Fate of Nitrates in Field Nursery Production Systems

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Abstract: Nitrogen (N) fertilization is an integral part of managing field nursery production. However, growers must manage additions properly in order to optimize growth efficiency and avoid environmental impacts. In particular, leaching of nitrates below the crop root zone and into ground water is an increasing concern. Historically, field nurseries have often been located in areas with coarse-textured soils to facilitate seedling lifting and other nursery operations. These soils typically have low nutrient-holding capacities requiring frequent N inputs that may be subject to leaching. This paper will review the principle inputs and outputs in the N cycle of a typical nursery and the environmental concerns associated with nitrate leaching. We will discuss the results of our case studies of nitrate movement in field nursery systems in western Michigan and suggest management practices that growers may adopt to improve N use efficiency and reduce environmental impacts.

Keywords: ground water contamination, eutrophication, nitrogen balance, fertilization, plant mineral nutrition

Introduction

Leaching of nitrates and other contaminants has been recognized as a significant environmental issue in container production systems (Dumroese and others 1992, 1995; Dumroese and Wenny 1992; Juntunen and others 2003). Total nitrogen (N) concentrations of leachate from container nurseries may exceed 500 mg/l (0.019 oz/gal) (Juntunen 2003), and up to 60% of N applied to container nurseries may be lost in discharge water (Dumroese and others 1995).

Leaching of nitrate below the crop root zone and into ground water is an increasing concern in field nursery production systems as well. Studies of agronomic field crops suggest that 20 to 100 kg/ha (18 to 89 lb/ac) may leach to ground water each year (Powlson 1993). Historically, field nurseries have often been located in areas with coarse-textured soils to facilitate seedling lifting and other nursery operations. These soils typically have low nutrient-holding capacities requiring frequent N inputs that may be subject to leaching.

The Nitrate Problem

Nitrate is the pollutant most commonly identified in ground water. Though nitrate (NO_3^-) is the main form in which N occurs in ground water, dissolved N may also be present as ammonium (NH_4^+), nitrite (NO_2^-), nitrogen (N_2), nitrous oxide (N_2O), and as organic N (Burt and others 1993).

Agricultural practices are responsible for a major portion of the nitrate pollutants in surface water (Cooper 1993). In the UK, 1.6 million tons (1.45 million tonnes) of N are applied to crops as fertilizer every year, 10 to 60% of which is not incorporated by the crop (Sylvester-Bradley 1993). These non-point pollutants are difficult to measure, control, and regulate because they originate from a diffuse area, are generally not continuous, and can vary depending on weather and time of year. Any control requires altering land management practices (Carpenter 1998).

It has been shown that with agricultural crops, it takes a large amount of fertilizer to bring a crop to its maximum yield; indeed, to increase yield from 90% of maximum to 100%, doubling the fertilizer N is required to provide the last 10% of the yield (Sylvester-Bradley 1993). Because fertilizer is relatively inexpensive in terms of overall production costs, growers may over-apply to ensure that the crop will grow to its maximum potential. However, total N in the soil is often underestimated. Nitrogen can derive from a combination of organic compounds already present in the soil, can be released from mineralization of applied manure, or from non-organic fertilizers (Figure 1). The underestimation of available N can lead to a surplus of N in the soil and major contamination of ground water by large quantities of N (nitrate) in leachates (Powlson and others 1992; Shepherd and others 1996; Alt 1998; Goulding 2000). In the world's croplands, additions and removals of nutrients by humans have overwhelmed natural nutrient cycles. Worldwide, more nutrients are added as fertilizers than are removed by crops (Carpenter 1998).

Harm to Humans

The most susceptible individuals to the harmful effects of the ingestion of nitrates are infants under the age of 6 months.

