Efficacy of Three Nitrogen and Phosphorus Sources in Container-Grown Azalea Production[1]

Stuart L. Warren, Ted E. Bilderback, and Helen H. Tyler[2]
Department of Horticultural Science
North Carolina State University
Raleigh, NC 27695-7609

Abstract

Rooted stem cuttings of 'Sunglow' azalea (*Rhododendron* sp. 'Sunglow') were potted into 3.8 liter (#1) containers with a pine bark:sand (6:1 by vol) substrate and topdressed with 3.5 g (0.12 oz) N per container with resin-coated NH_4NO_3 and P [Osmocote 18N–2.6P–10K (18–6–12)], urea and sulfur-coated P [Woodace 20N–1.8P–9.1K (20–4–11)], or composted turkey litter (CTL) [Sustane 5N–0.9P–3.3K (5–2–4)]. A container-grown plant production area was constructed and subdivided into nine separate plots, 7.6 × 1.8 m (25 × 6 ft), with a 2% slope and lined with black plastic. At 5:00 AM daily, 1.3 cm (0.5 in) of water was applied by overhead irrigation at a rate of 1.6 cm/hr (0.6 in/hr) resulting in a leaching fraction of approximately 0.1 to 0.2. All effluent was collected individually from each plot. At 8:00 AM daily, volume of effluent was measured and sub-sampled for analysis of NO_3, NH_4, and P. The experiment, a RCB design with 3 replications, was conducted for 100 days. Thirty containers were placed in each plot for a total of 90 containers per treatment. After 100 days, 13%, 12%, and 9% of the N applied was recovered in the effluent from containers fertilized with resin-coated NH_4NO_3, urea, and CTL, respectively. Of the P applied, 8%, 27%, and 15% was recovered in the effluent with resin-coated P, sulfur-coated P, and CTL, respectively. Resin-coated NH_4NO_3 and urea produced greater shoot growth and higher shoot N content compared to CTL. Shoot and root P contents were greatest with resin-coated P. Nutrient efficiency defined as grams of nutrient the plant absorbed divided by total grams of nutrient found in effluent and plant resulted in resin-coated NH_4NO_3 and urea having the highest N efficiency (56%); while, resin-coated P had the highest P efficiency (43%).

Index words: nutrient efficacy, runoff, slow-release fertilizer, leaching.

Significance to the Nursery Industry

Nutrient contaminated effluent and its potential pollution of surface and ground waters are primary concerns of the nursery industry. Resin-coated NH_4NO_3 and urea lost more NO_3 in the effluent than composted turkey litter. Sulfur-coated P and composted turkey litter lost greater amounts of P_2O_5 in the effluent than resin-coated P. Resin-coated NH_4NO_3 and urea had the highest N efficiency (56%) while resin-coated P had the highest P efficiency (43%). Data herein emphasize that controlled release fertilizers are efficient, but nutrient sources which comprise each fertilizer and the mechanism which controls nutrient release regulate the level of efficiency. Adjustments in P sources and coating technology may improve P efficiency. In addition, cultural practices such as reduced irrigation volumes that may further curtail nutrients lost in runoff water need to be investigated.

Introduction

Due to the porous nature and limited water reserves of most container substrates, production of container-grown plants requires large amounts of water to promote rapid plant growth. Unfortunately, a significant portion of the applied water passes through the container carrying nutrients with it (18). Therefore, nutrient contaminated runoff water and its potential pollution of surface and ground waters are primary concerns of the nursery industry (17). Excessive NO_3 in surface waters encourages rapid growth of aquatic plants and algae blooms, in addition to causing health problems (1). The Safe Drinking Water Act set the maximum allowable NO_3-N contaminant level at 10 mg/liter.

