Effect of Leachate Fraction on Nitrate Loading to the Soil Profile Underlying a Greenhouse Crop[1]

R.J. McAvoy,[2] M.H. Brand,[2] E.G. Corbett,[3] J.W. Bartok, Jr.,[4] and A. Botacchi[5]
Department of Plant Science
University of Connecticut
Storrs, CT 06269-4067

Abstract

Poinsettia stock plants were grown in a greenhouse and irrigated with a 20 mM (280 ppm) N solution to produce a low (10%) or high (50%) leaching fraction (LF). At two week intervals, core samples were removed from the soil underlying the crop at 15 cm (6 in) increments to a depth of 90 cm (36 in). Leachate was collected from pots following each irrigation, and plant tissue and potting medium samples were collected. All samples (soil, leachate, plant tissue and potting medium) were analyzed for nitrate-N (NO_3-N) content. The rate of NO_3-N accumulation and the depth to which nitrate accumulated in the soil profile were significantly affected by leaching fraction. Under high LF treated plants, nitrate moved deeper into the soil profile and accumulated at higher concentrations than under low LF treated plants. Each irrigation event in the high LF treatment resulted in an average deposition of 243 ml (8.2 fl. ounces) of effluent containing 100 mg (3.53×10^{-3} oz) of NO_3-N. The average low LF irrigation event deposited an average of 65.7 ml (2.2 fl. ounces) of effluent containing 33.5 mg (1.18×10^{-3} oz) NO_3-N. Poinsettia cutting production and tissue nitrogen levels did not significantly differ between treatment groups.

Index words: Groundwater, crop management practices

Species used in this study: Poinsettia (*Euphorbia pulcherrima* Willd. cv. 'Lilo')

Significance to the Nursery Industry

Under film covered structures such as greenhouses, irrigation and fertilization practices directly affect the quantity and nutrient content of waste water deposited on the soil underlying the crop. Limiting waste water from containerized crops reduces both the downward movement of nitrate through the soil under the crop and the total nitrate load deposited on the soil surface. When low leach fraction irrigation practices are used, crop productivity is not adversely affected and less fertilizer (i.e. a lower rate) is required to maintain desired nutrient levels in the potting medium.

Introduction

Greenhouse agriculture is intensive, continues year-round and is heavily dependent on the regular use of nitrate-nitrogen (NO_3-N). Soils under greenhouse sites are often excessively compacted and the glazed structure excludes rainfall, altering hydraulic loading (and, presumably, the leaching patterns) at these sites.

There is strong evidence that considerable NO_3-N loading to groundwater occurs in the soil underlying greenhouses. In Europe, extremely high nitrate concentrations, up to 2000 kg N/Ha (1784.4 lbs/A), were found in the top meter of soil underlying commercial greenhouses (8). In Connecticut, NO_3-N accumulation exceeding 2300 kg/Ha (2052 lbs/A) was measured in the top meter of soil under decades-old greenhouses (9). Similar levels were found under old structures in New York (13).

Although these data indicate that greenhouses represent a potentially significant source of nitrate contamination, they do not indicate how specific crop management practices contribute to nitrate loading to groundwater, or how the exclusion of rainfall and increased soil compaction may influence nitrate movement through the soil profile.

Researchers have only recently begun to explore the effects of ornamental crop NO_3-N management practices on nitrate loading to the environment. Rathier and Frink (11) reported that both irrigation method and fertilizer form affected nitrogen runoff from containerized nursery stock grown in the field. Nitrogen runoff was reduced with trickle irrigation relative to overhead irrigation and with slow release fertilizer relative to soluble fertilizer. Wang and Boogher (12) examined the effect of hydrogel on the electrical conductivity (EC) of leachate from plants produced in shade house structures and reported leachate from hydrogel amended medium had higher salt levels than from medium without hydrogel. Rainfall was not excluded from either of these studies.

Poole and Conover (10) examined the effect of slow release fertilizer placement on foliage plants produced in glass greenhouses. Although the potential for ground water contamination was suggested, nitrate loading onto the soil and movement through the profile was not determined.

Studies related to greenhouse crop nutrient management practices have been primarily concerned with crop response, or changes in potting medium and leachate ion concentration (i.e. leachate EC), and have not addressed the effect of these practices on the soil profile underlying the crop. Ku and Hershey (6) studied the effect of leachate fraction on geraniums but only plant growth response was reported. Williams and Nelson (14) screened alternative slow release nitrogen sources with the intent of limiting environmental contamination, only plant growth response was reported.

