Effects of Fertilization on the Growth and Quality of Container-grown Areca Palm and Chinese Hibiscus during Establishment in the Landscape

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SUMMARY. The roots of container-grown ornamental plants primarily are concentrated within the original container substrate root ball during the establishment period following transplanting into the landscape. Plants growing in container substrates containing pine bark or peatmoss have higher nitrogen (N) requirements than in most landscape soils due to microbial immobilization of N by these organic components. However, use of high-N fertilizers, such as those used in container production of ornamentals, can cause imbalances with potassium (K) and magnesium (Mg) when used on palms in sandy landscape soils. Areca palm (*Dypsis lutescens*) and chinese hibiscus (*Hibiscus rosa-sinensis* 'President') that had been growing in containers were transplanted into a landscape soil to determine if high N fertilization during the establishment period could accelerate the rate of establishment without exacerbating K and Mg deficiencies. Although plants of both species had the darkest green color and largest size when continuously fertilized with high N fertilizer, this treatment did induce Mg deficiency in both species. Plant size and color for both species were highly correlated with cumulative N application rates, but also with initial N application rates, suggesting that high N fertilization during the first 6 months affected plant quality at 12 and 24 months after planting, even if high N fertilization was discontinued. However, continued use of a moderate N landscape palm maintenance fertilizer ultimately produced areca palm plants as good as those receiving high N during the establishment period.

Although the nutrition and fertilization of container-grown ornamental plants during production have been extensively studied, very little is known about the fertilizer requirements of container-grown ornamental plants following transplanting into the landscape. Because landscape soils differ greatly in physical and chemical properties from the substrates used in container production, the nutritional requirements are therefore also quite different. In the southeastern United States, pine bark is a major component in container substrates. Plants grown in pine bark substrates tend to have high nitrogen requirements due to the immobilization of N by microbes that degrade pine bark (Prasad, 1980). Thus, woody ornamental plants grow

best in such substrates when provided with high N analysis fertilizers (Jackson et al., 2008; Wright and Niemiera, 1987).

Landscape soils vary greatly by region, and even locally, in their physical and chemical properties. Landscape soils in many parts of the United States are sufficiently fertile that routine fertilization of established woody ornamental plants is not required (Harris et al., 2004; Neely, 1980; Perry and Hickman, 1992). In other areas, such as the highly leached sandy soils of the southern Atlantic coastal plain, nutrient deficiencies are common and corrective or prophylactic

fertilization may be needed (Gilman, 1987; Gilman et al., 2000). Palms (Arecaceae) in particular, which have high potassium, magnesium, and micronutrient requirements, usually exhibit some degree of K or other nutrient deficiency symptoms when grown on these soils (Broschat and Meerow, 2000). High N fertilization has been shown to exacerbate K and Mg deficiencies in these plants and thus recommended landscape fertilizers have lower N:K ratios than those used for turfgrass or container production of ornamentals, including palms (Broschat, 2005; Broschat et al., 2008).

Broschat et al. (2008) observed that container-grown areca palm plants became increasingly N deficient in appearance during the first 6 to 8 months following transplanting into a sandy soil in southeastern Florida. Such plants, even when fertilized as recommended for established palms in the landscape, showed little evidence of growth during this establishment period. Because the root systems of transplanted plants are believed to remain largely confined to the container substrate in which they had been growing during the first season after transplanting, N draw-down in the root ball could result in reduced growth rate and, therefore, slow establishment in the landscape unless the original container substrate root ball continues to receive the high N fertilizers required for these substrates. The purpose of this study was to determine if increasing the N content of fertilizers applied to transplanted container-grown areca palm and chinese hibiscus plants could accelerate the rate of establishment without exacerbating K and/or Mg deficiencies.

