

**Criteria Signaling Reapplication of Controlled-release  
Fertilizer for Maximum Growth of *Ilex crenata* Thunb. 'Helleri'**

by

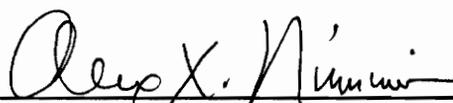
Melinda Cole Shiflett

Thesis submitted to the Faculty of the  
Virginia Polytechnic Institute and State University  
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Master of Science

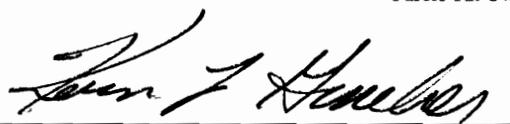
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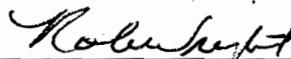
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**Criteria Signaling Reapplication of Controlled-release  
Fertilizer for Maximum Growth of *Ilex crenata* Thunb. 'Helleri'**

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Alex X. Niemiera, Committee Chairman

Horticulture

(ABSTRACT)

Medium solution N and electrical conductivity (EC), and foliar N levels were measured to determine criteria which signal the need for reapplication of a controlled-release fertilizer (CRF) in order to maximize growth of container-grown *Ilex crenata* Thunb. 'Helleri'. Rooted cuttings of 'Helleri' holly were initially fertilized (7 Mar. 1991) with 8-9 month (18N-2.6P-9.9K) or 12-14 month (17N-3.1P-9.9K) Osmocote. A subset of 12 plants received a CRF reapplication (half rate) of the respective Osmocote formulation on 19 July, 2 Aug., or 16 Aug. In addition to reapplication treatments, 12 plants received a liquid fertilizer (LF) solution with each irrigation starting on 19 July. Canopy widths of plants receiving LF or CRF reapplication on 19 July and 2 Aug. were greater than those plants without supplemental fertilizer (control). At the time of the second reapplication date (2 Aug.), medium solution N and EC, and foliar N levels of control plants were  $\approx 40 \text{ mg}\cdot\text{liter}^{-1}$ ,  $0.4 \text{ dS}\cdot\text{m}^{-1}$  and 2.3%, respectively. Since growth of control plants was less

than those of LF, CRF 19 July and 2 Aug. reapplications, medium solution N and EC, and foliar N values at the time of the second reapplication (2 Aug.) signaled the need for CRF reapplication or LF supplementation. There was a strong relationship between medium solution EC and N ( $\text{NO}_3 + \text{NH}_4$ ) ( $r^2 = 0.91$ ,  $P = 0.05$ ), indicating that growers could use EC measurements to predict medium solution N concentration, as well as to assess the adequacy of the fertilizer regime.

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## DEDICATION

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"The more you know,  
the less knowing the *meaning* of things means...  
so, forget the meaning of life."

..."it's not so much *what* we know,  
but *how* we know, and what  
it is about us that *needs* to know."

..."So, maybe we should  
stop trying to figure out the *meaning* of life  
and sit back and  
enjoy the *mystery* of life."

-Jane Wagner

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# CHAPTER ONE

## Literature Review

In recent years, the U.S. government and the public have become greatly concerned with, and involved in, the preservation of the environment. One of the leading environmental issues is nitrogen (N) contamination of surface water and groundwater by agriculture. The concern with nitrate ( $\text{NO}_3\text{-N}$ ) pollution in water supplies arises from the potential risk of methemoglobinemia, a disorder which reduces the oxygen carrying capacity of hemoglobin in the blood of bottle-fed infants (Coppock and Meyer, 1980). Consequently, U.S. Public Health Services has established a stringent upper limit of  $10 \text{ mg NO}_3\text{-N}\cdot\text{liter}^{-1}$  in water supplies for human consumption (Coppock and Meyer, 1980). Unfortunately, this standard is easily exceeded in runoff leaving nursery and greenhouse operations (Stewart et al., 1981; Hershey and Paul, 1982; Jarrell et al., 1983), as well as in agricultural soils (Coppock and Meyer, 1980).

Nitrogen fertilizer application and water management practices employed in greenhouse and nursery operations have been highly effective in terms of maximizing plant growth (Gilliam and Wright, 1979; Yeager et al., 1980; Niemiera

and Wright, 1982); however, the ecological impact of such cultural practices is often not considered. During commercial production of container-grown plants, 30% or more of applied N is leached (Stewart et al., 1981; Jarrell et al., 1983). Such practices may result in leachate N concentrations of 300 to 600 mg N·liter<sup>-1</sup> (Hershey and Paul, 1982), which may leave the production site and pollute surface water and groundwater. Demands by the U.S. government and the public for a clean and healthy environment are encouraging producers to become more efficient users of fertilizer N while maintaining maximum plant production (Whitesides, 1989; Biernbaum, 1990; Koval, 1991; Martens, 1991; Stockwin, 1991; Vetanovetz and Hulme, 1991).

