Research Reports

Plant Growth and NO_x-N in Leachate from *Dieffenbachia maculata* 'Camille'[1]

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Abstract

Dieffenbachia 'Camille' liners were planted and grown until "ready-for-market" in 1.6 liter pots containing Vergro Container Mix A without superphosphate. Plants were fertilized (FR) using 4, 8, 12, or 16 g 19N-2.6P-10K (0.14, 0.28, 0.42 or 0.56 oz 19–6–12) Osmocote 3-month release formula and were irrigated (IF) one, two or three times per week. Experiments were conducted during cooler months (20 weeks, January–May) and also during warmer months (13 weeks, June–September). Medium leachate samples were collected weekly for the duration of each experiment. Plant grade and top fresh weight (growth parameters) during the winter responded to an interaction between treatments (FR × IF). During the summer experiment, growth parameters were affected only by IF and were greatest at 3 irrigations per week. Weekly leachate characteristics (pH and electrical conductivity [EC], and P, NH_4-N and NO_x-N content) were affected only by FR, with increased fertilizer generally resulting in leachate with decreased pH and increased EC and increased P, NH_4-N and NO_x-N concentrations, in both winter and summer with the exceptions during the winter of P which increased with either an increase in FR or IF and of NO_x-N which also increased with increased IF. Interaction occurred between FR and IF for total mg P leached during each experiment and for total mg NO_x-N leached during the 20 week experiment, while total mg NO_x-N leached during the 13 week experiment and total mg NH_4-N leached in each experiment were affected only by FR.

Index words: ammoniacal nitrogen, BMPs (best management practices), controlled-release fertilizer, foliage plant production, ground water, nitrate nitrogen, phosphorus.

Species used in this study: dumb cane [*Dieffenbachia maculata* (Lodd) G. Don 'Camille'].

Significance to the Nursery Industry

Leaching of nitrates into ground water is a continuing concern for the agricultural community. Practices that reduce the potential for nitrate leaching are necessary and research is being conducted to determine best management practices (BMPs) which will allow plant producers to reduce the risk for contamination of ground water while producing profitable crops. BMPs for plant production depend on many factors and two important factors were combined in these experiments to provide information regarding leachate contents during crop production using various fertilizer rates and irrigation frequencies.

Introduction

Concern over leaching of nitrogen into ground water due to agricultural practices has resulted in regulations and restrictions of the agricultural industry by federal, state and local agencies (1, 5, 8). Most of the attention, until recently,

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has been focused on field crops and practices (4, 7, 8, 10, 11, 19); however, the plant nursery industry is directing more attention to the potential for ground water contamination and safe, but profitable, practices (3, 13, 14, 18). Limited information is available on greenhouse foliage crop production BMPs which minimize nitrogen leaching. Many aspects must be considered when formulating BMPs for the potted plant industry; both physical factors—such as temperature, humidity, light level and potting medium—and biological factors—such as plant physiological needs and desired size and form—play important roles in the development of any management practices. Several previous experiments have been conducted to determine the effects of various medium types, fertilizer rates and irrigation levels on foliage plant quality and medium leachate characteristics (3, 15, 16, 17), but few of these considered nitrogen leaching and ground water contamination aspects. This report describes experiments conducted using *Dieffenbachia maculata* 'Camille' planted in a commercially prepared medium, at 4 fertilizer rates and 3 irrigation frequencies (with 4 single-pot replications per treatment) to determine effects of these factors on nitrogen leaching from the pots. Since Florida produces foliage crops year-round, experiments were conducted during the slower growing season (winter) which extended over a twenty-week period before all plants were considered to be "ready-for-market" (i.e. salable), and repeated during the summer when all plants were "ready-for-market" after 13 weeks.

