 survey of orchid growers indicated that 60% used Douglas fir (*Pseudotsuga menziesii*) bark chips of various sizes as their growing media. Fir bark is widely available, has good drainage, and provides reasonably good growth (White, 1986). Despite the wide use of fir bark, little is known about its interactions with various fertilizers and how this affects the nutritional status of orchid plants. It was reported that *Phalaenopsis* and *Dendrobium* Swartz orchids planted in 100% large grade fir bark did not grow well and produced fewer flowers than those planted in a mixture of bark with more water-retaining materials, such as peat and vermiculite (Wang, 1996). Traditionally, high N fertilizers have been recommended for growing orchids in bark medium (Northen, 1990) because it was claimed that microorganisms in the bark use a large portion of the added N. The need for applying high N fertilizer to the bark medium

could possibly due to the low nutrient retention by fir bark. However, there have been no studies to compare the nutritional status of *Phalaenopsis* orchids planted in different media while receiving different fertilizers.

Poole and Sheehan (1977b) tested growth of small plants of a hybrid *Laeliocattleya* orchid in four media fertilized with various micronutrient rates. They concluded that a 50% peat and 50% perlite mix (by volume) with Perk micronutrients (Kerr-Magic Fertilizer Co., Jacksonville, Fla.) incorporated into the medium at a rate of 1.0 g per 10-cm clay pot (volume not reported) resulted in the best growth. However, the remaining three media, i.e., tree fern fiber, tree fern fiber plus redwood bark chips, and fir bark chips, resulted in similar growth. Perhaps, in their study, plants did not receive adequate amounts of nutrients when 30N–4.4P–8.3K was applied at a rate of 1.2 g·L<sup>-1</sup> every 2 weeks with two to three waterings per week.

Wang and Gregg (1994) determined that increasing fertility level from 0.25 to 1.0 g·L<sup>-1</sup> of a 20N–8.6K–16.6K fertilizer applied with every irrigation had a greater effect on plant growth than did the five media used in their study. They noted that since *Phalaenopsis* plants have relatively few but succulent roots, which usually do not have tight contact with the loose, porous medium, plants might benefit from higher fertilizer rates. In another study, Wang (1996) grew *Phalaenopsis* in a medium consisting of 7 fir bark : 3 peat (by volume) using six fertilizers of various N, P, and K analyses. They found that all fertilizers, at a common N rate of 200 mg·L<sup>-1</sup> and a wide range of P and K, resulted in similar vegetative growth and flower production. Since orchid propagators price plants by their sizes, using proper fertility and media to provide the fastest possible growth results in reduced production time and costs.

The objectives of this study were to investigate the interaction of

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several commercial fertilizers and medium composition on vegetative growth and the concentration of mineral nutrients in leaves of a hybrid *Phalaenopsis*. Changes in pH, salt level, and mineral nutrients in 100% bark and a bark plus peat medium were also monitored.

## Materials and Methods

**PLANT MATERIALS AND TREATMENTS.** Vegetatively propagated 'TSC 22' plants of *Phalaenopsis* Atien Kaala with a 15-cm wide leaf span were selected on 23 June 1995 and potted in 0.6-L plastic pots in either 100% fine grade Douglas fir bark or a mixture of 7 fine grade Douglas fir bark : 3 Canadian sphagnum peat (by volume). Granular Aqua Gro wetting agent (Aquatrols of America, Pensauken, N.J.) at a rate of 0.5 g·L<sup>-1</sup> was added to both media. At each irrigation, plants were provided with one of three water-soluble fertilizers at 2 g·L<sup>-1</sup> of 10N–13.1P–16.6K (10N–30P<sub>2</sub>O<sub>5</sub>–20K<sub>2</sub>O), 1 g·L<sup>-1</sup> of 20N–2.2P–15.8K (20N–5P<sub>2</sub>O<sub>5</sub>–19K<sub>2</sub>O), and 1 g·L<sup>-1</sup> of 20N–8.6P–16.6K (20N–20P<sub>2</sub>O<sub>5</sub>–20K<sub>2</sub>O) (all from Scotts, Milpitas, Calif.). The liquid fertilizer used was 2N–0.4P–1.7K (2N–1P<sub>2</sub>O<sub>5</sub>–2K<sub>2</sub>O, Wilder's AutoGro, Wilder Agri. Products Co., New Wilmington, Pa.) to provide 0.2 g·L<sup>-1</sup> of N. The concentration of N from various N sources and the P and K concentrations from various fertilizers are presented in Table 1.

