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Nitrate, Phosphate, and Potassium Leaching from Container-grown Plants Fertilized by Several Methods

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***Abstract. Spathiphyllum* Schott. 'Mauna Loa Supreme' and areca palm (*Chrysalidocarpus lutescens* H. Wendl.) were grown for 6 months in 3.5-liter containers using a pine bark–sedge peat–sand container medium or a native sand soil. Plants were fertilized with equivalent amounts of a 21N–3P–12K fertilizer applied weekly as a liquid, monthly as a soluble granular, bimonthly as a lightly coated controlled-release, or every 6 months as a heavily coated controlled-release fertilizer. All leachates were collected and analyzed weekly for NO_3-N, PO_4-P, and K. Amounts of all three nutrients leached per week varied considerably in response to fertilizer reapplications or high rainfall. Nitrate leaching generally decreased over time, PO_4-P leaching increased, and K remained relatively constant. Shoot dry weights of spathiphyllum were equivalent for all fertilization methods, but areca palm shoot dry weights were highest with liquid fertilization and lowest with the soluble granular fertilizer. Nutrient leaching for all three ions was highest for the soluble granules and lowest for the two controlled-release formulations.**

Environmental contamination from NO_3-N and PO_4-P has become an important concern in many areas of the United States. Nitrate levels >10 ppm in drinking water are considered unsafe for humans (U.S. Environmental Protection Agency, 1982), and PO_4-P often is associated with algal blooms and eutrophication of lakes and ponds (Wetzel, 1975). Although PO_4-P is considered rather immobile within many soils, it is much more readily leached from container media composed of pine bark, spaghnum peat, vermiculite, or sand (Marconi and Nelson, 1984; Yeager and Barrett, 1984). Nitrate is readily leached from most mineral soils and container media (Handreck and Black, 1984). Although K is not usually considered an environmental pollutant, K leaching from soil may affect plant growth and quality.

Fertilizers often are applied to tropical foliage plants at high rates, yet little is known about the leaching of nutrients from containers into the environment. Yeager and Cashion (1993) showed NO_3-N concentrations in the leachate from several fertilizer sources at various times during the production cycle of temperate woody ornamental plants. Hershey and Paul (1982) measured N leaching losses in potted chrysanthemums [*Dendranthema grandiflorum* (Ramat.) Kitamura] fertilized with controlled-release and liquid fertilizers. Rathier and Frink (1989) determined total NO_3-N output from a container nursery fertilized with various controlled-release and soluble N fertilizers, and Cox (1993) performed a similar study using marigolds (*Tagetes erecta* L.). However, to our knowledge, there are no equivalent studies evaluating PO_4-P and K output.

Soluble granular fertilizers are known to be quickly solubilized in the soil, with many nutrients lost to leaching. High soluble salts injury also is a common occurrence on plants fertilized with soluble granular fertilizers. Frequent applications of liquid fertilizers often are used to provide less variable and safer nutrition for plants. Similarly, controlled-release fertilizers have been used to reduce soluble salts injury and nutrient loss from leaching. Although many studies (see Maynard and Lorenz, 1979) have compared growth and quality of ornamental plants fertilized with controlled-release, liquid, or soluble granular fertilizers, to our knowledge, no studies to date have used the same nutrient sources and ratios in their fertilizer treatments. Such comparisons are less valid due to N, P, and K source differences, as well as slightly different elemental ratios among the various fertilizer treatments. The purpose of our study was to determine the total amounts of NO_3-N, PO_4-P, and K leached from container-grown tropical foliage plants during a 6-month production period and to determine if fertilization method affects the amounts of these nutrients leached during that time.

