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Influence of Fertilizer Placement on Plant Quality, Root Distribution, and Weed Growth in Container-grown Tropical Ornamental Plants

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Additional index words. ***Hibiscus rosa-sinensis*, *Jasminum multiflorum*, *Plumbago auriculata*, *Pseuderanthemum laxiflorum*, *Dypsis lutescens*, *Chamaedorea seifrizii*, *Caryota mitis*, *Archontophoenix alexandrae*, *Wodyetia bifurcata*, *Ptychosperma macarthurii*, controlled-release fertilizers**

Summary. In two experiments, chinese hibiscus (*Hibiscus rosa-sinensis*), bamboo palm (*Chamaedorea seifrizii*), areca palm (*Dypsis lutescens*), fishtail palm (*Caryota mitis*), macarthur palm (*Ptychosperma macarthurii*), shooting star (*Pseuderanthemum laxiflorum*), downy jasmine (*Jasminum multiflorum*), plumbago (*Plumbago auriculata*), alexandra palm (*Archontophoenix alexandrae*), and foxtail palm (*Wodyetia bifurcata*) were transplanted into 6.2-L (2-gal) containers. They were fertilized with Osmocote Plus 15N–3.9P–10K (12-to14-month formulation) (Expt. 1) or Nutricote Total 18N–2.6P–6.7K (type 360) (Expt. 2) applied by either top dressing, substrate incorporation, or layering the fertilizer just below the transplanted root ball. Shoot dry weight, plant color, root dry weights in the upper and lower halves of the root ball, and weed shoot dry weight were determined when each species reached marketable size. Optimal fertilizer placement method varied among the species tested. With the exception of areca palm, none of the species tested grew best with incorporated fertilizer. Root dry weights in the lower half of the root ball for chinese hibiscus, bamboo palm, and downy jasmine were greatest when the fertilizer was layered and root dry weights in the upper half of the root ball were greatest for top-dressed chinese hibiscus. Weed growth was lower in pots receiving layered fertilizer for four of the six palm species tested.

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Although numerous papers discuss the effects of controlled-release fertilizers on the growth and quality of container-grown plants, relatively few studies have compared the effectiveness of different application methods. These have generally shown that different species grow better with different application methods and that no single application method was consistently superior (Blessington et al., 1981; Cobb, 1985; Conover and Poole, 1985; Yeager and Ingram, 1987). Other studies have shown that response to fertilizer placement is affected by irrigation method (Coleman et al., 1978; Hicklenton, 1990; Klock-Moore and Broschat, 1999).

There have been no published comparisons of fertilizer placement effects on the growth and quality of container-grown palms. Although some palms produce rather fibrous root systems that uniformly fill the container, other species have relatively coarse, unbranched root systems that tend to be concentrated near the bottom of the container (T.K. Broschat, personal observation). A preliminary study on fertilizer placement effects suggested that palms may grow better with fertilizer layered just below the transplanted root ball, whereas dicot shrubs such as chinese hibiscus and ixora (*Ixora* spp.) may perform better with top-dressed or incorporated fertilizer (T.K. Broschat and H. Donselman, unpublished data). They also observed that fewer weeds grew in pots with layered fertilizer than with top-dressed or incorporated controlled-release fertilizer. Thus the purpose of this study was to determine how fertilizer placement affects shoot and root growth, root distribution within the container, and weed growth in container-grown tropical ornamental plants.