There are two standard methods of applying nutrients to container-grown crops, soluble or liquid fertilizer (LF) injected into irrigation systems, and controlled-release fertilizer (CRF) applied to the growing medium. Liquid fertilizer is often used because of its ease of application; the crop is fertilized as it is irrigated, reducing the costs of fertilizer application. Recommended LF concentrations for maximum growth were in the range of 50 to 200 mg N·liter<sup>-1</sup>, depending on plant species (Wright and Niemiera, 1987).

The benefits of LF are offset by environmental disadvantages. Studies comparing LF and CRF, on the basis of NO<sub>3</sub>-N runoff, have shown CRF to be the more efficient method of N application. Rathier and Frink (1989) grew container-grown woody plants under various irrigation and N fertilization regimes and reported

that LF leached ten times the amount of  $\text{NO}_3\text{-N}$  as CRF. Brown et al. (1982), using different N sources to fertilize golfing greens, also demonstrated that soluble fertilizer leached ten times more N than CRF. Hershey and Paul (1982) hypothesized that greater leaching losses from LF were due to the rate of LF application being greater than plant nutrient uptake. Controlled-release fertilizer has been shown to be an effective method of supplying nutrients to plants and reducing N leaching losses compared to LF (van der Boon, 1981; Hershey and Paul, 1982; Jarrell et al., 1983; Sanderson, 1987; Worrall et al., 1987). Recent observations have shown that reducing the leaching fraction at which irrigation water is applied reduced container leaching (Ku and Hershey, 1991).

Controlled-release fertilizers are categorized by the chemical, physical, or biological mode of nutrient release (Maynard and Lorenz, 1979). In general, nutrient release rates are regulated by solubility of fertilizer compounds (e.g., IBDU), microbial activity (e.g., urea formaldehyde), or permeable coatings (e.g., Osmocote, Grace-Sierra, Milpitas, Calif.) (Maynard and Lorenz, 1979; Hauck, 1985). Controlled-release fertilizers can be incorporated, dibbled into growing media at time of planting, or top dressed after planting anytime during the season. Meadows and Fuller (1984) compared the placement and rate of CRF and found increased levels of N and K in leachate when CRF was top dressed as compared to dibbled or incorporated, but that top dressed and dibbled treatments resulted in higher quality plants for all rates tested.

Osmocote encases a water soluble fertilizer within a polymer/resin coating. Nutrient release is initiated by water vapor entering the permeable membrane coating of the prill. Nutrients in solution inside the prill, diffuse out of the membrane and into the surrounding medium (Maynard and Lorenz, 1979; Sanderson, 1987). Nutrient release rate of Osmocote is temperature dependent and increases with increasing temperature (Harbaugh and Wilfret, 1982; Lamont et al., 1987). However, nutrient release rate of Osmocote is not affected by soil pH, microbial activity, or medium moisture content between the wilting point and field capacity (Maynard and Lorenz, 1979; Harbaugh and Wilfret, 1982; Hauck, 1985). Hershey and Paul (1982) and Meadows and Fuller (1983) described CRF release patterns and demonstrated that, regardless of fertilizer formulation, a higher level of nutrients was released at the beginning of the growing season, with less released as the season progressed.

Other studies have investigated CRF in terms of application rates (mass of fertilizer per volume of media) for maximum growth of various species. Optimal application rates depended on species, media used, and CRF formulation (Gouin and Link, 1973; Graca and Hamilton, 1981; Worrall et al., 1987; Smith and Treaster, 1988). Since these recommended CRF application rates did not take into consideration differences in mode of nutrient release, duration of release rate, and fertilizer formulation, there was no basis for comparing application rates. Therefore, determining N levels in the medium solution and plant is a more direct and useful means of interpreting nutritional status of containerized crops. Jarrell et al. (1983),

using four CRF on *Ligustrum texanum*, reported that greatest shoot fresh weights were attained when average leachate N concentrations were between 100 and 200 mg N·liter<sup>-1</sup>. Their conclusions were determined by a correlation between the average leachate N concentrations and shoot fresh weights. Calculation of average leachate N concentrations were based on total N leached divided by total water leached during the experiment and not a direct measurement of medium solution N concentration. In addition, they reported that foliar N concentrations for maximum growth were between 1.8 and 2.0%. Thus, if growth limiting medium solution and tissue N concentrations are known for specific containerized crops, then medium solution and tissue N can be monitored to signal the need for fertilizer reapplication or supplementation.

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## CHAPTER TWO

### **Criteria Signaling Reapplication of Controlled-release Fertilizer for Maximum Growth of *Ilex crenata* Thunb. ‘Helleri’**

#### **Introduction**

Nutrients are predominately supplied to container-grown plants by two methods, soluble or liquid fertilizer (LF) or controlled-release fertilizer (CRF). Both methods are effective in supplying nutrients to plants (Gouin and Link, 1973). However, on the basis of N leached from containers, research has shown CRF to be the more efficient method of N application (Brown et al., 1982; Hershey and Paul, 1982; Rathier and Frink, 1989). Recommended medium solution N concentrations for LF fertilized plants are well documented (Wright and Niemiera, 1987). However, CRF studies have often used application rates (mass of fertilizer per volume of media) rather than determining N levels in the medium solution and plant to evaluate nutritional status of containerized plants (Gouin and Link, 1973; Worrall et al., 1987; Smith and Treaster, 1988). An exception to this was Jarrell et al. (1983) who

reported that greatest shoot fresh weights of *Ligustrum texanum* were obtained when average N leachate concentrations were between 100 and 200 mg N·liter<sup>-1</sup>, and tissue N concentrations between 1.8 and 2.0%. Their conclusions were a result of an average of N leached from containers and not a direct measurement of the medium solution N concentration.