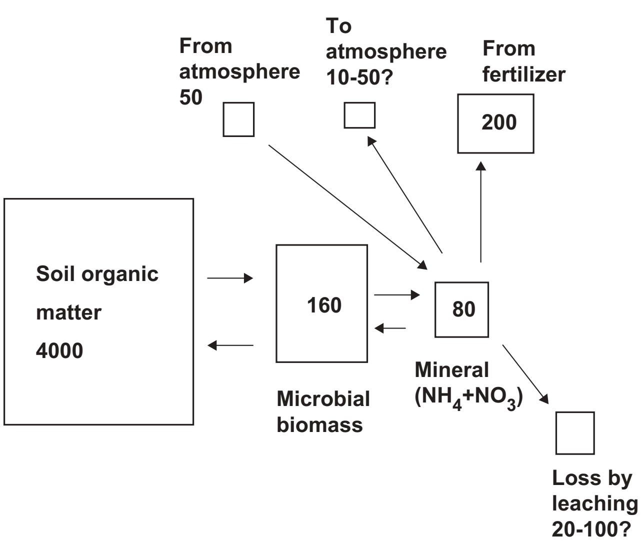

Figure 1—Nitrogen pathways in soil. The quantity of nitrogen in each pool (kg/ha) or undergoing each process (kg/ha/yr) is proportional to the size of the square (Powlson 1993) (1 kg/ac = 0.9 lb/ac).

Adults and older children can excrete ingested nitrate through their urine. Other groups at risk are pregnant women, cancer patients, and people with reduced stomach acidity (Carpenter 1998; Mahler and others 1991). Infants under the age of 6 months have low levels of acid in their digestive tract. To help with digestion, they have high levels of bacteria, which convert nitrate to the toxic nitrite (Mahler and others 1991). In the bloodstream, nitrite combines with hemoglobin and forms methemoglobin. Unlike hemoglobin, this compound is unable to carry oxygen. As more methemoglobin is produced, suffocation starts to take place from the lack of oxygen. This is called "methemoglobinemia" (Mahler and others 1991). When babies contract this it is termed "blue-baby syndrome." To protect babies less than 6 months old, the US Environmental Protection Agency has established a maximum contaminant level for nitrate in drinking water of 10 mg/l (Carpenter 1998).

Nitrate may also interact with organic compounds to form nitrosamines, which are known to cause cancer. Compounds that can interact with nitrate include some pesticides. This is important because areas contaminated with nitrates have a high probability of containing pesticides (Mahler and others 1991).

Effect on Aquatic Ecosystems

Eutrophication is defined by Carpenter (1998) as "the fertilization of surface waters by nutrients that were previously scarce." The nutrients that cause the most harm in this process are phosphorus and N. Eutrophication is currently the most widespread water quality problem in the US, and in many other nations.

There are severe consequences to eutrophication which include: premature aging of lakes, proliferation of algae, increase in bacterial populations, decrease in dissolved oxygen, and fish kills. Eutrophication is part of the aging process of shallow lakes. With the increase in plant and algae populations in a lake system there is also an increase in dead plant material, which causes the bacterial decomposer population to increase dramatically. These bacteria consume dissolved oxygen, leaving an inadequate supply for fish and causing fish kills (Carpenter 1998).

Protecting surface and ground water quality is critical for the nursery industry, an industry that generates over US $700 million in annual sales in Michigan alone. Approximately half of the acreage in nursery production in Michigan is concentrated in 4 western counties near Lake Michigan. Soils in this area are coarse textured, have low organic matter, and are therefore vulnerable to nitrate leaching. Nitrogen addition rates for some high N-demanding nursery crops, such as *Euonymus alatus* 'Compactus', may range as high as 250 kg/ha (223 lb/ac). Estimating N losses from field production systems can be problematic compared to container systems. In container systems, a mass balance analysis can be used to develop a "check book" approach to account for N additions and losses (Dumroese and others 1995). In field systems, N fluxes are often difficult to estimate.

Specific Objectives and Hypotheses

In the present study, we tested the hypothesis that scheduling N applications to meet crop demand will result in optimal growth and reduce nitrate movement to ground water. The research applied Ingestad and Ågren's principle of relative addition rate (Ingestad and Ågren 1988, 1992) to nursery production as proposed by Alt (1998a,b) and Dumroese and others (1995).

Based on Ingestad and Ågren's theory, plant mineral nutrition is optimized when nutrient supply, either from native soil fertility or nutrient additions, is in balance with plant nutrient demand. A mitigation to the application of Ingestad and Ågren's concepts to field crops is the logistical difficulty of estimating nutrient demand of a standing crop. Recently, however, Alt (1998a) demonstrated that the N demand of nursery crops can be reasonably estimated from the total fresh weight of new shoots.

