Nitrate Loading to the Soil Profile Underlying Two Containerized Nursery Crops Supplied Controlled Release Fertilizer[1]

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Abstract

Cornus amomum and *Rhododendron* 'Cary's Red' were grown in #3 (10 l) containers outdoors and supplied with a controlled release fertilizer (CRF). At two week intervals, core samples were removed from the soil underlying the crop at 30 cm (12 in) increments to a depth of 90 cm (36 in). Soil samples and foliar samples were analyzed for nitrate nitrogen (NO_3-N) concentration. NO_3-N accumulated rapidly in the upper 30 cm (12 in) of soil underlying containerized crops. Accumulation in the 30–60 cm (12–24 in) layer occurred later in the growing season and NO_3-N buildup in the 60–90 cm (24–36 in) layer lagged behind both upper soil layers. Maximum NO_3-N concentrations exceeded 40 mg/kg (6.36×10^{-4} oz lb^{-1}) of soil and levels above 20 mg/kg (3.18×10^{-4} oz/lb) of soil were sustained throughout the 90 cm (36 in) soil profile for much of the growing season. Patterns of soil NO_3-N concentration suggest that, by the middle of the growing season, rapid-growing *Cornus* may better utilize released N fertilizer than slower growing *Rhododendron*. Foliar samples confirm significantly higher NO_3-N uptake by *Cornus* than by *Rhododendron*.

Index words: silky dogwood, *Rhododendron* 'Cary's Red', nitrogen, crop management practices, groundwater.

Species used in this study: silky dogwood (*Cornus amomum* Mill.); Cary's Red rhododendron (*Rhododendron* 'Cary's Red').

Significance to the Nursery Industry

Compared to soluble fertilizers, controlled release fertilizers (CRFs) are considered to be an environmentally sound method for delivering nutrients to container-grown nursery stock. Under a typical container production system, CRFs can contribute significant NO_3-N to the soil profile beneath a growing area. Peak levels above 40 mg of NO_3-N per kg (6.36×10^{-4} oz/lb) of soil can be measured, while sustained, elevated concentrations throughout the upper 90 cm (36 in) of soil are also possible. Such NO_3-N levels, in combination with irrigation frequencies typical of container production, may pose an environmental threat in the form of ground and surface water contamination. This is especially true given the compact, intensive nature of container production nurseries. Matching N release from fertilizers with crop growth, recovery of leachate using largely closed or contained systems, and production of rapid-growing species may limit loading of NO_3-N to soil and contamination of ground and surface water.

Introduction

Nitrate is the most frequently detected agricultural chemical in drinking water wells in both community water systems and in rural domestic wells (3). This finding is in contrast to the public opinion that pesticides are the most common well water contaminant. Agricultural activities, including nursery crop production, are typically implicated in non-point source NO_3-N contamination of ground and surface water.

Increasingly, nursery stock is produced in containers, and this trend away from field production is likely to continue. Nursery crops in containers are grown in porous, highly organic media that require substantial and frequent irrigation (4). Larger volumes of water supplied to containerized crops increase the volume of leachate (7) and the amount of N leaving the container (9).

CRFs release their nutrients slowly and are considered more efficient and environmentally sound for container production (8, 10, 11). In comparison to soluble fertilizers, use of CRFs on nursery crops results in reduced NO_3-N in leachate and runoff water (9). Similarly, use of CRFs on golf greens constructed with organic, porous media may prevent sudden losses of N (1).

Most, if not all, studies examining the use of CRFs on nursery and ornamental crops restrict their scope to monitoring NO_3-N in leachate or runoff water. Scientific examination of NO_3-N concentration and dynamics in the soils beneath container nursery production areas is lacking. It is difficult to meaningfully apply leachate and runoff NO_3-N data to predict NO_3-N concentration and movement in the soil profile, due to the number and complexity of factors that impinge upon the container-soil profile ecological system.

The primary objective of this study was to quantify changes over time in the NO_3-N profile in the top 90 cm (36 in) of soil underlying container-grown nursery crops. A secondary objective was to determine if soil NO_3-N dynamics were influenced by the nursery crop grown. A fast-growing species, *Cornus amomum* was compared to a slower-growing species, *Rhododendron* 'Cary's Red'. Rhododendron is generally recognized to perform best when supplied low N fertilizers (2). In addition, species differences in root system density and type, canopy shape, canopy density, branching

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pattern, as well as other plant characteristics may influence soil NO_3-N dynamics and leaching.