Other studies have described nutrient release patterns of various CRF formulations (Harbaugh and Wilfret, 1982; Meadows and Fuller, 1983). Meadows and Fuller (1983), using 8-9 month Osmocote (18N-2.6P-9.9K), found that leachate concentrations were initially 16 mg N·liter<sup>-1</sup> and slowly increased to a high of 21 mg N·liter<sup>-1</sup>. Leachate concentrations slowly decreased over a period of 154 days to 0.1 mg N·liter<sup>-1</sup>. Although the N levels of other CRF formulations tested were significantly different, N release patterns were similar to the 8-9 month Osmocote formulation. Since minimum medium solution N concentrations for CRF have not been established for container-grown plants, growers are concerned whether the relatively low medium solution N levels in the latter part of the growing season sustain maximum growth. Thus, minimum nutrient levels need to be established to indicate if or when CRF reapplication is necessary for maximum growth.

The objective of this study was to determine medium solution N and electrical conductivity (EC), and foliar N levels that signal the need for CRF reapplication for maximum growth of *Ilex crenata* Thunb. 'Helleri'.

## Materials and Methods

Multiple-branched, rooted cuttings of *Ilex crenata* 'Helleri' were transplanted on 7 Mar. 1991, into one hundred twenty 9.5 liter (22 cm diameter, 25 cm depth), plastic containers filled with a medium of 9 pine bark (*Pinus taeda* L.) : 1 sand (by volume). Medium 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 8-9 month (duration of release at 21C) Osmocote (18N-2.6P-9.9K, Grace-Sierra, Milpitas, Calif.) per container or 74.5 g 12-14 month Osmocote (17N-3.1P-9.9K) per container (manufacturer's recommended medium rates). Plants were grown pot-to-pot on raised benches in a greenhouse vented at 24C during the day and heated to a night minimum of 18C under natural photoperiod from 7 Mar. to 15 May. From 15 May to 1 Nov. 1991, plants were grown on a gravel bed in an outdoor nursery (Blacksburg, Va.), at a spacing of  $\approx$  20 cm between plant canopies. Plants were hand irrigated with a known volume of water to maintain a leaching fraction of  $\approx$  0.25.

On 19 July, 2 Aug., or 16 Aug., 12 plants from each fertilizer formulation treatment (8-9 month, 12-14 month) received a reapplication of the respective fertilizer at half the initial rate. In addition to CRF reapplication treatments, a set of 12 plants from each fertilizer formulation received a LF treatment at each irrigation (leaching fraction  $\approx$  0.25) beginning on 19 July. Plants that did not receive

a CRF reapplication or LF supplement were the control treatment. Nutrient content of LF solution was 50 mg N·liter<sup>-1</sup>, 10 mg P·liter<sup>-1</sup>, and 35 mg K·liter<sup>-1</sup>, supplied by NH<sub>4</sub>NO<sub>3</sub>, H<sub>3</sub>PO<sub>4</sub>, and KCl, respectively.

At two week intervals beginning on 27 Mar., container medium solution was extracted using the pour-through (PT) technique (Wright, 1986) and evaluated for NO<sub>3</sub>-N, NH<sub>4</sub>-N (ion selective electrodes) and EC. Approximately 25 leaves of the most recently mature foliage from one plant per treatment per block were harvested on PT dates, and analyzed for N using a modified micro-Kjeldahl method (Peterson and Chester, 1964).

All leachate, whether resulting from irrigation or rain, drained into collecting pans located beneath each container. Containers were placed on rings of PVC tubing (4 cm in height) within collecting pans to prevent re-absorption of accumulated water by the medium. Aluminum foil shield fitted around containers and collecting pans preventing extraneous water from entering the pans. After each irrigation or rain, leachate volume was measured and a sub-sample collected weekly from six plants per treatment for each formulation and analyzed for NO<sub>3</sub>-N and NH<sub>4</sub>-N.

On 1 Nov., plant canopy widths, the commercial criteria for growth, were measured to the nearest centimeter. Plants were arranged in a randomized complete block design with two plants per treatment per block (six blocks, 120 plants total). Data for leachate N and canopy widths were evaluated by ANOVA and Duncan's

mean separation using SAS (SAS Inst., Cary, N.C.). Linear regression analysis was performed on medium solution N and EC.