Specific objectives:

1. Evaluate impact of 3 fertilization approaches on:
   a. crop nutrition and growth;
   b. nitrate concentration of water under root zone;
   c. nitrate concentration of shallow ground water.
2. Develop baseline data on impact of nursery operations on ground water.
3. Determine the validity and logistics of applying relative addition rate principles to nursery crops.

Methods

Treatments

We established fertilization plots in Japanese yew (*Taxus* x *media*) and burning bush (*Euonymus alatus* 'Compactus') fields in 2 commercial nurseries in Ottawa County, Michigan, in the spring of 2001. Three replicate plots in each field were assigned to 1 of 3 fertilization treatments:

1. Control—no additional fertilization.
2. Operational—fertilization based on industry standard (150 kg N/ha [134 lb/ac] split into 2 applications [April and July]).
3. Relative addition rate (RAR)—fertilization based on crop growth rate. Crop biomass growth was estimated from periodic measurements of crown volume (Figure 2). Nitrogen uptake was estimated as the change in standing crop N between measurement periods. Nitrogen was added to replace the amount taken up assuming 50% uptake efficiency.

Data Collection

Foliar samples were collected from each plot on a monthly basis and analyzed for N concentration.

Two porous-cup suction lysimeters were installed to a depth of 45 cm (18 in) near the center of each plot. The vacuum on each lysimeter was set to 0.70 mbar (70 Pa), and soil water samples were collected after each significant rainfall during the 2001 growing season (Figure 3).

Figure 2—Seasonal changes in plant biomass were estimated from periodic measurements of crown volume.

Figure 3—Soil water sampling with a suction lysimeter.

Results

Nitrate Leaching

Nitrate concentrations of soil water collected in the lysimeters were affected by species and fertilizer treatment. In the *Taxus* fields, fertilization significantly increased soil water nitrate concentration below the root zone relative to the control (Figure 4). Soil water nitrate in the RAR plots were intermediate between the control and the operational treatment. Soil water nitrate levels were higher in the *Euonymus* than the *Taxus*, particularly on the control plots. Since the *Euonymus* fields were younger than the *Taxus* plots, this effect may reflect mineralization of residual organic matter from manuring and cover crops during the fallow period prior to plantation establishment. Nitrate levels in soil water ranged from 10 to 150 mg/l (0.001 to 0.02 oz/gal) in the *Euonymus* plots and from near zero to 100 mg/l (0.013 oz/gal) in the *Taxus* plots.