Materials and Methods

Experiments were conducted outdoors under full exposure at the University of Connecticut, Department of Plant Science Research Farm, Storrs. Uniform seedling liners of *Cornus amomum*, silky dogwood, pruned to 40 cm (15.7 in) tall, with approximately 8 mm (0.3 in) stem diameter, were used. *Rhododendron* 'Cary's Red' transplants used in the study were micropropagated plants raised in #1 (3 l) containers to 40 cm (15.7 in) height. Both the *Cornus* and *Rhododendron* transplants were potted in #3 containers on June 20, 1990. Potting medium consisted of composted pine bark; sphagnum peat: sand (3:2:1 by vol) amended with micronutrients at 0.9 kg/cu m (1.5 lb/cu yd) and dolomitic limestone at 2.4 kg/cu m (4 lb cu yd). All containers were topdressed with 60 g (2.1 ounces) of Osmocote 18N-2.6P-10K (18-6-12), 8–9 month formulation which supplies 53.3% of its N as ammonium and 46.4% of its N as nitrate. Fertilizer applications were held constant for *Cornus* and *Rhododendron*, to enable comparisons between rapid and slower growing genera. It should be noted that lower rates of CRF are generally suggested for *Rhododendron*.

One cubic meter (1.09 cu yd) wooden boxes were recessed into a grassed field and filled with native field soil (Woodbridge fine sandy loam) that had been screened through expanded steel with approximately 3 cm (1.2 in) by 5.0 cm (2.0 in) diamond-shaped orifices. Boxes were bottomless, to enable contact with the subsoil. Screened soils were settled by repeated irrigation, which also served to leach any residual NO_3-N from the soil. Residual NO_3-N levels were determined at the start of the experiment (week 0) by sampling the leached soil profile prior to the application of experimental treatments. Nine plants were placed evenly on the surface of each box in a 3 by 3 arrangement.

Plants were irrigated when the potting medium became dry. Temperature and precipitation data were recorded daily during the duration of the study. The area of each soil box, including the plants, was watered by hand from above for 2 minutes. A crossing pattern and a water break were used to deliver the water uniformly to the entire box. It was important to provide water from above, to both the plant canopy and interplant spaces, since typical nursery overhead irrigation delivers water in this fashion. Approximately 6 gal (25 l) of water was applied to each soil box at a rate of 3 gal/min (12.5 l/min).

At two week intervals, June 20 to September 25, 1990, a soil profile at 30 cm (12 in) increments to 90 cm (36 in) depth was obtained from each box with a 1.9 cm (0.75 in) Dutch auger. Each box was divided into an 8 by 8 grid containing 48 possible sample sites and two soil cores were randomly selected from each box on each sampling date. The two soil cores were pooled to make a single composite sample per box, per collection time. Samples were keep cold during collection, then were immediately spread in a thin layer (1 cm, or 0.4 in) and dried 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 until analysis. After removing samples, auger holes were filled with screened, native field soil with NO_3-N concentrations equal to those at week 0. Previous sample sites were noted and were not resampled.

At week 12 (September 11, 1990), 20 leaves were harvested from each plant. Tissue was dried at 70°C (158°F) and ground to pass a 40 mesh screen. Ground samples were stored in sealed, acid-washed vials.

NO_3-N was extracted from soil samples using 2N KCl, and from plant tissue using an aqueous solution and quantitatively determined (6) using an Auto-Analyzer (Scientific Instruments Corp., Pleasantville, NY).

Treatments were arranged in a completely random design with two replications per treatment. A separate box was used for each plant genus and each genus was replicated using identical soil boxes.

Results and Discussion

The NO_3-N concentration in soils underlying container-grown nursery crops was shown to vary considerably during the growing season (Fig. 1 & 2). Some differences in NO_3-N concentration and accumulation in various parts of the soil profile did appear to be influenced by the crop growing in containers on the surface.