Nitrogen is required in large quantities by plants and is easily leached from container substrates during irrigation making it the most difficult nutrient to manage in containerized plant production (6). Stewart et al. (15) reported a 15% N efficiency [g N absorbed by plant / (g N absorbed by plant + g N loss in effluent)] when privet (*Ligustrum japonicum*) was grown in a greenhouse using liquid fertilization. Controlled-release fertilizers (CRFs) are more efficient than liquid fertilization; thus, many growers have switched to CRFs to decrease the quantity of nutrients lost via leaching (7). However, N losses from CRFs can vary from 12 to 29% depending upon nutrient sources, control release mechanisms and irrigation regime (7, 13). Limited information is available on nutrient losses from different nutrient sources and control release mechanisms in a typical southeastern U. S. containerized plant production. Therefore, the objective of this study was to determine the effect of different nutrient sources of N and P contained in two commercial synthetic controlled release fertilizers and one organic fertilizer on N and P efficiency in containerized plant production.

Materials and Methods

The experiment, a randomized complete block design with three fertilizer sources and three replications, was conducted at North Carolina State University, Horticulture Field Laboratory, Raleigh. Fertilizer source treatments included resin-coated N and P, urea and sulfur-coated P, and composted turkey litter. Osmocote (Grace/Sierra Horticultural Products,

[1]Received for publication January 30, 1995; and in revised form June 8, 1995. This research was funded by the North Carolina Agricultural Research Service (NCARS), Raleigh, NC 27695-7643. Technical assistance of William Reece; Mary Lorscheider; the Horticultural Substrates Laboratory, NCSU, Department of Horticultural Science; and the Analytical Service Laboratory, NCSU, Department of Soil Science is gratefully acknowledged. **This research was supported, in part, by the nursery industry through contributions to the Horticulture Research Institute, 1250 I Street, N.W., Suite 500, Washington, DC 20005.**

[2]Associate Professor, Professor, and Graduate Teaching Assistant, respectively.

Milpitas, CA) 18N–2.6P10K (18–6–12) was used as the resin-coated N and P source with the N divided into 10.4% NH_4 and 7.6% NO_3 (hereafter referred to as resin-coated NH_4NO_3), and P supplied by ammonium and calcium phosphates (hereafter referred to as resin-coated P). Woodace (Vigoro Industry, Inc., Fairview Heights, IL) 20N–1.8P–9.1K (20–4–11) composed of 0.8% NH_4, 1.35% NO_3, 15.5% urea, and 2.7% water insoluble N (hereafter referred to as urea) and sulfur-coated ammonium phosphate (hereafter referred to as sulfur-coated P) supplied urea and sulfur-coated P. Sustane (Sustane Corp., Cannon Falls, MN) 5N–0.9P–3.3K (composted turkey litter, 5–2–4) consisted of 1.5% NH_4 and 3.5% organic N and organic P . Each container was top-dressed with 3.5 g (0.12 oz) N which resulted in 1.2 (0.04 oz), 0.7 (0.02), and 1.4 g (0.05) P applied per container for resin-coated P, sulfur-coated P, and composted turkey litter (CTL), respectively.

Rooted stem cuttings of 'Sunglow' azalea (*Rhododendron* sp. 'Sunglow') were potted into 3.8 liter (#1) containers with a pine bark:sand (6:1 by vol) substrate on May 14. Thirty containers were placed in each plot for a total of 90 containers per treatment. Substrate of plants that received resin-coated NH_4NO_3 and P was amended with 2.4 kg/m^3 (4.0 lbs/yd^3) dolomitic limestone and 0.9 kg/m^3 (1.5 lbs/yd^3) micronutrient fertilizer (Micromax, Grace/Sierra Horticultural Products). Plants receiving urea and sulfur-coated P were potted into a substrate amended with 2.4 kg/m^3 (4.0 lbs/yd^3) dolomitic limestone only, as this material contained micronutrients. Plants fertilized with CTL were potted into substrate that received no additional amendments as this product adequately replaces dolomitic limestone and micronutrients (16).

A container-grown plant production area was constructed and subdivided into nine separate plots, 7.6 × 1.8 m (25 × 6 ft), with a 2% slope and lined with black plastic. All nutrients were applied at initiation (Day 0; June 3, 1992) and the study was terminated 100 days later.

Table 1. Effect of nutrient source on 'Sunglow' azalea shoot dry weight, and shoot and root nutrient contents.