Materials and Methods

January 3–May 19, 1989. Rooted liners of *Dieffenbachia maculata* 'Camille' were planted into 1.6 liter pots containing Vergro Container Mix A (Verlite Company, Tampa, FL 33610) without superphosphate. Containers were placed in a glass greenhouse where the maximum light range at plant level varied from 190 to 380 μmol/m^2/s (1000–2000 ft-c) depending upon time of year and switch-on set-point temperatures were 18° and 35°C (65° and 95°F) for heating and cooling, respectively. Pots were fertilized at the recommended rate of 4 g (2), or 8, 12 or 16 g 19N-2.6P-10K (0.14, 0.28, 0.42 or 0.56 oz 19-6-12) Osmocote 3-month release formula (Grace-Sierra, Milpitas, CA 95035) on January 3, 1989 and again on April 4, 1989. Irrigation treatments, utilizing well water with a 7.8 pH, an EC of 0.4 dS/m and 0.3, 0.05, and 0.05 mg P, NH_4-N, and NO_3-N/liter, respectively, occurred either once a week (on Wednesday), twice a week (Monday and Friday), or 3 times a week (Monday, Wednesday and Friday). Before each irrigation, each pot was placed in a beaker just large enough to hold the pot by the rim so that leachate could be collected. At each irrigation, 3–5 sample pots with the irrigation treatment(s) for the day received 100 ml (3.4 oz) of water poured into the pot so that it dispersed over the surface of the medium. If no leachate was collected from these sample pots, they then received water in 50 ml (1.7 oz) increments every 3–4 minutes until sufficient leachate (approx. 30 ml [1.0 oz]) was obtained from each pot to ensure enough for sample analysis. The amount per treatment was recorded and the same amount of water was applied at that irrigation to each pot with that irrigation schedule. Irrigation began on January 3. All leachate per pot was collected and refrigerated at 4°C (40°F) and combined with other leachate, if any, for the week for the same pot. Quantity of total leachate per pot per week was measured and recorded; leachate was then filtered to remove any contaminants that might plug the analytical equipment and collected in a 20-ml polyethylene scintillation vial, and any remaining leachate was discarded. Samples were sent weekly to the University of Florida, Institute of Food and Agricultural Sciences' Analytical Research Laboratory, Gainesville, FL 32611 for analysis, and were stored frozen until the laboratory could schedule analysis of the samples. Leachate samples were analyzed for pH, electrical conductivity, and concentrations of NO_x-N, NH_4-N and P, using RFA A303-S625, RFA A303-S020 and ICP methodologies for nitrate/nitrite, ammonium, and P, respectively. All plants were determined to be marketable (based on a scale of 1 = dead; 2 = poor quality, unsalable; 3 = fair quality, salable; 4 = good quality; and 5 = excellent quality) on May 19, 1989, and treatments were discontinued. Plant grades were recorded and fresh weights of plant tops were measured. Data were statistically analyzed with Analysis of Variance (PROC ANOVA) or General Linear Models (PROC GLM) procedures, using Statistical Analysis System (SAS Institute, Inc., Cary, NC 27512–8000) software. Conversion of pH to hydrogen ion concentration was performed before statistical analysis, but results are discussed as pH.

June 8–September 8, 1989. The same experimental design described for the previous experiment was used for this experiment. Glass greenhouse conditions varied from 210 to 380 μmol/m^2/s (1100–2000 ft-c) maximum light and greenhouse fans were set to switch on at 35°C (95°F). Once again, with each irrigation the amount of leachate per pot was collected, measured and recorded. Sampling procedures and analyses were the same as in the earlier experiment.

Table 1. Effects of treatment interaction on plant grade and fresh weight of *Dieffenbachia* 'Camille' growing in Vergro Container Mix A, fertilized at 4 levels, and irrigated at 3 frequencies from January 3 to May 19, 1989.

Fertilizer rate[z] (g/1.6 liter pot)	Irrigation frequency (times/week)	Plant grade[y]	Fresh weight (g)
4	1	4.1	220
4	2	4.4	258
4	3	4.4	290
8	1	4.0	178
8	2	4.9	305
8	3	4.9	298
12	1	3.8	160
12	2	4.5	241
12	3	5.0	326
16	1	3.1	126
16	2	4.5	232
16	3	4.9	282
Significance			
Fertilizer rate (FR)		NS[x]	NS
Irrigation frequency (IF)			
Linear		0.0001	0.0001
Quadratic		0.0104	0.0218
FR × IF		0.0001	0.0001

[z]19N-2.6P-10K applied 1/3/89 and 4/4/89.

[y]Based on a scale of 1 to 5 where 1 = dead; 2 = poor quality, unsalable; 3 = fair quality, salable; 4 = good quality, salable; and 5 = excellent quality.

[x]Numbers indicate probability of a significant F value. Neither linear, quadratic or cubic fertilizer rate contrasts were significant.

