Effects of Fertilization on Potassium and Magnesium Deficiencies Associated with Flowering in Hong Kong Orchid Tree (*Bauhinia × blakeana* Dunn)

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Abstract. Hong Kong orchid tree is an outstanding flowering tree for tropical and subtropical areas, but in south Florida's nutrient-poor sand soils, it typically develops moderate to severe K and Mg deficiency symptoms during the fall, winter, and spring months. A 3-year field experiment was conducted to determine if flowering was responsible for the development of these deficiencies and to determine if these deficiencies could be prevented by fertilization with medium or high rates of a 24N–0P–9.2K turf fertilizer (24–0–11) an 8N–0P–10K–4Mg plus micronutrients palm fertilizer (8–0–12) or a 0N–0P–13.3K–6Mg plus micronutrients palm fertilizer (0–0–16). Onset of deficiency symptoms coincided with the beginning of flowering, but leaf nutrient concentrations of N, P, K, and Mg continued to decline after flowering ceased in late January, presumably because of movement of these elements from the leaves to stem tissue. Leaf nutrient concentrations were poorly or negatively correlated with all measured plant quality variables and were poor indicators of plant quality or nutritional status. Although fertilization with a high rate of 24–0–11 or either rate of 8–0–12 increased tree height, caliper, and number of flowers, no treatment significantly decreased the severity of K and Mg deficiencies.

Hong Kong orchid tree is an outstanding flowering tree for tropical and subtropical regions of the world (Barwick, 2004). It is a hybrid between *Bauhinia purpurea* L. and *Bauhinia variegata* L. and, unlike its parents, does not set fruit and, thus, is not weedy. It has an extended flowering period, which in south Florida lasts from early November through January. Although these trees have attractive green foliage during the summer months, by October older leaves on each shoot typically develop moderate to severe K, Mg or both deficiency symptoms on south Florida's sandy, nutrient-poor soils. These deficiencies are not only unsightly, but also cause premature senescence of the older leaves, leading to complete defoliation by April. Thus, these deficiency symptoms detract from the esthetic appearance of these trees during their showiest season. Potassium deficiency symptoms appear as an extensive interveinal and marginal necrosis of the oldest leaves, whereas Mg deficiency symptoms appear as an interveinal chlorosis of these

same-aged leaves (Broschat, 2008; Dickey, 1983). Some trees display deficiency symptoms of both elements simultaneously, but typically only one element is deficient on a particular tree at any point in time.

Because the terminal inflorescences of Hong Kong orchid tree produce about a dozen large flowers over the course of 3 months, it is suspected that the flowers are acting as a sink for mobile nutrient elements resorbed from older leaves on the same shoot. There are few published data relating nutrient mobilization from leaves to flowers in woody plants, although the mobilization of nutrients from leaves to stems and developing fruits is well documented (Hill, 1980; Tagliavini et al., 2000; Williams, 1955). As individual flowers within an inflorescence of Hong Kong orchid tree open sequentially, perhaps even senescing flowers provide nutrients for redistribution to younger flowers. Trivellini et al. (2011) demonstrated that senescing flowers of *Hibiscus rosa-sinensis* L. contain notably less N, P, K, and Mg than open flowers, suggesting remobilization of these elements.

Because most nutrient deficiencies can be prevented or treated with appropriate fertilizers, it would be useful to determine if the K and Mg deficiencies that plague Hong Kong orchid trees during the fall, winter, and spring months could be prevented. The objectives of this study were 1) to determine the seasonality of these nutrient deficiencies and their relationship to flowering and new leaf growth and 2) to determine how fertilization affects

the growth, flowering, and development of K and Mg deficiencies in Hong Kong orchid trees growing in south Florida.