Nutrient source[z]	'Sunglow' azalea shoot dry wt (g)	Nitrogen content (g) Shoot
Resin-coated NH_4NO_3	31.3a[y]	0.49a
Urea	29.2a	0.44a
CTL	13.0b	0.13b
Initial[x]		0.02
	Phosphorus content (g)	
	Shoot	**Root**
Resin-coated P	0.06a	0.017a
Sulfur-coated P	0.02b	0.006c
CTL	0.03b	0.012b
Initial	0.002	0.001

[z]Nutrient source treatments included resin-coated NH_4NO_3 and P supplied by Osmocote 18N–2.6P–10K (18–6–12). Woodace 20N–1.8P–9.1K (20–4–11) supplied the urea and sulfur-coated P. Composted turkey litter (CTL) [Sustane 5N–0.9P–3.3K (5–2–4)] supplied organic N and P.

[y]Means followed by the same letter within each column are not significantly different as determined by LSD, p = 0.05.

[x]Initial nutrient contents determined at Day 0.

Table 2. Effect of nutrient source on total nutrient loss per container in effluent 100 days after nutrient application.

Nutrient source[z]	N loss (g) NH_4	N loss (g) NO_3
Resin-coated N	0.13a[y]	0.32a
Urea	0.16a	0.27a
CTL	0.11a	0.20b
	P loss (g)	
Resin-coated P	0.10b	
Sulfur-coated P	0.19a	
CTL	0.21a	

[z]Nutrient source treatments included resin-coated NH_4NO_3 and P supplied by Osmocote18N–2.6P–10K (18–6–12). Woodace 20N–1.8P–9.1K (20–4–11) supplied the urea and sulfur-coated P. Composted turkey litter (CTL) [Sustane 5N–0.9P–3.3K (5–2–4)] supplied organic N and P.

[y]Means followed by the same letter within each column are not significantly different as determined by LSD, p = 0.05.

At 5:00 AM daily, 1.3 cm (0.5 in) of water was applied by overhead irrigation at a rate of 1.6 cm/hr (0.6 in/hr) resulting in a leaching fraction of approximately 0.1 to 0.2. All effluent was collected individually from each plot. At 8:00 AM daily, volume of effluent was measured and sub-samples were collected, filtered, and frozen for future NO_3 (2), NH_4 (4), and P (3, 8, 11) analyses using a spectrophotometer (Spectronic 1001 Plus, Milton Roy Co., Rochester, NY).

One hundred days after initiation, shoots (aerial tissue) were removed and roots were placed over a screen and washed with a high pressure water stream to remove substrate. All plant tissues were dried at 62C (144F) for 5 days. After drying, shoots and roots were ground in a Wiley mill to pass a 40 mesh (0.425 mm) screen. Each tissue sample (1.25 g) was combusted at 490C (914F) for 6 hr. The resulting ash was dissolved in 10 ml (0.03 oz) 6 N HCl and diluted to 50 ml (1.5 oz) with distilled deionized water. Phosphorus was determined by a P-2000 inductively coupled plasma emission spectophotometer (Perkin-Elmer, Norwalk, CT). Nitrogen concentration was determined using 10 mg (0.03 oz) samples in a Perkin-Elmer 2400 CHN elemental analyzer. Nutrient content was determined by multiplying the plant part dry weight by the nutrient concentration.

All variables were tested for differences using analysis of variance procedures (14). All reported mean separations were performed via least significant difference (LSD) procedures at p = 0.05. Nutrient efficiency was defined as grams of nutrient the plant absorbed divided by total grams of nutrient found in effluent and plant (hereafter referred to as recovered nutrient).

Results and Discussion

Shoot dry weight and shoot N content for resin-coated NH_4NO_3 and urea were higher than CTL (Table 1). Root dry weight and root N content were not effected by N source (data not presented). Shoot and root P contents were highest with resin-coated P. Thus, plants absorbed more N when grown with resin-coated NH_4NO_3 and urea, and more P when grown with resin-coated P.

Nutrient source affected total NO_3 and P recovered in the effluent while NH_4 was not effected (Table 2). Resin-coated NH_4NO_3 and urea lost more NO_3 in the effluent than CTL.