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Materials and Methods

Areca palm liners from seed and *Spathiphyllum* 'Mauna Loa Supreme' from tissue culture were planted into 3.5-liter polypropylene containers using a 5 pine bark : 4 sedge peat : 1 sand medium (by volume) amended with 880 g Micromax (Grace-Sierra, Milpitas, Calif.), a complete micronutrient blend, and 4.9 kg dolomite/m^3 (the container medium). Pots containing one plant each were fertilized with a total of (in grams) 7.65 N–1.37 P–4.5 K per container every 6 months, or no fertilizer was added (control). Four fertilizer treatments using the same raw material [uncoated 21N–3P–12K prills derived from ammonium nitrate, ammonium phosphates, calcium phosphates, and potassium sulfate (Grace-Sierra)] were applied in the following manner: 1) liquid form (LF), 1.4 g prills dissolved in 50 ml water and applied weekly to the medium surface of each container; 2) soluble granular fertilizer (SGF), 6.1 g prills applied monthly to the medium surface of each pot; 3) lightly coated, controlled-release fertilizer (LCCRF), 13.4 g Osmocote 19N–3P–10K (3- to 4-month release at 20C) applied every 2 months to the surface of the medium; and 4) heavily coated, controlled-release fertilizer (HCCRF), 45.0 g of Osmocote 17N–3P–10K (12- to 14-month release at 20C) applied once to the surface of the medium. Each treatment was replicated 10 times.

Similar treatments also were applied to spathiphyllum potted into a Margate fine sand soil to determine if soil type affected leaching rate. This soil is typical for the Atlantic coastal plain in the southeastern United States where many ornamental plants are field-grown. Because it has little cation exchange capacity (3 meq/100 g), nutrients not absorbed by plants are leached readily into the groundwater below.

Our experiment was performed under typical subtropical production nursery conditions. The plants were grown in a shadehouse with a maximum PPF of 840 and 225 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for palms and spathiphyllum, respectively. All plants received ≈20 mm of water from overhead irrigation daily. The water used for irrigation contained 0.54 ppm NO_3-N, <0.5 ppm PO_4-P, 0.83 ppm K, and 41.5 ppm Ca. All leachates were collected from each container by setting each one on a 15-cm azalea pot inverted within a 4-liter polyethylene bucket. This system excluded virtually all nonpot irrigation and rain water from the leachate collection container. The accumulated leachates from each container were measured for volume weekly, and a sample was analyzed for NO_3-N using an NO_3-N electrode, PO_4-P using the ascorbic acid method, and K using atomic absorption spectrophotometry. Total milligrams of each nutrient ion leached per week was calculated from the total volume and the sample ion concentrations. At the end of the 6-month production cycle, shoot dry weight was determined for each plant. Data were analyzed using analysis of variance with mean separation by the Waller–Duncan k ratio method.

Results and Discussion

Nitrate. Nitrate leached per week from the container medium fertilized with SGF decreased rapidly from ≈350 mg for week 1 to ≈10 mg for week 5 (Fig. 1). Reapplication during week 5 resulted in a rapid increase followed by another decline 4 weeks later. Subsequent oscillations were reduced considerably in amplitude. Container medium fertilized weekly with LF showed generally increasing NO_3-N leaching through week 6, followed by smaller peaks about every 2 to 4 weeks. Medium fertilized with LCCRF leached from 50 to 100 mg NO_3-N per week, except during weeks 6, 13, 17, and 22 when somewhat more NO_3-N was leached, presumably in response to higher rainfall during those weeks (Fig. 1). HCCRF-fertilized medium also showed considerable weekly variation in NO_3-N leached, although leaching generally decreased over time. This trend toward reduced leaching over time for these controlled-release fertilizers may be due to the increased plant uptake by the larger plants coupled with a reduced release rate from these fertilizers. Hershey and Paul (1982) described a similar trend in potted chrysanthemums. Our data suggest that reducing soluble fertilizer concentrations during the first part of the growing cycle could significantly reduce NO_3-N leaching losses without reducing plant growth.

Nitrate leached from the sandy soil fertilized with SGF peaked every 4 weeks when it was reapplied, but quickly dropped to <50 mg per week between applications (Fig. 2). Nitrate leaching from LF was relatively constant, although maxima during the first 13 weeks were often twice as high as the minima. LCCRF-fertilized soil had low levels of NO_3-N leached during the first 6 weeks, but it eventually peaked at ≈300 mg during week 13. HCCRF-fertilized soil had peaks from 200 to 300 mg NO_3-N leached per week, but minima of ≈100 mg. After week 17, NO_3-N leaching gradually decreased to ≈0 mg by week 26. This decrease was probably due to less N being released from the HCCRF plus increased uptake by larger plants later in the production cycle.