Plants were grown in a greenhouse covered with two layers of 0.015 mm polyethylene plastic and shade cloth to give ≈12% full sunlight. The photosynthetic photon flux (PPF) of full sunlight at this location (latitude 26.15° N) is 2300 μmol·m<sup>-2</sup>·s<sup>-1</sup> in July and 1700 μmol·m<sup>-2</sup>·s<sup>-1</sup> in January. A blend of 50% local municipal water and 50% reverse osmosis water with a final electrical conductivity (EC) of ≈0.7 dS·m<sup>-1</sup> was used. This EC was chosen since it was reported that water with high EC resulted in severe root injury (Wang, 1998). All of the plants in the same medium were fertigated at once to obtain about consistent moisture content throughout. Water was applied to each pot individually, using a small cup (240 mL), to ensure that medium was uniformly wetted and the root system, but not the leaves, absorbed nutrients.

**EC AND pH MEASUREMENTS.** Leachate samples were collected monthly throughout the experiment, from June 1995 to Mar. 1996 and during the months of June and July 1996 using the pour-through technique described by Wright (1986). All of the pots were fertigated the previous afternoon and leachate samples were collected the next morning on five random replications by placing the pot in a saucer with a raised ridge designed for drainage, and adding 50 to 70 mL of distilled water evenly to the surface of the medium. A minimum of 5 min was allowed to drain leachate into the saucer for collection. About 25 to 35 mL was collected and transferred to a glass tube for pH and EC measurements.

**GROWTH MEASUREMENTS.** After planting, the uppermost fully expanded leaf present on each plant was marked. At the conclusion of this experiment (8 July 1996), the new leaves which had been produced above the marked leaf were counted. Growth data, includ-

ing shoot fresh weight (FW), root FW, and total leaf area measured with an area meter (LI-6000; LI-COR, Lincoln, Neb.) were collected.

**LEAF MINERAL NUTRIENT ANALYSIS.** Leaf samples for mineral nutrient analysis were collected from three random replications by harvesting the second acropetal mature leaves individually as described by Poole and Sheehan (1974). These leaves were washed with dilute detergent in distilled water, quickly rinsed in a bath of distilled water, blotted dry, and placed separately in paper bags. These samples were dried at 70 °C for 48 h. Dried leaf samples were ground in a Wiley mill to pass a 0.635-mm (40-mesh) screen. The ground samples were sent to Scotts Testing Lab (Allentown, Pa.) for mineral nutrient analysis. The amount of P in the foliage was calculated by multiplying the foliage FW by percentage dry matter (5.5%) and then multiplied by the percentage of P.

**MEDIUM MINERAL NUTRIENT ANALYSIS.** Plants from three replications selected at random were removed from their pots and the medium in each pot was individually mixed to ensure that the top and bottom portions of the medium were thoroughly mixed. From each pot, 400 mL of the medium was collected in a brown paper bag and allowed to air dry for 3 weeks on a greenhouse bench. Once dried, 160 mL of medium (≈39 g of the bark medium or 30 g of the bark-peat medium) was placed in a beaker with 110 mL of distilled water. The beakers were covered and weighted so that all of the medium samples remained submerged. After 48 h, vacuum was applied for 20 s and water extracts were collected. A 20 mL portion of each sample was placed in a liquid scintillation vial, packed with dry ice, and sent to Scotts Testing Lab for mineral nutrient analysis.

**EXPERIMENTAL DESIGN AND DATA ANALYSIS.** Treatments were a factorial combination of two media and four fertilizers and arranged in a randomized complete block design and data were analyzed as such. A single plant in a pot represented an experimental unit that was replicated 12 times across a possible gradient of light and temperature.