## Results and Discussion

Canopy widths of plants in LF, CRF reapplication 1 and 2 treatments were greater than widths of control (initial application, 7 Mar.) and CRF reapplication 3 treatments (Table 1). In terms of commercial plant size categories, plants of LF, CRF reapplication 1 and 2 treatments would be sold in the size category of 61-76 cm compared to the plants in control and reapplication 3 treatments which would be in the 46-61 cm category after one growing season. Thus, CRF reapplication has economical advantages by increasing revenue of a dollar or more per plant when sold in a larger size category (personal observation from nursery catalogs). Wright and Niemiera (1991) conducted a similar experiment with 'Helleri' holly, demonstrating that CRF reapplication during midsummer increased growth compared to the control treatment. In evaluating reapplication practices, growers need to determine whether the profits from the increase in growth will offset fertilizer and reapplication labor costs.

Beginning on 27 Mar., medium solution N and EC, and foliar N levels were 138 mg·liter<sup>-1</sup>, 1.5 dS·m<sup>-1</sup>, and 2.2%, respectively, for the 8-9 month formulation

control treatment (Tables 2-4). Levels rapidly increased until peaks of 324 mg·liter<sup>-1</sup>, 2.4 dS·m<sup>-1</sup>, and 3.0% were reached on 23 May for medium solution N and EC, and on 9 May foliar N, respectively. Levels slowly decreased thereafter to 3 mg·liter<sup>-1</sup>, 0.2 dS·m<sup>-1</sup>, and 1.9%, respectively. Although N concentrations for 12-14 month formulation were different from the 8-9 month formulation, the pattern of N concentration was similar (Tables 5-7). Osmocote's nutrient release rate is primarily affected by coating type and temperature (Maynard and Lorenz, 1979; Lamont et al., 1987). Thus, the initial increase of medium solution N observed for control treatment was likely due to the high greenhouse temperatures causing an increase in release rate. This overall seasonal nutrient release pattern of a relatively high medium solution N concentration at the beginning of the season with a decrease in N concentration toward the latter part of the season is similar to that described by Harbaugh and Wilfret (1982) and Meadows and Fuller (1983).

Two weeks following each CRF reapplication, medium solution N and EC were two times greater than the control treatment (both formulations) and were significantly greater than the control treatment for the duration of the experiment (Tables 2, 3, 5, 6). By the end of the experiment, medium solution N and EC, and foliar N levels for all reapplication treatments decreased to  $\approx 8$  mg·liter<sup>-1</sup>,  $\approx 0.3$  dS·m<sup>-1</sup>, and  $\approx 2.3\%$ , respectively. Since growth of control plants was less than plants in LF, and CRF reapplication 1 and 2 treatments, medium solution N and EC, and foliar N values of control treatment at the second reapplication date signaled the

need for reapplication of CRF or LF supplementation. Those levels for the control treatment (both formulations) at the second reapplication date were  $\approx 40 \text{ mg N}\cdot\text{liter}^{-1}$ ,  $0.4 \text{ dS}\cdot\text{m}^{-1}$ , and 2.3%, respectively. Foliar N levels of 2.3% for maximum growth is similar to that reported by Gilliam and Wright (1977) for ‘Helleri’ holly. However, Wright and Niemiera (1991) found medium solution N and EC, and foliar N levels of  $12 \text{ mg}\cdot\text{liter}^{-1}$ ,  $0.2 \text{ dS}\cdot\text{m}^{-1}$ , and 2.4%, respectively, signaled the need for CRF reapplication. These lower reapplication criteria levels may have been due to differences in experimental conditions.

The minimum medium solution N concentrations established in this experiment for maximum growth were less than recommended LF concentrations of 50 to  $200 \text{ mg}\cdot\text{liter}^{-1}$  (Wright and Niemiera, 1987). However, Jarrell et al. (1983), using Osmocote 18N-2.6P-9.9K applied to container-grown *Ligustrum texanum*, found maximum shoot fresh weights were obtained when average leachate N concentrations were between 100 and  $200 \text{ mg N}\cdot\text{liter}^{-1}$ . Their conclusions were determined by correlating the average leachate N concentrations with fresh weight of shoots. Calculation of average leachate N concentrations were based on total N leached divided by total water leached during the experiment. The fact that the data in this study were based on actual medium solution N concentrations extracted at two week intervals may account for the difference in recommended concentration values.

There was a strong relationship between medium solution N and EC ( $r^2 = 0.91$ ,  $P = 0.05$ ) (Fig. 1). From a commercial standpoint, growers could use EC

measurements to predict medium solution N concentrations and assess the adequacy of the fertilizing regime. Furthermore, growers are more apt to routinely monitor medium solution EC due to the relatively low cost, simplicity, and portability of EC meters, as compared to the technical nature and high costs of N analysis.

