Effectiveness of Pasteurized Poultry Litter as a Partial Substitute for Controlled-release Fertilizers in the Production of Container-grown Ornamental Plants

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SUMMARY. In two experiments, pasteurized poultry litter (PPL) was evaluated as a potential substitute for controlled-release fertilizers in the production of container-grown downy jasmine (*Jasminum multiflorum*), chinese hibiscus (*Hibiscus rosa-sinensis*), and areca palm (*Dyopsis lutescens*). Downy jasmine and chinese hibiscus generally grew better when provided with PPL as a micronutrient source than with no micronutrients or with an inorganic micronutrient blend (MN). However, areca palm grew poorly with PPL as a fertilizer supplement compared with MN-fertilized areca palm. PPL provided high levels of ammonium nitrogen, phosphorus, and potassium during the first few weeks, but soil solution levels of these elements dropped off rapidly in subsequent weeks. The large amount of phosphorus leached from the containers fertilized with PPL is an environmental concern.

Container production of ornamental plants requires large amounts of nitrogen (N) and other nutrients due to N-binding by pine bark and related substrate components, as well as extensive leaching that typically occurs in well-drained substrates (Ogden et al., 1987). Controlled-release fertilizers (CRFs) have been very effective in supplying plant nutrient needs and minimizing the loss of environmentally problematic ions such as nitrate nitrogen (NO₃-N) and phosphate phosphorus (PO₄-P) (Maynard and Lorenz, 1979; U.S. Environmental Protection Agency, 1976). However, one of the biggest drawbacks to CRFs is their high cost.

Composted turkey litter has shown promise as a slow-release and economical source of nutrients for container production of ornamental plants (Gils et al., 2005; Kraus and Warren, 2000; Tyler et al., 1993a). Tyler et al. (1993b) showed that composted turkey litter provided all

of the nutrients required for the production of 'Skogholm' cotoneaster (*Cotoneaster dammeri* 'Skogholm') and 'Red Magic' daylily (*Hemerocallis* 'Red Magic') except for potassium (K) and micronutrients. Kraus and Warren (2000) demonstrated that composted turkey litter was capable of producing 'Skogholm' cotoneaster and 'Goldsturn' rudbeckia (*Rudbeckia fulgida* 'Goldsturn') comparable in size to Osmocote (Scotts Co., Marysville, OH)-fertilized plants. The purpose of this study was to determine if pasteurized poultry litter (PPL) could be used to reduce the amount of a CRF required for the production of container-grown tropical ornamental plants.

Materials and methods

EXPT. 1. Liners of areca palm and downy jasmine were transplanted into #2 (6.2-L) plastic containers filled with a 5 pine bark:4 Canadian peat:1 sand (by volume) potting substrate

on 2 June 2005. This substrate was amended with 12 lb/yard³ of dolomitic limestone. Fertilizer treatments were incorporated into the substrate before planting according to the following treatments: 1) NMR [Nutricote 20-7-10 type 270 (20N-3.1P-8.3K; Florikan, Sarasota, FL) incorporated at the medium label rate of 12 lb/yard³]; 2) NMR + PPL [Nutricote at the medium rate plus 31.5 lb/yard³ of PPL (4N-0.9P-2.5K; Perdue AgriRecycle, Seaford, DE), this combination of the medium rate of Nutricote plus PPL provides the same amount of N as the high label rate of Nutricote]; 3) NMR + MN [Nutricote incorporated at the medium label rate plus 3 lb/yard³ of a micronutrient blend (Leonard's Ornamental Mix; Harrell's, Lakeland, FL)]; and 4) NHR (Nutricote incorporated at the high label rate of 19 lb/yard³). The granular form of PPL used in this experiment had been pasteurized, but not composted. It contained 4% N [0.4% ammonium nitrogen (NH₄-N)], 0.9% P, 2.5% K, 3% calcium (Ca), 0.5% magnesium (Mg), 0.8% sulfur (S), 0.13% iron (Fe), 0.07% manganese (Mn), 0.07% zinc (Zn), and 0.07% copper (Cu), with a pH of 6.5. The inorganic MN used contains 3.3% K, 7.8% Mg, 7.5% Fe, 2.0% Mn, 0.7% Zn, and 0.3% Cu.