NO_3-N concentration in the top 0–30 cm (0–12 in) soil profile beneath *Cornus* (Fig. 1) began to rise slightly by week 2, and then increased rapidly until week 6, where it reached a maximum level of 30.8 mg/kg (4.90×10^{-4} oz/l) soil. NO_3-N concentration in the upper 30 cm (12 in) of soil then remained fairly constant throughout the remainder of the growing season. In the 30–60 cm (12–24 in) soil layer, NO_3-N concentrations rose after 4 weeks. A sharp increase in concentration was noted between weeks 6 and 8, with a maximum concentration of 41.5 mg of NO_3-N/kg (6.60×10^{-4} ox/lb) of soil occurring 10 weeks after the application of CRF. This NO_3-N level is the highest concentration detected in any part of the 90 cm (36 in) soil profile during the growing season and is over 4 times the concentration found in the soil at week 0. Following this peak at week 10, NO_3-N levels in the 30–60 cm (12–24 in) soil layer fell to 30.7 mg/kg (4.88×10^{-4} oz/lb) of soil by the end of the study. NO_3-N in the 60–90 cm (24–36 in) layer rose

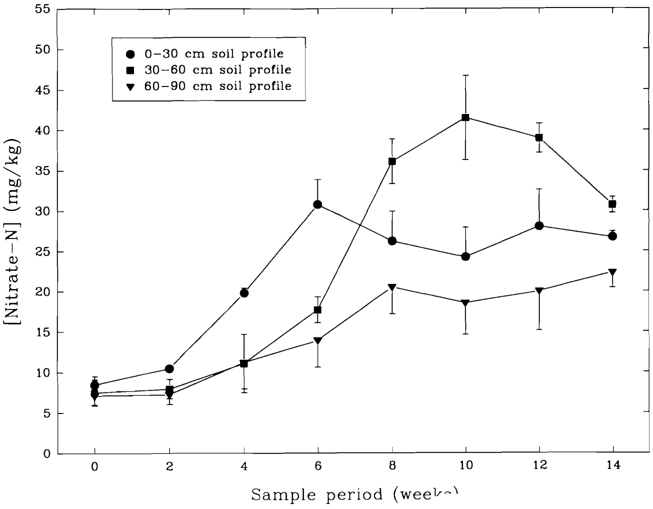

Fig. 1. **Changes in nitrate nitrogen concentration, over the course of a growing season, in three soil layers underlying container-grown *Cornus ammomum* receiving controlled release fertilizer. Vertical bars represent ± S.E. of means. Error bars which do not appear on the graph are smaller than the symbols.**

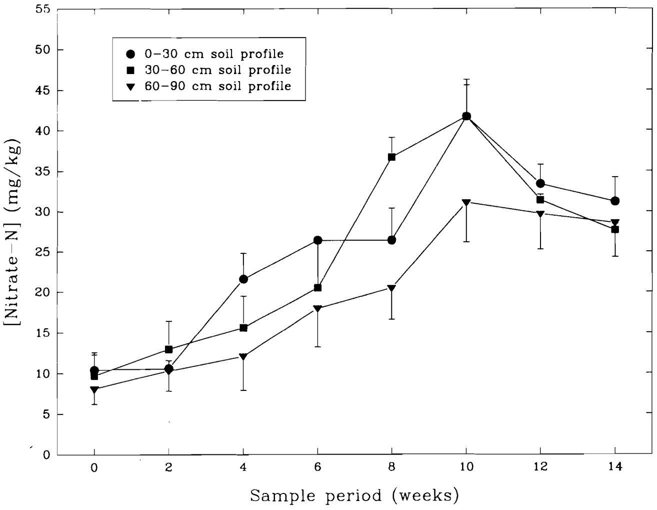

Fig. 2. Changes in nitrate nitrogen concentration, over the course of a growing season, in three soil layers underlying container-grown *Rhododendron* 'Cary's Red' receiving controlled release fertilizer. Vertical bars represent ± S.E. of means. Error bars which do not appear on the graph are smaller than the symbols.

gradually over the course of the growing season, reaching its maximum (22.3 mg/kg or 3.55 × 10^{-4} oz/lb) at week 14.