Materials and Methods

Hong Kong orchid trees growing in 10-L containers were transplanted into a field plot of Margate fine sand soil (siliceous, hyperthermic Mollic Psammaquent) in Davie, FL (lat. 26°5'1.7"N, long. 80°14'15.2"W) on 5 June 2012. This soil had a pH of 5.1, 5.0% organic matter, and a cation exchange capacity of 7.5 meq/100 g. Trees were spaced 3 m apart in all directions. A completely randomized design with seven fertilization treatments and seven replicate trees per treatment were used. Fertilizer treatments were applied by broadcasting each material over a 1 m² area surrounding each tree on 2 July 2012 and every 3 months thereafter. Treatments included 1) no fertilizer; 2) a turf fertilizer (Lescro 24–0–11; Lescro, Cleveland, OH) applied at a rate of 41.7 g/tree; 3) the same turf fertilizer applied at 83.4 g/tree; 4) a palm fertilizer (Nurserymen's Sure Gro 8–0–12–6Mg plus micronutrients; Nurserymen's Sure Gro, Vero Beach, FL) applied at 125 g/tree; and 5) the same palm fertilizer applied at 250 g/tree. The turf and palm fertilizer application rates provided equivalent amounts of N equal to 10 and 20 g/tree of N per application for the low and high rates, respectively. Two additional treatments (6 and 7) provided equivalent K levels to those of treatments 4 and 5 (12.5 and 25 g/tree of K, respectively) from a no N palm fertilizer (Nurserymen's Sure Gro 0–0–16–6Mg plus micronutrients). Fifty percent of the N in the turf fertilizer was in controlled release form (polymer-coated urea), with the remainder being water soluble (urea). Water-soluble K was provided by potassium chloride, but 2% iron (Fe) and 1% manganese (Mn) were in insoluble sucate forms. All of the N, K, and Mg in the palm fertilizers were controlled release (polymer-coated urea, polymer- and sulfur-coated potassium sulfate, and kieserite) and 1.25% Mn, 1.17% Fe, 0.15% zinc (Zn), 0.06% copper (Cu), and 0.6% boron (B) were provided by manganese sulfate, iron sulfate, iron ethylenediaminetetraacetate, iron diethylenetriaminepentaacetate, zinc sulfate, copper sulfate, and sodium borate. All trees, including controls, received 40 g of triple super phosphate to prevent P deficiency from limiting tree growth and quality.

All trees received ≈2 cm of water from overhead irrigation three times per week during the first 6 months and twice per week thereafter. An area of ≈1 m² was maintained weed-free using glyphosate. Trees were not pruned, but were staked to encourage a central leader. All trees were measured for total height and stem caliper at 30 cm above the ground at the time of transplanting and at the end of the experiment 3 years later. Trees were subjectively rated monthly for severity of K and Mg deficiencies on a scale of 1 to 5, with the rating of 1 being severe and 5 being completely free of deficiency symptoms for

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Fig. 1. Total number of flowers across all treatments by month for Hong Kong orchid trees grown in south Florida with two rates of three different fertilizers from Apr. 2013 through Apr. 2016. $N = 49$.

Fig. 2. Potassium and Mg deficiency severity ratings across all treatments by month for Hong Kong orchid trees grown in south Florida with two rates of three different fertilizers from Mar. 2013 through Apr. 2016. Data represent means with standard error bars. $N = 49$.

that element. The number of open flowers per tree was also counted at the time that the ratings were performed.

Because plant quality variables such as height, caliper, flower number, and nutrient deficiency severity ratings are typically highly intercorrelated, principal component analysis was performed on the data to reduce

the five original variables to a single index of overall quality, namely, the scores on the first principal component (PC1) (Broschat, 1979). All quality data were standardized to a mean of 0 and a sd of 1 to eliminate the effects of differences in scale among the original variables using PROC STANDARD (SAS, version 9.4; SAS Institute, Cary, NC). Principal

component analysis was performed using PROC PRINCOMP with scoring by PROC SCORE. In this analysis the PC1 typically contains high positive correlations for most or all of the original variables with the PC1, making it a useful index of overall quality. Scores for each tree on the PC1 were further subjected to analysis of variance (ANOVA) (PROC GLM) with mean separation by the Waller–Duncan k -ratio method ($P = 0.05$) to determine treatment effects.

Every month for the last 16 months of the experiment leaf samples consisting of the youngest fully expanded leaves on each shoot were collected from each tree for nutrient analysis. Unwashed leaf samples were dried, ground, ashed, and analyzed for N using a carbon/nitrogen Determinator (LECO Corp., St. Joseph, MI) and P, K, and Mg by inductively coupled plasma spectroscopy (Perkin-Elmer, Waltham, MA). Flower samples were collected from each tree on 12 Dec. 2015 and similarly analyzed for N, P, K, and Mg. Leaf and flower nutrient concentration data for each element were analyzed using ANOVA with mean separations by the Waller–Duncan k -ratio method.

Mean leaf nutrient concentrations of N, P, K, and Mg for 2015–16, tree caliper and height, and final K and Mg deficiency rating data were subjected to correlation analysis (PROC CORR) to determine the relationships between these variables.