[1]Received for publication December 16, 1991; in revised form June 8, 1992. Storrs Agricultural Experiment Station scientific contribution NO# 1425. This research was funded, in part, by the U.S. Department of Agriculture, Extension Service—under Special Project #90-EWQI-1-9212.

[2]Assistant professors, Plant Science Department.

[3]Associate professor, Plant Science Department.

[4]Professor of Extension, Department of Natural Resource Management and Engineering.

[5]Extension Educator, University of Connecticut Cooperative Extension System.

Conover and Poole (2) studied the effects of leachate fraction and fertilizer form on plant growth and NO_3^-, NH_4^+ and P ion content in the leachate. Fare et al. (3) implemented split-interval irrigation practices and reported a significant reduction in effluent volume. However, none of the above studies determined the fate of effluent in the soil profile.

Scientific scrutiny of existing management practices with regard to soil NO_3-N loading has not been reported. Consequently, little is known about the environmental impact caused by normal greenhouse ornamental crop management practices.

The objective of this study was to quantify changes over time in the NO_3-N profile in the top 0.9 meters (36 in) of soil underlying a greenhouse crop when low and high leaching fractions were used.

Materials and Methods

On July 2, 1990 rooted poinsettia cuttings (*Euphorbia pulcherrima* Willd. cv. 'Lilo') were planted in Fafard 2, a commercial peat:lite medium (Fafard, Inc., Agawam, MA), in 15 cm (6 in) plastic pots. The plants were then placed on top of soil filled boxes at a density of 25 per m^2 (20.9 per yd^2) and irrigated to attain a leachate fraction of either 0.1 or 0.5 (i.e. 10 or 50% LF). Leachate fraction is defined as the portion of the applied irrigation volume which leaches out of the growing container. At each irrigation, plants were fertilized with 20 mM (280 ppm) N from Peters 20N-4.4P-16.6K (20-10-20) water soluble fertilizer (Grace/Sierra, Cambridge, MA), with 60% of the nitrogen in the nitrate form.

One cubic meter wooden boxes were recessed into the earthen floor of a greenhouse and filled with soil screened through 1.6 cm (⅝ in) hardware cloth. Boxes were bottomless to establish contact to the sub-soil. The native soils underlying the greenhouse were placed in the boxes in stratified layers of similar depth to those in the existing greenhouse soil profile. The top 19 cm layer of soil (7.5 in) was a coarse sand, the next 51 cm layer (20 in) was a silty loam and the bottom 30 cm layer (12 in) was a clay loam. As each 15 cm (6 in) layer of soil was added to the box, the soil was compacted to simulate the conditions in a commerical greenhouse. Soil compaction was achieved by applying a uniform pressure of 5 lb/in^2 to each 6 inch soil layer. Prior to the start of the study, the soil was leached with tap water to reduce the level of residual NO_3-N in the profile. Residual levels were determined at the start of the experiment (week 0) by sampling the leached soil profile prior to the application of the experimental treatments.

Plants were irrigated when the potting medium became dry, about every 5 to 7 days on average (see Fig. 1). Prior to each irrigation, the water holding capacity of the pots was estimated by adding either 550 or 1000 ml of nutrient solution (18.6 or 33.8 fl. oz. respectively) to test plants located in the greenhouse but outside of the experimental matrix. The leachate quantity from these plants was measured and the amount of nutrient solution required to produce a 10% and a 50% leachate fraction was calculated. Nutrient solution volumes equal to the calculated 10% and 50% LF quantities were then applied by hand, directly to all 25 pots on each box using a graduated cylinder. Leachate was collected from each of three pots within each treatment group and actual leachate volume was determined using a graduated cylinder. Actual leachate volume and initial irrigation volume were used to calculate LF (i.e. LF = volume leached/volume applied). Leachate samples were frozen and stored in an ultra-low temperature freezer, at −60°C (−76°F), for future analysis. At two week intervals, July 2 to Sept. 24, 1990, a soil profile at 15 cm (6 in) increments to 0.9 meter (36 in) depth was obtained with a 1.9 cm (0.75 in) dutch auger from each box. Each box was divided into a 1 dm^2 (15.5 in^2) grid containing 100 possible sample sites and two soil cores were randomly selected from each box on each sampling date. Samples were immediately spread in a thin layer (1 cm or 0.4 in) and dried overnight at ambient temperature (20–25°C or 68–77°F) in a continuously ventilated room. Dried samples were then screened, and stored in acid washed bottles for future analysis. After removing samples, auger holes were filled with soil and the location marked so that sites were not re-sampled.

