Mid-Season Reapplication of Controlled Release Fertilizers Affect 'Helleri' Holly Growth and N Content of Substrate Solution and Effluent[1]

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Abstract

The objective of this study was to determine how a mid-season CRF (controlled release fertilizer) reapplication to container-grown *Ilex crenata* 'Helleri' Thunb. affected growth, substrate solution N content, and the amount on N leached compared to a single early season CRF application (control). 'Helleri' holly liners were initially fertilized (March 7) with an 8 to 9 month CRF, Osmocote 18N-2.6P-9.9K (18-6-12), or a 12 to 14 month CRF, Osmocote 17N-3.1P-9.9K (17-7-12). A subset of plants received a CRF reapplication (half rate) of the respective Osmocote formulation on July 19, August 2, or August 16. In addition, 12 plants received a water soluble fertilizer solution (WSF) with each irrigation starting on July 19. All effluent was collected and analyzed for N. Substrate solution N and electrical conductivity (EC) levels (via the pour-through method) and foliar N concentrations were determined every two weeks. Throughout the experiment, plants were irrigated with an irrigation amount that resulted in an $\approx$ 0.25 leaching fraction (LF). Plant width was determined on November 1. Plant width values were higher for the first and second reapplication and WSF treatments for both formulations than the control. However, in terms of commercial size grades, plants of all treatments were in the same grade. Thus, there was no economic advantage to reapplying CRF. We concluded that CRF reapplication was not necessary when substrate solution N and foliar N values were $\geq$ 20 mg N/liter and $\geq$ 2.3%, respectively. Irrigating at a LF of 0.2, the mid-season CRF application increased the amount of N lost from containers by 42% compared to a single, early season CRF application.

Index words: leaching fraction, container-grown, electrical conductivity.

Significance to the Nursery Industry

Compared to early season values, substrate solution N and EC (electrical conductivity) values for plants fertilized with controlled release fertilizers (CRFs) are at relatively low levels during the latter half of the growing season. Growers must then determine whether these low levels are suboptimal in terms of producing plants of a desired size and whether to reapply CRF during the growing season. We found that 'Helleri' holly that received a mid-season CRF reapplication were larger than plants that received a single early season CRF application but the increase in plant width was about 5 cm (2 in). Thus, plants of both treatments would be sold in the same size category, and hence reapplication did not increase the economic value of the plants. By relating substrate solution data with growth data, we concluded that there was no advantage to mid-season CRF reapplication if

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the substrate solution N and foliar N values were ≥ 20 mg/liter and ≥ 2.3%, respectively. Compared to a single, early season CRF application, mid-season CRF reapplication increased the amount of N leached from the container by as much as 42%. Thus, the decision to reapply CRF not only requires determining whether the larger plant size as a result of reapplication will more than offset the cost of reapplication, but also requires considering the impact of the additional nutrients entering ground and surface water.

Introduction

Nutrients are predominately supplied to container-grown plants by two methods, water soluble fertilizer (WSF) or controlled-release fertilizer (CRF) and both methods are effective (4). However, on the basis of N leached from containers, CRFs have been shown to be the more efficient method of N application (1, 6, 12). Generally, substrate nutrient concentrations for CRF-fertilized soilless substrates gradually decrease over time (5, 10). Thus, growers must judge fertilizer sufficiency and the need for CRF reapplication by plant appearance and substrate solution N and electrical conductivity (EC) values. There are only a few reports (7, 13, 18) that suggested minimum substrate solution N and EC values for CRFs; these values were usually less than the 50 mg N/liter and 0.5 dS/m EC values considered to be minimum levels for WSF-fertilized plants (17). Wright and Niemiera (18) showed that dry weight of *Ilex crenata* Thunb. 'Helleri' was highest when Osmocote reapplication coincided with a substrate NO_3-N concentration of 10 mg/liter and an EC level of 0.2 dS/m. Jarrell et al. (7), working with two CRFs, reported greatest shoot fresh weights of *Ligustrum texanum* (Thunb.) were obtained when average leachate N concentration was in the range of 100 to 200 mg/liter. However, this range was the average of leachate N concentrations throughout the experiment and may not indicate a minimum. Since container-grown plants are usually sold on the basis of size, any decision to reapply CRF is dependent on 1) whether the extra growth resulting from reapplication, and hence profit, offsets the cost of CRF reapplication, and 2) the impact of CRF reapplication on the environment. Ruter (13), using a growth index as a measure of plant size, indicated that an EC value < 0.2 dS/m within 90 days of CRF application signaled the need for CRF reapplication for maximum growth of *Ilex cornuta* Lindl. & Paxt. 'Burfordii' and *Ilex* x 'Nellie R. Stevens'. However, Ruter developed a predictive relationship between substrate EC and leachate NO_3-N (NO_3-N = EC • 414) using data from three CRFs. The relationship indicated that an EC of 0.2 dS/m was equal to a substrate NO_3-N concentration of 83 mg/liter, which is similar to values recommended for WSF regimes (17). Objectives of this work are to determine 1) how an early season CRF application and a mid-season CRF reapplication to container-grown 'Helleri' holly affects substrate solution N and EC, foliar N, the amount of N leached, and plant size, 2) if the increase in growth justified CRF application, and 3) N leaching losses for CRF application and reapplication treatments.