Amount of N leached (per week) from containers of control plants (8-9 month formulation) was less than 0.05 g until the second week in May. At this time leachate levels rapidly increased to 0.47 g, and decreased again to 0.06 g by 1 June (Fig. 2). From the first week in June to middle of Aug., the amount of N leached was in the range of 0.05 to 0.15 g N, and slowly decreased to 0.004 g N by the end of the experiment (24 Oct.). Since Osmocote's nutrient release rate is primarily affected by temperature and coating type, the relatively high N levels observed during May were most likely due to relatively high greenhouse temperatures. A peak in N leached was observed immediately after each CRF reapplication resulting from the addition of Osmocote. The peak in leachate N levels observed in the middle of Sept. for CRF reapplication 3, may be explained by the unseasonably high temperatures that week (data not shown). Decrease in N leached toward the end of the season for CRF reapplication treatments may be explained by decrease in seasonal temperatures, rather than a depletion of nutrients within Osmocote prills. The amount of N leached for the LF treatment decreased due to the reduced irrigation frequency in Sept. and Oct. (Fig.2). The pattern of N leached for all treatments of

the 12-14 month formulation (data not shown) was similar to respective 8-9 month formulation treatments.

Total N leached over the course of the experiment for the 8-9 month formulation was 69, 129, 107, 104, and 135 mg for control, CRF reapplication 1, 2, 3, and LF treatments, respectively. Nitrogen leached from the 12-14 month formulation was similar to that of 8-9 month formulation (data not shown). Reapplying on 2 Aug. when medium solution N and EC of control treatment decreased to  $\approx 40 \text{ mg}\cdot\text{liter}^{-1}$  and  $0.4 \text{ dS}\cdot\text{m}^{-1}$ , respectively, resulted in 17% less N leached (both formulations), and no growth differences between reapplication 1 and 2.

A conservative estimate can be made using our data to illustrate the quantity of N which would be leached per hectare in one growing season. Based on 9.5 liter containers spaced pot to pot, plants irrigated at a leaching fraction of  $\approx 0.25$ , and receiving an initial CRF application compared to a reapplication in midsummer would leach 75 and 148  $\text{kg N}\cdot\text{ha}^{-1}$ , respectively. Growers often irrigate at leaching fraction  $> 0.25$  (personal observation), thereby leaching even more N from the media. Hence, the additional loss of N into the environment must be considered when deciding if CRF reapplication is necessary.

This experiment demonstrated that medium solution N and EC, and foliar N levels of  $40 \text{ mg}\cdot\text{liter}^{-1}$ ,  $0.4 \text{ dS}\cdot\text{m}^{-1}$ , and 2.3%, respectively, signaled the need for reapplication of CRF or LF supplementation and resulted in an increased canopy

width relative to plants receiving only an initial CRF application. The strong relationship between medium solution N and EC ( $r^2 = 0.91$ ,  $P = 0.05$ ) indicated that EC measurements were a reliable predictor of medium solution N and can signal the need for reapplication of CRF or LF supplement. However, in assessing the need for CRF or LF supplementation, growers need to consider the environmental impact of increased N leached, as well as the economic advantages of increased plant growth.

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**Table 1.** ‘Helleri’ holly canopy widths after one growing season fertilized with either 8-9 or 12-14 month Osmocote fertilizer formulations.

Treatment	Plant width (cm) <sup>z</sup>	
	Fertilizer formulation	
	8-9 Month	12-14 Month
Control 7 Mar.	61 c <sup>y</sup>	61 d
Liquid fertilizer 19 July	66 a	71 a
Reapplication 1 19 July	66 a	66 b
Reapplication 2 2 Aug.	64 ab	65 bc
Reapplication 3 16 Aug.	62 bc	63 cd

<sup>z</sup>Plant widths equation:  $(W_1 + W_2)/2$ .

<sup>y</sup>Means separation within column by Duncan’s multiple range test,  $P = 0.05$ .

**Table 2.** Effect of initial and reapplication of 8-9 month Osmocote and LF supplement on medium solution N ( $\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$ ) concentration of ‘Helleri’ holly.

Sample date	Medium Solution N concentration ( $\text{mg}\cdot\text{liter}^{-1}$ )				
	Initial application	Liquid fertilizer	Osmocote reapplication date		
			7 Mar.	19 July	19 July
27 Mar.	138	-	-	-	-
11 Apr.	185	-	-	-	-
27 Apr.	205	-	-	-	-
9 May	240	-	-	-	-
23 May	324	-	-	-	-
8 June	97	-	-	-	-
21 June	117	-	-	-	-
3 July	114	-	-	-	-
17 July	80	-	-	-	-
31 July	88 b <sup>z</sup>	98 b	195 a	-	-
14 Aug.	40 c	90 b	97 b	148 a	-
31 Aug.	20 b	60 a	61 a	60 a	69 a
14 Sept.	8 b	39 a	34 a	28 a	30 a
27 Sept.	6 c	34 a	22 b	29 ab	22 b
12 Oct.	3 c	30 a	8 b	7 b	9 b
24 Oct.	3 b	8 a	7 a	8 a	8 a

<sup>z</sup>Means separation within rows by Duncan’s multiple range test,  $P = 0.05$ .

**Table 3.** Effect of initial and reapplication of 8-9 month Osmocote and LF supplement on medium solution EC of ‘Helleri’ holly.