## Results

**PLANT GROWTH.** When grown in bark-peat, plants fertilized with similar N and K levels (20N–2.2P–15.8K and 20N–8.6P–16.6K) had similar growth, despite the large difference in applied P (Table 2). Both fertilizers resulted in plants with higher leaf numbers, greater leaf and root FW, and larger leaf areas than the 10N–13.1P–16.6K and 2N–0.4P–1.7K fertilizers. However, when grown in bark, the 20N–2.2P–15.8K fertilizer resulted in the best overall growth. In general, plants in bark-peat were much larger (125% greater leaf FW when using 20N–8.6P–16.6K) than those grown in bark ( $P \leq 0.001$ ). It is possible that urea, which accounts for half the N in the 20N–8.6P–16.6K fertilizer, was barely or not adsorbed by the bark and hence was less available for supplying N to the roots. When the 10N–13.1P–16.6K fertilizer was used at a rate to provide N at 200 mg·L<sup>-1</sup>, it provided much higher levels of P (260 mg·L<sup>-1</sup>) and K (332 mg·L<sup>-1</sup>) than the other fertilizers (Table 1), but resulted

Table 1. N, P, and K levels in aqueous solutions of four commercial fertilizers.

Fertilizer (N–P–K)	Nutrient (mg·L <sup>-1</sup> )					
	Total N	N source			P	K
		NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	Urea		
10–13.1–16.6	200	112.8	87.2	0	262	332
20–8.6–16.6	200	56.3	39.7	104	86	166
20–2.2–15.8	200	60.0	121.0	19	22	158
2–0.4–1.7	200	120.0	80.0	0	44	176

Table 2. Effects of two media and four fertilizers on vegetative growth of *Phalaenopsis* Atien Kaala 'TSC 22'.

Fertilizer (N-P-K)	Leaves			Root fresh wt (g)
	Gain in leaf no.	Fresh wt <sup>z</sup> (g)	Total area (cm <sup>2</sup> )	
<b>Bark</b>				
10-13.1-16.6	4.6 ab <sup>y</sup>	49.7 c	287 c	26.2 b
20-8.6-16.6	4.3 b	58.0 bc	321 bc	40.3 a
20-2.2-15.8	5.1 a	74.8 a	433 a	44.3 a
2-0.4-1.7	4.8 ab	62.9 b	383 ab	28.4 b
<b>Bark-peat<sup>x</sup></b>				
10-13.1-16.6	5.3 b	85.5 b	464 b	30.2 b
20-8.6-16.6	6.7 a	131.1 a	658 a	62.2 a
20-2.2-15.8	6.6 a	130.1 a	666 a	53.5 a
2-0.4-1.7	6.3 ab	85.6 b	479 b	24.7 b
Media	***	***	***	NS

<sup>z</sup>Total fresh weight of all leaves.

<sup>y</sup>Mean separation within columns for a medium by Duncan's multiple range test,  $P \leq 0.05$ ;  $n = 12$ .

<sup>x</sup>7 fine grade douglas fir bark : 3 sphagnum peat (by volume).

ns,\*\*\* Nonsignificant or significant at  $P \leq 0.001$ , respectively. ANOVA.

in less foliage growth (Table 2). Although the effect of various P levels on flowering was not determined, larger plants are often capable of producing more flowers than small plants (Wang, 1996).

**MEDIUM LEACHATE AND pH AND EC.** Regardless of media, the

20N-2.2P-15.8K fertilizer resulted in significantly higher medium pH (Table 3), except in June and July. Over time, there was only a slight increase in pH of either medium. However, leachate from the bark medium had more than one pH unit higher than that

Table 3. Effect of two media and four fertilizers on medium pH from June 1995 to July 1996.