Poinsettia cuttings were harvested from stock plants on week six (Aug 13) and week 11 (Sept 17) and the number of cuttings recorded. Tissue was then dried at 70°C (158°F) and ground to pass a 40 mesh screen. At final harvest, potting medium samples were collected and dried for analysis.

NO_3-N was extracted from soil and media samples using 2N KCl and from plant tissue using an aqueous solution and quantitatively determined (5) using an Auto-Analyzer (Scientific Instruments Corp, Pleasantville, NY). Total nitrogen in plant tissue samples was determined with a thermal conductivity LECO LP-428 Nitrogen Determinator (LECO Corp, St. Joseph, MI).

Treatments were arranged in a completely random design with two replications per treatment. A separate box was used for each leachate fraction treatment and each treatment was replicated using identical soil boxes. NO_3-N concentrations in the low (10%) and high (50%) LF treatment soil profiles were compared at each depth on each sample date using one-way analysis of variance procedures (4). The effects of LF treatments over time, on NO_3-N concentrations at each soil depth, were determined using a split-plot analysis over time and single-degree-of-freedom orthogonal contrasts (4).

Results and Discussion

The actual LF obtained from the low (10%) LF treatment over the course of the 12-week study averaged 13% or 65.7 ml (2.2 fl. oz) of effluent per pot per irrigation. The high (50%) LF treatment resulted in an actual LF of 36% or 243 ml (8.2 fl. oz) of effluent per pot per irrigation (Fig. 1).

After four weeks of fertilization, NO_3-N concentrations were significantly higher ($P < 0.01$) in leachate from pots irrigated to 13% LF than from pots irrigated to 36% LF, Fig. 1. In the low (13%) LF treatment, NO_3-N concentrations averaged 509 mg NO_3-N/l (4.248×10^{-3} lbs/gal) of effluent over the course of the study. In the high (36%) LF treatment, NO_3-N concentrations averaged 411.6 mg/l (3.435×10^{-3} lbs/gal) of effluent.

These data demonstrate that effluent NO_3-N concentrations increased when LF's were reduced. Previously, Yelanich and Biernbaum (15) and Ku and Hershey (7) reported an increase in total electrical conductivity (EC) in response to reduced leach fractions. These studies are consistent in that one might expect individual ions to increase as overall salt levels (EC) increase.

Nitrate-N movement down through the vertical soil profile

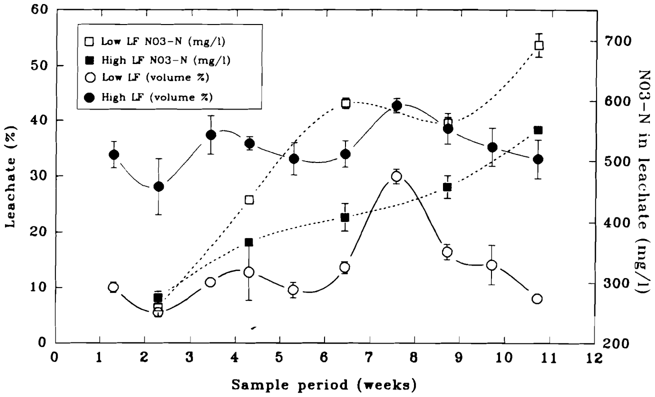

Fig. 1. Average leachate fraction (volume %) recorded following each irrigation event and NO_3-N concentration measured in the leachate from pots irrigated to produce either a low or high leachate fraction. Vertical bars represent ±S.E. of means, error bars which do not appear on graphs are smaller than symbols.