Materials and Methods

Multiple-branched, rooted cuttings of *Ilex crenata* 'Helleri' were transplanted on March 7, 1991, into one hundred twenty 9.5 liters (10 qt), 22 cm (8.7 in) diam, 25 cm (9.8 in) depth, plastic containers filled with a pine bark *(Pinus taeda L.)*:sand substrate (9:1 by vol). The substrate had a particle analysis distribution (by weight) of 18.1% > 2.80 mm, 22.9% > 1.00 mm, 34.0% > 0.25 mm, and 25.0% < 0.25 mm. Following transplanting, 60 plants received a surface application of 54 g (1.9 oz) per container of Osmocote 18N-2.6P-9.9K (18-6-12), 8 to 9 months release time (Grace-Sierra, Milpitas, CA) or 74.5 g (2.6 oz) of Osmocote 17N-3.1P-9.9K (17-7-12) per container, 12 to 14 months release time (manufacturer's recommended rates). Plants were grown pot-

Table 1. Effect of reapplications of 8 to 9 month Osmocote and LF supplement on substrate solution N concentration of 'Helleri' holly measured every two weeks.

	Substrate solution N concentration (mg/l)					
	Initial application	Liquid fertilizer	Reapplication date			
Date	March 7	July 19	July 19	August 2	August 16	SE
March 27	138	—	—	—	—	
April 11	185	—	—	—	—	
April 27	205	—	—	—	—	
May 9	240	—	—	—	—	
May 23	324	—	—	—	—	
June 8	97	—	—	—	—	
June 21	117	—	—	—	—	
July 3	114	—	—	—	—	
July 17	80	—	—	—	—	
July 31	88	98	195	—	—	10.0 (36)[z]
August 14	40	90	97	148	—	6.9 (48)
August 31	20	60	61	60	69	3.1 (60)
September 14	8	39	34	28	30	2.1 (60)
September 27	6	34	22	29	22	1.8 (56)
October 12	3	30	8	7	9	1.4 (59)
October 24	3	8	7	8	8	0.5 (60)
SE	7.1 (191)	4.0 (83)	7.3 (83)	6.1 (71)	3.3 (59)	

[z]Number in parentheses = n.

to-pot on raised benches in a greenhouse vented at 24°C (75°F) during the day and heated to a night minimum of 18°C (64°F) under natural photoperiod from March 7 to May 15, 1991; maximum greenhouse air temperature was 31°C (88°F). From May 15 to November 1, 1991, plants were grown on a gravel bed in an outdoor nursery (Blacksburg, VA), at a spacing of 81 cm (32 in) between containers. Plants were hand irrigated (beaker-applied) with a volume of water to maintain a LF of about 0.25; water EC was 0.1 dS/m. Irrigation frequency was usually daily or every other day depending on plant need for water. At two-week intervals beginning on March 27, container substrate solution was extracted using the pour-through (PT) technique (16) and analyzed for NO_3-N, NH_4-N (ion-selective electrodes) and EC.

Throughout the experiment, liquid exiting containers (leachate) whether resulting from irrigation or rain, drained into collecting pans beneath each container. Containers were placed on PVC rings (height = 4 cm) within collecting pans to prevent substrate from re-absorbing the accumulated solution. Aluminum foil shields were fitted around containers and collecting pans to prevent extraneous water from entering the pans. Two hours after each irrigation or as soon as possible after a rain, leachate volume was measured and a sub-sample collected weekly from six plants per treatment for each CRF formulation. Samples were stored at 2°C (35°F) and analyzed for NO_3-N and NH_4-N concentrations using ion-selective electrodes. Total N was calculated by multiplying the ion concentration by the leachate volume.