Materials and methods

Areca palm and chinese hibiscus grown in 2-gal containers were

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.0929	ft ²	m ²	10.7639
0.0283	ft ³	m ³	35.3147
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
1	meq/100g	cmol·kg ⁻¹	1
33.9057	oz/yd ²	g·m ⁻²	0.0295
1	ppm	mg·kg ⁻¹	1
1	ppm	mg·L ⁻¹	1

transplanted into a field in Davie, FL (lat. 26°5'1.7"N, long. 80°14'15.2"W) on the dates indicated below. The soil was a Margate fine sand (siliceous, hyperthermic mollic psammaquent). Soil samples ($n = 6$) were taken at the time of planting and were analyzed by A & L Southern Laboratories (Pompano Beach, FL). Mean soil organic matter content was 5.0%, cation exchange capacity was 7.5 meq/100 g, and pH was 5.1. Available phosphorus as P_2O_5 (P1) averaged 9.0 ppm, K was 16.3 ppm, Mg was 35.8 ppm, and calcium (Ca) was 2308 ppm. Plants were spaced 8 ft apart and arranged in a completely randomized design with 10 replicate plants per treatment. In the first experiment (Expt. 1), areca palm plants were planted on 14 July 2006 and chinese hibiscus on 26 July 2006. A second identical experiment (Expt. 2) was initiated for both species on 23 Jan. 2007. All controlled-release fertilizers were scraped off the surface of each root ball before transplanting.

On the day following transplanting, plants were fertilized by broadcasting uniformly over the 1-m² area surrounding each plant. Fertilizers included an 8N-0.9P-10K-4Mg plus micronutrients landscape palm fertilizer with controlled-release N from sulfur-coated urea, K from sulfur-coated potassium sulfate, and Mg from kieserite [PALMFERT (Nurserymen's Sure Gro, Vero Beach, FL)], PALMFERT blended with sulfur-coated urea (Lesco, Rocky River, OH) in a 2:1 ratio by weight equivalent to 18N-0.6P-6.7K-2.6Mg plus micronutrients (HIGHNFERT), or no fertilizer according to the schedule shown in Table 1. All fertilizers were applied at a rate of 75 g·m⁻² at 3-month intervals. Initial N fertilization rate, plus cumulative N applied per plant for each treatment up to the 6-, 12-, and 24-month sampling dates are provided in Table 2.

During the first 6 months, plots were irrigated every other day with ≈ 2 cm of water, regardless of rainfall, from overhead irrigation (Rainbird 5000 rotary heads; Rainbird, Tucson, AZ) mounted on 5-ft-tall risers spaced 30 ft on centers during plant establishment. Irrigation water was obtained from a nearby pond, had a pH of 7.0, and contained 0.5 ppm K and 1.4 ppm Mg. Monthly rainfall data were collected by the Florida

Table 1. Fertilizer treatments applied at 75 g·m⁻² (2.2 oz/yard²) every 3 mo. to the soil surface of areca palm and chinese hibiscus plants transplanted from containers into the landscape ($n = 10$).

Treatment no.	Treatment description ^z
1	Control—no fertilizer
2	HIGHNFERT at 0 and 3 mo. and PALMFERT at 6, 9, 12, 15, 18, and 21 mo.
3	HIGHNFERT at 0, 3, 6, and 9 mo. and PALMFERT at 12, 15, 18, and 21 mo.
4	HIGHNFERT at 0 and 3 mo., PALMFERT at 6 and 9 mo., and no fertilizer thereafter
5	HIGHNFERT at 0, 3, 6, and 9 mo. and no fertilizer thereafter
6	HIGHNFERT at 0, 3, 6, 9, 12, 15, 18, and 21 mo.
7	PALMFERT at 0 and 3 mo. and no fertilizer thereafter
8	PALMFERT at 0, 3, 6, and 9 mo. and no fertilizer thereafter
9	PALMFERT at 0, 3, 6, 9, 12, 15, 18, and 21 mo.

^zHIGHNFERT has an analysis of 18N-0.6P-6.7K-2.6Mg plus micronutrients. PALMFERT has an analysis of 8N-0.9P-10K-4Mg plus micronutrients. Both use sulfur-coated urea as the nitrogen source.

Table 2. Initial and cumulative nitrogen (N) amount applied to the soil surface of areca palm and chinese hibiscus plants transplanted from containers into the landscape. The N source was sulfur-coated urea and application rates were the same for both experiments.

Treatment no.	Initial N (g·m ⁻²) ^z	Cumulative N		
		6 mo. (g·m ⁻²)	12 mo. (g·m ⁻²)	24 mo. (g·m ⁻²)
1	0	0	0	0
2	13.1	26.3	38.0	61.3
3	13.1	26.3	52.6	75.9
4	13.1	26.3	38.0	38.0
5	13.1	26.3	52.6	52.6
6	13.1	26.3	52.6	105.1
7	5.8	11.7	11.7	11.7
8	5.8	11.7	23.4	23.4
9	5.8	11.7	23.4	46.7

^z1 g·m⁻² = 0.0295 oz/yard².