Sulfur-coated P and CTL lost more P in the effluent than resin-coated P. Of the N applied, 13%, 12%, and 9% was recovered in the effluent from containers fertilized with resin-coated NH_4NO_3, urea, and CTL, respectively. Rathier and Frink (13) reported similar NO_3 losses (18%) when juniper (*Juniperus horizontalis* 'Plumosa Compacta Youngstown') was fertilized with resin-coated NH_4NO_3 [Osmocote 18N–2.6P–10K (18–6–12)] and irrigated as needed via overhead irrigation. However, Jarrell et al. (9) reported higher N losses (32% of the N applied) from containers that were fertilized with resin-coated NH_4NO_3 [Osmocote18N–2.6P–10K (18–6–12)] and irrigated with higher (0.2 or 0.4) leaching fractions compared to this study (0.1 to 0.2), illustrating that irrigation management can affect nutrient losses.

The remaining 71%, 72%, and 86% of applied N which was not recovered in either the effluent or the plant for resin-coated NH_4NO_3, urea, or CTL, respectively, may have been lost via ammonia volatilization, denitrification, or remained in the substrate or fertilizer prills. Rathier and Frink (13) found that depending upon N source, 58% to 80% of applied N was not recovered in either the plant or effluent. Substrates composed of pine bark and sand have been reported to lose 18% of applied N via denitrification (15). Plastic containers may further increase the loss due to denitrification (15). In addition, Hershey and Paul (7) and Niemiera and Leda (12) reported 20% and 23%, respectively, of applied N remained in resin-coated NH_4NO_3 [Oscomote14N–6.2P–11.6K (14–14–14) (3 to 4 month)] prills 77 days after application.

Resin-coated NH_4NO_3 and urea had rapid losses of NO_3 during days 1 and 2 probably due to broken prills (Fig. 1). All three N sources displayed similar linear trends in NO_3 leaching losses from days 18 to 100, suggesting the rate of NO_3 loss was constant throughout the experiment. However, the quantity of daily NO_3 loss varied with N source ($p = 0.001$) with resin-coated NH_4NO_3 having the highest average daily rate of loss (3.7 mg NO_3/day), followed by urea (3.1 mg NO_3/day), and CTL (2.3 mg NO_3/day). Even though

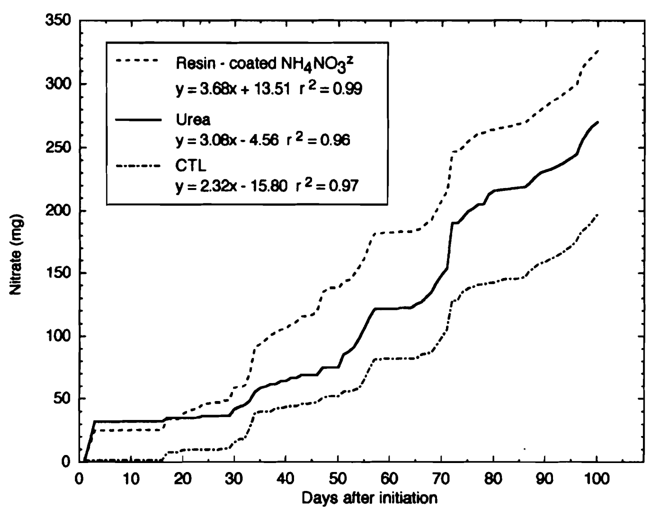

Fig. 1. Cumulative NO_3 losses per container in effluent 100 days after application. [^{z}Resin-coated NH_4NO_3 = Osmocote 18N–2.6P–10K (18–6–12), urea = Woodace 20N–1.8P–9.1K (20–4–11), and CTL (composted turkey litter) = Sustane 5N–0.9P–3.3K (5–2–4)]