On July 19, August 2, or August 16, 12 plants from each fertilizer formulation treatment (8 to 9 month and 12 to 14 month) received a reapplication of the respective fertilizer at half the initial rate; a set of 12 plants did not receive a CRF reapplication and were regarded as the control treatment. Data from similar experiments were used to select these dates which corresponded to relatively low leachate N concentrations and potential growth responses to CRF reapplication. In addition to CRF reapplication treatments, a set of 12 plants from each fertilizer formulation received a WSF treatment at each irrigation (LF = 0.25) beginning on July 19. Nutrient content of the WSF solution was 50 mg N/liter, 10 mg P/liter, and 35 mg K/liter, supplied by NH_4NO_3, H_3PO_4, and KCl, respectively.

Approximately 25 leaves of the most recently matured foliage from one plant per treatment per block were harvested on PT dates, and analyzed for N using a modified micro-Kjeldahl method (11). On November 1, plant canopy widths were determined by measuring two canopy widths (perpendicular measurements) per plant. Plants were arranged in a randomized complete block design with six blocks and two plants per treatment per block. Plant width was analyzed by ANOVA and Duncan's mean separation using SAS (SAS Inst., Cary, NC). PROC GLM was used to determine the relationship between substrate solution EC and N concentration data.

Results and Discussion

Substrate solution (via PT) and foliar N data for the 8 to 9 month Osmocote formulation were similar to the 12 to 14 month formulation and therefore only data for the former formulation are presented. Substrate solution N and EC levels for the control treatment (initial CRF application without reapplication) were relatively high from March 27 to May 23, decreased abruptly, and then gradually decreased throughout the experiment (Tables 1, 2). These relatively high leachate N concentrations may be related to an initially high release characteristic of the fertilizer prills. Compared to the control treatment, substrate solution N concentrations following CRF reapplication (half rate) were high. Osmocote nutrient release is temperature dependent (8, 9); however, separation of the effects of temperature and fertilizer prill release characteristics was not possible in this study. The decreasing trend of substrate solution N from June 8

Table 2. Effect of reapplications of 8 to 9 month Osmocote and LF supplement on substrate solution EC of 'Helleri' holly measured every two weeks.

	Substrate solution EC (dS/m)					
	Initial application	Liquid fertilizer	Reapplication date			
Date	March 7	July 19	July 19	August 2	August 16	SE
March 27	1.5	—	—	—	—	
April 11	1.8	—	—	—	—	
April 27	2.0	—	—	—	—	
May 9	2.0	—	—	—	—	
May 23	2.4	—	—	—	—	
June 8	1.0	—	—	—	—	
June 21	1.0	—	—	—	—	
July 3	0.8	—	—	—	—	
July 17	0.9	—	—	—	—	
July 31	0.8	1.0	1.7	—	—	0.09 (36)[z]
August 14	0.4	0.9	0.9	1.1	—	0.05 (48)
August 31	0.3	0.7	0.7	0.7	0.7	0.03 (60)
September 14	0.3	0.6	0.6	0.6	0.5	0.02 (60)
September 27	0.2	0.6	0.5	0.5	0.4	0.02 (55)
October 12	0.2	0.5	0.4	0.3	0.3	0.02 (59)
October 24	0.2	0.3	0.3	0.4	0.3	0.01 (60)
SE	0.06 (192)	0.04 (82)	0.05 (84)	0.04 (70)	0.02 (58)	

[z]Number in parentheses = n.

and thereafter was similar to that described by Harbaugh and Wilfret (5), Meadows and Fuller (10) and Ruter (13). Within one to two weeks following application of WSF (commenced July 19) and CRF reapplication (reapplied at ½ initial rate on July 19, August 2, or August 16), substrate solution N and EC values were higher than control treatment values (Tables 1, 2); similar to the control treatment, values for CRF reapplication treatments gradually decreased with time. Increases and decreases in foliage N concentrations for both CRF formulations, and WSF and reapplication treatments (Table 3) generally corresponded to increases and decreases in substrate solution N concentrations.