Automated Weather Network (University of Florida, 2009) station located ≈ 400 m from the planting site (Fig. 1). After 6 months, the plots were similarly irrigated twice per week. In both experiments, all hibiscus were cut back to a uniform height of 50 cm after 12 months. At 0, 6, 12, and 24 months after planting, all plants were subjectively rated on a 1 to 5 scale to the nearest 0.1 unit for N deficiency severity (1 = very light yellow foliage, 5 = very dark green foliage for the species), hereafter referred to as color. Areca palm plants were rated on a similar scale for severity of K and Mg deficiency symptoms, which cause leaf discoloration and tip necrosis (K deficiency) or marginal chlorosis (Mg deficiency) on the oldest leaves (Elliott et al., 2004). Chinese hibiscus plants were rated for Mg deficiency severity at the end of both experiments, with

interveinal and marginal chlorosis of the oldest leaves being the characteristic symptom. Areca palm plants were measured for total height to the tip of the longest vertically extended leaf, while size, calculated as height $\times$ width₁ $\times$ width₂, was determined for chinese hibiscus on the same sampling dates. Maximum root extension was determined by excavating the longest root on opposite sides of the plant parallel to the rows and measuring its length from the stem. Roots were excavated by gently removing the surface soil from an area 30 cm wide and 100 cm from the base of the plant and digging toward the plant until the outermost roots were encountered. Maximum root extension per plant was the mean of the two roots sampled.

Data were analyzed by analysis of variance, with mean separation by the Waller-Duncan k-ratio method

Fig. 1. Monthly rainfall during Expts. 1 and 2 obtained from the Florida Automated Weather Network (University of Florida, 2009) station located about 400 m (437.4 yards) from the planting site. Areca palm and chinese hibiscus plants were planted in July 2006 for Expt. 1 and Jan. 2007 for Expt. 2, with both experiments ending 2 years after planting (1 inch = 2.54 cm).

($P = 0.05$) (SAS PROC GLM, version 9.1; SAS Institute, Cary, NC). Pearson correlations of plant deficiency severity, size, and growth with initial and cumulative N application rates were also performed using SAS PROC CORR.

Results and discussion

Six months after transplanting, areca palm plants showed no differences in color among the nine fertilizer treatments in either experiment (Table 3). Similarly, there were no treatment differences in areca palm height or growth in Expt. 1. However, in Expt. 2, treatment 6 (HIGHNFERT, 24 months) areca palm plants were significantly taller than treatments 1, 2, 3, and 7.

At 12 months after transplanting, treatment 6 (HIGHNFERT for 24 months) areca palm plants had darker color than unfertilized control plants (treatment 1) or those receiving only PALMFERT for the first 6 months (treatment 7) or high N for only 6 months followed by PALMFERT (treatment 2) in both experiments (Table 3). Color differences were more pronounced at 24 months after transplanting, with treatments 3 and 6 resulting in good color in both experiments. The unfertilized controls (treatment 1) and treatments 4, 5, 7, and 8 (no fertilizer during the second year) consistently produced areca palm plants with the poorest color at 24 months in both experiments. Areca palm height and growth rates in both experiments were consistently high for treatment 6 and low

for treatment 1 at 12 and 24 months. Thus, color and growth of areca palm appeared to be strongly influenced by N fertilizer application rates and schedules.

For chinese hibiscus, plant color and size were also consistently best for treatment 6 plants in both experiments on all measurement dates where significant differences existed (Table 4). Not surprisingly, the unfertilized control plants (treatment 1) consistently had poor color. By 24 months, treatments having no fertilizer applications during the second year (treatments 4, 5, 7, and 8) also tended to have poor color, especially in Expt. 2. After 12 months, treatment 7, which had only moderate amounts of N (PALMFERT) for 6 months and nothing thereafter, and the unfertilized controls (treatment 1), tended to have the smallest plant size in Expt. 2. Gilman (1987) also found that this species, when transplanted from containers, responded strongly to applications of controlled-release N compared with unfertilized controls. Nitrogen fertilization improved growth in container-grown japanese ligustrum (*Ligustrum japonicum*), but not in laurel oak (*Quercus hemisphaerica*) when transplanted into similar soils in Florida (Gilman and Yeager, 1990).