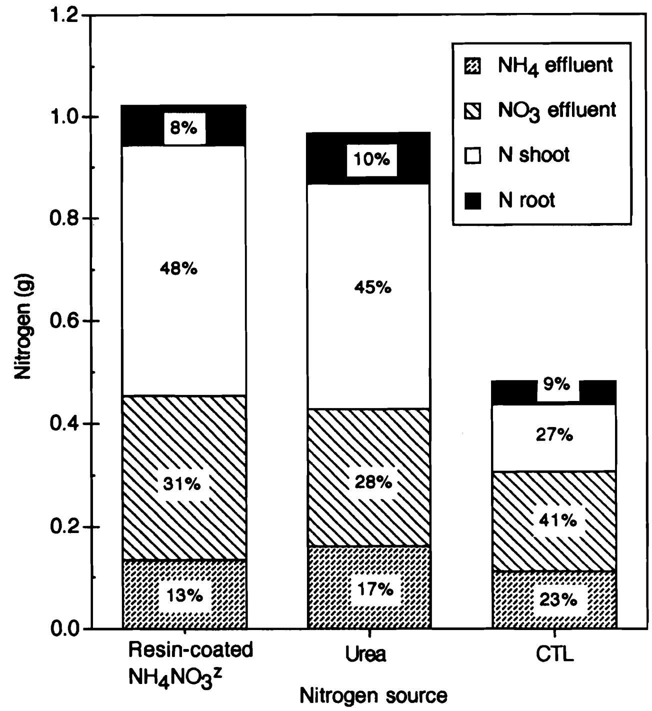

Fig. 2. Recovered N (N found in effluent + plant) per container of 3.5 g N applied 100 days after application. Percentages based on recovered N. [^{z}Resin-coated NH_4NO_3 = Osmocote 18N–2.6P–10K (18–6–12), urea = Woodace 20N–1.8P–9.1K (20–4–11), and CTL (composted turkey litter) = Sustane 5N–0.9P–3.3K (5–2–4)].

urea contained little NH_4-N or NO_3-N, sufficient urea hydrolysis and nitrification occurred in the substrate so that urea had similar effluent and plant nutrient values as resin-coated NH_4NO_3. This conclusion is supported by Jarrell et al. (9) who reported adequate nitrification and approximately equal NO_3 losses regardless of initial N source. There was a similar linear trend in NH_4 leaching losses in the effluent over the 100 days (data not shown). These release trends of NO_3 and NH_4 are similar to those reported by Hershey and Paul (7) with resin-coated NH_4NO_3 [Osmocote14N–6.2P–11.6K (14–14–14)]. In contrast, Rathier and Frink (13) reported N losses from several N sources leveled off 30 days after fertilizer application. Similar linear responses in NO_3 loss in effluent regardless of mechanism of N release and N source suggest that NO_3 was present in the substrate solutions in excess of the quantity taken up by the plant and that the method of irrigation may substantially affect losses from the production system.

Of the 3.5 g N applied to each container, 1.0 g was recovered from resin-coated NH_4NO_3 with 44% in the effluent and 56% in the plant (Fig. 2). Comparable leachate and plant nutrient values were reported by Cox (5). Urea had similar effluent and plant nutrient values as resin-coated NH_4NO_3 (Fig. 2). Only 0.48 g N of N applied was recovered from CTL. Most of the N in CTL was organic N which is made available only after being mineralized to an inorganic form. In addition, the rate of N release from CTL was dependent upon mineralization while N release from synthetic fertilizers was dependent upon diffusion only. Therefore, total N lost in the effluent was less for CTL compared to resin-coated

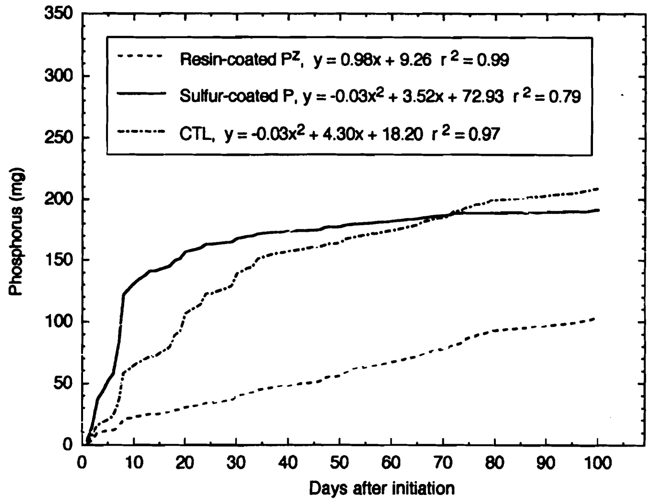

Fig. 3. Cumulative P losses per container in effluent 100 days after application. [zResin-coated P = Osmocote 18N–2.6P–10K (18–6–12), sulfur-coated P = Woodace 20N–1.8P–9.1K (20–4–11), and CTL (composted turkey litter) = Sustane 5N–0.9P–3.3K (5–2–4)].