Materials and methods

In the first experiment (Expt. 1), liners [5.1 cm (2 inches) diameter × 5.1 cm deep] of chinese hibiscus and 0.5-L (1-pt) pots of bamboo palm, areca palm, fishtail palm, and macarthur palm were transplanted into 6.2-L plastic containers using a 5 pine bark : 4 sedge peat : 1 sand substrate. This substrate was amended with dolomitic limestone at 7.1 kg·m^{-3} (12 lb/yard^3) and Micromax (Scotts Co., Marysville, Ohio) at 890 g·m^{-3} (1.5 lb/yard^3). Osmocote Plus 15–9–12 [15N–3.9P–10K, 12 to 14 months at 21.1 °C (70 °F); Scotts Co.] was applied at a rate of 88 g (3.1 oz) per pot by top dressing, substrate incorporation, or by layering the fertilizer just below the bottom of the liner during transplanting. Ten replicate pots of each species and treatment were arranged in a completely randomized design within each species block. Plants were placed in a shadehouse providing 55% light exclusion (maximum photosynthetic photon flux = 855 µmol·m^{-2}·s^{-1}) in Fort Lauderdale, Fla. All plants received about 2 cm (0.75 inch) of water from daily overhead irrigation plus natural rainfall [about 152 cm (60 inches) per year].

Experiment 1 was established on 14 Feb. 2000 and individual plant species were harvested when they reached a marketable size for a 6.2-L container. The hibiscus were harvested after 16 weeks, bamboo palms after 58 weeks, areca palms and macarthur palms after 46 weeks, and fishtail palms after 56 weeks. At harvest time plant color was rated subjectively on a 0 to 5 scale, with 5 = darkest green color, 3 = light green color, and 1 =completely yellow color. Plant tops were cut off at the soil line and dried at 62.8 °C (145 °F) until constant weight was achieved. Any weeds growing in the pots were similarly harvested for each pot. Root balls were cut transversely into equal upper and lower halves with a saw and roots within the top and bottom halves of each root ball were rinsed free of substrate with water. Plant roots within each root ball half and all weed roots were dried separately to constant weight as was done for plant tops.

A second similar experiment (Expt. 2) was initiated on 27 Apr. 2001 using chinese hibiscus, shooting star, downy jasmine, plumbago, alexandra palm, and foxtail palm. Expt. 2 differed from Expt. 1 in that Nutricote Total 18–6–8 (18N–2.6P–6.7K, type 360; Florikan, Sarasota, Fla.) was used instead of Osmocote and a 0.5-cm-deep (0.25-inch) layer of substrate was used to separate the bottom of the liner root ball from the fertilizer layer. The application rates were the same for both products. The hibiscus and shooting stars were harvested after 21 weeks, downy jasmines after 26 weeks, plumbago after 27 weeks, alexandra palms after 34 weeks, and foxtail palms after 47 weeks.

Data were analyzed using analysis of variance (SAS PROC GLM, SAS Inst., Cary, N.C.) with mean separations within each species by the Waller-Duncan k ratio method (k = 100).

Results and discussion

Responses to fertilizer placement varied considerably among species in both experiments (Tables 1 and 2). In Expt. 1 shoot dry weight was significantly higher for hibiscus that received top-dressed or layered fertilizer than incorporated fertilizer (Table 1). However, areca palms had highest shoot dry weights with incorporated fertilizer and the least with top-dressed fertilizer. Shoot dry weights were not affected by fertilizer placement for bamboo, fishtail, and macarthur palms.

In Expt. 2 layering resulted in greater shoot dry weights than soil incorporation for chinese hibiscus, downy jasmines, alexandra palms, and foxtail palms, but top dressing produced similar dry weights for chinese hibiscus, downy jasmines, and foxtail palms as layering (Table 2). Shoot dry weight was not significantly affected by fertilizer placement for shooting star or plumbago. Surface and/or dibble applications of Osmocote resulted in better shoot growth than incorporation for other broadleaf evergreen shrubs such as golden privet (*Ligustrum* ×*vicaryi*), sweet viburnum (*Viburnum odoratissimum*), and 'Hinodegiri' azalea (*Rhododendron obtusum*) (Blessington et al., 1981; Cobb, 1985; Conover and Poole, 1985), whereas incorporated fertilizer produced superior top growth for 'Radicans' gardenia (*Gardenia jasminoides*) (Cobb, 1985).

None of the four palm species in Expt. 1 had significantly greater shoot dry weights for layered fertilized containers, whereas both palm species tested in Expt. 2 did. In a preliminary study (T.K. Broschat and H. Donselman, unpublished data), both bamboo and

Table 1. Effects of Osmocote Plus 15N–3.9K–10K (12 to14-month formulation) placement on shoot and root dry weights, root distribution, plant color, and weed growth in container-grown tropical ornamental plants (Expt. 1).