Maximum root extension was not significantly different among treatments for either species at any time for either experiment (data not shown). Root growth in dicot trees and shrubs generally has not been promoted by N fertilization (Gilman, 1990;

Hamilton et al., 1981), but little is known about palm root responses to fertilization.

Although the various treatments used in these experiments can be useful in determining the optimum fertilization approach to use for transplanted container-grown areca palm and chinese hibiscus plants, it is difficult to determine the overall effects of N on the growth and quality of these species from an analysis of variance of the treatment data. Because both N amounts and the duration of N applications were varied in the experimental design, correlation analysis was used to show relationship of plant growth and quality with cumulative N amounts applied. For areca palm, plant color at 6 months was not correlated with cumulative N applied in either experiment, but was strongly correlated at 12 and 24 months in both experiments (Table 5). Because areca palm grows rather slowly, it is not surprising that plant color, height, and growth rate differences did not change rapidly in response to N fertilization. Areca palm height and growth rate were also highly correlated with cumulative N amount applied at 24 months for both experiments and also at month 12 in Expt. 2.

Chinese hibiscus color had significant correlations with cumulative N applied in both experiments at all sampling dates except at 6 months in Expt. 1 (Table 5). Growth rate and size were correlated with cumulative N at all sampling dates in both experiments except at 12 months in Expt. 1. Because chinese hibiscus grows rapidly, color and growth differences were apparent by 6 months after transplanting.

Although overall quality and size at the end of the experiment was highly correlated with cumulative N applied for both species, it is difficult to determine if differences in size or quality at 12 or 24 months were a result of the fertilization provided at the time of transplanting or if subsequent fertilization also was important. Correlation analysis of plant growth and quality variables with initial N application rates showed significant correlations between areca palm color and initial N fertilizer application rates in both experiments at all sampling dates except 6 months in Expt. 2 (Table 6). Areca palm height and growth rate were also strongly correlated with initial N application rate at 24 months

Table 3. Foliage color ratings, height, growth rate, and magnesium (Mg) deficiency severity ratings of areca palm transplanted from containers into the landscape (n = 10).

Time since transplanting										
<i>Expt. 1</i>										
Treatment no. ^z	6 mo.			12 mo.			24 mo.			
	Color (1–5 scale) ^y	Ht (cm) ^x	Growth (cm) ^w	Color (1–5 scale)	Ht (cm)	Growth (cm)	Color (1–5 scale)	Mg rating (1–5 scale) ^v	Ht (cm)	Growth (cm)
1	4.46 ^u	77.9	16.3	4.48 c	123.9	46.0 b	4.66 e	4.49 a	197.9 bc	74.0 d
2	4.44	72.2	13.5	4.59 bc	142.5	70.3 a	4.71 de	3.99 bc	236.0 ab	93.5 bcd
3	4.40	76.0	16.6	4.70 ab	142.2	66.2 a	4.80 ab	3.78 c	247.3 a	123.8 a
4	4.36	73.7	12.3	4.63 ab	134.7	61.0 ab	4.70 de	3.91 bc	230.6 ab	98.9 bcd
5	4.42	74.1	13.7	4.65 ab	130.2	56.1 ab	4.72 cd	4.03 bc	224.0 abc	93.8 bcd
6	4.38	76.3	13.5	4.73 a	132.8	56.5 ab	4.83 a	3.81 bc	247.3 a	114.5 ab
7	4.30	75.4	13.0	4.59 bc	142.5	67.1 a	4.72 cd	4.14 abc	222.0 abc	79.5 cd
8	4.38	79.3	16.6	4.64 ab	142.1	62.8 ab	4.72 cd	4.46 a	219.8 bc	77.7 cd
9	4.44	73.7	13.2	4.68 ab	139.6	65.9 a	4.77 bc	4.21 ab	239.5 ab	99.9 abc
<i>P</i> value	0.9672	0.1775	0.8163	0.0042	0.1689	0.0311	<0.0001	0.0019	0.0001	0.0006
<i>Expt. 2</i>										
Treatment No.	6 mo.			12 mo.			24 mo.			
	Color (1–5 scale)	Ht (cm)	Growth (cm)	Color (1–5 scale)	Ht (cm)	Growth (cm)	Color (1–5 scale)	Mg rating (1–5 scale)	Ht (cm)	Growth (cm)
1	4.42	103.5 bc	0.0	4.18 c	145.7 cd	42.1 cd	4.63 cd	4.91	188.9 e	43.3 c
2	4.47	104.4 bc	1.4	4.54 b	170.4 ab	66.1 a	4.75 ab	4.98	242.0 ab	71.6 a
3	4.39	104.3 bc	3.0	4.61 ab	155.2 bc	51.0 bc	4.75 ab	4.96	219.2 cd	64.0 ab
4	4.41	115.9 ab	8.9	4.61 ab	170.4 ab	54.5 abc	4.71 bc	4.85	233.8 abc	63.5 ab
5	4.40	109.1 abc	5.4	4.61 ab	160.1 bc	51.0 bc	4.69 bcd	4.96	212.9 cd	52.9 bc
6	4.37	120.6 a	14.5	4.70 a	179.9 a	59.4 ab	4.83 a	4.92	242.3 a	62.4 ab
7	4.34	102.3 c	5.7	4.24 c	136.6 d	34.4 d	4.58 d	5.00	190.7 de	54.1 abc
8	4.38	108.8 abc	3.9	4.56 b	165.1 ab	56.4 abc	4.68 bcd	4.90	222.3 bcd	57.2 abc
9	4.42	114.3 abc	9.1	4.52 b	156.7 bc	42.4 cd	4.74 abc	4.93	225.1 abcd	68.4 ab
<i>P</i> value	0.6866	0.0182	0.0825	0.0001	<0.0001	0.0006	0.0001	0.4390	<0.0001	0.0181