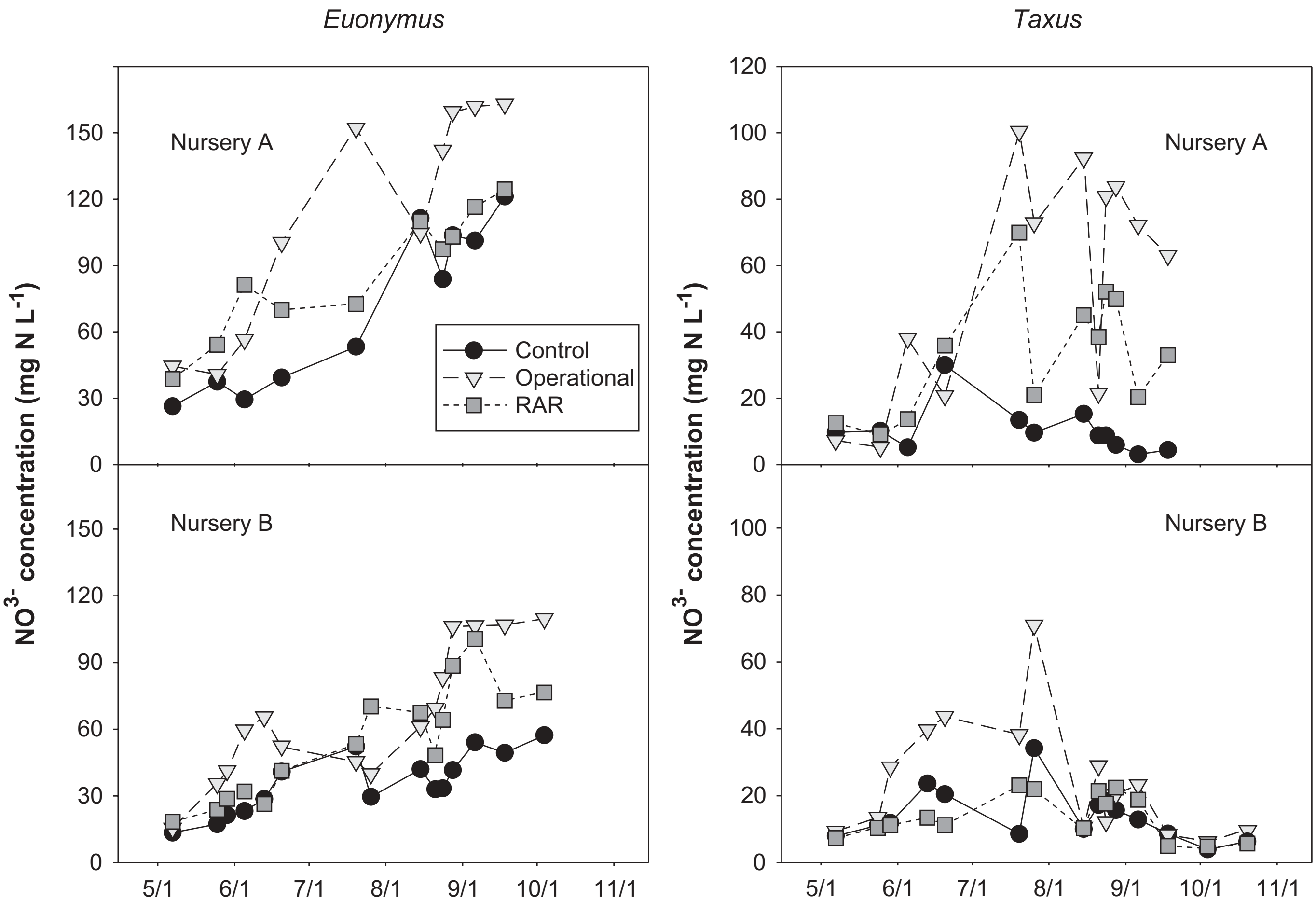

Figure 4—Soil water nitrate concentration of samples collected at 45 cm (18 in) depth in field nursery plots of *Euonymus alatus* 'Compactus' and *Taxus* x *media* grown under three levels of fertilization.

Growth and Foliar Nutrition

Crown volume growth of *Euonymus* and *Taxus* did not differ ($P > 0.42$) among the fertilization treatments (data not shown). Fertilization increased foliar N levels relative to the controls in *Taxus* but not *Euonymus*. Vector analyses indicated luxury uptake of N in the *Taxus* plants (Rios 2002).

Conclusions

Overall the results of this study indicate that growth of nursery crops can be maintained, and nitrate losses reduced, by matching N additions to crop demand. Moreover, a better understanding of the overall N balance in field nursery crops is needed to further optimize crop growth and quality while minimizing N losses and adverse environmental impacts. Nursery managers need to consider crop species, age, and growth habit in developing nutrient prescriptions. Our research indicates attention needs to be paid to:

1. Understanding mineralization rates and other factors controlling availability of N besides fertilizer additions. In our study, the nonfertilized controls grew as well as either of the fertilized treatments in both species. This raises the questions of how long N supply from mineralization of organic matter can meet crop demand.

2. Crop growth and development. In the present study, *Euonymus* has a determinant growth habit, completing crown growth by mid-July. In contrast, the *Taxus* plants continued to grow late into summer depending on availability of soil moisture. This suggests that *Taxus* would be better able to take advantage of late season N additions than the *Euonymus*. Also, more detailed information of total crop demand for N can help guide fertilization decisions.

3. Importance of other N forms, particularly organic N. Dissolved organic N can be an important component of agricultural N losses (Murphy and others 2000). Juntunen and others (2003) found that organic N may contribute over half of the N in soil water beneath container forest nurseries during the spring. Organic N is also being recognized as an important source of N for plant uptake in various ecosystems (Näsholm and others 2000; Näsholm and Persson 2001).

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