Ten replicate containers of each species were arranged in a completely randomized design in full sun [maximum photosynthetic photon flux = 2175 μmol·m⁻²·s⁻¹] at a nursery in Davie, FL. Plants received 0.5 inches of water daily from overhead irrigation plus natural rainfall of 43 inches. The leaching fraction averaged between 0.20 and 0.30. Pour-through extractions (Wright, 1986) were performed monthly on six of the areca palm containers. Extracts were analyzed for NH₄-N, NO₃-N, P, K, Mg, Fe, Mn, and Zn, with NH₄-N and NO₃-N determined by selective ion electrodes (Greenberg et al., 1992).

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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
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
0.5933	lb/yard ³	kg·m ⁻³	1.6856
28.3495	oz	g	0.0353
28,350	oz	mg	3.5274 × 10 ⁻⁵
1	ppm	mg·kg ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

and the remaining elements by inductively coupled plasma emission spectroscopy (Soltanpour et al., 1996).

After 6 months, plants were rated for N and Mn deficiency severities on a 1 to 5 scale (1 = severe deficiency symptoms, 5 = deficiency symptom-free). N deficiency symptoms appeared on downy jasmine as a uniform light-green color (Broschat, 2008; Dickey, 1977), whereas on areca palm, N deficiency was manifested as yellow to orange petioles and rachi and light-green leaflets (Broschat, 2005). Mn deficiency appeared on new growth of downy jasmine as tiny puckered leaves with varying degrees of chlorosis and marginal necrosis. Shoot tip dieback occurred in severely deficient plants (Broschat, 2008). On areca palm, Mn deficiency appeared as chlorotic new leaves with longitudinal necrotic streaking (Broschat, 2005). Samples consisting of the youngest fully expanded leaf blades on each shoot were collected from all plants for nutrient analysis. Dried leaf samples were digested using a sulfuric acid-hydrogen peroxide method (Hach et al., 1987) with total N determined by ammonia electrode and P, K, Mg, Fe, Mn, and Zn by inductively coupled plasma emission spectroscopy. Shoots of all plants were then cut off at soil level and dried at 60 °C for 1 week for dry weight determinations. Total plant nutrient content was calculated as the percentage of composition of the element multiplied by plant dry weight. All data were analyzed using analysis of variance, with mean separation by the Waller-Duncan k-ratio method. Relationships among variables were determined using Pearson correlation coefficients (SAS, version 9.1; SAS Institute, Cary, NC).

EXPT. 2. A second experiment was initiated on 6 June 2006. It differed from the first experiment in that an additional treatment consisting of Nutricote 20-7-10 incorporated at the high rate of 19 lb/yard³ plus the micronutrient blend at 3 lb/yard³ (NHR + MN) was added. Also, another dicot species, chinese hibiscus, was included and no pour-through soil extractions were performed at week 26. Natural rainfall during this experiment was about 46 inches. All other procedures were identical to those used in Expt. 1.

Results

EXPT. 1. Within 1 month after initiating this experiment, we observed what appeared to be severe Mn deficiency symptoms on all of the downy jasmine except those receiving PPL or MN. This species had been included in the experiment because it is a good indicator of N deficiency. However, because Mn deficiency on most treatments essentially halted all vegetative growth, it was impossible to obtain a good indication of N response in this species. A few areca palm also showed some signs of Mn deficiency, therefore both species were rated visually for N and Mn deficiency symptom severity.

Downy jasmine grown with NMR and NHR had the highest N ratings (darkest color), while those receiving NMR + PPL had the lowest N ratings (Table 1). Conversely, downy jasmine grown with NMR + PPL or NMR + MN had the highest Mn ratings (least deficiency symptoms). Dry weights were positively correlated with Mn ratings ($r = 0.72$, $P < 0.0001$) and negatively with N ratings ($r = -0.55$, $P = 0.0006$), with NMR + PPL producing the largest plants and NMR and NHR the smallest. Foliar N, P, K, and Fe concentrations were significantly lower for downy jasmine grown with NMR + PPL or NMR + MN and foliar Mg concentrations were lower for NHR than all other treatments (Table 2). While N concentration was highest for NMR and NHR, total plant N content was higher for NMR + PPL and NHR than for NMR-treated plants. Total P content was greater for NMR + PPL than for NMR or NHR. Leaf Mn concentrations were

higher for NMR + MN and NMR + PPL than for NMR or NHR.

