Landscape Types Influence Severity of Nitrate Leaching

By Richard J. Hull and José A. Amador

The leaching of nitrate-nitrogen (NO_3-N) from turf has received considerable attention by those concerned with preserving groundwater quality in suburban communities. While turf has generally been found to leach less than 10 percent of applied fertilizer nitrogen below its root zone (Petrovic 1990), very little information is available concerning nitrogen retention by other components of residential, institutional, municipal or recreational landscapes. Before the true environmental impact of landscape designs and maintenance can be assessed fully, all planted elements of the landscape must be evaluated for their contribution to nitrate leaching losses. What follows is a report on a 21-month study of nitrate leaching from eight planting elements of an established landscape in southern New England that we published recently (Amador et al. 2007).

To give this research maximum practical value, we conducted the study in the University of Rhode Island Botanical Garden, an area that had been a landscaped garden complex for at least 50 years and had undergone its most recent renovation more than 10 years before this study began. Data were collected from a nearby native woodland, and some areas in the garden that were not planted but covered with pine-bark mulch. To collect soil-water samples to be analyzed for NO_3-N, 2-foot-long suction lysimeters were installed vertically so the porous ceramic sampling cup was at a soil depth of 20 inches. Soil water samples were collected on 23 occasions between June 2002 and November 2003, one day following each rain event of approximately 1 inch or more. Sampling involved creating suction within a lysimeter for one hour during which time soil-water was drawn into the ceramic cup from which it was later pumped into a collection flask. Soil samples were collected monthly from the upper 4 inches of each site and analyzed for extractable NO_3 and ammonium (NH_4) as well as soil pH and organic matter content.

Soil water nitrate

The concentration range of NO_3-N in soil-water spanned more than two orders of magnitude (100- to 1,000-fold differences) but did not show any consistent seasonal patterns. The various vegetation types exhibited soil water NO_3-N levels that fell into four significantly different concentration ranges. The highest median concentrations (mid-point values between 1.4 milligrams of nitrogen per liter (mg N/liter) to 7.8 mg N/liter [parts per million or ppm] NO_3-N) were found under ground covers, unplanted mulched sites, turf, and deciduous and evergreen trees with no true differences among these five vegetation types. The middle concentration range (0.2 ppm to 0.3 ppm NO_3-N) was observed under perennial and annual flowers and deciduous and evergreen shrubs. Again, no real differences existed among these four plant types. Not surprisingly the unfertilized native woodland yielded the lowest median soil water NO_3-N concentration at 0.01 ppm.

Of these vegetation types, only forests and turf have had soil-water NO_3-N concentrations reported by others. We are encouraged that our values fell within published ranges. For example, Gold et al. (1990) reported an earlier study on similar soils in Rhode

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PHOTO 1

The University of Rhode Island Botanical Garden shows some vegetation types studied for their nitrate leaching. In foreground: perennial flowers; mid-ground: unplanted site; background: evergreen shrubs; background left: deciduous trees.

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Island and found fertilized lawn turf and an unfertilized oak-pine forest had soil water NO_3-N levels of 3.7 and 0.54 ppm, respectively. Numerous other studies reporting NO_3-N concentrations of soil water under cool-season turf are in close agreement with our findings (Petrovic 1990). Actually the turf NO_3-N levels found in this study were a bit higher than those from earlier investigations by us and others (Jiang et al. 2002 & Petrovic 1990). Values less than 5 ppm NO_3-N are more typical. It is possible that the presence of white clover in some of the turf sampling sites might have contributed nitrate to soil water in addition to that from the 50 pounds N/acre applied each spring as sulfur-coated urea. Soil water nitrate did exceed the minimum safe level of 10 ppm NO_3-N in 20 percent of the water samples taken under turf. Other vegetation types that exceeded the 10 ppm NO_3-N safety standard for drinking water were ground covers (39 percent) and unplanted mulched sites (10 percent).

Unplanted sites would be expected to leach more NO_3-N because there are no roots present to absorb NO_3 mineralized from soil organic matter and nitrogen deposited from the atmosphere.

Nitrate leaching

Nitrate leaching from the sampling sites was determined by multiplying the volume of rainwater percolating through the soil by the NO_3-N concentration in water samples collected 24 hours following the rain event. Water percolation was calculated from precipitation and evaporation data obtained from the University weather station. Evaporation was converted to plant transpiration using conversion constants for each vegetation type derived from the scientific literature. Whenever rainfall exceeded that necessary to compensate for plant transpiration and to saturate the soil, the excess water was assumed to leach through the soil profile, carrying nitrate with it. The total NO_3-N leached from each vegetation type is summarized for the 15 months in which leaching occurred. The amount of nitrogen leached is expressed in kilograms N/hectare (kg N/ha), roughly equivalent to pounds/acre.