Fertilizer (N-P-K)	Sampling date									
	26 June	28 July	29 Aug.	26 Sept.	1 Nov.	1 Dec.	11 Jan.	7 June	2 July	
<b>Bark</b>										
10-13.1-16.6	5.24 b <sup>z</sup>	5.32 c	5.42 d	5.33 c	5.23 c	5.13 c	5.15 c	5.32 c	5.53 b	
20-8.6-16.6	5.33 b	5.70 b	5.79 b	5.59 b	5.62 b	5.44 b	5.55 b	5.58 ab	5.97 a	
20-2.2-15.8	5.44 a	6.44 a	6.18 a	6.18 a	5.86 a	5.63 a	5.72 a	5.69 a	5.97 a	
2-0.4-1.7	5.03 c	5.50 c	5.62 c	5.55 b	5.67 b	5.50 ab	5.57 ab	5.46 bc	5.70 b	
<b>Bark-peat<sup>y</sup></b>										
10-13.1-16.6	4.00 c	4.21 c	4.46 c	4.43 c	4.56 c	4.64 b	4.47 c	4.30 b	4.51 c	
20-8.6-16.6	4.08 b	4.47 b	4.85 b	4.70 b	4.87 b	4.66 b	4.77 b	4.40 b	4.70 b	
20-2.2-15.8	4.24 a	5.25 a	5.46 a	5.42 a	5.55 a	5.28 a	5.29 a	4.71 a	4.95 a	
2-0.4-1.7	4.03 c	4.27 c	4.48 c	4.52 c	4.87 b	4.61 b	4.62 bc	4.35 b	4.56 bc	

<sup>z</sup>Mean separation within columns for a medium by Duncan's multiple range test at  $P \leq 0.05$ ;  $n = 5$ .

<sup>y</sup>7 fine grade douglas fir bark : 3 sphagnum peat (by volume).

Table 4. Effect of two media and four fertilizers on electrical conductivity (dS·m<sup>-1</sup>) of leachate from medium between June 1995 and July 1996.

Fertilizer (N-P-K)	Sampling date									
	26 June	28 July	29 Aug.	26 Sept.	1 Nov.	1 Dec.	11 Jan.	8 Mar.	7 June	2 July
<b>Bark</b>										
10-13.1-16.6	0.59 b <sup>z</sup>	1.46 b	1.52 b	1.88 b	1.97 b	2.07 b	1.61 b	1.04 b	1.09 ab	1.04 b
20-8.6-16.6	0.46 c	0.98 c	1.00 c	1.40 c	1.36 c	1.49 c	1.27 c	1.06 b	0.80 b	0.78 b
20-2.2-15.8	0.49 c	0.90 c	0.88 c	1.04 d	1.20 c	1.37 c	1.09 c	0.85 b	0.85 b	0.80 b
2-0.4-1.7	0.74 a	1.85 a	1.83 a	2.33 a	2.25 a	2.57 a	2.15 a	1.38 a	1.35 a	1.35 a
<b>Bark-peat<sup>y</sup></b>										
10-13.1-16.6	1.46 b	2.63 b	2.73 b	3.28 b	3.26 b	2.81 b	3.10 b	2.30 b	2.27 b	2.24 b
20-8.6-16.6	1.08 c	1.79 c	1.87 c	2.31 c	2.34 c	2.37 c	2.21 c	1.93 c	1.81 c	1.62 c
20-2.2-15.8	1.04 c	1.58 c	1.70 c	2.04 c	1.98 d	1.72 d	1.99 c	1.58 d	1.39 d	1.39 d
2-0.4-1.7	2.16 a	3.62 a	3.42 b	4.13 a	4.27 a	4.02 a	4.20 a	3.08 a	2.85 a	2.83 a

<sup>z</sup>Mean separation within columns for a medium by Duncan's multiple range test at  $P \leq 0.05$ ;  $n = 5$ .

<sup>y</sup>7 fine grade douglas fir bark 3 sphagnum peat (by volume).

Table 5. Concentration of various mineral nutrients in leachate from two media following application of selected fertilizers.