underlying the crop was directly influenced by the leachate fraction originating from the crop (Fig. 2A–F). As cumulative leachate volumes increased over time, NO_3-N moved deeper into the underlying soil profile and higher concentrations accumulated. No significant difference in the NO_3-N profile was detected, in the top 0.9 m (36 in) of soil under the low and high LF treatments, after four weeks (Fig. 2A and 2B). After six weeks, however, NO_3-N concentrations at the 0–15 cm (0–6 in) and 15–30 cm (6–12 in) depths became significantly higher ($P < 0.05$) under the high LF pots than under the low LF pots (Fig. 2C). At week eight, nitrate levels continued to increase under the high LF pots and NO_3-N concentrations began to increase in the 0–15 cm (0–6 in) depth under the low LF pots as well. After 10 weeks, NO_3-N at the 30–45 cm (12–18 in) depth of the high LF profile began to increase, reaching 25.5 mg/kg (4.09×10^{-4} oz/lb) a level more than double the week 0 to 8 average of 11.1 mg/kg (1.78×10^{-4} oz/lb). By comparison, the level of NO_3-N at the 30–45 cm (12–18 in) depth of the low LF profile only reached 16.3 mg/kg (2.61 ×

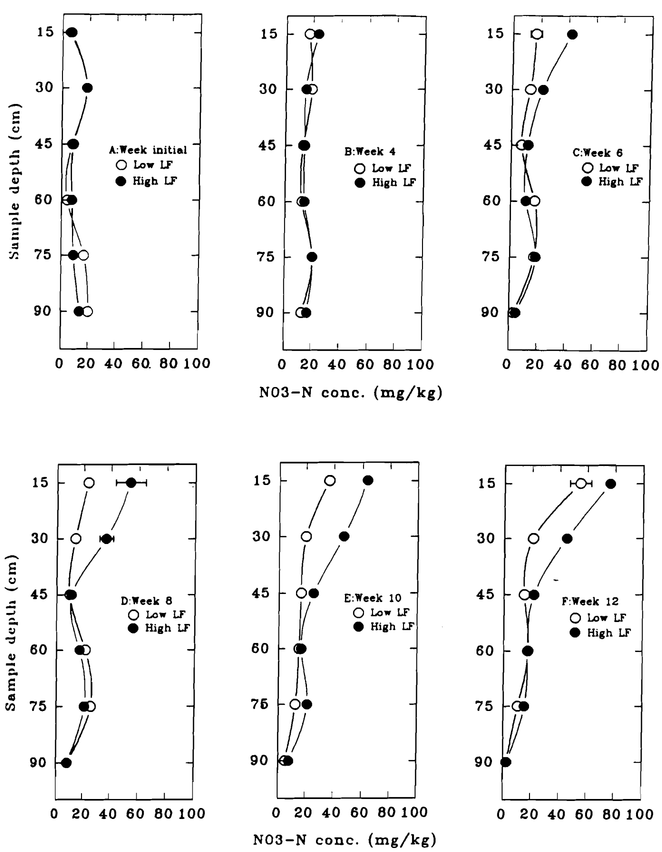

Fig. 2. NO_3-N profile in top 0.9 m (36 in) soil depth under both the low and high LF treated pots. NO_3-N profile (A) initial (week zero and two), (B) week four, (C) week six, (D) week eight, (E) week 10, and (F) week 12. Horizontal bars represent ±S.E. of means, error bars which do not appear on graphs are smaller than symbols.