Plants received only one fertilizer application (June 9, 1989) in this experiment since they were deemed marketable on September 8, 1989, at which time treatments were discontinued, plants graded, and fresh top weights obtained. Data analysis and reporting are similar to the previous experiment.

Results and Discussion

Growth parameters. During the cooler months, interaction between fertilizer rate (FR) and irrigation frequency (IF) resulted for plant grade and fresh top weight (Table 1). Plants achieved high quality and fresh weights at most of the fertilizer/irrigation combinations in this experiment, demonstrating that acceptable plants could be grown over a wide range of treatments.

There was no interaction (FR × IF) seen for plant grade or fresh weight during the warmer months, and fertilizer rate was not significant (plant grades of 3.9, 4.0, 4.0 and 3.9 and fresh weights of 114, 120, 110 and 98 g for 4, 8, 12 and 16 g of fertilizer, respectively), but as irrigation frequency increased plant grade and fresh weight increased (Table 2).

Leachate characteristics: pH. [data not shown]. There was no interaction between fertilizer rate and irrigation frequency during the 20 week winter experiment, and an interaction occurred only one week during the warmer growing season experiment. However, as fertilizer rate increased, weekly pH decreased. Over the duration of each experiment, initial pH increased by experiment end at both the 4 g and 8 g rates due to the use of water with a pH of 7.8, whereas at higher fertilizer rates pH change was suppressed by the greater amount of acidic fertilizer.

Electrical conductivity. [data not shown]. No interaction occurred for electrical conductivity (EC), but in both production cycles as fertilizer rate increased, EC increased. During the 20 week winter experiment, initial ECs were all near 4.0 dS/m and declined to less than 2.5 dS/m at experiment end. In the 13 week summer experiment, initial ECs had a wider range, but all were below the starting EC of the previous experiment. Electrical conductivities of 2.2 and 3.5 dS/m (4 g and 16 g, respectively) changed to 1.1 and 4.1 dS/m, respectively, while the ECs at the 8 and 12 g rates remained relatively constant. At 13 weeks in both experiments, ECs for each fertilizer rate were similar, i.e. 1.4 vs 1.1, 2.3 vs 2.5, 3.5 vs 3.4 and 4.7 vs 4.1 dS/m for 4, 8, 12 and 16 g fertilizer, respectively.

Phosphorus (mg/pot). Phosphorus concentration in the weekly leachate samples in the winter cycle exhibited interaction between FR and IF early in the experiment and again after the fertilizer application during week 14 (data not shown). Phosphorus in the leachate increased as fertilizer rate or irrigation frequency increased until about eight weeks into the experiment; after refertilization, P increased as fertilizer rate increased and as irrigation went to 2 times per week, but generally decreased as irrigation increased to 3 times per week. The summer experiment showed no interaction between FR and IF for weekly phosphorus concentration in the leachate, but as fertilizer rate increased, so did leachate P. In both experiments, total phosphorus leached (mg/pot) during the experiment exhibited an interaction between FR and IF at the $P = 0.05$ level (Table 3). Phosphorus losses were above the minimum required for acceleration of eutrophication (20).

Table 2. Irrigation frequency effect on fresh weight and plant grade of *Dieffenbachia* 'Camille' growing in Vergro Container Mix A and irrigated at 3 frequencies from June 8 to September 8, 1989.

Irrigation frequency (times/week)	Growth parameters: Plant grade[z]	Fresh weight (g)
1	3.6	91
2	4.1	113
3	4.2	128
Significance		
Linear	0.0014[y]	0.0001
Quadratic	NS	NS

[z]Based on a scale of 1 to 5 where 1 = dead; 2 = poor quality, unsalable; 3 = fair quality, salable; 4 = good quality, salable; and 5 = excellent quality.

[y]NS = not significant; numbers indicate the calculated probabilities that the differences between main effects were due to chance alone.

NH_4-N (mg/pot). Though NH_4-N in some of the weekly leachate samples exhibited an interaction between FR and IF, increased fertilizer rate increased NH_4-N in the leachate 90% of the time in the winter experiment and all of the time in the summer experiment (data not shown). Irrigation frequency did not affect leaching of NH_4-N. It was noted that generally more NH_4-N was recorded in leachate from the first 13 weeks of the winter cycle than during the 13 weeks of the summer production. Ammoniacal N in the leachate in the winter months was greater than in the summer months

Table 3. Effects of treatment interaction on total mg P leached from medium in pots containing *Dieffenbachia* 'Camille' growing in Vergro Container Mix A, fertilized at 4 levels, and irrigated at 3 frequencies.