		Dry wt (g)[z]					
Species	Fertilization method	Shoot	Upper root	Lower root	Total root	Weeds	Color[y]
Chinese hibiscus	Top	66.1 a[x]	8.6 a	1.8 b	10.4a	0.0 a	5.0 a
	Incorporated	47.7 b	5.2 b	2.2 ab	7.4 b	0.0 a	5.0 a
	Layered	58.9 a	6.4 b	3.2 a	9.6 a	0.0 a	5.0 a
Bamboo palm	Top	98.6 a	15.3 ab	8.5 b	23.8 b	19.1a	4.6 a
	Incorporated	86.3 a	12.3 b	9.0 b	21.4 b	14.6 a	4.5 a
	Layered	111.4 a	20.7 a	15.2 a	35.9 a	8.0 a	4.0 b
Areca palm	Top	25.9 c	3.6 c	6.2 c	10.7 c	14.9 a	3.5 b
	Incorporated	86.9 a	11.9 a	30.2 a	42.0 a	2.6 b	4.7 a
	Layered	53.6 b	7.5 b	15.4 b	23.0 b	3.0 b	4.4 a
Fishtail palm	Top	128.2 a	19.2 a	43.7 a	62.9 a	4.9 a	3.9 a
	Incorporated	124.7 a	14.8 a	35.7 a	50.5 a	0.6 b	4.3 a
	Layered	157.9 a	20.0 a	47.1 a	67.2 a	1.0 b	4.1 a
Macarthur palm	Top	74.1 a	10.7 a	24.8 a	35.5 a	9.4 a	4.0 a
	Incorporated	40.2 a	6.3 a	12.6 a	18.9 a	6.1 a	4.1 a
	Layered	58.9 a	11.2 a	23.8 a	35.0 a	10.4 a	3.6 b

[z]1.0 g = 0.035 oz.
[y]Scale = 1 to 5, with 5 = darkest green, 3 = light green, and 1 = completely yellow.
[x]Mean separation within columns and species by the Waller-Duncan k ratio method, k = 100.

areca palms had significantly greater shoot dry weights when grown with layered Osmocote than with incorporated or top-dressed fertilizer. In Expt. 1, many of the palms of all four species that received layered Osmocote directly below the root ball of the liner showed evidence of stunting and salt injury during the first 6 weeks of growth and this may have resulted in lower final shoot and root dry weights for palms receiving layered fertilizer. For this reason, in Expt. 2 we used Nutricote instead of Osmocote and a 0.5-cm-deep layer of substrate separated the bottom of the liner root ball from the fertilizer layer. By using a controlled release fertilizer with a slower release rate under Florida conditions (T.K. Broschat and K.A. Klock, unpublished data) and a thin layer of substrate as a barrier between the liner roots and the fertilizer layer, no stunting or salt injury symptoms were observed on plants receiving layered fertilizer in Expt. 2.

Total root dry weight was significantly greater for chinese hibiscus grown with top dressed or layered fertilizer than with incorporated fertilizer (Tables 1 and 2). The heaviest root growth occurred in the upper half of the root ball for top dressed plants and in the lower half of the root ball for layered fertilizer. For bamboo palms the greatest total root dry weights occurred in plants receiving layered fertilizer (Table 1). However, for areca palms, the highest total root dry weights occurred in palms with incorporated fertilizer. Root distribution and total root dry weights were not affected by fertilizer placement in macarthur palms, alexandra palms, or fishtail palms (Tables 1 and 2). The differing root growth responses in bamboo and areca palms may be due to their different root growth patterns. We observed that areca palms tend to produce a root ball with uniform root distribution throughout the container, whereas bamboo palm roots tend to concentrate in the bottom of the container.