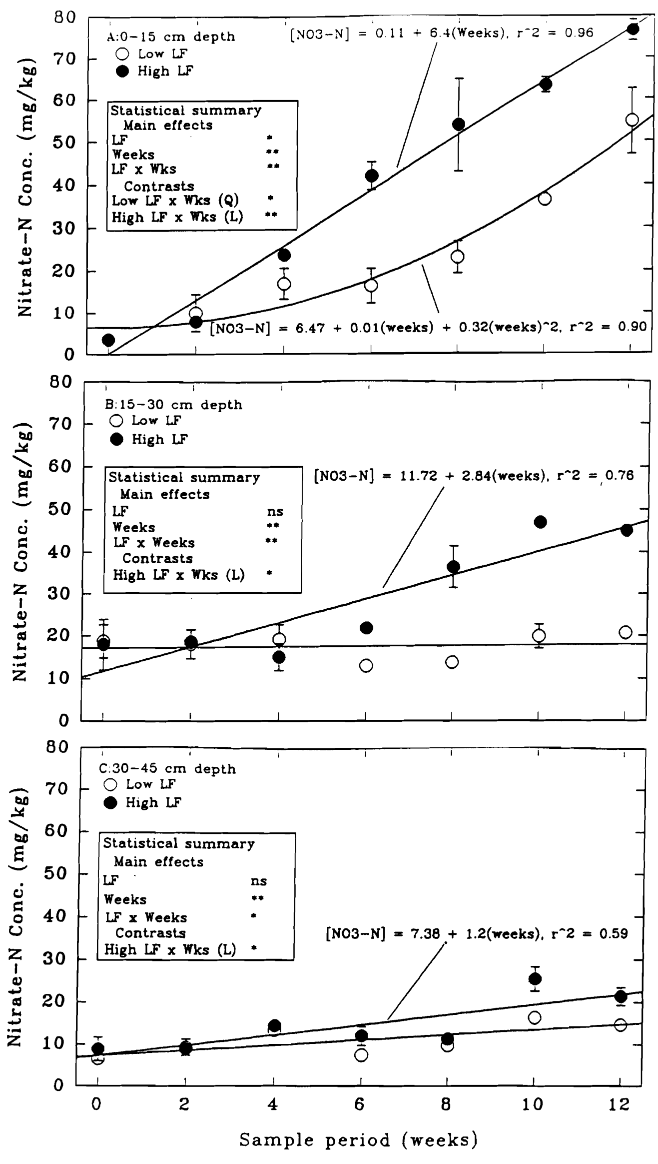

Fig. 3. Temporal change in NO_3-N concentrations in the soil under poinsettias irrigated to a low (13%) or high (36%) leach fraction at each irrigation: (A) 0–15 cm (0–6 in) depth, (B) 15–30 cm (6–12 in) depth, and (C) 30–45 cm (12–18 in) depth. The symbols *, **, and ns in the statistical summary denote significance at the 5% level, 1% level and non-significance, respectively. The (L) and (Q) designations following statistically significant single-degree-of-freedom orthogonal contrasts, indicate linear and quadratic effects respectively. Vertical bars represent ±S.E. of means, error bars which do not appear on graphs are smaller than symbols.

Table 1. Poinsettia cutting production (number per plant), tissue NO_3-N and total nitrogen content, and final NO_3-N levels in the potting medium under low and high LF irrigation regimes.

Treatment	Harvested cuttings per plant	Tissue NO_3-N (% of dry weight)	Total tissue N (% of dry weight)	NO_3-N in potting medium, μg/cm³ (lbs/ft³)
	Harvest date: August 13, 1990			
Low leachate fraction	5.2	0.320	6.42	—
High leachate fraction	4.9	0.341	6.39	—
Treatment effects	ns[z]	ns	ns	—
	Harvest date: September 17, 1990			
Low leachate fraction	5.3	0.310	6.72	294.1 (18.4×10^{-3})
High leachate fraction	5.8	0.314	6.63	225.2 (14.1×10^{-3})
Treatment effects	ns	ns	ns	**

[z]The notations ** and ns denote significant (1% level) and non-significant treatment effects respectively.

10^{-4} oz/lb) by week 10 (Fig. 2E). At week 12, NO_3-N in the 0–15 cm (0–6 in) depth of the low LF treatment continued to increase, however, no increase was detected at the 15–30 cm (6–12 in) depth for this treatment (Fig. 2F).

From these data, it appears two factors affect nitrate accumulation and movement in the soil profile. First, at low leach rates (i.e. the low LF treatment in our study), hydraulic loading is limited and nitrate does not move as far down through the soil profile as when higher leaching rates are used. Second, at low leach rates, a smaller total nitrate load is delivered to the soil surface relative to the nitrate load deposited under higher leach rates; this occurs even though low LF treatments result in effluent containing higher nitrate concentrations. For example (Fig. 1), under the low LF treatment, the average irrigation event resulted in a deposition of 33.5 mg (1.18×10^{-3} oz) NO_3-N (i.e. 65.7 ml or 2.2 fl oz of effluent with a NO_3-N concentration of 509 mg/l or 4.248×10^{-3} lbs/gal). Under the high LF treatment, each irrigation event deposited 100 mg (3.53×10^{-3} oz) NO_3-N (243 ml or 8.2 fl. oz of effluent with a NO_3-N concentration of 411.6 mg/l or 3.435×10^{-3} lbs/gal).