^zTreatments are described in Tables 1 and 2.^y1 = very light yellow, 5 = very dark green for the species.^x1 cm = 0.3937 inch.^wGrowth rate was calculated as follows: 6-mo. height minus initial height, 12-mo. height minus 6-mo. height, and 24-mo. height minus 12-mo. height.^v1 = severe marginal chlorosis of the middle aged and older leaves, 5 = completely free of all marginal chlorosis.^uMean separation by the Waller–Duncan k-ratio method at *P* = 0.05. Means within columns followed by the same letter or no letter are not statistically different.

in both experiments and at 12 months in Expt. 2. The slow growth rate of areca palm may be responsible for the lack of a measurable response at 6 months following transplanting. Areca palm plants in all treatments grew very little during the first 6 months compared with the next 6 to 18 months (Table 3).

Chinese hibiscus, on the other hand, showed significant correlations of color, growth, and size with initial N fertilization rate at most sampling dates in both experiments (Table 6). Thus, high N fertilization at the time of transplanting can influence later growth, even if they receive less N at subsequent fertilizations. After 24 months, treatments 3 and 6, which received high N for at least 1 year, generally produced the largest and greenest areca palm and chinese hibiscus plants in both experiments (Table 4). Only when these species

received PALMFERT continuously for 24 months did these plants equal those receiving HIGHNFERT for 1 year or longer (Tables 3 and 4).

Although continuous fertilization with HIGHNFERT (treatment 6) resulted in the best growth and color in both species, high N fertilization is known to exacerbate Mg and/or K deficiencies in areca palm (Broschat et al., 2008). In Expt. 1, areca palm plants receiving HIGHNFERT for 6 months or longer (treatments 2–6) tended to have more severe Mg deficiencies at 24 months than those receiving PALMFERT for 12 months (treatment 8), or even the unfertilized controls (Table 3). The negative correlations between Mg deficiency symptom severity and initial ($r = -0.362$) and cumulative ($r = -0.375$) N application rates were highly significant ($P < 0.0001$) in Expt. 1, but were not

significant in Expt. 2. Although Mg deficiency severity was negatively correlated with N deficiency (color) ratings ($r = -0.320$, $P = 0.002$), it was also negatively correlated with growth ($r = -0.278$, $P = 0.008$) and areca palm height at 24 months ($r = -0.319$, $P = 0.002$), suggesting a dilution effect. Potassium deficiency severity was not significantly correlated with initial or cumulative N application rates (data not shown), but was negatively correlated with both growth ($r = -0.289$, $P = 0.006$) and areca palm height at 24 months ($r = -0.240$, $P = 0.023$) in Expt. 1. Although there are no published reports of high N fertilizers causing nutritional imbalances in chinese hibiscus, plants receiving HIGHNFERT for 24 months (treatment 6) had significantly lower Mg deficiency ratings at 24 months than all other treatments, including the

Table 4. Foliage color ratings, plant size, growth rate, and magnesium (Mg) deficiency severity ratings of chinese hibiscus plants transplanted from containers into the landscape (n = 10).