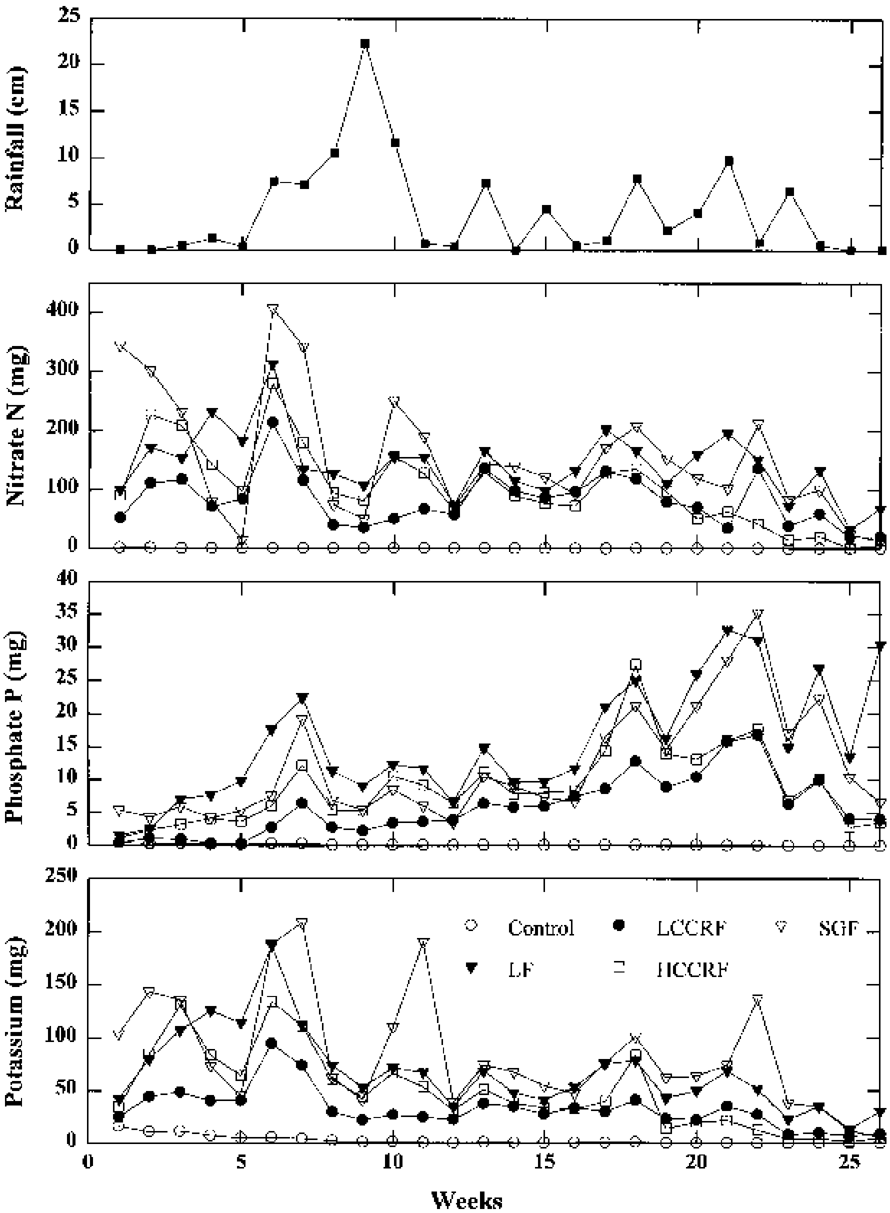

Fig. 1. Weekly rainfall and total NO_3-N, PO_4-P, and K leached per container per week from spathiphyllum grown in a pine bark–sedge peat–sand medium when fertilized by four methods. LF = liquid fertilizer; LCCRF = lightly coated, controlled-release fertilizer; HCCRF = heavily coated, controlled-release fertilizer; and SGF = soluble granular fertilizer.