Fertilizer (N-P-K)	EC (dS·m <sup>-1</sup> )	pH	Mineral nutrient (mg·L <sup>-1</sup> )					
			NH <sub>4</sub> -N	NO <sub>3</sub> -N	P	K	Ca	Mg
<b>Bark</b>								
10-13.1-16.6	1.3 ab <sup>z</sup>	5.26 a	3.5 a	0	188 a	189 a	57 ab	24 b
20-8.6-16.6	1.1 b	5.29 a	2.9 a	0	111 b	112 c	46 b	19 b
20-2.2-15.8	1.1 b	5.23 a	2.9 a	0	89 b	108 c	47 b	19 b
2-0.4-1.7	1.6 a	5.25 a	6.0 a	0	113 b	149 b	73 a	57 a
<b>Bark-peat<sup>y</sup></b>								
10-13.1-16.6	1.9 ab	4.54 a	17.8 a	21 a	247 a	223 b	99 a	34 b
20-8.6-16.6	1.3 c	4.68 a	8.3 a	20 a	109 b	86 c	66 a	20 b
20-2.2-15.8	1.6 bc	4.44 a	10.0 a	24 a	94 b	101 c	88 a	28 b
2-0.4-1.7	2.1 b	4.62 a	10.7 a	21 a	88 b	175 b	99 a	83 a
<b>Medium</b>	***	***	*	**	NS	NS	***	NS

<sup>z</sup>Mean separation within columns for a medium by Duncan's multiple range test at  $P \leq 0.05$ ;  $n = 3$ .

<sup>y</sup>7 fine grade douglas fir bark : 3 sphagnum peat (by volume).

NS,\*\*\*Nonsignificant or significant at  $P = 0.05, 0.01, \text{ or } 0.001$ , respectively. ANOVA.

Table 6. Concentration of various mineral nutrients in leachate from two media following application of selected fertilizers.

Fertilizer (N-P-K)	Mineral nutrient (mg·L <sup>-1</sup> )								
	Mn	Fe	Na	Cu	Cl	B	Mo	Al	Zn
<b>Bark</b>									
10-13.1-16.6	3.7 bc <sup>z</sup>	0.03 a	88 a	0.011 a	114 a	0.19 a	0.007 ab	0.06 a	0.58 a
20-8.6-16.6	3.2 c	0.02 a	88 a	0.011 a	125 a	0.19 a	0.006 b	0.07 a	0.26 b
20-2.2-15.8	3.1 c	0.03 a	90 a	0.005 a	139 a	0.18 a	0.009 ab	0.11 a	0.33 ab
2-0.4-1.7	4.7 ab	0.03 a	90 a	0.003 a	122 a	0.22 a	0.013 a	0.03 a	0.57 a
<b>Bark-peat<sup>y</sup></b>									
10-13.1-16.6	3.9 a	0.62 a	134 a	0.010 a	156 a	0.33 ab	0.007 b	0.38 a	0.30 a
20-8.6-16.6	2.9 a	0.27 b	119 a	0.005 a	164 a	0.28 ab	0.010 ab	0.28 a	0.25 a
20-2.2-15.8	3.7 a	0.53 ab	145 a	0.008 a	197 a	0.32 b	0.013 ab	0.41 a	0.30 a
2-0.4-1.7	3.9 a	0.76 a	128 a	0.017 a	156 a	0.39 a	0.017 a	0.35 a	0.50 a
<b>Medium</b>	NS	***	***	NS	***	***	NS	***	NS

<sup>z</sup>Mean separation within columns for a medium by Duncan's multiple range test at  $P \leq 0.05$ ;  $n = 3$ .

<sup>y</sup>7 fine grade douglas fir bark : 3 sphagnum peat (by volume).

NS,\*\*\*Nonsignificant or significant at  $P = 0.001$ , respectively. ANOVA.

from the bark-peat medium.

For any given fertilizer, leachate samples taken from the bark-peat medium always had higher EC than that from the bark (Table 4), indicative of the former being able to retain higher amounts of nutrients. Regardless of medium, the 20N-2.2P-15.8K and 20N-8.6P-16.6K fertilizers resulted in lower EC than the other fertilizers, possibly due to containing urea. In both media, leachate had lower EC when taken between March and August than between September and January (Table 4). This may have been due to the active growth of plants during the warm period in the spring and summer that resulted in more frequent watering and nutrient absorption by plants and microbial activity.

Medium extracts collected at the conclusion of this study had similar trends of EC as leachate samples collected earlier. Extracts collected from either medium all had similar pH, regardless of fertilizer used (Table 4). Extracts collected from bark medium had 0.6 to 1.0 pH unit higher than those from the bark-peat medium.