Results and Discussion

Hong Kong orchid trees in Florida flowered primarily between the months of November and January (Fig. 1). At this site, this species was leafless from April to early May when new leaves emerged entirely free of K or Mg deficiency symptoms (Fig. 2). Leaves remained largely free of deficiency symptoms until about October when the severity of K, Mg, or both deficiency symptoms gradually increased. Individual trees at any given sampling

Fig. 3. Leaf concentrations of N, P, K, and Mg across all treatments by month for Hong Kong orchid trees grown in south Florida with two rates of three different fertilizers from Jan. 2015 through Jan. 2016. Data represent means with standard error bars. $N = 49$.

date showed a predominance of either K or Mg deficiency symptoms and, occasionally, both. Trees that displayed only K deficiency 1 month might show mostly Mg deficiency symptoms during a different month or vice versa. When severe, either deficiency caused premature leaf drop and when that occurred, leaves that would have shown more severe visible deficiency symptoms of either element were not present for rating. This resulted in few deficiency rating values less than 3.0, and if a severe deficiency of one element caused defoliation of the older leaves, then the loss of those leaves which would have shown more severe deficiency symptoms of the other element, probably resulted in artificially higher nutrient deficiency ratings for the nondefoliating element. Thus, the deficiencies of these two elements were actually more severe than the visible symptom ratings indicated. Interestingly, another tree from the same lot as those used in this study that was planted in a moist muck soil ≈ 20 km from the study site grew at least three times larger, never became deciduous, and only rarely exhibited minor Mg deficiency symptoms (T.K. Broschat, personal observations). Clearly, soil type and its fertility are important determining factors in the physiological behavior of this species.

Analysis of leaf nutrient concentrations showed highest concentrations of N, P, K, and Mg in May followed by a decline in concentrations of all of these elements through July and another increase in concentrations in

August through September (Fig. 3). Because fertilizer applications were performed in early January, April, July, and October and even unfertilized control trees exhibited similar trends (Table 1), it is unlikely that this late summer increase in nutrient concentrations was related to fertilizer application. Nutrient concentrations in the leaves began to decline in October and November as flower buds began to emerge from the shoot tips (Table 1; Fig. 1). The flowers of Hong Kong orchid trees contained about as much N, P, K, and Mg as healthy leaves. Concentrations of these elements in the flowers were unaffected by fertilizer treatments (data not shown) and averaged 0.20% Mg, 1.83% K, 0.24% P, and 2.03% N across all treatments. Because each terminal inflorescence produces about a dozen large flowers, this represents a substantial sink for these nutrients. Whether these elements were similarly recycled from senescing flowers is not known. Concentrations of N, P, K, and Mg notably decreased in senescing flowers of Chinese hibiscus (*H. rosa-sinensis*) which are similar in size to those of Hong Kong orchid trees (Trivellini et al., 2011). Fortunately, Hong Kong orchid trees do not produce fruit as do other *Bauhinia* species. Developing fruits are known to be important sinks for nutrients mobilized from older leaves (Hill, 1980; Kotur and Keshava Murthy, 2010; Tagliavini et al., 2000; Williams, 1955).

Leaf nutrient concentrations of N, K, and Mg continued to decrease over time even after flower production ceased in January. However, visible deficiency symptom ratings declined during this period only for Mg (Fig. 2). Presumably, this decrease in leaf nutrient concentrations after flowering was because of storage of these mobile elements in the stem tissue for later use in the new leaves (Hill, 1980; Marschner, 1986). Although sufficiency data for leaf nutrient concentrations of many species of plants have been published (Mills and Jones, 1996), equivalent data for *Bauhinia* species are not available.

Correlation analysis revealed that height, stem caliper, and number of flowers were highly intercorrelated, i.e., large trees produce more flowers (Table 2). Magnesium deficiency ratings were positively correlated with all of these size/quality variables, but K deficiency ratings were not correlated with any other quality variable. This finding suggests that although K deficiency was present and detracted from the esthetic appearance of the trees, it was Mg deficiency that limited tree growth and flowering. Leaf concentrations of N, P, and K were negatively correlated with Mg deficiency ratings indicating that as Mg deficiency ratings increased, leaf N, P, and K concentrations decreased. Because Mg deficiency rating was positively correlated with growth, it suggests that N, P,

Table 1. Monthly leaf concentrations (%) of N, P, K, and Mg in Hong Kong orchid trees when fertilized with two rates of three different fertilizers. $N = 8$.