Fertilizer rate[z] (g/1.6 liter pot)	Irrigation frequency (times/week)	Total mg P leached/pot: Jan 3 through May 19, 1989	Jun 8 through Sep 8, 1989
4	1	12.4	5.4
4	2	16.9	8.3
4	3	19.9	5.5
8	1	45.2	13.6
8	2	50.0	19.1
8	3	66.2	19.3
12	1	76.3	32.3
12	2	118.2	34.5
12	3	117.9	38.3
16	1	142.9	48.2
16	2	174.4	52.2
16	3	177.2	69.1
Significance			
Fertilizer rate (FR)			
Linear		0.0001[y]	0.0001
Quadratic		0.0276	0.0244
Irrigation frequency (IF)		NS	NS
FR × IF		0.0191	0.0492

[z]19N-2.6P-10K applied 1/3/89 and 4/4/89, or 6/8/89, respectively.

[y]Numbers indicate probability of a significant F value. Neither cubic contrast for fertilizer rate nor linear or quadratic irrigation frequency contrasts were significant.

Table 4. **Fertilizer rate effect on total mg NH_4-N in leachate from medium in pots containing *Dieffenbachia* 'Camille' and irrigated at 3 frequencies from January 3 through May 19, 1989 (20 weeks) and for total mg NH_4-N and NO_x-N in leachate from June 8 to September 8, 1989 (13 weeks).**

	Total mg NH_4-N/pot		Total mg NO_x-N/pot
Fertilizer rate[z] (g/1.6 liter pot)	20 week production cycle	13 week production cycle	13 week production cycle
4	8.2	3.4	304.7
8	23.1	12.2	589.5
12	88.0	22.8	830.6
16	270.2	54.6	1091.7
Significance			
Linear	0.0001[y]	0.0001	0.0001
Quadratic	0.0001	NS	NS

[z]19N-2.6P-10K applied 1/3/89 and 4/4/89, or 6/8/89, respectively.

[y]NS = not significant; numbers indicate the calculated probabilities that the differences between main effects were due to chance alone.

by 200, 25, 200 and 300% at 4, 8, 12 and 16 g, respectively. Earlier research (12) has shown that dieffenbachia grow better with nitrate sources of N than with ammonium-N sources, therefore, the slower growing plants in the winter may have utilized less of the NH_4-N than they did in the warmer months when they were growing more rapidly, thus more NH_4-N would have been available for leaching from the pots. Lower winter soil temperatures would slow the transformation of NH_4^+ to NO_3^- and, combined with reduced plant use, this would result in leaching of NH_4^+ if exchange sites were filled. In neither the winter or the summer experiment was there an interaction between FR and IF for total mg NH_4-N leached throughout the experiment; however, in

Table 5. **Effects of treatment interaction on total mg NO_x-N leached from medium in pots containing *Dieffenbachia* 'Camille' growing in Vergro Container Mix A, fertilized at 4 levels, and irrigated at 3 frequencies from January 3 through May 19, 1989.**

Fertilizer rate[z] (g/1.6 liter pot)	Irrigation frequency (times/week)	Total mg NO_x-N leached/pot
4	1	360.8
4	2	508.7
4	3	570.7
8	1	918.0
8	2	1215.3
8	3	1430.3
12	1	1367.1
12	2	2222.1
12	3	2062.7
16	1	2163.8
16	2	2828.0
16	3	2719.6
Significance		
Fertilizer rate (FR)		
Linear		0.0001[y]
Irrigation frequency (IF)		NS
FR × IF		0.0323

[z]19N-2.6P-10K applied 1/3/89 and 4/4/89.

[y]Numbers indicate probability of a significant F value. Neither quadratic or cubic contrasts for fertilizer rate nor linear or quadratic irrigation frequency contrasts were significant.

both experiments as fertilizer rate increased, total mg NH_4-N in the leachate increased (Table 4).