Phosphate. Leached PO_4-P from the container medium generally increased over time for all fertilizer treatments, although leachate PO_4-P from LCCRF and HCCRF declined after week 22 (Fig. 1). Leachate PO_4-P was almost always higher for LF and SGF than for the two controlled-release formulations. Except for a peak around week 7, leachate PO_4-P levels remained quite low for the first 16 weeks for all fertilization methods on the sandy soil (Fig. 2). Leachate PO_4-P levels for all fertilization methods increased from week 16 to week 22 but decreased thereafter. Fixation within the soil might have caused these initially low PO_4-P leachate levels, with PO_4-P leaching at higher rates only after saturation of the soil's adsorption capacity.

Potassium. In the container medium, the amount of K leached per container fertilized with LF gradually increased to a maximum of ≈190 mg K at week 6, but from weeks 8 to 22, it remained relatively constant at ≈40 to 80 mg/week (Fig. 1). After week 22, K leached from all fertilizer treatments decreased to <25 mg/ week, presumably in response to increased plant uptake at that time. As with NO_3-N and PO_4-P, K leached from SGF-fertilized container media peaked every 4 weeks as it was reapplied. The height of these peaks decreased somewhat over time as plant size and uptake increased. The LCCRF-fertilized containers showed rather low (<50 mg K/week) but constant K leaching, except for a higher peak at weeks 6 and 7. Potassium leached from the HCCRF-fertilized containers at higher rates than LCCRF for the first 16 weeks but at lower rates thereafter. Similar responses were reported by Rathier and Frink (1989) and Cox (1993) for NO_3-N leaching from a single application vs. multiple applications of controlled-release fertilizers.

In the sandy soil, K leaching generally varied between 40 and 120 mg K/week for LCCRF-, HCCRF-, and LF-fertilized containers (Fig. 2). Containers fertilized with SGF, however, showed monthly peaks and valleys associated with its reapplication and depletion due to leaching. As in the container medium, K leaching declined for all treatments during the last 3 or 4 weeks.

Leaching data from this experiment generally indicated variable rates of NO_3-N, PO_4-P, and K leaching over time for most of the fertilization methods. Unusually high rainfall starting on week 6 resulted in larger amounts of all three ions being leached from these containers, but other factors also may have contributed to the week-to-week variation. Based on these data, it seems that leachate sampling at any one time may not be a good predictor of total nutrients leached during the production cycle.

Plant dry weight and total N, P, and K leached. After 6 months, dry weights of spathiphyllum grown in the container medium and fertilized by the four methods were equivalent, and all fertilizer treatments produced much larger plants than the nonfertilized controls (Table 1). For areca palms, however, plants fertilized with LF were larger than those fertilized with SGF (Table 1). The controlled-release fertilizers produced palms equal in size to those grown with LF but no better than those receiving SGF. Thus, in terms of plant growth response, there was relatively little difference among fertilization methods in the container medium.