With areca palm, where Mn deficiency was less serious, plant dry weights were positively correlated with N ratings ($r = 0.43$, $P = 0.006$) and Mn ratings ($r = 0.46$, $P = 0.003$). There were no significant differences in N or Mn deficiency ratings for areca palm, but NMR + MN and NMR produced heavier plants than NHR (Table 1). Foliar N, P, and K concentrations were significantly higher for areca palm grown with NHR than with other fertilizer treatments (Table 2). However, NMR + PPL- and NMR + MN-fertilized areca palm had higher foliar Mn concentrations than those grown without a micronutrient source. Leaf Zn concentrations for areca palm were greater for NMR- and NMR + PPL-fertilized than for NMR + MN- or NHR-fertilized areca palm. Fertilizer treatment did not significantly affect total N or P content of areca palm.

Initial substrate pH was significantly higher for NMR + PPL than for other treatments (Table 3), while the percentage of porosity of the substrate was significantly lower ($P < 0.0001$) for this treatment than for other treatments (data not shown). Substrate solution nutrient concentrations differed significantly among treatments for all elements at week 1, but the number of significant differences decreased slightly over the 26-week sampling period. At week 1, NH₄-N concentrations were highest for NMR + PPL, but by week 11 and thereafter, NHR had higher levels of NH₄-N in the substrate solution than NMR + PPL, indicating that the addition of PPL to the medium rate of Nutricote did not provide N at

Table 1. Nitrogen (N) and manganese (Mn) deficiency ratings and dry weights of downy jasmine and areca palm grown with Nutricote 20-7-10 (20N-3.1P-8.3K; Florikan, Sarasota, FL) at the medium rate (NMR), NMR + pasteurized poultry litter (PPL), NMR + inorganic micronutrient blend (MN), or Nutricote at the high rate (NHR) in Expt. 1 (n = 10).

Treatment	Downy jasmine			Areca palm		
	N rating (1-5 scale) ^z	Mn rating (1-5 scale) ^z	Dry wt (g) ^y	N rating (1-5 scale)	Mn rating (1-5 scale)	Dry wt (g)
NMR	4.88 a ^x	1.38 c	12.4 c	3.2	4.9	57.6 a
NMR+PPL	3.59 c	4.75 a	108.6 a	2.8	4.9	46.7 ab
NMR+MN	4.25 b	4.10 a	52.6 b	3.4	5.0	61.4 a
NHR	4.44 ab	2.33 b	31.3 bc	2.9	4.7	34.5 b

^z1 = severe deficiency symptoms, 5 = no deficiency symptoms.

^y1 g = 0.0353 oz.

^xMean separation within columns by the Waller-Duncan k-ratio method at $P = 0.05$.

Table 2. Leaf concentrations of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) for downy jasmine and areca palm grown with Nutricote 20–7–10 (20N–3.1P–8.3K; Florikan, Sarasota, FL) at the medium rate (NMR), NMR + pasteurized poultry litter (PPL), NMR + inorganic micronutrient blend (MN), or Nutricote at the high rate (NHR) in Expt. 1 (n = 10).

Species	Treatment	N (%)	P (%)	K (%)	Mg (%)	Fe (ppm) ^z	Mn (ppm)	Zn (ppm)	Total N (g) ^y	Total P (mg) ^x
Downy jasmine	NMR	3.03a ^w	0.23 a	1.15 a	0.34 a	189.7 a	117.6 c	31.1 b	0.39 b	28 c
	NMR+PPL	1.12b	0.10 b	0.27 b	0.34 a	113.9 b	273.9 b	35.1 a	1.37 a	112 a
	NMR+MN	1.80b	0.14 b	0.47 b	0.28 a	115.9 b	412.5 a	26.5 c	0.89 ab	75 ab
	NHR	2.92a	0.23 a	1.03 a	0.19 b	141.5 ab	52.5 d	24.3 c	0.96 a	68 bc
Areca palm	NMR	1.80 b	0.18 b	1.24 b	0.18	62.2	42.7 b	25.1 a	1.04	101
	NMR+PPL	1.87 b	0.16 bc	1.13 b	0.17	59.7	120.9 a	29.9 a	0.84	73
	NMR+MN	1.63 b	0.15 c	0.93 c	0.15	51.1	97.9 a	19.5 b	1.02	89
	NHR	2.24 a	0.23 a	1.43 a	0.16	67.0	40.8 b	18.8 b	0.78	81

^z1 ppm = 1 mg·kg⁻¹.

^yTotal N and P are the products of concentration times plant dry weight; 1 g = 0.0353 oz.

^x1 mg = 3.5274 × 10⁻⁵ oz.