**MINERAL NUTRIENTS IN MEDIUM EXTRACT.** Water extracts from the bark-peat medium had higher concentrations of N, Ca, Fe, Na, Cl, B, and Al (Tables 5 and 6). The most marked difference in mineral nutrients between the two media was in the concentration of NO<sub>3</sub>-N. While adequate levels of NO<sub>3</sub>-N were found in extracts of bark-peat medium, with no difference among fertilizers, no detectable level of NO<sub>3</sub>-N was found in the bark extract regardless of which

fertilizer was applied. In either medium, the low P fertilizer 20N-2.2P-15.8K (P at 22 mg·L<sup>-1</sup>) resulted in similar concentrations of P in the medium as the high P 20N-8.6P-16.6K fertilizer (P at 86 mg·L<sup>-1</sup>, Tables 5 and 6). The 10N-13.1P-16.6K fertilizer (K at 332 mg·L<sup>-1</sup>) resulted in elevated K concentration in both media when compared to the two fertilizers with lower but similar K analyses (K at 158 or 166 mg·L<sup>-1</sup>). The bark-peat medium had much higher water soluble iron (0.27 to 0.76 mg·L<sup>-1</sup>) than bark alone (0.02 to 0.09 mg·L<sup>-1</sup>).

**LEAF MINERAL NUTRIENTS.** The two media resulted in no difference in leaf mineral concentrations, except that leaves from plants grown in bark had higher P, but lower B and Al than those in the bark-peat medium (Tables 7 and 8). Elevated P concentration in the leaves from the bark medium was consistent with results of another study in which plants were irrigated with water having the same EC (Wang, 1998). Plants in either medium that received the highest P (262 mg·L<sup>-1</sup>) had the highest P concentration in their leaves. Although plants in the bark-peat medium were much larger than their counterparts in the bark medium, plants receiving any given fertilizer in both media absorbed the same or similar amounts of P (Table 8). The 2N-0.4P-1.7K fertilizer resulted in the lowest Ca, but highest Mg concentrations in leaves. All of the plants appeared healthy, with no apparent mineral nutrient toxicity or deficiency symptoms.

Table 7. Concentration of various mineral nutrients in leaves of *Phalaenopsis* Atien Kaala 'TSC 8' from two media following the application of various fertilizers.

Fertilizer (N-P-K)	Mineral nutrient (% dry wt)				
	N	P	K	Ca	Mg
<b>Bark</b>					
10-13.1-16.6	1.23 ab <sup>z</sup>	1.42 a (39) <sup>y</sup>	5.80 a	1.23 bc	0.42 b
20-8.6-16.6	1.10 b	1.10 b (23)	5.69 a	1.82 a	0.40 b
20-2.2-15.8	1.18 b	0.56 c (35)	4.69 c	1.75 ab	0.49 b
2-0.4-1.7	1.42 a	0.57 c (20)	4.00 d	0.91 c	0.80 a
<b>Bark-peat<sup>x</sup></b>					
10-13.1-16.6	1.32 ab	0.91 a (39)	5.87 a	1.12 a	0.42 b
20-8.6-16.6	1.15 b	0.49 b (22)	5.42 ab	1.63 a	0.50 b
20-2.2-15.8	1.60 a	0.31 b (35)	4.75 b	1.50 a	0.43 b
2-0.4-1.7	1.26 b	0.36 b (17)	4.95 ab	0.51 b	0.84 a
<b>Medium</b>	NS	**	NS	NS	NS

<sup>z</sup>Mean separation within columns for a medium by Duncan's multiple range test at  $P \leq 0.05$ ;  $n = 3$ .

<sup>y</sup>Total P (mg) in all leaves. Assuming 5.5% average dry matter, using FW data in Table 2 to estimate the total leaf DW.

<sup>x</sup>7 fine grade douglas fir bark : 3 sphagnum peat (by volume).

NS, \*\* Nonsignificant or significant at  $P = 0.01$ , respectively. ANOVA.

Table 8. Concentration of various mineral nutrients in leaves of *Phalaenopsis* Atien Kaala 'TSC 8' from two media following the application of various fertilizers.