NO_x-N (mg/pot). Interaction between FR and IF occurred only 20% of the time (weeks 3, 4, 15 and 18) in the 20 week experiment and not at all in the 13 week experiment. Fertilizer rate had a major effect, resulting in an increase in NO_x-N in the weekly leachate as fertilizer rate increased (data not shown), in both experiments. The generally linear increase in leached NO_x-N is to be expected, since once exchange sites are saturated and plant needs are satisfied, remaining ions can be easily leached. These data show that excess fertilization can result in large amounts of NO_x-N leaching out of pots with potential risk to the environment. Irrigation frequency also had an effect. In the 20 week experiment, NO_x-N in the leachate generally increased with an increase in irrigation frequency until midway through the experiment; when the second fertilizer application was made on Tuesday of week 14, NO_x-N in the leachate increased immediately. The effect of the refertilization was seen in week 14 results for the one time per week irrigation (Wednesday), while transitional effects occurred for that week for the 2 times per week schedule (Monday and Friday) and 3 times per week (Monday, Wednesday, and Friday) (data not shown). For the first few weeks thereafter as irrigation frequency went to 2 times per week, leached NO_x-N increased, then declined as irrigation was increased to 3 times per week. Irrigation frequency did not have an effect on leachate NO_x-N in the summer experiment.

In the 20 week experiment, total mg NO_x-N exhibited an interaction between FR and IF (Table 5). At each irrigation frequency, NO_x-N in the leachate increased as fertilizer rate increased. At 4 and 8 g fertilizer levels, NO_x-N in the leachate increased linearly with irrigation frequency, while at the 12 and 16 g fertilizer levels, NO_x-N increased as irrigation was increased to 2 times per week and then decreased as irrigation went to 3 times per week. Since plant grade and fresh weight increased as irrigation frequency increased in this experiment, these plants may have been able to utilize more of the nitrate nitrogen as irrigation frequency increased, thus decreasing the amount in the leachate. Only FR affected total mg NO_x-N in the 13 week experiment (Table 4).

Hershey and Paul (6) and Ingram and Yeager (9) reported that most of the N-loss (both NO_x-N and NH_4-N) occurred within the first half of the crop cycle when using controlled-release fertilizer. In these experiments, N-loss did generally occur in the first half of the fertilizer cycle, but not always and at the 16 g fertilizer rate this pattern was reversed.

Results indicate that in this medium, irrigation frequency is important for plant quality although less important in NO_x-N leaching; however, fertilizer rate has a strong effect on nutrient content of the leachate. During the 20 week production cycle, fertilizer rate alone did not have a significant effect on plant grade or fresh weight; therefore using 4 g fertilizer and irrigating 3 times per week could maximize plant quality (Table 1) and reduce contamination risk from excess fertilizer.

In a typical 30.5 m by 18.3 m (100 ft × 60 ft) greenhouse used for production of *Dieffenbachia* 'Camille' in 1.6 liter pots, depending on design, there could be sixteen 1.5 m × 13.8 m (5 ft × 45 ft) benches with four 0.9 m × 13.8 m (3 ft × 45 ft) benches along the sides; these would hold approximately 4140 pots. Using the treatment which maximized

Table 6. **Average total leachate collected and average mg/liter NO_x-N in leachate from pots with Vergro container mix A used for growing *Dieffenbachia* 'Camille' with 4 fertilizer rates and 3 irrigation frequencies throughout the production cycles from January 3 to May 19, 1989 (20 weeks) and from June 12 to September 8, 1989 (13 weeks).**

Treatment		Average total leachate collected/treatment (ml)		Average mg/liter NO_x-N leached/treatment	
Fertilizer rate[z] (g/1.6 liter pot)	Irrigation frequency (times/week)	20 week production cycle	13 week production cycle	20 week production cycle	13 week production cycle
4	1	1205	1081	288.9	206.2
4	2	1851	1273	273.7	223.8
4	3	2328	2098	234.9	170.3
8	1	1774	1464	525.6	377.7
8	2	2021	1508	548.5	380.2
8	3	2838	1880	490.5	334.7
12	1	2022	1541	697.4	491.5
12	2	3066	1673	712.5	476.7
12	3	3072	2031	677.8	471.6
16	1	2481	1733	888.6	572.7
16	2	3254	1748	875.9	607.4
16	3	3747	2444	769.8	501.7

[z]19N-2.6P-10K applied 1/3/89 and 4/4/89, or 6/8/89, respectively.

plant quality with the least potential risk to the environment (4 g fertilizer at 3 irrigations per week) and multiplying the average amount of leachate per pot during the production cycle (Table 6) by the number of pots in a typical greenhouse set up would indicate that approximately 9,638 liter with an average NO_x-N concentration of 235 mg/liter would be leached to the greenhouse floor. During the shorter summer production cycle (13 weeks), only irrigation frequency was important and 3 irrigations per week produced the best quality plants. Once again using the average leachate for the 4 g fertilizer rate and 3 times per week irrigation frequency treatment, the typical greenhouse might have 8,686 liter with an average NO_x-N concentration of 170 mg/liter leached to the greenhouse floor.