^wMean separation within columns for each species by the Waller–Duncan k-ratio method at *P* = 0.05.

Table 3. Substrate solution pH and ammonium-nitrogen (NH₄-N), nitrate-N (NO₃-N), phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) concentrations from pour-through extracts of areca palm containers fertilized with Nutricote 20–7–10 (20 N–3.1P–8.3K; Florikan, Sarasota, FL) at the medium rate (NMR), NMR + pasteurized poultry litter (PPL), NMR + inorganic micronutrient blend (MN), or Nutricote at the high rate (NHR) in Expt. 1 (n = 6).

Week	Treatment	pH	NH ₄ -N (ppm) ^z	NO ₃ -N (ppm)	P (ppm)	K (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
1	NMR	5.9 b ^y	23.9 b	14.0 b	4.89 b	10.4 b	2.17 b	1.00 a	0.05 b	0.04 b
	NMR+PPL	6.6 a	35.4 a	0.7 d	43.74 a	59.5 a	2.44 b	1.07 a	0.12 b	0.19 a
	NMR+MN	5.7 c	11.5 c	8.6 c	3.62 b	19.5 b	9.9 a	0.67 b	0.66 a	0.19 a
	NHR	5.7 c	15.9 c	17.0 a	4.61 b	10.5 b	1.96 b	0.59 b	0.05 b	0.03 b
6	NMR		45.9	65.0 b	3.66 b	29.7 c	3.82 c	0.12 b	0.07 b	0.02 b
	NMR+PPL		39	93.7 ab	12.64 a	55.7 a	12.3 a	0.08 b	0.15 b	0.05 b
	NMR+MN		40.3	68.7 b	3.62 b	32.2 c	7.26 b	0.17 a	0.49 a	0.10 a
	NHR		50.6	104.7 a	4.50 b	44.0 b	4.79 bc	0.08 b	0.09 b	0.03 b
11	NMR		14.6 a	25.1	3.17	19.2 ab	1.69 c	0.11 b	0.03 b	0.03
	NMR+PPL		4.9 b	21.3	3.25	14.3 b	3.65 ab	0.08 b	0.06 b	0.03
	NMR+MN		9.5 ab	24	2.33	18.5 ab	3.93 a	0.17 a	0.24 a	0.06
	NHR		18.1 a	37.6	3.73	27.9 a	1.95 bc	0.11 b	0.05 b	0.03
16	NMR		3.2 b	16.3	3.31	9.5 b	2.43	0.09 b	0.04 b	0.04
	NMR+PPL		0.2 c	19.6	4.95	11.0 ab	6.11	0.06 c	0.10 b	0.05
	NMR+MN		2.9 b	19	3.69	11.8 ab	4.84	0.15 a	0.34 a	0.08
	NHR		7.1 a	27.5	4.94	17.4 a	2.82	0.09 b	0.07 b	0.04
21	NMR		0.6 b	6.7 b	1.72 c	3.0 b	0.79 c	0.09 ab	0.02 b	0.03 b
	NMR+PPL		0.6 b	10.2 b	3.10 ab	6.1 b	2.16 a	0.07 b	0.07 ab	0.04 ab
	NMR+MN		1.0 b	9.5 b	2.46 bc	5.0 b	1.61 ab	0.13 a	0.12 a	0.07 a
	NHR		3.9 a	17.7 a	4.03 a	10.5 a	1.15 bc	0.05 b	0.03 b	0.04 ab
26	NMR		7.5 b	40.7 b	4.06 c	14.1 b	4.56 b	0.08 b	0.06 b	0.05 b
	NMR+PPL		6.2 b	54.2 ab	17.28 a	35.8 a	10.25 a	0.09 b	0.38 b	0.16 ab
	NMR+MN		10.7 b	50.5 ab	4.39 c	22.8 ab	10.51 a	0.23 a	0.90 a	0.26 a
	NHR		26.9 a	93.0 a	10.86 b	39.1 a	5.00 b	0.11 b	0.10 b	0.09 b

^z1 ppm = 1 mg·kg⁻¹.

^yMean separation within columns for each week by the Waller–Duncan k-ratio method at *P* = 0.05.

levels equivalent to that of the high rate of Nutricote after the first few weeks.