Time since transplanting									
<i>Expt. 1</i>									
Treatment no. ^z	6 mo.			12 mo.			24 mo.		
	Color (1–5 scale) ^y	Size (m ³) ^x	Growth (m ³) ^w	Color (1–5 scale)	Size (m ³)	Growth (m ³)	Color (1–5 scale)	Size (m ³)	Growth (m ³)
1 ^w	4.45 ^v	1.06 c	0.64 b	4.55	1.62	0.56	4.30 d	1.43 cd	0.99 ab
2	4.51	1.21 abc	0.75 ab	4.62	2.07	0.86	4.65 ab	2.17 bc	1.25 a
3	4.54	1.27 abc	0.81 ab	4.67	2.30	1.03	4.67 ab	2.35 ab	1.20 a
4	4.56	1.29 ab	0.91 a	4.65	2.19	0.90	4.53 bc	2.16 bc	1.12 a
5	4.55	1.36 a	0.92 a	4.64	2.35	0.99	4.61 abc	2.04 bc	0.84 ab
6	4.59	1.28 ab	0.90 a	4.68	2.62	1.33	4.78 a	2.70 a	1.24 a
7	4.52	1.17 abc	0.74 ab	4.65	2.56	1.39	4.52 bc	1.40 cd	0.00 b
8	4.51	1.12 bc	0.67 b	4.66	2.03	0.91	4.46 cd	1.91 bc	1.02 ab
9	4.51	1.16 abc	0.74 ab	4.68	2.37	1.22	4.61 abc	2.36 ab	1.13 a
<i>P</i> value	NS	0.0324	0.0184	NS	0.3837	NS	<0.0001	0.0001	0.1099
<i>Expt. 2</i>									
Treatment no.	6 mo.			12 mo.			24 mo.		
	Color (1–5 scale)	Size (m ³)	Growth (m ³)	Color (1–5 scale)	Size (m ³)	Growth (m ³)	Color (1–5 scale)	Size (m ³)	Growth (m ³)
1	4.39 c	0.25 b	0.15 b	4.18 b	0.79 d	0.49 c	4.66 ef	1.62 b	0.88
2	4.67 ab	0.28 b	0.19 b	4.61 a	0.91 bcd	0.64 bc	4.79 ab	2.30 b	1.37
3	4.65 abc	0.35 ab	0.26 ab	4.49 a	1.34 ab	1.00 ab	4.75 bcd	2.68 ab	1.45
4	4.67 ab	0.31 b	0.22 b	4.58 a	1.11 bcd	0.80 bc	4.75 bcd	2.27 b	1.16
5	4.74 a	0.29 b	0.19 b	4.56 a	1.31 abc	0.98 ab	4.71 de	2.20 b	1.05
6	4.59 abc	0.45 a	0.36 a	4.64 a	1.69 a	1.19 a	4.82 a	3.52 a	1.88
7	4.62 abc	0.27 b	0.17 b	4.40 ab	0.81 cd	0.55 c	4.65 f	1.74 b	0.93
8	4.58 abc	0.27 b	0.18 b	4.53 a	0.93 bcd	0.66 bc	4.73 cd	1.81 b	0.88
9	4.44 bc	0.33 b	0.23 b	4.50 a	1.08 bcd	0.75 bc	4.77 abc	2.18 b	1.06
<i>P</i> value	0.0523	0.0106	0.0082	0.0110	0.0040	0.0017	<0.0001	0.0061	0.1273

^zTreatments are described in Tables 1 and 2.

^y1 = very light yellow, 5 = the darkest green possible for the species

^xSize was calculated as height x width1 x width2; 1 m³ = 35.3147 ft³.

^wGrowth rate was calculated as follows: 6-mo. size minus initial size, 12-mo. size minus 6-mo. size, and 24-mo. size minus 12-mo. size.