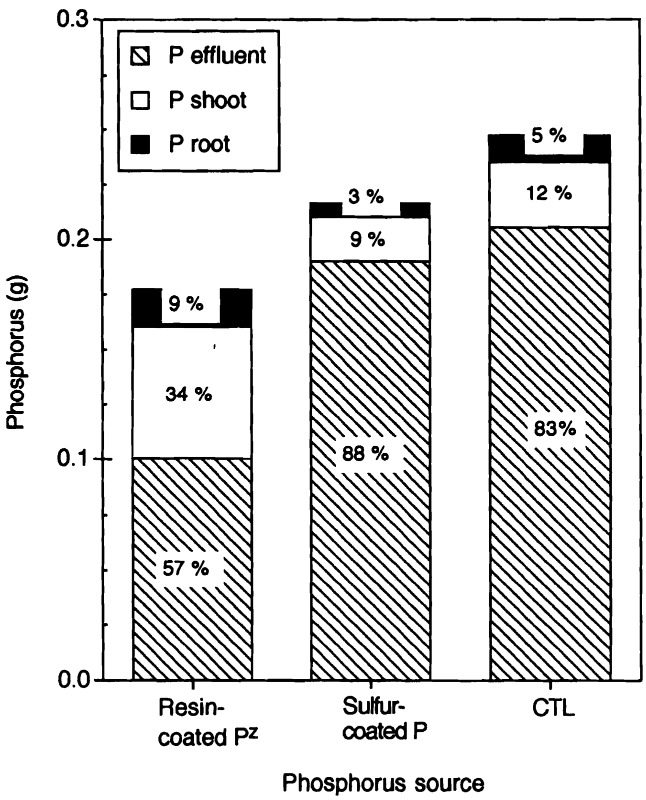

Fig. 4. Recovered P (P found in effluent + plant) per container of 1.2, 0.7, and 1.4 g P applied for resin-coated P [Osmocote 18N–2.6P–10K (18–6–12)], sulfur-coated P [Woodace 20N–1.8P–9.1K (20–4–11)], and CTL (composted turkey litter) [Sustane 5N–0.9P–3.3K (5–2–4)], respectively 100 days after application. Percentages based on recovered P.

NH_4NO_3 and urea. Due to less N being available for plant uptake, plant growth was also reduced with CTL. Thus, proportionally more of CTL's recovered N was found in the effluent (64%) with the remaining 36% found in the plant (Fig. 2).

Of the P applied, 8%, 27%, and 15% was found in the effluent from containers fertilized with resin-coated P, sulfur-coated P, and CTL, respectively. In contrast to NO_3, P losses varied with P source reflecting differences in specific P sources (Fig. 3). There was a quadratic response in P loss for sulfur-coated P and CTL; while, P loss from resin-coated P was linear and resulted in a lower quantity of P loss compared to sulfur-coated P and CTL. Phosphorus loss from sulfur-coated P and CTL reached a plateau at Day 35 and 72, respectively, where 90% of the lost P had been collected in the effluent. High losses of P during the early part of the growing season coincided with a period of low plant uptake which likely contributed to high leaching losses and low tissue P contents. The remaining 85%, 69%, and 82% unaccounted P from resin-coated P, sulfur-coated P, and CTL, respectively was surprising, since P has been reported to leach readily from pine bark based substrates due to their low P fixation capacities (10, 19) and does not volatilize. Some of the unaccounted for P may have remained in the fertilizer prills or organic material. Of the 1.2 g P applied per container with resin-coated P, 0.18 g was recovered, with 57% in the effluent and 43% in the plant (Fig. 4). Sulfur-coated P and CTL lost more P in the effluent than resin-coated P and contained proportionally less in the plant.