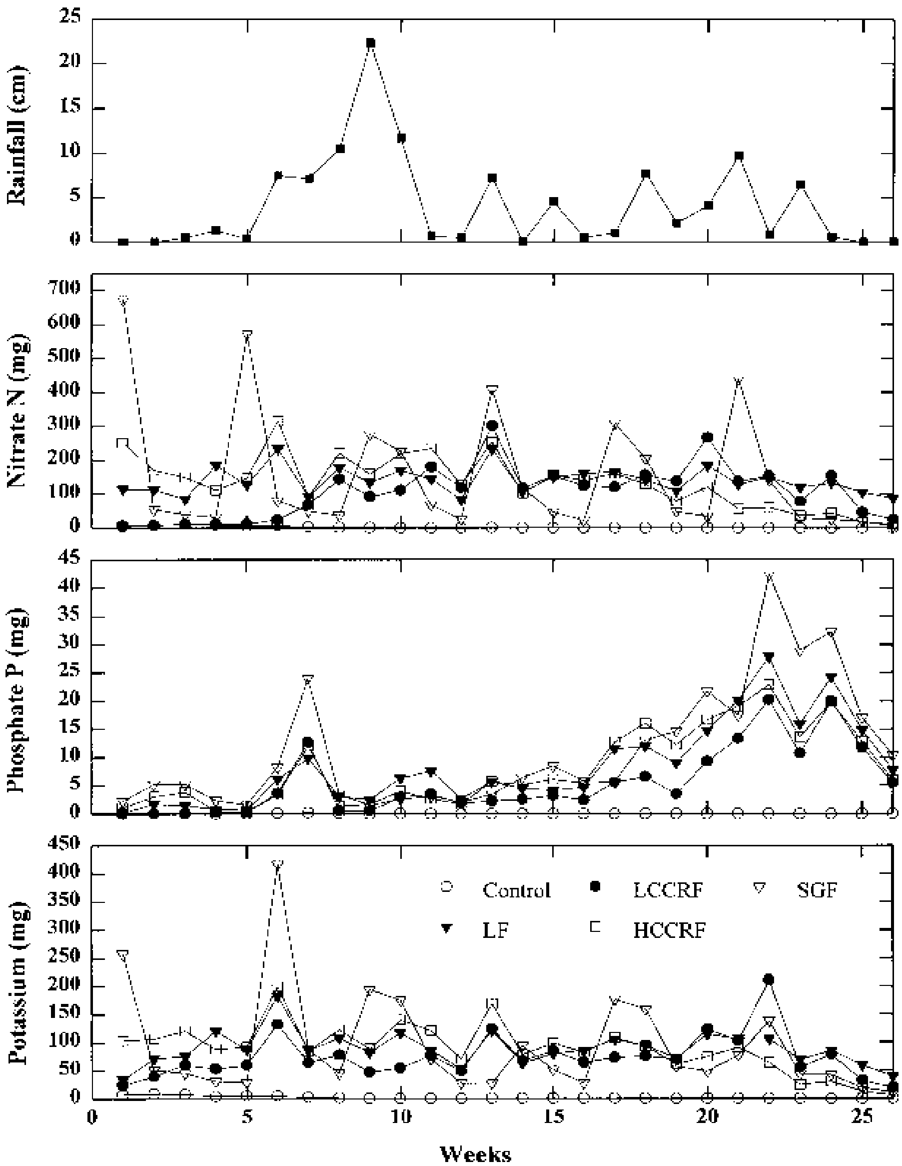

Fig. 2. Weekly rainfall and total NO_3-N, PO_4-P, and K leached per container per week from spathiphyllum grown in a Margate fine sand soil fertilized by four methods. LF = liquid fertilizer; LCCRF = lightly coated, controlled-release fertilizer; HCCRF = heavily coated, controlled-release fertilizer; and SGF = soluble granular fertilizer.

Table 1. Spathiphyllum and areca palm dry weights and total NO_3-N, PO_4-P, and K leached per spathiphyllum container over 6 months when grown in a pine bark–sedge peat–sand medium and fertilized by four methods.

	Dry wt (g)		Leachate/container (mg)		
Method[z]	Spathiphyllum	Areca palm	NO_3-N	PO_4-P	K
Control	0.8 b[y]	28.5 c	13 e	3 e	75 e
LCCRF	31.3 a	77.0 ab	2226 d	156 d	837 d
SGF	27.5 a	73.9 b	4160 a	309 b	2106 a
LF	29.7 a	92.9 a	3710 b	382 a	1747 b
HCCRF	32.6 a	75.0 ab	2655 c	237 c	1256 c

[z]LCCRF = lightly coated, controlled-release fertilizer; SGF = soluble granular fertilizer; LF = liquid fertilizer; and HCCRF = heavily coated, controlled-release fertilizer.
[y]Mean separation within columns by Waller–Duncan k ratio method at k = 100.