Substrate NO₃-N concentrations were lowest for NMR + PPL at week 1, but those for NHR were equal to or higher than those for any other treatment throughout the experiment (Table 3). Solution P

concentrations were very high for NMR + PPL at week 1 and remained significantly higher than other treatments through week 6. For reasons unknown, P concentrations for NMR + PPL-treated soil increased significantly between weeks 21 and 26.

Substrate K levels were also highest for NMR + PPL during the first 6

weeks, but by week 11 had dropped back to levels similar to those for other treatments (Table 3). At weeks 16 and thereafter, NHR-treated soil had the soil K concentrations equal to or greater than other treatments. Mg concentrations in the substrate started out low in NMR + PPL, but increased over time and were generally among

the highest Mg concentrations after week 6. Substrate Fe concentrations were initially highest for NMR and NMR + PPL, but at week 6 and thereafter, NMR + MN generally had the highest Fe concentrations. Substrate Mn levels were significantly higher for NMR + MN throughout the experiment, while NMR + PPL and NMR + MN provided equivalent amounts of Zn at weeks 1, 21, and 26.

EXPT. 2. As in the first experiment, Mn deficiency symptoms quickly appeared on downy jasmine, and symptoms believed to be caused by Mn or Zn deficiency were also observed on chinese hibiscus. Areca palm showed signs of minor Fe deficiency [chlorotic new leaves, Broschat (2005)], but appeared to be unaffected by Mn deficiency in this experiment. As a result, these species were visually rated for N and either Mn or Fe deficiency severities.

As in Expt. 1, downy jasmine grown with NMR + PPL had significantly lower N ratings (lighter color) than plants grown with other treatments (Table 4). Similarly, NMR + PPL-treated downy jasmine had the highest Mn ratings (least amount of deficiency) and dry weights of any treatments. Treatments with the highest N ratings tended to have the lowest Mn ratings ($r = -0.79$, $P < 0.0001$) and dry weights ($r = -0.73$, $P < 0.0001$). Leaf N concentrations were significantly lower for treatments receiving NMR + PPL, but total N and P contents were higher than for other treatments (Table 5). There were no significant differences among leaf concentrations of P, K, Mg, Fe, Mn, or Zn in Expt. 2 downy jasmine. Thus, downy jasmine grew larger and accumulated more N with NMR + PPL than with other treatments.

Chinese hibiscus also had the lowest N rating (lightest color) and heaviest dry weights when grown with NMR + PPL, while plants grown with NHR had the highest N ratings, but lowest Mn ratings and dry weights (Table 4). As with downy jasmine, N ratings were negatively correlated with Mn ratings ($r = -0.41$, $P = 0.004$) and dry weights ($r = -0.65$, $P < 0.0001$), while Mn ratings and dry weights were positively correlated ($r = 0.61$, $P < 0.0001$). Leaf N and P concentrations were higher for plants grown with NHR than with NMR + PPL, but

Table 4. Final nitrogen (N), iron (Fe), and manganese (Mn) deficiency ratings and plant dry weights of downy jasmine, chinese hibiscus, and areca palm grown in containers fertilized with Nutricote 20-7-10 (20N-3.1P-8.3K; Florikan, Sarasota, FL) at the medium rate (NMR), NMR + pasteurized poultry litter (PPL), NMR + inorganic micronutrient blend (MN), Nutricote at the high rate (NHR), or NHR+MN in Expt. 2 ($n = 10$).

Species	Treatment	N rating (1-5 scale) ^z	Fe rating (1-5 scale) ^z	Mn rating (1-5 scale) ^z	Dry w (g) ^y
Downy jasmine	NMR	4.78 ab ^x		2.33 c	10.64 c
	NMR+PPL	3.83 c		4.72 a	96.32 a
	NMR+MN	4.65 b		3.41 b	32.21 b
	NHR	5.00 a		1.60 d	16.37 bc
	NHR+MN	5.00 a		2.67 c	29.83 b
Chinese hibiscus	NMR	4.78 b		4.35 b	23.57 c
	NMR+PPL	4.14 c		4.64 ab	100.06 a
	NMR+MN	4.59 b		4.98 a	74.82 b
	NHR	5.00 a		3.15 c	19.56 c
	NHR+MN	4.71 b		4.99 a	89.15 ab
Areca palm	NMR	5.00	4.06 ab		36.34 ab
	NMR+PPL	5.00	4.12 ab		22.42 c
	NMR+MN	5.00	4.56 a		42.63 ab
	NHR	5.00	3.73 b		34.26 b
	NHR+MN	5.00	4.59 a		45.68 a

^x1 = severe deficiency symptoms, 5 = no deficiency symptoms.