Sample date	Medium Solution EC (dS·m <sup>-1</sup> )					
	Initial application	Liquid fertilizer	Osmocote reapplication date			
			7 Mar.	19 July	19 July	2 Aug.
27 Mar.	1.5	-	-	-	-	-
11 Apr.	1.8	-	-	-	-	-
27 Apr.	2.0	-	-	-	-	-
9 May	2.0	-	-	-	-	-
23 May	2.4	-	-	-	-	-
8 June	1.0	-	-	-	-	-
21 June	1.0	-	-	-	-	-
3 July	0.8	-	-	-	-	-
17 July	0.9	-	-	-	-	-
31 July	0.8 b <sup>z</sup>	1.0 b	1.7 a	-	-	-
14 Aug.	0.4 c	0.9 b	0.9 b	1.1 a	-	-
31 Aug.	0.3 b	0.7 a	0.7 a	0.7 a	0.7 a	0.7 a
14 Sept.	0.3 b	0.6 a	0.6 a	0.6 a	0.6 a	0.5 a
27 Sept.	0.2 c	0.6 a	0.5 b	0.5 b	0.5 b	0.4 b
12 Oct.	0.2 c	0.5 a	0.4 b	0.3 b	0.3 b	0.3 b
24 Oct.	0.2 c	0.3 b	0.3 ab	0.4 a	0.4 a	0.3 ab

<sup>z</sup>Means separation within rows by Duncan’s multiple range test, *P* = 0.05.

**Table 4.** Effect of initial and reapplication of 8-9 month Osmocote and LF supplement on foliar N of ‘Helleri’ holly.

Sample date	Foliar N (%)				
	Initial application	Liquid fertilizer	Osmocote reapplication date		
			7 Mar.	19 July	19 July
27 Mar.	2.2	-	-	-	-
11 Apr.	2.7	-	-	-	-
27 Apr.	3.0	-	-	-	-
9 May	3.0	-	-	-	-
23 May	2.7	-	-	-	-
8 June	2.9	-	-	-	-
21 June	2.5	-	-	-	-
3 July	2.6	-	-	-	-
17 July	2.2	-	-	-	-
31 July	2.3 a <sup>z</sup>	1.9 a	2.0 a	-	-
14 Aug.	2.3 a	2.5 a	2.4 a	2.6 a	-
31 Aug.	2.0 c	2.2 ab	2.3 a	2.3 a	2.3 a
14 Sept.	1.9 a	1.9 a	1.9 a	1.9 a	1.9 a
27 Sept.	1.9 b	2.0 ab	2.1 ab	2.2 a	2.0 ab
12 Oct.	1.9 a	2.0 a	1.9 a	1.9 a	2.1 a
24 Oct.	1.9 a	2.1 a	2.3 a	2.3 a	2.2 a

<sup>z</sup>Means separation within rows by Duncan’s multiple range test,  $P = 0.05$ .

**Table 5.** Effect of initial and reapplication of 12-14 month Osmocote and LF supplement on medium solution N ( $\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$ ) concentration of 'Helleri' holly.

Sample date	Medium solution N concentration ( $\text{mg}\cdot\text{liter}^{-1}$ )				
	Initial application	Liquid fertilizer	Osmocote reapplication date		
			7 Mar.	19 July	19 July
27 Mar.	175	-	-	-	-
11 Apr.	290	-	-	-	-
27 Apr.	290	-	-	-	-
9 May	301	-	-	-	-
23 May	338	-	-	-	-
8 June	72	-	-	-	-
21 June	74	-	-	-	-
3 July	82	-	-	-	-
17 July	63	-	-	-	-
31 July	60 b <sup>z</sup>	89 b	183 a	-	-
14 Aug.	47 c	94 b	117 a	136 a	-
31 Aug.	30 c	83 b	69 b	92 ab	114 a
14 Sept.	11 b	52 a	42 a	52 a	54 a
27 Sept.	9 b	36 a	26 a	30 a	32 a
12 Oct.	6 c	28 a	11 bc	15 b	13 bc
24 Oct.	6 b	11 ab	10 b	16 a	13 ab

<sup>z</sup>Means separation within rows by Duncan's multiple range test,  $P = 0.05$ .

**Table 6.** Effect of initial and reapplication of 12-14 month Osmocote and LF supplement on medium solution EC of ‘Helleri’ holly.