Temporal changes in soil NO_3-N accumulation varied significantly with leaching fraction at the 0–15 cm or 6 in ($P < 0.01$), 15–30 cm or 12 in ($P < 0.01$) and 30–45 cm or 18 in ($P < 0.05$) depths (Fig. 3A–C). In the top layer of soil (0–15 cm or 0–6 in), NO_3-N concentrations in the high LF profile displayed a significant linear increase over time ($P < 0.01$, $r^2 = 0.96$). Over the course of the study, NO_3-N concentrations were significantly higher ($P < 0.05$) under the high LF crop than under the low LF crop (Fig. 3A). At this same depth, NO_3-N levels in the low LF profile showed a significant quadratic increase over time ($P < 0.05$, $r^2 = 0.90$). At the 15–30 cm (6–12 in) soil depth, NO_3-N in the high LF soil profile increased linearly ($P < 0.01$, $r^2 = 0.76$) while NO_3-N concentrations in the low LF soil profile did not significantly change during the study. At the 30–45 cm (12–18 in) soil depth, a significant linear increase ($P < 0.05$, $r^2 = 0.59$) in the NO_3-N concentration in the high LF profile was observed over the course of the study. The low LF profile showed no increase in NO_3-N at this depth throughout the study. NO_3-N concentrations did not significantly change in the 45–90 cm (18–36 in) soil profile zones (data not shown) for either LF treatment during the 12-week study period.

Poinsettia cutting production and tissue nitrogen content, both NO_3-N and total N, were similar for plants produced under high and low leachate fraction regimes (Table 1). Ku and Hershey (7) also reported poinsettia growth to be unaffected by leachate fraction in the range 0 to 40%.

Final NO_3-N levels in the potting medium at the end of the study were significantly higher ($p < 0.01$) in the low LF treated pots than in the high LF treated pots (Table 1). NO_3-N concentrations in both leachate and potting medium were significantly higher at low leach rates than at high leach rates. As a result, leachate from the low LF treatment contained significantly higher NO_3-N levels than leachate from the high LF treatment when a similar fertilizer rate was used. Biernbaum (1991) showed that, with reduced leaching, a corresponding decrease in fertilizer concentration is required in order to maintain root medium electrical conductivity levels similar to those resulting from high LF's and high fertility levels.

The data obtained in this study indicate that altering irrigation management practices to reduce leach fractions when water soluble liquid fertilizer is applied, will decrease the movement of NO_3-N down through the soil profile and the accumulated levels of NO_3-N in the profile. These data also help to explain the excessively high levels of NO_3-N found in the soil profiles under decades old greenhouses. Through the exclusion of rainfall, hydraulic loading onto the soil profile and subsequent movement of soluble fertilizers down through the profile, is controlled exclusively by irrigation practices within the greenhouse. By limiting downward movement of water, NO_3-N levels accumulate in the upper layers of the underlying soil profile.

Reduced fertilizer rates coupled with lower LF's, as demonstrated by Biernbaum (1) and reinforced in this study, and the application of stricter irrigation practices as per Fare et al. (7) are recommendations which will help reduce nitrate loading to soil and its downward movement in the soil profile in a greenhouse crop management situation.

Literature Cited

1. Biernbaum, J.A. 1991. Greenhouse water management. Proc. 12th Ann. Conf. Hydroponics. pp. 30–37.

2. Conover, C.A. and R.T. Poole. 1990. Leachate levels of NH_4^+, NO_3^-, and P from *Nephrolepis* 'Green Valley' due to fertilizer source, irrigation level and time. HortScience 25(9):1170 (Abstract).

3. Fare, D.C., C.H. Gilliam, and G.J. Keever. 1991. Split-interval irrigation: Water effluent and Ageratum growth. HortScience 26(6):719 (Abstract).

4. Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley & Sons, New York, NY.

5. Keeney, D.R. and D.W. Nelson. 1982. Nitrogen-Inorganic forms. *In* Methods of Soil Analysis: Part 2. Chemical and Microbiological Properties. 2nd ed. *Edited by* A.L. Page, R.H. Miller, and D.R. Keeney. Madison, WI. pp. 643–693.

6. Ku, C.S.M. and D.R. Hershey. 1990. Potted geranium (*Pelargonium × hortorum*) growth with leaching fractions of 0 to 0.4. HortScience 25(9):1104 (Abstract).