Treatment	Rate (g·m ⁻²)	Element	Mo.															
			Jan.	Feb.	Mar.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	
Control	0	K	1.25	1.09	1.19	1.49	1.19	1.25	1.51 a ^z	1.61 a	1.56 a	1.14	0.95	0.94	0.96	0.95	0.95	0.77
24-0-11	41.7		1.06	0.94	0.98	1.35	1.08	1.01	1.17 d	1.25 c	1.29 bc	1.08	0.89	0.82	0.92	0.89	0.79	0.72
24-0-11	83.4		1.14	0.94	0.96	1.33	1.10	1.16	1.27 cd	1.19 c	1.23 c	1.22	0.96	0.85	0.86	0.81	0.70	
8-0-12	125		1.29	1.08	0.98	1.41	1.14	1.18	1.38 bc	1.51 ab	1.32 abc	1.04	0.85	0.87	0.95	0.87	0.75	
8-0-12	250		1.14	1.12	0.99	1.50	1.11	1.09	1.35 c	1.35 bc	1.33 abc	1.11	0.86	0.92	0.91	0.85	0.70	
0-0-16	94		1.10	1.05	1.00	1.60	1.15	1.14	1.59 a	1.63 a	1.51 ab	1.11	1.01	1.02	1.05	0.95	0.90	
0-0-16	188		0.87	0.81	1.19	1.59	1.15	1.06	1.63 a	1.64 a	1.33 abc	1.07	0.87	0.87	0.97	0.92	0.79	
P value			NS ^y	NS	NS	NS	NS	NS	<0.0001	0.0005	0.039	NS	NS	NS	NS	NS	NS	NS
Control	0	Mg	0.110 a	0.089 a	0.098	0.299 a	0.278 a	0.247 a	0.224	0.255 ab	0.282 a	0.256 a	0.207	0.127	0.106	0.092	0.087	
24-0-11	41.7		0.064 bc	0.039 c	0.032	0.223 c	0.209 bc	0.176 b	0.176 b	0.235	0.222 d	0.229 bcd	0.197 b	0.168	0.080	0.066	0.063	
24-0-11	83.4		0.062 c	0.051 abc	0.051	0.223 c	0.176 c	0.177 b	0.177 b	0.235	0.223 cd	0.201 d	0.195 b	0.155	0.111	0.082	0.069	0.070
8-0-12	125		0.056 c	0.040 bc	0.035	0.242 bc	0.220 bc	0.206 ab	0.206 ab	0.246	0.246 bc	0.232 bcd	0.182 b	0.155	0.093	0.080	0.060	0.074
8-0-12	250		0.067 bc	0.059 abc	0.053	0.265 abc	0.273 a	0.245 a	0.245 a	0.256	0.244 bcd	0.205 cd	0.180 b	0.134	0.092	0.067	0.061	0.076
0-0-16	94		0.104 ab	0.091 a	0.062	0.289 ab	0.252 ab	0.234 a	0.234	0.232	0.249 ab	0.247 ab	0.209 ab	0.149	0.094	0.078	0.066	0.070
0-0-16	188		0.117 a	0.083 ab	0.051	0.304 a	0.289 a	0.247 a	0.247 a	0.234	0.269 a	0.240 bc	0.200 b	0.170	0.123	0.105	0.066	0.064
P value			0.0046	0.018	NS	0.019	<0.0001	0.0009	0.0009	NS	0.0013	0.0017	0.037	NS	NS	NS	NS	NS
Control	0	N	2.11	1.85	2.07	2.81	2.13	1.99	1.98	2.34	2.45	2.26	2.38	2.17	2.07 a	1.65	1.51	
24-0-11	41.7		2.02	1.67	1.52	2.60	2.05	1.95	1.86	2.06	2.55	2.39	2.39	2.34	1.98	1.85 b	1.50	1.38
24-0-11	83.4		1.93	1.82	1.77	2.77	2.11	1.82	1.90	2.14	2.53	2.58	2.58	2.28	2.07	1.80 b	1.56	1.42
8-0-12	125		2.05	1.73	1.49	2.42	2.08	1.75	1.81	2.27	2.64	2.37	2.37	2.38	2.10	1.90 ab	1.52	1.41
8-0-12	250		2.12	2.02	1.75	2.93	2.00	1.98	1.89	2.25	2.68	2.39	2.39	2.40	2.17	1.96 ab	1.54	1.45
0-0-16	94		1.87	1.54	1.54	2.84	2.09	2.02	2.04	2.34	2.32	2.32	2.33	2.39	2.17	1.93 ab	1.64	1.51
0-0-16	188		1.85	1.61	1.65	2.98	1.94	1.91	2.00	2.41	2.44	2.44	2.20	2.33	2.03	1.96 ab	1.59	1.48
P value			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0378	NS	NS
Control	0	P	0.149	0.140	0.138	0.228	0.173	0.178	0.227	0.243	0.222	0.185	0.181 a	0.187 a	0.190 a	0.146	0.141	
24-0-11	41.7		0.128	0.125	0.120	0.198	0.145	0.159	0.153	0.200	0.235	0.201	0.163	0.146 bc	0.140 bc	0.148 b	0.133	0.122
24-0-11	83.4		0.141	0.145	0.140	0.211	0.152	0.153	0.153	0.208	0.211	0.199	0.164	0.143 c	0.138 c	0.143 b	0.140	0.135
8-0-12	125		0.127	0.136	0.114	0.199	0.154	0.163	0.163	0.211	0.227	0.207	0.152	0.148 bc	0.154 bc	0.156 b	0.146	0.125
8-0-12	250		0.121	0.151	0.127	0.243	0.150	0.144	0.144	0.198	0.223	0.207	0.156	0.146 bc	0.152 bc	0.146 b	0.133	0.126
0-0-16	94		0.111	0.111	0.118	0.222	0.155	0.147	0.147	0.226	0.227	0.204	0.156	0.174 ab	0.167 ab	0.160 ab	0.148	0.148
0-0-16	188		0.106	0.107	0.108	0.255	0.150	0.148	0.148	0.210	0.229	0.193	0.151	0.158 abc	0.160 abc	0.160 ab	0.153	0.137
P value			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.021	0.0059	0.0336	NS	NS