Fertilizer (N-P-K)	Mineral nutrient (mg·kg <sup>-1</sup> dry wt)							
	Mn	Fe	Na	Cu	B	Mo	Al	Zn
<b>Bark</b>								
10-13.1-16.6	433 ab <sup>z</sup>	24 b	3488 ab	4.6 a	35 ab	1.24 a	50 a	14.5 a
20-8.6-16.6	572 a	26 b	5593 a	7.8 a	44 a	1.06 a	43 a	15.0 a
20-2.2-15.8	606 a	23 b	5163 a	6.3 a	42 a	1.11 a	49 a	18.3 a
2-0.4-1.7	249 b	32 a	2367 b	5.7 a	30 b	1.40 a	41 a	16.9 a
<b>Bark-peat<sup>y</sup></b>								
10-13.1-16.6	506 ab	25 bc	3593 bc	10.2 a	40 b	1.08 b	39 ab	17.1 a
20-8.6-16.6	579 a	22 c	5397 a	5.2 a	53 a	1.16 b	48 a	24.2 a
20-2.2-15.8	474 ab	22 c	4960 ab	5.1 a	39 b	1.18 b	30 b	27.5 a
2-0.4-1.7	359 b	31 ab	2900 c	9.2 a	43 ab	1.53 a	39 ab	15.5 a
<b>Medium</b>	NS	NS	NS	NS	*	NS	**	NS

<sup>z</sup>Mean separation within columns for a medium by Duncan's multiple range test at  $P \leq 0.05$ ;  $n = 3$ .

<sup>y</sup>7 fine grade douglas fir bark : 3 sphagnum peat (by volume).

NS, \*\*, \*\*\* Nonsignificant or significant at  $P = 0.05$  or  $0.01$ , respectively. ANOVA.

## Discussion

Both the 20N-2.2P-15.8K and 20N-8.6P-16.6K soluble fertilizers contained urea (9.4% and 52% of N, respectively; Table 1). When urea is used at more than 25% of the total applied N, most greenhouse crops respond by producing lush growth and increased internode lengths (Nelson, 1995). This effect was most evident in the bark-peat medium in that plants receiving these two fertilizers had increased leaf production and greater total leaf area. In the bark medium, the 20N-8.6P-16.6K fertilizer did not benefit as much from the urea due to lower water retention and, possibly, leaching of urea.

No differences were noted in the size of the youngest mature leaves among fertilizer treatments and between media (data not presented). However, leaves produced by plants in the bark had less fresh and DWs than those grown in bark-peat, which is consistent with a previous report (Wang, 1998). Therefore, differences in overall leaf weight and area were the result of fewer leaves that were produced by plants in the bark medium (Table 3). In a study by Lin (1994), it was revealed that the assimilates from a single leaf never meet the demand of an inflorescence. Many leaves contributes to the

flower spike and flower formation. Therefore, if mature leaves were shaded or removed, flower count and diameter may decrease (Guo, 1999). Since *Phalaenopsis* orchids are sold by size, producers would benefit from medium and fertilizer combinations that promote rapid leaf area increase. In addition, *Phalaenopsis* plants with more leaves and larger total leaf areas produce a higher number of inflorescences and flowers than those with fewer leaves (Wang and Gregg, 1994).

Addition of sphagnum peat to fir bark chips promoted plant growth, regardless of the fertilizer used. This is due in part to the greater water-holding capacity in the bark-peat medium than the bark alone (Konow, 1998). It is also well known that peat has a high cation exchange capacity (CEC). The bark-peat medium provided higher concentrations of many mineral nutrients (Tables 5 and 6), particularly N, than the bark alone that may have contributed to improved growth of plant in this medium.

Regardless of the fertilizer used, the bark-peat medium had a higher EC than the bark medium. The higher EC, as a result of applying the 20N-8.6P-16.6K and 20N-2.2P-15.8K fertilizers, was associated with decreased root weight. In a previous report, Wang (1998) determined that increasing irrigation water salinity

resulted in increased root injury. The higher medium EC during the cooler winter months may have been the result of slower growth due to reduced *PPF* and lower air temperatures. A lower growth rate would decrease mineral nutrient uptake by roots and result in higher mineral concentrations in the medium and thus a higher EC. The lower pH level observed in the bark–peat medium did not result in any adverse effects and was likely the result of the acidic nature of peat (Nelson, 1985). Wang and Gregg (1994) also observed a low pH of 4.4 had no apparent negative effects on *Phalaenopsis*.