The rapid increase in surface soil (0–30 cm or 0–12 in) NO_3-N observed between weeks 2 and 6 is probably due to a poor correlation between crop growth and nutrient release. Ideally, nutrient release from a CRF should coincide with uptake by the plant (8). Hershey and Paul (5) found that a poor correlation between N release from Osmocote and N uptake by chrysanthemums during the early part of the crop cycle resulted in substantial leaching-losses. During the first 6 weeks of the experiment, the *C. amomum* liners were poorly established, had small canopies, and were likely exhibiting a low N uptake. Nursery crops are often overpotted at the beginning of the crop cycle to avoid the labor costs incurred when plants must be repotted into larger containers. Such production practices may contribute to considerable NO_3-N leaching in the early part of the crop production cycle.

The strong increase in NO_3-N in the 30–60 cm (12–24 in) soil layer, and apparent drop in the 0–30 cm (0–12 in) soil layer between weeks 6 and 8, may be due to environmental factors. During the period from week 7 to week 8, over 11.35 cm (4.5 in) of rainfall was received (Fig. 3). This large volume of water may have leached NO_3-N from the containers, through the upper 30 cm (12 in) of soil and into the 30–60 cm (12–24 in) soil layer. The drop in NO_3-N concentration in the soil surface layer may also be correlated with the period of most rapid growth of the silky dogwood during late July and early August. At this time, the plants were beginning to fill their containers with roots, and nutrient uptake was probably high to sustain the rapid growth. One can speculate that the high N use efficiency reduced NO_3-N leaching from the containers. The NO_3-N already loaded into the soil profile continued to leach downward with irrigations, resulting in a stabilization of NO_3-N concentrations in the 0–30 cm (0–12 in) soil layer and concommitant increase in the lower soil profile.

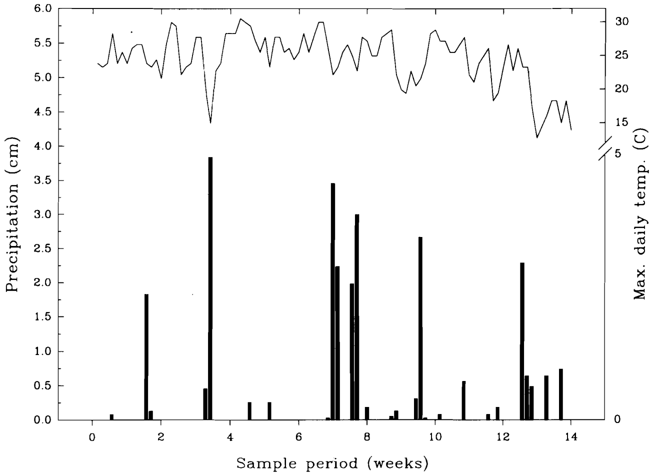

Fig. 3. Daily precipitation and maximum temperature during the experimental period from June 20 to September 25, 1990.

Overall, NO_3-N concentration patterns in soil underlying *Rhododendron* (Fig. 1) are similar to those observed for *Cornus* (Fig. 2), although there are some notable differences. With *Rhododendron*, there was a similar rapid rise in NO_3-N concentration in the 0–30 cm (0–12 in) soil profile. However, after a brief plateau between weeks 6 and 8, probably due to heavy rainfall, NO_3-N levels continued to rise to a high of 41.7 mg per kg (6.63 × 10^{-4} oz/lb) of soil by week 10. This maximum NO_3-N concentration seen in the 0–30 cm (0–12 in) soil layer beneath *Rhododendron* is over 10 mg/kg (1.59 × 10^{-4} oz/lb of soil higher than the maximum level seen in the upper soil layer beneath *Cornus*. The rise in NO_3-N levels in the 0–30 cm (0–12 in) soil layer beneath *Rhododendron* after week 6 may be due to the lack of a rapid growth phase by *Rhododendron*. *Rhododendron* grows slowly by producing growth flushes and does not have the rapid mid-season growth phase exhibited by *Cornus*. After week 10, levels declined through the remainder of the growing season.