^aMean separation within columns and elements using the Waller-Duncan *k*-ratio method ($P = 0.05$).^yNonsignificant at $P > 0.05$.

Table 2. Pearson correlation coefficients among plant quality and leaf nutrient concentration variables for Hong Kong orchid trees fertilized with two rates of three different fertilizers. Values represent correlation coefficients with *P* values shown below. *N* = 49.

	Caliper	Ht	Flowers	K rating	Mg rating	N concn	P concn	K concn
Height	0.704 <0.0001							
Flowers	0.833 <0.0001	0.695 <0.0001						
K rating	-0.051 0.730	-0.032 0.828	-0.003 0.984					
Mg rating	0.318 0.026	0.318 0.026	0.352 0.013	-0.102 0.487				
N concn	0.029 0.840	-0.029 0.841	-0.073 0.616	-0.140 0.337	-0.755 <0.0001			
P concn	-0.075 0.610	-0.284 0.048	-0.144 0.323	-0.281 0.050	-0.676 <0.0001	0.681 <0.0001		
K concn	-0.139 0.342	-0.222 0.126	-0.295 0.040	-0.115 0.431	-0.670 <0.0001	0.698 <0.0001	0.755 <0.0001	
Mg concn	0.065 0.657	-0.082 0.576	0.002 0.988	-0.369 0.009	0.008 0.955	0.172 0.238	0.289 0.044	0.269 0.062

and K were less diluted within the smaller Mg-deficient trees.

Because plant quality variables such as height, stem caliper, number of flowers, and K and Mg visual deficiency ratings were highly intercorrelated, principal component analysis was performed on these variables to generate a single overall index of plant quality (Broschat, 1979). Stem caliper, height, number of flowers, and Mg deficiency ratings all had high positive correlations with the PC1 which accounted for nearly 54% of the total variability in the five original variables (Table 3). Potassium deficiency rating was not significantly correlated with PC1, but was highly correlated with the second principal component (PC2) which accounted for an additional 20% of the variance in the original five variables. Thus, the scores of individual trees on PC1 or PC1 plus PC2 can be used as an overall plant quality index in subsequent analyses.