For both CRF formulations, canopy widths were larger for plants in the WSF and reapplication treatments 1 and 2 than for the control treatment (Table 4). For 'Helleri' holly and shrubs with a similar canopy, plant width is generally the commercial criterion for establishing plant grade and hence price. In terms of commercial size grades, plants in all treatments for both formulations would be sold in the 53 to 61 cm (24 to 30 in) grade. Since plants of all treatments would be sold in the same size grade, there would be no economic advantage to CRF reapplication or WSF supplementation. In plant hardiness zone 6 (USDA), nursery-grown plants would not be fertilized after August to avoid a late season growth flush which would not have ample time to harden off and would be vulnerable to low temperature damage. In Aug. the minimum substrate N concentration and EC values were 20 mg/liter and 0.3 dS/m, respectively. Thus, we concluded that during the mid to late growing season a substrate solution N concentration of 20 mg/liter and an EC value of 0.3 dS/m are sufficient. Wright and Niemiera (18) and Ruter (13) suggested that a 0.2 dS/m value signalled CRF reapplication which implied that the substrate solution EC values of this experiment were approaching a minimum. Because irrigation water electrolyte content varies depending on water source, a threshold EC value to signal reapplication should be based on the specific fertilizer used and on the EC of the indigenous water supply. Irrigation water EC of this work was 0.1 dS/m and our recommendation of 0.2 dS/m is only valid for nurseries with an irrigation water EC of ≤ 0.1 dS/m. In this work, foliar N concentrations for July 31 and August 14 were 2.3% (Table 3). Thus, we consider a foliar N concentration of 2.3% to be adequate for CRF-fertilized plants which was the similar to the 2.4% adequacy value found by Wright and Niemiera (18).

In a WSF regime, reapplication of a WSF to plants is recommended (18) when pour-through or leachate N concentrations and EC values are less than 50 to 100 mg/liter and 0.5 to 1.0, respectively, which contrasts the relatively low CRF N concentrations and EC values that signal CRF reapplication. The reason that recommended substrate solution N and EC levels are lower for CRF than WSF may be due to the fact that under most growing conditions CRF nutrient release to the substrate solution is constant; with a WSF regime, nutrient resupply only occurs when fertilizer is injected into the irrigation system (except for nutrient release from the substrate). In support of this hypothesis, plant nutrition studies that supplied a relatively low but constant supply of nutrients via recirculating nutrient solutions or frequently applied solutions showed acceptable growth of many species at ultralow N concentrations (< 10 mg/liter) (2, 3, 15). Williams and Nelson (14) showed maximum dry weight of container-grown *Dendranthema* x *grandiflorum* (Ramat.) when a 7 mg N/liter solution was applied 14 times a day. Thus, similar to recirculating or frequently applied solutions, the relatively constant CRF nutrient release may result in a nutrient supply entering the rhizosphere of CRF-fertilized plants that is greater than for WSF-fertilized plants. Current understanding of how CRFs supply nutrients to roots is very limited and further investigation is needed.

Relatively high amounts of N were leached in mid to late May from containers of control plants (Fig. 1). These high amounts were most likely associated with the April and May peaks in substrate solution N concentrations (Table 1) which

Table 3. Effect of reapplications of 8 to 9 month Osmocote and LF supplement on foliar N concentration of 'Helleri' holly measured every two weeks.

	Foliar N (%)					
	Initial application	Liquid fertilizer	Reapplication date			
Date	March 7	July 19	July 19	August 2	August 16	SE
March 27	2.2	—	—	—	—	
April 11	2.7	—	—	—	—	
April 27	3.0	—	—	—	—	
May 9	3.0	—	—	—	—	
May 23	2.7	—	—	—	—	
June 8	2.9	—	—	—	—	
June 21	2.5	—	—	—	—	
July 3	2.6	—	—	—	—	
July 17	2.2	—	—	—	—	
July 31	2.3	1.9	2.0	—	—	0.08 (18)[z]
August 14	2.3	2.5	2.4	2.6	—	0.03 (24)
August 31	2.0	2.2	2.3	2.3	2.3	0.03 (30)
September 14	1.9	1.9	1.9	1.9	1.9	0.04 (30)
September 27	1.9	2.0	2.1	2.2	2.0	0.04 (30)
October 12	1.9	2.0	1.9	1.9	2.1	0.03 (29)
October 24	1.9	2.1	2.3	2.3	2.2	0.06 (30)
SE	0.05 (96)	0.04 (41)	0.05 (42)	0.05 (36)	0.04 (30)	

[z]Number in parentheses = n.

Table 4. 'Helleri' holly canopy widths after one growing season for the control, LF, and reapplication treatments fertilized with 8 to 9 or 12 to 14 month Osmocote.