^vMean separation by the Waller–Duncan k-ratio method at *P* = 0.05. Means within columns followed by the same letter or no letter are not statistically different.

Table 5. Correlations (*r*) of plant height or size, growth rate, and foliage color with cumulative nitrogen applied to container-grown areca palm and chinese hibiscus plants that were transplanted into the landscape.

	Expt. 1. Areca palm			Expt. 2. Areca palm		
	Time after planting			Time after planting		
	6 mo.	12 mo.	24 mo.	6 mo.	12 mo.	24 mo.
Height	0.108	0.054	0.432***	0.239*	0.415***	0.482***
Growth ^z	0.04	0.097	0.471***	0.217*	0.321**	0.274**
Color ^y	0.02	0.392***	0.467***	0.014	0.592***	0.509***
	Expt. 1. Chinese hibiscus			Expt. 2. Chinese hibiscus		
	6 mo.	12 mo.	24 mo.	6 mo.	12 mo.	24 mo.
	6 mo.	12 mo.	24 mo.	6 mo.	12 mo.	24 mo.
Size	0.285**	0.176	0.618***	0.412***	0.449***	0.459***
Growth ^x	0.285**	0.118	0.214*	0.415***	0.456***	0.358***
Color	0.161	0.339***	0.568***	0.277**	0.228*	0.498***

^zGrowth rate was calculated as follows: 6-mo. height minus initial height, 12-mo. height minus 6-mo. height, and 24-mo. height minus 12-mo. height.

^yColor is a subjective rating of nitrogen deficiency severity on a 1 to 5 scale with 1 = very light yellow and 5 = very dark green for the species.

^xGrowth rate was calculated as follows: 6-mo. size minus initial size, 12-mo. size minus 6-mo. size, and 24-mo. size minus 12-mo. size.

*, **, and *** indicate significance at 0.05, 0.01, and 0.001 levels, respectively.

unfertilized controls (treatment 1) in Expt. 1 (Table 4). No Mg deficiency symptoms were observed in this species in Expt. 2. Cooler air and soil temperatures during the first 4 months after planting in Expt. 2 plants may

have slowed the release of N from decomposing organic matter in the soil and thus reduced the N:Mg ratio in the soil.

In conclusion, although continuous applications of HIGHNFERT

resulted in the largest size and darkest green color for container-grown areca palm plants transplanted into the landscape, the negative interactions of N with Mg in this species reduced overall plant quality due to induced

Table 6. Correlations (r) of plant height or size, growth rate, and foliage color with initial nitrogen applied to container-grown areca palm and chinese hibiscus plants that were transplanted into the landscape.

	Expt. 1. Areca palm			Expt. 2. Areca palm		
	Time after planting			Time after planting		
	6 mo.	12 mo.	24 mo.	6 mo.	12 mo.	24 mo.
Height	0.196	0.089	0.369***	0.187	0.353***	0.411***
Growth ^z	0.084	0.164	0.377***	0.145	0.347***	0.272**
Color ^y	0.315**	0.239*	0.302**	0.030	0.597***	0.533***

	Expt. 1. Chinese hibiscus			Expt. 2. Chinese hibiscus		
	Time after planting			Time after planting		
	6 mo.	12 mo.	24 mo.	6 mo.	12 mo.	24 mo.
Height	0.386***	0.160	0.476***	0.249*	0.341**	0.335**
Growth	0.371***	0.075	0.141	0.253*	0.374***	0.261*
Color	0.340***	0.390***	0.432***	0.298**	0.202*	0.457***

^zGrowth rate was calculated as follows: 6-mo. height minus initial height, 12-mo. height minus 6-mo. height, and 24-mo. height minus 12-mo. height.