NO_3-N concentrations in the 30–60 cm (12–24 in) layer underlying *Rhododendron* are nearly identical to those for *Cornus* over the course of the study. A sharp rise in NO_3-N concentration was evident between weeks 6 and 8 and levels rose to a maximum at week 10. This maximum (41.7 mg/kg of soil or 6.63 × 10^{-4} oz/lb) was nearly identical to the maximum concentration of NO_3-N found in the 30–60 cm (12–24 in) soil layer beneath *Cornus* at week 10 (41.5 mg/kg of soil or 6.60 × 10^{-4} oz/lb).

NO_3-N concentration in the 60–90 cm (24–36 in) soil layer increased steadily over the growing season to a maximum of 31.1 mg/kg (4.95 × 10^{-4} oz/lb) of soil at week 10. The maximum NO_3-N concentration beneath *Cornus* at this soil depth was nearly 9 mg per kg (1.43 × 10^{-4} oz/lb) of soil less than for *Rhododendron*. Concentrations of NO_3-N in the 60–90 cm (24–36 in) layer continued to be elevated for the remainder of the study.

If NO_3-N content for the entire 0–90 cm (0–36 in) profile is examined, it is obvious that regression lines for NO_3-N concentration beneath both species are very similar in shape (Fig. 4). However, NO_3-N concentrations for soils beneath *Rhododendron* were significantly ($\alpha = 0.5$) higher than NO_3-N concentrations beneath *Cornus* for the entire season.

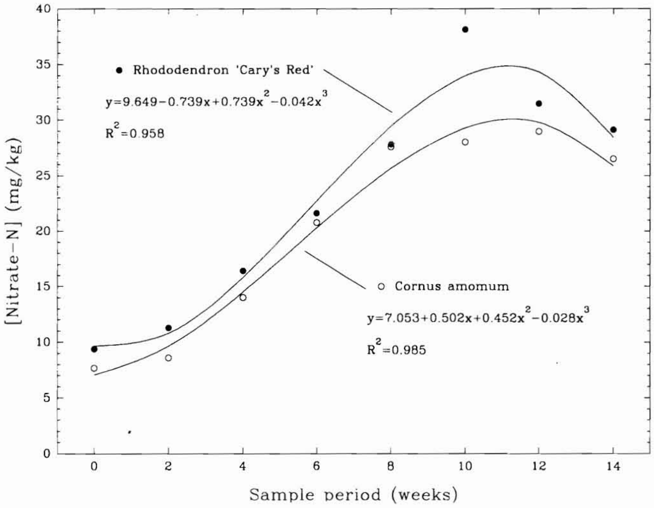

Fig. 4. Nitrate nitrogen concentrations in the upper 90 cm (36 in) of soil beneath container crops of *Cornus amomum* and *Rhododendron* 'Cary's Red' during the course of a growing season. Linear, quadratic and cubic effects were significant at the 1% level.

Cornus foliage collected at week 12 contained significantly ($\alpha = 0.5$) higher foliar NO_3-N levels than *Rhododendron*. When *Rhododendron* and *Cornus* received identical cultural conditions and fertilizer treatments, *Cornus* foliage (327.7 mg of NO_3-N/kg of tissue or 52.13×10^{-4} oz/lb) contained nearly 25 times more NO_3-N than *Rhododendron* foliage (13.3 mg of NO_3-N/kg of tissue or 2.18×10^{-4} oz/lb). Clearly, *Cornus* has a higher demand for NO_3-N, and, perhaps, is more efficient at NO_3-N uptake and utilization. It is recognized that it is desirable to supply N to *Rhododendron* as ammonium, rather than as NO_3.

The data obtained in this study indicate that NO_3-N levels in the soil underlying containerized nursery crops can reach high levels, even when CRFs are used. Six weeks following surface application of a CRF, NO_3-N levels throughout a 90 cm (36 in) soil profile can be above 20 mg per kg (3.18×10^{-4} oz/lb) of soil (Fig. 4). Such sustained levels of NO_3-N in the soil, combined with the frequent irrigations needed for container production, may pose an environmental risk to ground and surface water. These data also indicate that the crop grown can influence the dynamics of NO_3-N leaching into and through the soil profile underlying the crop. It is important to correlate N release by a CRF with crop growth to minimize NO_3-N loading to the soil.

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