Among the dicot species (chinese hibiscus, downy jasmine, shooting star, and plumbago) in these experiments, only jasmines showed any differences in root response to fertilizer placement. In this species, layered fertilizer resulted in significantly greater root dry weights in the lower portion of the root ball than incorporated fertilizer (Table 2). Cobb (1985) found that dibbled fertilizer resulted in a better root system for golden privet than incorporation, but top dressed and incorporated fertilizer produced better rooting than dibbling for azalea (Rhododendron x 'Amy'). Although similar to our layering technique, dibbling concentrates all of the fertilizer directly below the root ball of the transplanted plant, and thus our results may not be comparable to previous studies using the dibble method.

Plant color was significantly darker in bamboo and macarthur palms receiving top dressed or incorporated fertilizer than those receiving layered fertilizer (Table 1). However, areca palms had darker color with incorporated or layered fertilizer than with top dressed fertilizer. There were no significant differences in plant color for any of the other species tested (Tables 1 and 2).

In shrubby plants that quickly formed a dense container cover such as plumbago and shooting star, few weeds were encountered (Table 1). However, weeds became a serious problem in palms, which provide little pot surface coverage. Fertilizer placement did not affect weed shoot dry weight in two of the six palm species, but in areca, fishtail, and alexandra palms, pots with top dressed fertilizer had significantly higher weed shoot dry weights than those with layered fertilizer (Tables 1 and 2). For areca and fishtail palms, weed shoot dry weights were also greater for top-dressed fertilizer than incorporated fertilizer.

Weed growth in the unfertilized upper half of pots receiving layered fertilizer was expected to be less than in fertilized container substrates. It is possible that in long term crops such as palms that some weeds would eventually grow roots down into the fertilized

Table 2. Effects of Nutricote Total 18N–2.6P–6.7K (type 360) placement on shoot and root dry weights, root distribution, plant color, and weed growth in container-grown tropical ornamental plants (Expt. 2).

		Dry wt (g)[z]					
Species	Fertilization method	Shoot	Upper root	Lower root	Total root	Weeds	Color[y]
Chinese hibiscus	Top	89.3 a[x]	9.4 a	4.1 b	13.5 a	3.8 a	5.0 a
	Incorporated	67.7 b	5.0 b	2.5 b	7.6 b	0.4 a	5.0 a
	Layered	93.0 a	5.5 b	7.1 a	12.7 a	0.0 a	5.0 a
Shooting star	Top	69.0 a	6.5 a	4.9 a	11.4 a	1.5 a	5.0 a
	Incorporated	64.1 a	5.1 a	3.4 a	8.5 a	0.9 a	5.0 a
	Layered	69.1 a	6.2 a	4.8 a	11.0 a	0.5 a	5.0 a
Downy jasmine	top	64.9 ab	4.7 a	5.4 ab	10.1 a	4.8 a	5.0 a
	Incorporated	43.0 b	3.2 a	4.0 b	7.3 a	9.5 a	5.0 a
	Layered	77.0 a	3.1 a	7.6 a	10.6 a	0.8 a	5.0 a
Plumbago	Top	63.2 a	3.7 a	2.0 a	5.7 a	1.1 a	5.0 a
	Incorporated	49.0 a	3.8 a	1.5 a	5.2 a	2.1 a	5.0 a
	Layered	60.6 a	3.7 a	2.1 a	5.8 a	0.9 a	5.0 a
Alexandra palm	Top	78.9 b	7.1 b	12.9 a	20.0 a	15.5 a	4.5 a
	Incorporated	78.3 b	9.7 ab	11.9 a	21.5 a	7.4 ab	4.5 a
	Layered	100.6 a	10.8 a	13.2 a	24.0 a	4.0 b	4.5 a
Foxtail palm	Top	115.9 a	14.5 a	30.3 a	44.7 a	39.1 ab	4.5 a
	Incorporated	86.5 b	15.3 a	24.6 a	40.0 a	43.8 a	4.5 a
	Layered	121.5 a	19.3 a	29.1 a	48.4 a	33.4 b	4.5 a

[z]1.0 g = 0.035 oz.
[y]Scale = 1 to 5, with 5 = darkest green, 3 = light green, and 1 = completely yellow.
[x]Mean separation within columns and species by the Waller-Duncan k ratio method, k = 100.

lower half of containers with layered fertilizer and then grow rapidly to a large size by the time these palms reached a marketable size. If weed biomass in these long term crops had been measured after only a few months of growth, their biomass may have been lower for layered fertilized pots relative to top dressed or incorporated fertilized pots for those palm species that showed no significant differences in weed growth in these experiments.