^yColor is a subjective rating of nitrogen deficiency severity on a 1 to 5 scale with 1 = very light yellow and 5 = very dark green for the species

*, **, and *** indicate significance at 0.05, 0.01, and 0.001 levels, respectively.

deficiencies of Mg. Treatments 3 and 6, which received HIGHNFERT for 1 year and 2 years, respectively, had the most severe Mg deficiencies. Thus, the benefits of HIGHNFERT appear to be offset by the increased severity of Mg deficiencies in areca palm. Treatment 2 (HIGHNFERT for 6 months followed by 18 months with PALMFERT) had equivalent size and green color to treatments 3 and 6, but had much less severe Mg deficiency and thus would appear to be an optimum fertilization regime for this species. However, areca palm plants receiving PALMFERT for 24 months had equivalent quality and there was no early boost in growth by the addition of HIGHNFERT for the first 6 months only as in treatment 2. It is possible that use of higher application rates of PALMFERT, which would provide increased N with proportionally increased Mg, during the first year might provide the boost in growth rate without exacerbating the Mg deficiency problem, but unfortunately, this treatment was not tested. Chinese hibiscus appeared to grow best with a sustained medium to high rate of N regardless of the analysis, but only when HIGHNFERT was used for 24 months (treatment 6) did this treatment result in an increase in severity of Mg deficiency symptoms in one of the experiments. Thus, fertilization with HIGHNFERT for the first 12 months, followed by 12 months of PALMFERT (treatment 3) resulted in the best overall quality in both experiments.

Because Mg deficiencies were significant only at 24 months, these

data suggest that higher N:Mg ratio fertilizers exacerbate Mg deficiencies only after the roots have become established in the surrounding soil and a significant portion of their nutrient uptake occurs within the sandy soil. The only N source used in this study was sulfur-coated urea, a controlled-release product, but more quickly available N sources may have different effects on Mg deficiency severity in landscape plants in southeastern Florida and additional studies are needed to determine their effects.

Literature cited

- Broschat, T.K. 2005. Fertilization of field-grown and landscape palms in Florida. Univ. Florida, Environ. Hort. Dept. Circ. ENH1009.
- Broschat, T.K. and A.W. Meerow. 2000. Ornamental palm horticulture. University Press of Florida, Gainesville, FL.
- Broschat, T.K., D.R. Sandrock, M.L. Elliott, and E.F. Gilman. 2008. Effects of fertilizer type on quality and nutrient content of established landscape plants in Florida. *HortTechnology* 18:278–285.
- Elliott, M.L., T.K. Broschat, J.Y. Uchida, and G.W. Simone. 2004. Compendium of ornamental palm diseases and disorders. APS Press, St. Paul, MN.
- Gilman, E.F. 1987. Response of hibiscus to soil applied nitrogen. *Proc. Florida State Hort. Soc.* 100:356–357.
- Gilman, E.F. 1990. Tree root growth and development. II. Response to culture, management, and planting. *J. Environ. Hort.* 8:220–227.
- Gilman, E.F. and T.H. Yeager. 1990. Fertilizer type and nitrogen rate affect field-grown laurel oak and japanese ligustrum. *Proc. Florida State Hort. Soc.* 103:370–372.
- Gilman, E.F., T.H. Yeager, and D. Kent. 2000. Fertilizer rate and type impacts magnolia and oak growth in sandy landscape soil. *J. Arboriculture* 26:177–182.
- Hamilton, D.F., M.E.C. Graca, and S.D. Verkade. 1981. Critical effects of fertility on root and shoot growth of selected landscape plants. *J. Arboriculture* 7:281–290.
- Harris, R.W., J.R. Clark, and N.P. Matheny. 2004. *Arboriculture: Integrated management of landscape trees, shrubs, and vines*, 4th ed. Prentice-Hall, Upper Saddle River, NJ.
- Jackson, B.E., R.D. Wright, and M.M. Alley. 2008. Comparison of fertilizer nitrogen availability, nitrogen immobilization, substrate carbon dioxide flux, and nutrient leaching in peat-lite, pine bark, and pine tree substrates. *HortScience* 44:781–790.
- Neely, D. 1980. Tree fertilization trials in Illinois. *J. Arboriculture* 6:271–273.
- Perry, E. and G.W. Hickman. 1992. Growth response of newly planted valley oak trees to supplemental fertilizers. *J. Environ. Hort.* 10:242–244.
- Prasad, M. 1980. Retention of nutrients by peats and wood wastes. *Scientia Hort.* 12:203–209.
- University of Florida. 2009. Florida Automated Weather Network, report generator. 1 Oct. 2009. <<http://fawn.ifas.ufl.edu/data/reports/>>.
- Wright, R.D. and A.X. Niemiera. 1987. Nutrition of container-grown woody nursery crops. *Hort. Rev. (Amer. Soc. Hort. Sci.)* 9:75–101.