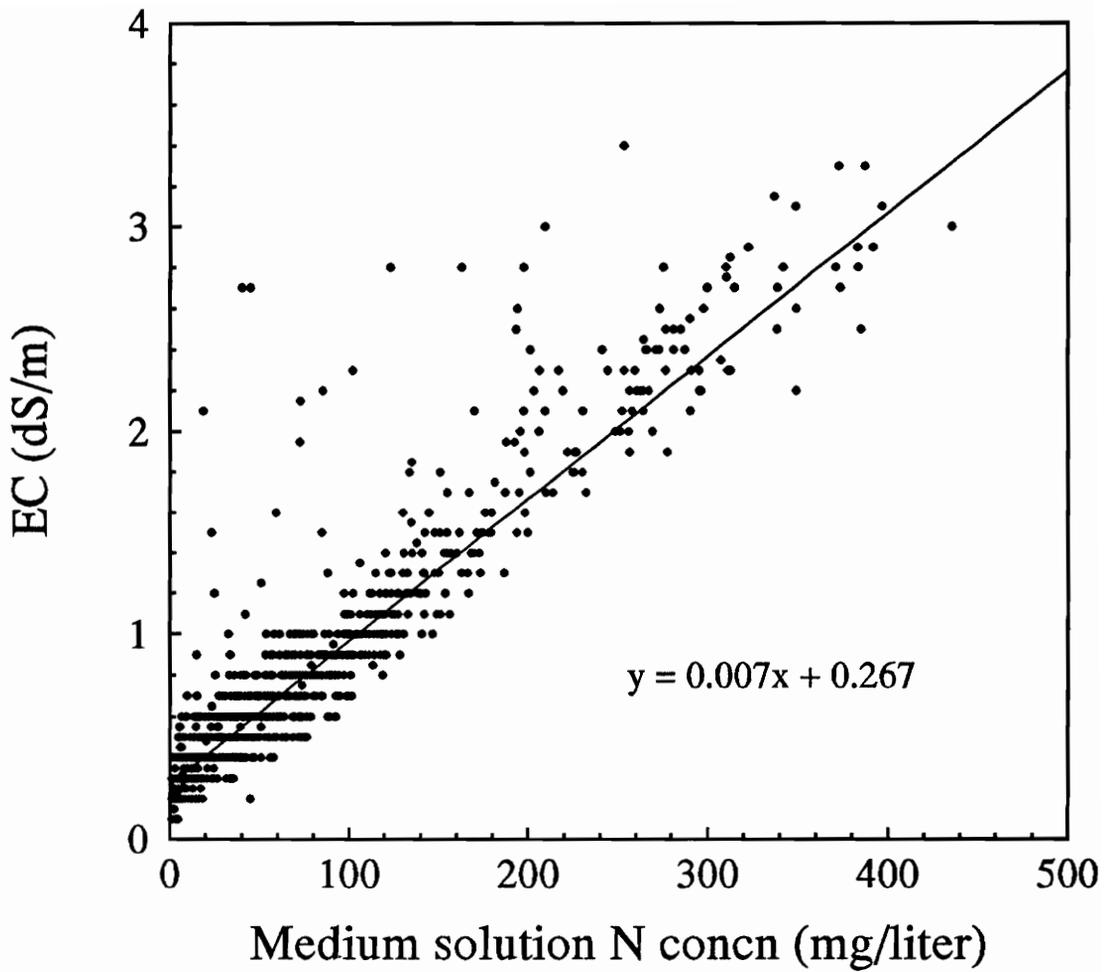
Sample date	Medium solution EC (dS·m <sup>-1</sup> )				
	Initial application	Liquid fertilizer	Osmocote reapplication date		
			7 Mar.	19 July	19 July
27 Mar.	1.8	-	-	-	-
11 Apr.	2.4	-	-	-	-
27 Apr.	2.6	-	-	-	-
9 May	2.6	-	-	-	-
23 May	2.5	-	-	-	-
8 June	0.7	-	-	-	-
21 June	0.6	-	-	-	-
3 July	0.6	-	-	-	-
17 July	0.7	-	-	-	-
31 July	0.7 b <sup>z</sup>	0.9 b	1.6 a	-	-
14 Aug.	0.4 d	0.9 c	1.0 b	1.3 a	-
31 Aug.	0.4 c	0.9 ab	0.8 b	0.9 ab	1.0 a
14 Sept.	0.3 c	0.8 a	0.6 b	0.8 a	0.8 a
27 Sept.	0.3 c	0.7 a	0.5 b	0.6 ab	0.5 b
12 Oct.	0.2 d	0.6 a	0.3 c	0.4 b	0.3 c
24 Oct.	0.2 c	0.3 b	0.3 b	0.4 a	0.3 b

<sup>z</sup>Means separation within rows by Duncan’s multiple range test, *P* = 0.05.