^y1 g = 0.0353 oz.

^zMean separation within columns by the Waller-Duncan k-ratio method at $P = 0.05$.

total N and P contents were higher for NMR + PPL than for NHR (Table 5). Leaf concentrations of other elements did not differ significantly among treatments.

For areca palm, there were no differences in N ratings among treatments (Table 4). However, ratings for Fe deficiency were significantly lower for areca palm grown with NHR than with NMR + MN or NHR + MN. Areca palm dry weights were positively correlated with Fe ratings ($r = 0.29$, $P = 0.04$). Plant dry weights were lowest for areca palm receiving NMR + PPL. There were no significant differences among treatments for leaf concentrations of any element for areca palm (Table 5). However, total N and P contents were lower for NMR + PPL than for the other treatments.

As in Expt. 1, initial substrate pH was significantly higher for NMR + PPL than for other treatments (Table 6). N concentrations in the substrate solutions were highest for $\text{NH}_4\text{-N}$ and lowest for $\text{NO}_3\text{-N}$ at week 1 for NMR + PPL. However, for weeks 6 through 11, substrate $\text{NO}_3\text{-N}$ levels were not significantly different. Substrate $\text{NO}_3\text{-N}$ concentrations also tended to be higher for containers with NHR, with or without MN, after week 16. Soil solution P concentrations were significantly higher

for NMR + PPL than any other treatment from weeks 1 through 6, and remained at levels equivalent to other treatment through week 22. Substrate K concentrations were also high for NMR + PPL-treated soils at week 1, but by week 6, K concentrations in these containers were equivalent to those in most other treatments. Substrate Mg concentrations were highest at week 1 for NMR + MN and NHR + MN. At weeks 16 and 22, NMR + MN and NMR + PPL generally had the highest substrate Mg levels. Magnesium levels increased from week 1 to week 6 and then decreased for all treatments in subsequent weeks, possibly due to the dissolution of the dolomite in the substrate.

Substrate solution Fe concentrations were significantly higher for NMR + PPL at week 1 than for other treatments, but these levels dropped off rapidly after the first week (Table 6). Substrate Fe levels were very low for all treatments at week 6 and thereafter. Manganese concentrations in the soil solutions at week 1 were highest for NMR + MN and NHR + MN. Manganese levels were very low for all treatments after week 6. Substrate Zn concentrations at week 1 were highest for NHR + PPL, but Zn levels were very low for all treatments

Table 5. Leaf nutrient concentrations of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) for downy jasmine, chinese hibiscus, and areca palm grown in containers fertilized with Nutricote 20-7-10 (20N-3.1P-8.3K; Florikan, Sarasota, FL) at the medium rate (NMR), NMR + pasteurized poultry litter (PPL), NMR (MN), Nutricote at the high rate (NHR), or NHR+MN in Expt. 2 (n = 10).

Species	Treatment	N (%)	P (%)	K (%)	Mg (%)	Fe (ppm) ^z	Mn (ppm)	Zn (ppm)	Total N (g) ^y	Total P (g)
Downy jasmine	NMR	2.44 b ^x	0.19	1.01	0.69	205.04	163.2	31.02	0.26 d	0.02 c
	NMR+PPL	1.25 d	0.12	1.63	0.57	237.20	246.6	33.81	1.20 a	0.11 a
	NMR+MN	2.09 c	0.18	1.23	0.62	227.14	168.7	35.08	0.67 bc	0.06 b
	NHR	3.20 a	0.24	1.16	0.65	211.25	238.4	31.59	0.52 cd	0.04 bc
	NHR+MN	3.24 a	0.21	1.58	0.56	231.56	273.8	34.84	0.97 ab	0.06 b
Chinese hibiscus	NMR	2.47 b	0.29 b	1.49	0.43	52.90	47.57	26.31	0.58 b	0.07 c
	NMR+PPL	1.53 c	0.21 b	1.87	0.47	52.70	41.96	27.39	1.52 a	0.21 a
	NMR+MN	1.74 bc	0.19 b	1.83	0.46	53.17	48.69	30.52	1.30 a	0.15 b
	NHR	4.11 a	0.55 a	1.37	0.43	54.59	69.81	27.79	0.84 b	0.12 bc
	NHR+MN	1.78 bc	0.29 b	2.42	0.46	54.95	51.36	31.64	1.55 a	0.20 a
Areca palm	NMR	1.91	0.16	1.08	0.30	82.62	29.50	24.66	0.68 ab	0.06 a
	NMR+PPL	1.99	0.16	1.18	0.30	73.55	36.14	20.72	0.45 c	0.04 b
	NMR+MN	1.67	0.16	1.27	0.30	86.42	38.84	24.47	0.71 ab	0.07 a
	NHR	1.85	0.17	1.09	0.30	98.26	37.54	22.00	0.62 bc	0.06 a
	NHR+MN	1.92	0.16	1.15	0.26	93.54	44.11	23.07	0.88 a	0.07 a