	Plant width (cm)[z]	
	Fertilizer type	
Treatment	8 to 9 Month	12 to 14 Month
Control March 7	61 c[y]	61 d
Liquid fertilizer July 19	66 a	71 a
Reapplication 1 July 19	66 a	66 b
Reapplication 2 August 2	64 ab	65 bc
Reapplication 3 August 16	62 bc	63 cd

[z]Plant widths equation: $(W_1 + W_2) / 2$.
[y]Means separation within column by Duncan's multiple range test, P = 0.05.

we hypothesized to be a result of the nutrient release characteristic of the Osmocote prills. The lag time between the dates of high substrate solution N concentrations (Table 1) and peaks in N leached (Fig. 1), about four weeks, was most likely due to the less frequent irrigations at the beginning of the growing season. The weekly amounts of N leached during September and October for the control and reapplication treatments were generally low, which was most likely due to low temperature effecting a reduced N release by CRF prills. As in the beginning of the experiment, irrigation frequency for all treatments was less than during the mid-season which decreased the amount of N leached. Despite the fact the relatively low weekly amounts of N were lost late in the growing season, cumulative N losses during these months would be significant for a large scale commercial nursery. The pattern of N leached for all treatments of the 12 to 14 month formulation (data not shown) was similar to respective 8 to 9 month formulation treatments.

Using substrate solution data for the 8 to 9 month formulation during the 1991 growing season, we found a strong relationship between substrate solution EC and N (NO_3-N + NH_4-N), N conc = (126.8 • EC) – 27.8 (R^2 = 0.91, P = 0.05). A similar relationship was found for the 12 to 14 month formulation (data not shown). Ruter (13) also showed a strong relationship between substrate solution EC and NO_3-N. Since the relationship between EC and NO_3-N is most likely fertilizer specific and because irrigation water electrolyte content varies depending on water source, a threshold EC value to signal CRF reapplication should be based on the specific fertilizer used and on the EC of the indigenous water supply.

For the 8 to 9 month formulation, the amounts of N leached during the experiment for the control, CRF reapplications 1, 2, and 3, and WSF treatment were 2.1, 0.9, 0.5, 0.4, and 1.0 g, respectively (different at P = 0.05). By adding the amount of N leached in the control treatment to amount of N leached for each of the other treatments, the total amounts of N leached per container over the course of the experiment were 3.0, 2.6, 2.5, and 3.1 g for the CRF reapplication