Nitrogen leaching over the 18-month study ranged from 0.17 kg N/ha for woodland to 34.97 kg N/ha for ground covers. The vegetation types separated into three statistically different NO_3-N leaching groups. The low leaching group (less than 2 kg N/ha) included woodland, evergreen and deciduous shrubs and annual and perennial flowers. A medium leaching group (2 to 10 kg N/ha) encompassed deciduous and evergreen trees and turf. The high leaching group (>10 kg N/ha) consisted of ground covers and unplanted mulched soil.

The NO_3-N leaching losses from woodlands and turf observed here are in line with those reported by others. Gold et al. (1990) reported a woodland range in nitrogen losses of 1.2 to 1.5 kg N/ha/year that was roughly comparable to our annual loss of 0.14 kg N/ha/year. Our nitrogen leaching loss from turf averaged 2.81 kg N/ha/year that was within the range of 1.1 kg N/ha/year for unfertilized turf and 25.8 kg N/ha/year for turf fertilized at 150 lbs N/acre/year reported by Guillard and Kopp (2004). Gold et al. (1990) reported a turf N leaching rate of 1.9 to 9.3 kg N/ha/year that also encompass our 2.81 rate. We have no way to compare our estimates of NO_3-N leaching from other landscape vegetation types with those of other investigators, but our agreements in turf and forests give us confidence that our values are reasonable.

Unplanted sites would be expected to leach more NO_3-N because there are no roots present to absorb NO_3 mineralized from soil organic matter and nitrogen deposited from the atmosphere (10 kg N/ha/year). Nitrate leaching from vegetated

PHOTO 2

Suction lysimeter inserted in soil to a depth of 20 inches. Rubber stopper at top is removed to evacuate the lysimeter tube and withdraw soil water sample.

sites seem to be inversely related to the density of roots within the upper soil layers. Mixed stands of annual and perennial flowers produce a dense mass of roots capable of absorbing most available NO_3. The same can be said for both deciduous and evergreen shrubs especially when they are well established. Mature trees have massive root systems but most fine absorptive roots are beyond the drip line not under the canopy where our soil water samples were collected and NO_3 leaching is likely.

The high leaching rate from ground cover vegetation was not expected but not unreasonable. Our sampling sites for ground covers were in the open so as not to be confounded by roots from over-story trees. Thus, these shade-adapted plants were growing in greater than optimum light and were likely stressed. This could result in photosynthetically inefficient foliage and less dense root systems. Superficial observations of these plants during mid-summer droughts suggested they were experiencing stress and likely not absorbing soil nutrients effectively.

It is evident that there are differences in the amount of NO_3-N that can leach from the various vegetation types that constitute most managed landscapes. These differences can be moderated by appropriate plant placement and management practices. Our results also indicate that nitrate leaching from landscape plantings might be minimized by avoiding unplanted bare ground (even if mulched), large areas planted to ground covers exposed to full sun, and by concentrating on multi-species plantings of herbaceous flowering plants and shrubs. Clearly, this study is just the beginning of what should be a new research area on environmental horticulture.

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REFERENCES

Amador, J.A., R.J. Hull, E.L. Patenaude, J.T. Bushoven and J.H. Goerres. 2007. Potential nitrate leaching under common landscaping plants. Water, Air & Soil Pollution, 185:323-333.

Gold, A.J., W.R. DeRagon, W.M. Sullivan, and J.L. Lemunyon. Nitrate-nitrogen losses to ground water from rural and suburban land uses. Journal of Soil & Water Conservation, 45:305-310.

Guillard, K. and K.L. Kopp. 2004. Nitrogen fertilizer form and associated nitrate leaching from cool-season lawn turf. Journal of Environmental Quality, 33:1822-1827.

Jiang, Z., J.T. Bushoven, H.J. Ford, C.D. Sawyer, J.A. Amador and R.J. Hull. 2002. Mobility of soil nitrogen and microbial responses following the sudden death of established turf. Journal of Environmental Quality, 29:1625-1631.

Petrovic, M.A. 1990. The fate of nitrogenous fertilizers applied to turfgrasses. Journal of Environmental Quality, 19:1-14.