^z1 ppm = 1 mg·kg⁻¹.

^y1 g = 0.0353 oz.

^xMean separation within columns for each species by the Waller-Duncan k-ratio method at *P* = 0.05.

Table 6. Substrate solution pH and ammonium-nitrogen (NH₄-N), nitrate-N (NO₃-N), phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) concentrations from pour-through extracts of areca palm containers fertilized with Nutricote 20-7-10 (20 N-3.1P-8.3K; Florikan, Sarasota, FL) at the medium rate (NMR), NMR + pasteurized poultry litter (PPL), NMR + inorganic micronutrient blend (MN), or Nutricote at the high rate (NHR) in Expt. 2 (n = 6).

Week	Treatment	pH	NH ₄ -N (ppm) ^z	NO ₃ -N (ppm)	P (ppm)	K (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
1	NMR	5.9 d ^y	4.73 b	11.00 b	1.57 b	25.49 b	8.0 b	0.20 b	0.08 b	0.06 c
	NMR+PPL	6.7 a	49.20 a	0.52 c	77.9 a	111.53 a	7.4 b	1.02 a	0.25 b	0.29 a
	NMR+MN	6.2 b	6.98 b	12.47 b	1.35 b	43.67 b	29.9 a	0.48 b	1.40 a	0.18 b
	NHR	6.4 b	9.92 b	15.03 ab	1.64 b	25.72 b	11.9 b	0.13 b	0.03 b	0.00 c
	NHR+MN	6.1 c	8.30 b	18.47 a	1.53 b	38.44 b	23.2 a	0.26 b	0.70 ab	0.09 bc
6	NMR		0.83	76.33	0.82 c	24.62 c	36.5	0.03 a	0.04 b	0.01
	NMR+PPL		0.51	77.25	3.35 a	25.54 bc	39.5	0.03 a	0.02 b	0.02
	NMR+MN		2.83	78.67	1.28 bc	29.24 abc	41.4	0.00 b	0.09 b	0.05
	NHR		4.89	101.00	1.80 b	34.85 ab	40.9	0.00 b	0.04 b	0.01
	NHR+MN		4.44	112.00	1.80 b	37.06 a	48.5	0.00 b	0.30 a	0.04
11	NMR		0.21 c	8.07	0.55 b	6.67	8.1 b	0.02 bc	0.00 b	0.00 b
	NMR+PPL		0.38 c	12.03	1.23 a	10.45	13.2 a	0.02 c	0.00 b	0.01ab
	NMR+MN		0.35 c	11.13	0.64 ab	9.37	10.3 ab	0.07 a	0.00 b	0.01ab
	NHR		0.90 a	17.63	1.21 a	11.81	8.0 b	0.01 c	0.01 b	0.00 b
	NHR+MN		0.69 b	14.50	1.12 ab	10.10	8.0 b	0.05 ab	0.02 a	0.02 a
16	NMR		0.11	1.55 c	0.23 c	1.84 b	5.92 b	0.00 b	0.00 b	0.00
	NMR+PPL		0.09	4.63 bc	0.81 ab	3.71 ab	9.94 a	0.00 b	0.00 b	0.00
	NMR+MN		0.12	2.81 c	0.43 bc	2.28 b	8.66 a	0.03 a	0.00 b	0.00
	NHR		1.04	9.05 a	1.26 a	5.86 a	5.57 b	0.00 b	0.01 ab	0.00
	NHR+MN		0.21	6.89 ab	1.16 a	4.11 ab	5.12 b	0.03 a	0.01 a	0.06
22	NMR		0.21 a	1.57 bc	0.39 b	2.49	3.75 bc	0.01 c	0.00	0.00
	NMR+PPL		0.24 a	2.58 ab	1.00 ab	3.95	5.10 a	0.05 b	0.00	0.01
	NMR+MN		0.14 b	0.66 c	0.19 b	1.33	4.76 ab	0.06 ab	0.00	0.00
	NHR		0.21 a	4.23 a	1.24 a	4.56	2.81 c	0.04 b	0.00	0.00
	NHR+MN		0.24 a	3.02 ab	1.46 a	5.80	3.63 bc	0.07 a	0.00	0.00

^z1 ppm = 1 mg·kg⁻¹.