When scores for individual trees on PC1 and PC2 were subjected to ANOVA with mean separations for the seven fertilizer treatments, results were virtually identical when PC1 or PC2 scores were used (Table 4). In either case, the highest quality trees were obtained when fertilizing with the high rate of 8-0-12, although equivalent quality was obtained with the high rate of 24-0-11 or the lower rate of 8-0-12. The low rate of 0-0-16 fertilizer was not different from that of the unfertilized control plants, although the high rate of this product produced a noteworthy improvement over the controls. This suggests that even though N deficiency symptoms were not observed in this study, N was important in the fertilization of this species in this soil. Although many leguminous trees are N-fixing plants, *Bauhinia* species are not (Gehring et al., 2005; Hogburg, 1990). When K and Mg deficiency rating data were subjected individually to ANOVA, none of the treatments improved symptom severity over that of the unfertilized control plants (data not shown). Thus, although overall tree size and quality were affected by fertilizer treatments, severity of visible K and Mg deficiency symptoms was not.

Leaf nutrient concentrations of N, P, K, and Mg were majorly affected by fertilizer treatment at some times of the year, but not at

others (Table 1). Leaf N concentrations differed among treatments only in Feb. 2016 and in that case, the highest concentrations were observed in the unfertilized control trees and the lowest in those receiving the high N:K ratio turf fertilizer 24-0-11. Thus, the smallest plants had the highest concentrations of N because of dilution. For P, treatment differences were significant only during the Winter of 2015-16 when again the smallest trees had the highest leaf P concentrations. Leaf K concentrations differed among treatments only during August through Oct. 2015. In this case, the treatments with the lowest K concentrations were usually those with the highest N:K ratio (24-0-11 treatments), whereas the unfertilized controls and those receiving no N fertilizer (0-0-16) had the highest leaf K concentrations. Nitrogen fertilization is known to induce or exacerbate K deficiencies (Mulder, 1956). Leaf Mg concentrations differed among treatments for most of 2015, with unfertilized controls always having the highest Mg concentrations. However, the two palm fertilizers (8-0-12 and 0-0-16), which contain large amounts of Mg, typically resulted in similarly high leaf Mg concentrations. The lowest Mg concentrations were obtained with the turf fertilizer 24-0-11 which contained no Mg but contained N to stimulate growth, which in turn diluted Mg concentrations. These fertilizers also contain K which is known to be antagonistic to Mg uptake (Barker and Pilbeam, 2007). Leaf nutrient concentrations appear to be poor predictors of overall plant quality in Hong Kong orchid trees because leaf concentrations of N, P, and K were negatively correlated with some of the plant quality variables, and Mg concentrations were not correlated with any of the plant quality variables (Table 2).

In conclusion, the terminal inflorescence of Hong Kong orchid trees appeared to be a major sink for N, P, K, and Mg remobilized from older leaves on the same shoot. However, leaf concentrations of these elements continued to decrease after flowering ceased in January. These elements may have been stored in the stem tissue for later use in newly developing leaves. Although the 8-0-12 palm fertilizer at 125 and 250 g·m⁻² and the

Table 3. Correlations of original plant quality variables with the first two principal components (PC1 and PC2) for Hong Kong orchid trees fertilized with two rates of three different fertilizers. *N* = 49.

Variable	PC1	PC2
Caliper	0.556	0.073
Height	0.523	0.077
Flowers	0.557	0.112
K rating	-0.047	0.939
Mg rating	0.323	-0.308
Eigenvalue	2.687	1.026
Proportion	0.538	0.205

Table 4. Effects of fertilizer treatment on overall quality scores (scores on first two principal components, PC1 and PC2) for Hong Kong orchid trees fertilized with two rates of three different fertilizer types. *N* = 8.

Fertilizer	Rate	PC1	PC2
Control	0	147.7 d ^a	26.1 d
24-0-11	41.7	198.3 bc	34.6 bcd
24-0-11	83.4	227.3 ab	40.0 ab
8-0-12	125	211.7 abc	37.3 abc
8-0-12	250	252.4 a	44.7 a
0-0-16	94	164.3 cd	28.8 cd
0-0-16	188	199.8 bc	35.0 bc
<i>P</i> value		0.0006	0.0007

^aMean separation by the Waller-Duncan *k*-ratio method, *P* = 0.05.

24-0-11 turf fertilizer at 83 g·m⁻² improved overall size and number of flowers, no treatment was capable of reducing K and Mg deficiency symptom severity in this species on this nutrient-poor sand soil. Leaf concentrations of N, P, K, and Mg were poorly or negatively correlated with plant quality variables and were poor indicators of tree health or esthetic appearance.

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