Economically and environmentally, growers should practice BMPs that apply fertilizer at no higher than the recommended rate and achieve plant quality through water management on the crop. This will reduce nutrient leaching and help contain or reduce fertilizer costs while decreasing risk of contamination to the ground water. Additionally, the data indicate that unless leachate levels are maintained at very low levels it may be necessary to recycle leachate due to the significant levels of NO_x-N leaching out of pots. Further studies need to be conducted to follow the course of the leached materials through the ground to determine how much, if any, of the leached nitrates have the potential for reaching the surficial aquifer (ground water).

Literature Cited

1. Carriker, R.R. 1988. Groundwater, nurseries and government regulation. Florida Nurseryman 35(5):36–38.

2. Conover, C.A. and R.T. Poole. 1990. Light and fertilizer recommendations for production of acclimatized potted foliage plants. Nursery Digest 24(10):34–36, 58–59.

3. Conover, C.A. and R.T. Poole. 1992. Effect of fertilizer and irrigation on leachate levels of NH_4-N, NO_3-N, and P in container production of *Nephrolepis exaltata* 'Fluffy Ruffle'. J. Environ. Hort. 10:238–241.

4. Heatwole, C.D., A.B. Bottcher and L.B. Baldwin. 1987. Modeling cost-effectiveness of agricultural nonpoint pollution abatement programs on two Florida basins. Water Resources Bull. 23(1):127–131.

5. Hegewald, M. 1988. Setting the water quality agenda: 1988 and beyond. J. Water Pollution Control Federation 60:588–593.

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

7. Hubbard, R.K., G.J. Gascho, J.E. Hook, and W.G. Knisel. 1986. Nitrate movement into shallow ground water through a coastal plain sand. Amer. Soc. Agric. Eng. Trans. 29:1564–1571.

8. Hurlburt, S. 1988. The problem with nitrates. Water Well J. 42(8):37–42.

9. Ingram, D.L. and T.H. Yeager. 1987. Evaluation of slow-release fertilizers in Florida. Univ. of Fla., Inst. Food and Agric. Sci., The Woody Ornamentalist 12(11):5 pp.

10. Keeney, D.R. 1986. Sources of nitrate to ground water. Critical Reviews in Environ. Control 16:257–304.

11. Lee, L.K. and E.G. Nielsen. 1987. The extent and costs of groundwater contamination by agriculture. J. Soil and Water Conserv. 42:243–248.

12. McCall, J.W. 1983. Nitrogen sources for dieffenbachia. Res. Ext. Series, Hawaii Inst. Trop. Agric. and Human Resources No. 037:37–40.

13. Morey, D. 1987a. Arresting the problem. What growers are doing to regain control of runoff water quality. Nursery Business-Grower Edition 32(4):40–42, 44.

14. Morey, D. 1987b. Issue of the eighties? Could fertilizer pollution of groundwater be the coming 'big issue' for nursery growers? Nursery Business-Grower Edition 32(2):44–45.

15. Poole, R.T. and A.R. Chase. 1986. Growth of six ornamental plants and soluble salts of the growing media. Proc. Fla. State Hort. Soc. 99:278–280.

16. Poole, R.T. and C.A. Conover. 1982. Influence of leaching, fertilizer source and rate, and potting media on foliage plant growth, quality, and water utilization. J. Amer. Soc. Hort. Sci. 107:793–797.

17. Poole, R.T. and C.A. Conover. 1990. Leachate electrical conductivity and pH for ten foliage plants. J. Environ. Hort. 8:166–172.

18. 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.

19. Romander, L. 1988. Groundwater logic. Agrichemical Age 32(9):26–27, 29.

20. Sharpley, A.N., S.J. Smith and J.W. Naney. 1987. Environmental impact of agricultural nitrogen and phosphorus use. J. Agric. Food Chem. 35:812–817.