7. Ku, C.S.M. and D.R. Hershey. 1991. Leachate electrical conductivity and growth of potted poinsettia with leaching fractions of 0 to 0.4. J. Amer. Soc. Hort. Sci. 116:802–806.

8. Molitor, H-D. 1990. The European perspective with emphasis on subirrigation and recirculation of water and nutrients. Acta Hort. 272:165–173.

9. McAvoy, R.J., M.H. Brand, E.G. Corbett, J.W. Bartok, Jr. and A. Botacchi. Unpublished data. Department of Plant Science, Univ. Connecticut, Storrs.

10. Poole, R.T. and C.A. Conover. 1989. Fertilization of four indoor foliage plants with Osmocote or Nutricote. J. Environ. Hort. 7:102–108.

11. 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.

12. Wang, Y-T. and C.A. Boogher. 1987. Effect of medium-incorporated hydrogel on plant growth and water use of two foliage species. J. Environ. Hort. 5:125–127.

13. Walker, M. 1990. Cornell University Greenhouse Study Report. New York State Water Resources Institute. Cornell University. pp. 1–12.

14. Williams, K.A. and P.V. Nelson. 1990. Development of a nutrient source for sustaining low concentrations in greenhouse substrates. HortScience 25(9):1170 (Abstract).

15. Yelanich, M.V. and J.A. Biernbaum. 1990. Effect of fertilizer concentration and method of application on media nutrient content, nitrogen runoff and growth of *Euphorbia pulcherrima* V-14 Glory. Acta Hort. 272:185–189.

Micropropagation and Field Establishment of *Tiarella cordifolia*[1]

S.L. Kitto and A. Hoopes[2]
Delaware Agricultural Experiment Station
Department of Plant and Soil Sciences
College of Agricultural Sciences
University of Delaware
Newark, DE 19717

Abstract

Tiarella cordifolia L. (foamflower) was proliferated on an MS-based nutrient medium. Proliferation was maximal on medium gelled with 0.4% Difco-Bacto agar containing 1.0 mg benzyladenine (BA)/l and 0 or 0.025 mg naphthaleneacetic acid (NAA)/l. Proliferation of *T. cordifolia* var. *collina* was maximal on medium gelled with Gelrite® containing 0.25, 0.5 or 1.0 mg BA/l plus NAA (0, 0.025, 0.05, 0.1, 0.5 mg/l). Greenhouse rooting and survival was directly related to an increase in microcutting length, whereas leaf number (two to six leaves per microcutting) had no effect. At least 48% of the microcuttings of *T. cordifolia* inserted directly in the field rooted and survived.

Index words: native plant, tissue culture, herbaceous perennial, Saxifragaceae

Significance to the Nursery Industry

Methods are described for rapid clonal mircopropagation of the native herbaceous perennial, *Tiarella cordifolia* (foamflower). This research demonstrates that microcuttings of *T. cordifolia* are fairly resilient. Thus nurseries should be able to purchase less expensive Stage II microcuttings from commercial tissue culture companies and root them with little difficulty. One advantage of this tissue culture protocol is that for plants found to have desirable characteristics, potentially new cultivars, can be quickly multiplied and made available to the public.

[1]Received for publication February 14, 1992; in revised form June 12, 1992. Published as Miscellaneous Paper no. 1398 of the Delaware Agricultural Experiment Station. This research was supported in part by an Undergraduate Research Grant from the University of Delaware Honors Program. The authors wish to thank Dr. J. Pesek for statistical assistance.

[2]Associate Professor of Horticulture and former student, resp.

Introduction

As demand for native plants in the landscape increases, nurserymen must seek more economical means of propagation (9, 13) since collecting of plants in the wild is harmful to the environment and such plants are less likely to survive transplanting (7, 13). Propagation of selected natives using conventional methods such as division is a slow process compared to micropropagation which offers economical, year-round production in a disease-free environment. However, while in vitro proliferation is relatively inexpensive, the rooting/acclimatization phase is labor intensive and usually requires a greenhouse with a mist or high humidity system (5). Therefore, there is interest in developing protocols for direct field establishment of microcuttings both to reduce costs and to improve acclimatization success (2).

Tiarella cordifolia (foamflower) is a native perennial groundcover of rosette growth habit having evergreen leaves.