When spathiphyllums were grown in a sandy field soil with virtually no cation exchange, growth was superior for plants fertilized with either of the controlled-release fertilizers, although LF produced plants equivalent in size to those receiving LCCRF (Table 2). Plants receiving SGF had lower dry weights than those fertilized by any other method.

The total amount of NO_3-N leached from the container medium was significantly greater for spathiphyllum (Table 1) and areca palms (data not shown) fertilized with SGF. LF contributed the second most NO_3-N in the leachate for both species and the controlled-release fertilizers the least. For the sandy field soil, NO_3-N leached at equivalent rates for all fertilization methods. On average, ≈27% to 54% of the applied N was lost from the containers during the 6-month production for the sandy soil. The percentage of N lost to leaching in the container medium ranged from 28% for LCCRF to 52% for SGF.

Relatively little PO_4-P leached from any fertilizer treatment, and total leached PO_4-P levels were similar for the medium and the sandy soil. Because PO_4-P is not retained in either soil type, plant use or precipitation must be responsible for most PO_4-P losses. Between 11% and 28% of the applied PO_4-P was lost due to leaching from the containers. Leachate PO_4-P amounts, however, differed among the fertilizer treatments. For spathiphyllum on sandy soil, SGF resulted in the highest amounts of PO_4-P in the leachate. Among fertilizer treatments, LCCRF resulted in the least PO_4-P leaching for both species and both soil types.

For both soil types and species, the highest amounts of K leached from containers fertilized with SGF (Tables 1 and 2). LF resulted in significantly less K leaching than SGF, and LCCRF resulted in the least K leaching. The percentage of applied K lost to leaching ranged from 19% for LCCRF in the container medium with spathiphyllums to 59% for SGF on the sandy field soil.

Although the levels of NO_3-N and PO_4-P leached from the two soil types seem to be roughly equivalent, K generally leached from the sandy soil at a higher rate than from the container medium. Potassium deficiency is a serious problem on this sandy soil due to rapid leaching of this ion (Broschat, 1990); such leaching occurred in the spathiphyllums as well. Plants receiving no fertilizer in this soil were severely stunted due to N deficiency, but all those receiving any fertilizer exhibited moderately severe K deficiency symptoms. None of the plants of either species growing in the medium showed any visible K deficiency symptoms, suggesting that K retention by the cation exchange capacity of the container medium is important in the K nutrition of spathiphylum.

Conclusions

This study showed that NO_3-N, PO_4-P, and K leaching losses from a typical foliage plant nursery are substantial. Assuming a density of 80,000 pots/ha, using SGF in the container medium would result in annual losses of (in kg•ha^{-1}) 666 NO_3-N, 49.4 PO_4-P, and 337 K. Using controlled-release fertilizers can significantly reduce these leaching losses. These data support the findings of Yeager and Cashion (1993), which indicated that leachate NO_3-N concentrations vary considerably during the production period, and sampling at any given time will probably yield misleading results in terms of overall NO_3-N or PO_4-P input into the environment. Furthermore, leachate volume also must be considered to determine the total amount of NO_3-N or other ion input into the environment.

Table 2. Spathiphyllum dry weight and total NO_3-N, PO_4-P, and K leached per container over 6 months when grown in a Margate fine sand soil and fertilized by four methods.

	Dry wt	Leached/container (mg)		
Method	(g)	NO_3-N	PO_4-P	K
Control	5.8 d[z]	57 b	1 d	49 d
LCCRF[y]	24.4 ab	3437 a	148 c	1916 c
SGF	18.2 c	3538 a	296 a	2662 a
LF	21.9 b	3637 a	224 b	2309 b
HCCRF	26.5 a	3513 a	218 b	2317 b

[z]Mean separation within columns by Waller–Duncan k ratio method at k = 100.

[y]LCCRF = lightly coated, controlled-release fertilizer; SGF = soluble granular fertilizer; LF = liquid fertilizer; and HCCRF = heavily coated, controlled-release fertilizer.

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