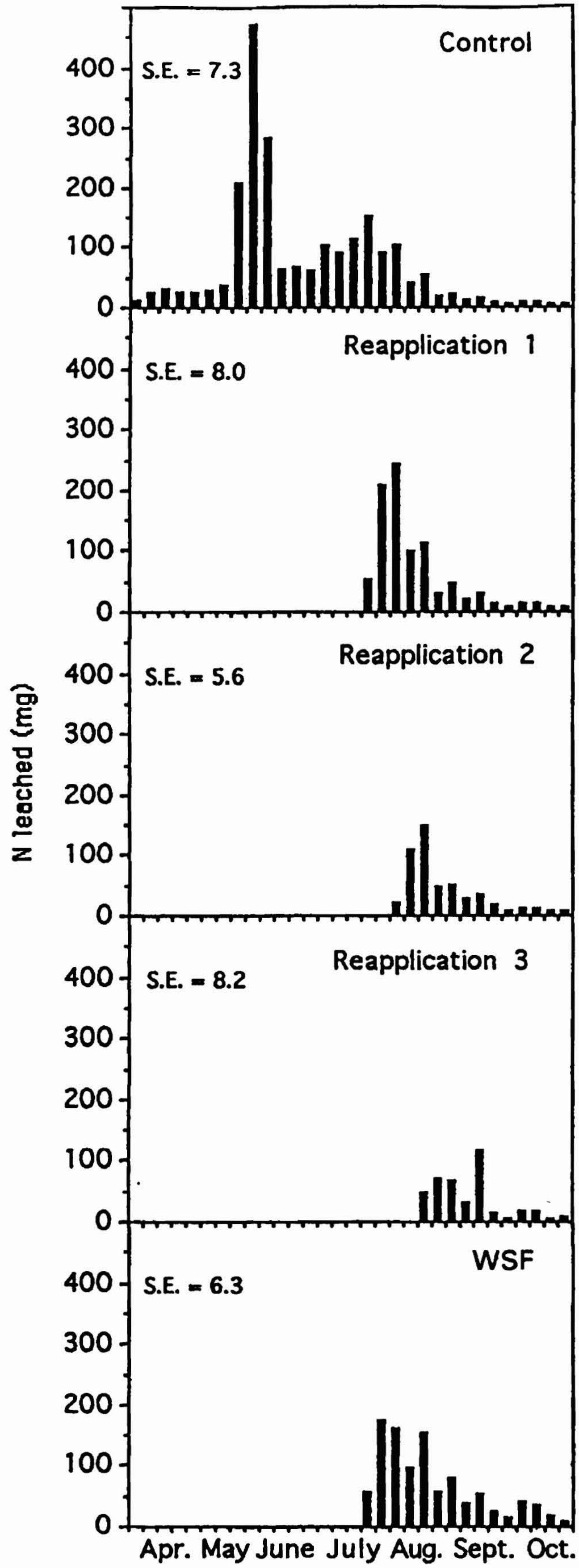

Fig. 1. Nitrogen leached from containers (8 to 9 month formulation) for control, reapplications 1 (July 19), 2 (August 2), and 3 (August 16) and WSF treatments measured weekly.

treatments 1, 2, 3 and the WSF treatment, respectively. Thus, compared to a single, early season CRF application, a CRF reapplication (half rate) increased N leaching losses by as much as 42%. A grower's irrigation practices greatly impacts the amount of leaching that occurs. We irrigated at a LF of 0.2, which is somewhat typical of a nursery operation. By reducing the LF, the amount of N leached will also be reduced. Regardless of fertilizer type, the impact of fertilizer application or reapplication as well as irrigation technique on the amount of N lost to the environment must be considered.

Literature Cited

1. Brown, K.W., J.C. Thomas, and R.L Duble. 1982. Nitrogen source effect on nitrate and ammonium leaching and runoff losses from greens. Agron. J. 74:947–950.

2. Clement, C.R., M.J. Hopper, R.J. Canaway, and J. Jones. 1974. A system for measuring the uptake of ions by plants from a flowing solutions of controlled composition. J. Expt. Bot. 24:81–99.

3. Elliot, G.C. and P.V. Nelson. 1983. Relationships among nitrogen accumulation, nitrogen assimilation, and plant growth in chrysanthemums. Physiol. Plant. 57:250–259.

4. Gouin, F.R. and C.B. Link. 1973. Growth response of container-grown woody ornamentals to slow-release fertilizers. HortScience 8:208–209.

5. Harbaugh, B.K. and G.J. Wilfret. 1982. Correct temperature is the key to successful use of Osmocote. Florists' Rev. 170:21–23.

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

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

8. Lamont, G.P., R.J. Worrall, M.A. O'Connell. 1987. The effects of temperature and time on the solubility of resin-coated controlled-release fertilizers under laboratory and field conditions. Scientia Hort. 32:265–273.

9. Maynard, D.N. and O.A. Lorenz. 1979. Controlled-release fertilizers for horticultural crops, p. 79–97. *In*: J. Janick (ed.). Hort. Reviews. Vol. 1. AVI, Westport, CT.

10. Meadows, W.A. and D.L. Fuller. 1983. Nitrogen and potassium release patterns of five formulations of Osmocote fertilizers and two micronutrient mixes for container grown woody ornamentals. Southern Nurserymen's Assoc. Nursery Res. 9:28–34.

11. Peterson, H.C. and G. Chester. 1964. A reliable total nitrogen determination of plant tissue accumulation nitrate nitrogen. Agron. J. 56:89–90.

12. 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.

13. Ruter, J.M. 1992. Leachate nutrient content and growth of two hollies as influenced by controlled release fertilizers. J. Environ. Hort. 10:162–166.

14. Williams, K.A. and P.V. Nelson. 1992. Growth of chrysanthemum at low, relatively steady nutrient levels in a commercial-style substrate. HortScience 27:877–880.

15. Winsor, G.W. and D.M. Massey. 1978. Some aspects of the nutrition of tomatoes grown in recirculating solution. Acta Hort. 82:121–132.

16. Wright, R.D. 1986. The pour-through nutrient extraction procedure. HortScience 21:227–229.

17. Wright, R.D. and A.X. Niemiera. 1987. Nutrition of container-grown woody nursery crops, p. 75–101. *In*: Hort. Reviews. J. Janick (ed.) Vol. 9. Van Nostrand Reinhold, New York, NY.

18. Wright, R.D. A.X. Niemiera. 1991. Timing of Osmocote reapplication on growth of 'Helleri' holly. Proc. Southern Nurserymen's Assoc. Res. Conf. 36:74–76.