In conclusion, plant growth response to fertilizer placement varied considerably among species, but with the exception of areca palm, none of the species tested grew best with incorporated fertilizer. Layering of controlled-release fertilizer just below the liner root ball can reduce weed growth and improve plant growth in some species, but potential root injury is an important consideration if the roots are in direct contact with the fertilizer layer.

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Correcting Iron Deficiency in Calibrachoa Grown in a Container Medium at High pH

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SUMMARY. The objective was to evaluate and compare foliar spray and soil drench application methods of iron (Fe) for correcting Fe deficiency in hybrid calibrachoa (*Calibrachoa ×hybrida*) grown in a container medium at pH 6.9 to 7.4. Untreated plants showed severe chlorosis and necrosis, stunting, and lack of flowering. An organosilicone surfactant applied at 1.25 mL·L^{-1} (0.160 fl oz/gal) increased uptake of Fe from foliar applications of both ferrous sulfate ($FeSO_4$) and ferric ethylenediamine tetraacetic acid (Fe-EDTA). Foliar sprays at 60 mg·L^{-1} (ppm) Fe were more effective when Fe was applied as Fe-EDTA than $FeSO_4$. Increasing Fe concentration of foliar sprays up to 240 mg·L^{-1} Fe from Fe-EDTA or 368 mg·L^{-1} Fe (the highest concentrations tested) from ferric diethylenetriamine pentaacetic acid (Fe-DTPA) increased chlorophyll content compared with lower spray concentrations, but leaf necrosis at the highest concentrations may have been caused by phytotoxicity. Drenches with ferric ethylenediaminedi(o-hydroxyphenylacetic) acid (Fe-EDDHA) at 20 to 80 mg·L^{-1} Fe were highly effective at correcting Fe-deficiency symptoms, and had superior effects on plant growth compared with drenches of Fe-DTPA at 80 mg·L^{-1} Fe or foliar sprays. Efficacy of Fe-DTPA drenches increased as concentration increased from 20 to 80 mg·L^{-1} Fe. An Fe-EDDHA drench at 20 to 80 mg·L^{-1} Fe was a cost-effective option for correcting severe Fe deficiency at high medium pH.

Micronutrient deficiency at high medium pH is a common problem for container plant production (Nelson, 1994). Solubility of micronutrients, other than molybdenum, has been shown to decrease as pH increases in organic soils (Lucas and Davis, 1961) and soilless growing media (Peterson, 1981).

Iron is often the nutrient that becomes limiting first for plant growth at high pH in both calcareous field soils (Miller et al., 1984) and greenhouse media (Nelson, 1994). However, plant species differ in their ability at taking up Fe at the same medium pH. The term iron-inefficient species has been used to describe crops such as calibrachoa and petunia (*Petunia ×hybrida*) hybrids that are inefficient at taking up Fe into the plant tissue (Argo and Fisher, 2002; Marschner, 1995; Nelson, 1994). The most common problems with Fe deficiency occur when Fe-inefficient plants (with low ability to take up Fe) are grown at high medium pH (with low Fe solubility).

There are a number of strategies for correcting Fe deficiency in plant tissue caused by high medium pH. One approach is to lower medium pH, which increases the solubility of Fe (and other micronutrients) already in the medium and therefore will increase the uptake of Fe by plant roots (Argo and Fisher, 2002; Bailey, 1996). Another strategy is to apply additional Fe to the plant, either using soil drenches or foliar sprays, to reduce the effect of medium pH on Fe nutrition (Argo and Fisher, 2002; Nelson, 1998; Swietlik and Faust, 1984; Wallace et al., 1957).

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