^yMean separation within columns for each week by the Waller-Duncan k-ratio method at *P* = 0.05.

in subsequent weeks. Micronutrients from all sources appeared to be largely depleted by week 6.

Discussion

In both experiments, downy jasmine growth appeared to be limited by Mn deficiency because plants with the highest Mn ratings (least deficiency) also had the greatest dry weights. These plants also had the lowest N ratings (lightest color), presumably due to a dilution effect. Conversely, those plants that were growth limited by Mn deficiency had darker green color and accumulated higher concentrations of N and P in both experiments and K in Expt. 1. Downy jasmine grown in NMR + PPL grew larger and accumulated greater total N amounts than with other treatments.

Like downy jasmine, chinese hibiscus also had the greatest dry weights and lowest N ratings when grown with NMR + PPL, suggesting that larger plant size diluted N concentrations within the plant. Chinese hibiscus with the lowest Mn ratings (most severe deficiencies) had the highest N ratings and smallest dry weights, suggesting that Mn deficiency limited growth and concentrated N and P in the foliage of this species as a result. NMR and NHR predictably had the lowest Mn ratings because the Nutricote formulation used contains no micronutrients.

In Expt. 1, NHR produced the smallest areca palm, as did NMR + PPL in Expt. 2. In both cases, micronutrient deficiencies (Mn in Expt. 1 and Fe in Expt. 2) may have resulted in stunted growth in this species. Thus, PPL produced the highest quality plants for the two dicot species, downy jasmine and chinese hibiscus, while areca palm generally grew poorly with this treatment compared with other treatments. Although substrate pH was significantly higher for NMR + PPL than for other treatments in both experiments, these differences do not appear to have affected the uptake of Mn or Fe because this treatment had the highest Mn and Fe ratings for all species in both experiments. Although substrate percentage of porosity was lower for NMR + PPL than for other treatments, poor soil aeration is usually associated with Fe deficiency in palm (Broschat, 2005).

While analysis of substrate solution can be useful for determining available nutrient levels for plant growth, these data are also of environmental interest because the leachates obtained from our pour-through extracts would normally represent runoff from the nursery containers under typical irrigation regimes. This study shows that large amounts of P were leached from containers treated with PPL during the first few weeks. While PPL-treated containers also contained higher concentrations of $\text{NH}_4\text{-N}$ and K than most other treatments at week 1, these levels were similar to those encountered at later samplings from most treatments. Also, $\text{NH}_4\text{-N}$ and K have not been identified by the U.S. Environmental Protection Agency as being of environmental concern as have $\text{NO}_3\text{-N}$ and P (U.S. Environmental Protection Agency, 1976). Plant requirements for N and K are also much higher than those for P (Joiner et al., 1983; Yeager and Wright, 1982). While Kraus and Warren (2000) concluded that composted turkey litter was as effective as Osmocote as a source of P and micronutrients on Skogholm cotoneaster and Red Magic rudbeckia, Warren et al. (1995) found that composted turkey litter was a much less efficient source of N and P than resin-coated fertilizers. In this study, very little of the initial rapidly released P from PPL was absorbed by the small, recently transplanted plants. Thus, the potential exists for excessive P runoff from container nurseries using PPL.

In conclusion, while PPL does provide significant amounts of N, P, K, and micronutrients such as Mn and Zn for plant growth, the release of these nutrients occurs primarily during the first few weeks after potting. However, the release of Mg appears to be delayed. PPL provided Mn and Zn about as well as an inorganic micronutrient blend. However, for reasons not understood, dicots such as downy jasmine and chinese hibiscus grew best with PPL amendment, whereas areca palm, a monocot, performed rather poorly with PPL compared with the inorganic micronutrient source. Thus, if plant growth and visual quality (lack of visible nutrient deficiencies) are the primary criteria for container plant production, then PPL was a suitable substitute for CRF

in downy jasmine and chinese hibiscus, but not for areca palm. The rapid initial release of P by PPL into the environment is a major drawback to the use of this material.

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