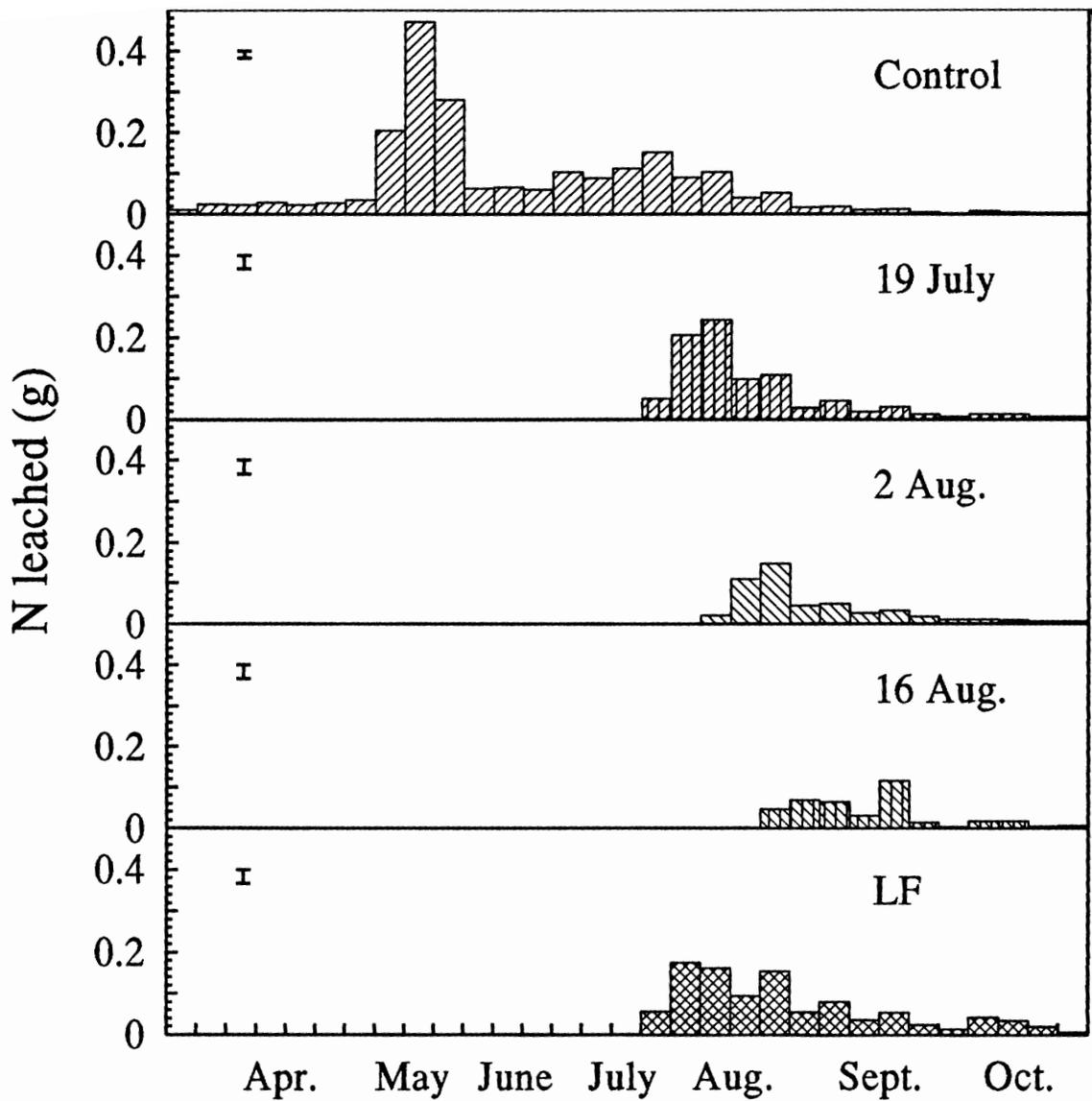
**Table 7.** Effect of initial and reapplication of 12-14 month Osmocote and LF supplement on foliar N of ‘Helleri’ holly.

Sample date	Foliar N (%)				
	Initial application	Liquid fertilizer	Osmocote reapplication date		
			7 Mar.	19 July	19 July
27 Mar.	2.2	-	-	-	-
11 Apr.	2.9	-	-	-	-
27 Apr.	3.1	-	-	-	-
9 May	3.0	-	-	-	-
23 May	2.9	-	-	-	-
8 June	2.9	-	-	-	-
21 June	2.6	-	-	-	-
3 July	2.5	-	-	-	-
17 July	2.4	-	-	-	-
31 July	2.3 a <sup>z</sup>	2.1 a	2.5 a	-	-
14 Aug.	2.3 a	2.6 a	2.7 a	2.3 a	-
31 Aug.	2.1 a	2.3 a	2.4 a	2.3 a	2.5 a
14 Sept.	1.7 b	2.1 a	2.1 a	2.1 a	2.2 a
27 Sept.	1.9 b	2.2 a	2.1 ab	2.2 a	2.1 ab
12 Oct.	1.9 b	2.0 ab	2.0 ab	2.0 ab	2.1 a
24 Oct.	1.9 b	2.3 a	2.2 a	2.3 a	2.2 a

<sup>z</sup>Means separation within rows by Duncan’s multiple range test,  $P = 0.05$ .



**Figure 1.** Relationship between medium solution N ( $\text{NO}_3 + \text{NH}_4$ ) and EC for all treatments.



**Figure 2.** Nitrogen leached from containers (8-9 month formulation) for CRF control, reapplication, and LF treatments over time. Vertical bars equal standard error.

## Vita

Melinda Cole Shiflett was born on 27 April 1968 in Charlottesville, Virginia. She received her primary and secondary education in the Albemarle County Public School system, graduating from Western Albemarle High School in 1986. In the Fall of 1987, she entered Old Dominion University where she graduated cum laude with a Bachelor of Science in Biology. She entered Virginia Polytechnic Institute and State University in the Fall of 1990 and was granted her Master of Science degree in Horticulture in October 1992.

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