Although micronutrient deficiencies are associated frequently with peat-based media (Nelson, 1985), this was not observed in either medium used in this study. Both media and fertilizer had little effect on the mineral nutrient composition of the leaves. Although the P concentration of the leachate did not differ between media, its concentration in leaves was 56% lower in plants grown with the bark–peat medium. Within a potting medium, the similar amounts of P being absorbed by plants fertilized with any given fertilizer was a surprise. Since plants were harvested before flowering took place, it is not clear how this differences in tissue P would affect flowering.

Media used in the present study did not result in differences in N concentration in the leaves (Table 7). However, due to the much larger size of plants produced in the bark–peat medium (Table 3), these plants absorbed larger amounts of N and other mineral nutrients than those in the bark. Although all fertilizers were used to provide the same N rate (200 mg·L<sup>-1</sup>), they resulted in different N concentrations in the foliage (Tables 7 and 8). A possible explanation for this may be the preference of absorbing NO<sub>3</sub>-N over NH<sub>4</sub>-N by roots (Mengel and Kirkby, 1982). Also, at lower pH, NH<sub>4</sub>-N is absorbed at a slower rate, while NO<sub>3</sub>-N absorption is increased (Mengel and Kirkby, 1982). In the bark medium, leaf N concentrations increased among fertilizers as NO<sub>3</sub>-N concentration increased. However, in the bark–peat medium, fertilizers with NH<sub>4</sub>-N resulted in higher leaf N. Due to the high CEC and water-holding capacity of peat, NH<sub>4</sub><sup>+</sup> may be more easily adsorbed and retained by peat than be bark alone. Therefore, the total N available to roots would be greater in the bark–peat medium than bark alone.

It has been recommended that, when orchids are grown in bark alone, a high concentration of N must be applied to meet the needs of both the plant and the wood-decaying microorganisms (Mastalerz, 1977; Nelson, 1985; Poole and Sheehan, 1977b). Leachate from the bark medium had no NO<sub>3</sub>-N. This may have been due in part to the fact that NO<sub>3</sub>-N had already been leached, preferably absorbed at low pH, and/or used by microorganisms in the bark. The latter seems less likely because the bark–peat medium contained 70% bark and could also harbor large colonies of microorganisms. The difference in NO<sub>3</sub>-N concentrations between the media could have been due to the increased CEC in the bark–peat medium, allowing more NH<sub>4</sub>-N to be adsorbed and then oxidized to NO<sub>3</sub>-N by microorganisms (Mengel and Kirkby, 1982). This process would release H<sup>+</sup> to the medium, lowering medium pH. It is also possible that there might not have been adequate microbial activity in the bark medium to convert NH<sub>4</sub><sup>+</sup> to NO<sub>3</sub><sup>-</sup>. Since there was no difference in P and K concentration between extracts from both media used in this study, having higher N in the bark–peat may be more important than P and K in contributing to increased plant growth in this medium.

The results from this study and others (Broschat and Klock-Moore, 2000; Wang, 1995) suggest that, N at 200 mg·L<sup>-1</sup> and K at 160 mg·L<sup>-1</sup>, a P level of 22 mg·L<sup>-1</sup> may be adequate to support excellent vegetative growth in bark medium with or without sphag-

num peat. The need for high P may have been overemphasized (Wang, 2000). Since this experiment was terminated in July, it is not known how this low level of P would affect flower count and size.

Plants fertilized with 2N–0.4P–1.7K had the highest leaf concentrations of Mg that was associated with the lowest Ca (Table 7), regardless which medium was used. However, Ca concentration in either medium receiving this fertilizer was similar to or higher than that in the same medium given one of the other fertilizers. It is well known that Ca and Mg antagonize the absorption of each other. The data from the present investigation suggest that, as long as plants appear to be healthy, one should not apply an unnecessarily high level of Mg to the medium as it may severely interfere with absorption of Ca.

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