Resin-coated NH_4NO_3 and urea had similar N efficiencies (56%) while CTL had a N efficiency value of 36%. Due to lower rates of N release with the CTL, supplemental fertilizer additions may improve growth and potentially N efficiency. Rathier and Frink (13) reported 20% to 42% N efficiency depending upon the CRF applied. Resin-coated P had the highest P efficiency (43%). Sulfur-coated P and CTL had similar but lower P efficiency values of 12% and 17%, respectively. Adjustments in P sources and control release mechanisms of these fertilizers may improve P efficiency.

Effluent NO_3 concentrations never exceeded 10 mg/liter (data not presented) probably due to dilution by large volumes of runoff water; however, substantial amounts of NH_4, NO_3, and P were lost in the effluent during the 100 days. Data herein emphasize that while CRF can reduce nutrient losses, other cultural practices such as reduced irrigation volumes that may further curtail nutrients lost in runoff water need to be investigated.

Literature Cited

1. Bateman, C. 1990. Less is better: A look at nitrate/phosphate contamination. Florida Nurseryman. Aug. p. 13–15, 17.

2. Calaldo, D.A., M. Haroon, L.E. Schrader, and V.L. Youngs. 1975. Rapid colorimetric determination of nitrate in plant tissue. Commum. Soil Sci. Plant Anal. 6:71–80.

3. Chapman, H.D. and P.F. Pratt. 1961. Methods of analysis for soils, plants and waters. Univ. of Calif., Div. of Agric. Sci., p. 169–170.

4. Chaney, A.L. and E.P. Marbach. 1962. Modified reagents for determination of urea and ammonia. Clin. Chem. 8:130–132.

5. Cox, D.A. 1985. Nitrogen recovery by seed geranium as influenced by nitrogen source. HortScience 20:923–925.

6. Green, J.L. 1989. Practices to minimize contamination of groundwater and runoff water in greenhouse and nursery production of container-grown plants. Ornamentals Northwest Newsletter 13(3):9–16.

7. Hershey, D.R. and J.I. Paul. 1982. Leaching-losses of nitrogen from pot chrysanthemums with controlled-release or liquid fertilization. Scientia Hortic. 17:145–152.

8. Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ.

9. Jarrell, W.M., S.J. Whaley, and B. Miraftabi. 1983. Slow release fertilizer and water management with container grown *Ligustrum texanum*. Scientia Hortic. 19:177–190.

10. Marconi, D.J. and P.V. Nelson. 1984. Leaching of applied phosphorus in container media. Scientia Hortic. 22:275–285.

11. Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta. 27:31–36.

12. Niemiera, A.X. and C.E. Leda. 1993. Nitrogen leaching from Osmocote-fertilized pine bark at leaching fractions of 0 to 0.4. J. Environ. Hort. 11:75–77.

13. Rathier, T.M. and C.R. Frink. 1989. Nitrate in runoff water from container grown juniper and Alberta spruce under different irrigation and N fertilization regimes. J. Environ. Hort. 7:32–35.

14. SAS Institute. 1985. SAS User's Guide: Statistics. Version 5 Edition. SAS Institute, Cary, NC.

15. Stewart, J.A., L.J. Lund, and R. L. Branson. 1981. Nitrogen balances for container-grown privet. J. Amer. Soc. Hort. Sci. 106:565–569.

16. Tyler, H.H., S.L. Warren, T.B. Bilderback, and W.C. Fonteno. 1993. Composted turkey litter: I. Effect on Chemical and Physical Properties of a Pine Bark Substrate. J. Environ. Hort. 11:131–136.

17. Urbano, C.C. 1989. The environmental debate: An industry issue. Amer. Nurs. 169(8):69–73, 83, 85.

18. Wright, R.D.and A.X. Niemiera. 1987. Nutrition of container-grown woody nursery crops. p. 76-101. *In*: J. Janick (Editor). Hort Reviews. AVI publishing Co., Inc. Westport, CT.

19. Yeager, T.H. and R.D. Wright. 1982. Phosphorus requirements of *Ilex crenata* Thunb. cv. Helleri grown in a pine bark medium. J. Amer. Soc. Hort. Sci. 107:558–562.