Nitrogen and Phosphorus Fate When Applied to Turfgrass in Golf Course Fairway Condition

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GOLF HAS GROWN tremendously in popularity in the United States. There are more than 14,000 golf courses that cover more than 1.3 million acres in the U.S. More than 488 million rounds of golf are played annually, and the total number of people who play golf in the United States is more than 27 million (Cohen et al., 1993).

In an urban landscape, turfgrass is partitioned in the following manner: 70% residential lawns, 10% parks and sport facilities, 9% golf courses, 9% educational facilities, 2% cemeteries, and 1% industrial purposes (Cockerham and Gibeault, 1985). Although golf courses are a small part of the total area of turfgrass in the urban community, they are readily visible to the public and are often identified as a possible source of fertilizer and pesticide contamination of groundwater and surface water supplies.

Fertilizers applied to turfgrass areas can have a variety of fates in the environment. They can be taken up by plants, volatilized into the atmosphere, carried by runoff in surface water, adsorbed to soil particles, degraded by biological and chemical processes, and leached through the soil profile (Balogh and Walker, 1992).

A potential detrimental effect of fertilizer usage is the contamination of surface water and groundwater (Balogh and Walker, 1992). Eutrophication of surface waters, the proliferation of aquatic plants, is caused by a surplus of available nutrients. Eutrophication can cause a decrease in dissolved oxygen in waterways, a situation that can kill fish. Phosphorus availability also can be a limiting factor for eutrophication (Mugaas et al., 1991; W. C. Huber, 1993).

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High levels of exposure to some fertilizer nutrients have been reported to be detrimental to humans (Cantor et al., 1988). There is, however, little conclusive evidence of health risks associated with low-level exposure to these nutrients.

Although golf courses have been associated with potential environmental hazards because of pesticide and fertilizer use, these important recreational facilities also provide positive benefits. Some of these benefits include: increased infiltration and reduced runoff compared to bare soil and to agricultural crops, minimal erosion losses, moderation of high temperatures in urban areas, low-cost playing fields, and contribution to the quality of life through aesthetic benefits (Beard, 1993).

Studies on the Fate of Fertilizers

Research results pertaining to the fate of fertilizers applied to turfgrass have been extensively reviewed by Petrovic (1990), and Balogh and Walker (1992). Soil characteristics that affect fertilizer fate include: water content, bulk density, pH, temperature, organic matter, structure, and cation exchange capacity. Climate and slope of the site also are important factors, as are the physiochemical properties, solubility, and chemical concentration of the fertilizer. Management practices that affect fertilizer fate include: application rate, placement, timing of application, formulation, and irrigation practices (Balogh and Walker, 1992).

In recent studies, Joo et al. (1992) investigated the volatilization of nitrogen-15 labeled urea when applied to turfgrass. When irrigation did not follow the liquid urea application, 50% of the urea volatilized within 7 days after the urea application. Starrett (1992) showed that less than 1% of the applied urea volatilized when a liquid urea application was followed with irrigation.

Erosion can be a major carrier of organic nitrogen in surface water runoff from agriculturally managed areas (Haynes, 1986). Turfgrasses greatly reduce erosion by decreasing surface runoff velocity, increasing infiltration, and stabilizing the soil. Few research projects have been conducted to study nutrient losses, specifically on the leaching of nutrients, from turfgrass areas (Petrovic, 1993). It has been claimed, however, that leaching of surface-applied fertilizer is responsible for nitrate in the groundwater in some urban areas (Flipse et al., 1984).

The turfgrass manager cannot control all site factors and climate conditions, but he or she can control irrigation rates, perform soil and plant tests to prevent over-fertilization, and plan the timing and placement of fertilizers (White and Peacock, 1993). Rieke and Ellis (1973) suggest a variety of techniques to reduce nitrogen losses: reduced annual nitrogen rates, lighter and more frequent nitrogen applications vs. single heavy applications, applying nitrogen only to healthy turf, and strict water practices to prevent excessive irrigation.

Iowa State University Research

Iowa State University is one of 21 universities and research centers that conducted environmentally related research funded by the USGA (USGA, 1991). Our research objectives were to investigate the hydrology of undisturbed soil columns with a Kentucky bluegrass turf and intact macropores under a single and split irrigation regime, and to measure the effect of the different irrigation regimes on the fate of nitrogen and phosphorus when they are applied to an undisturbed soil column.

Undisturbed columns of a Nicollet (fine-loamy, mixed, mesic-Aquic Hapludolls) soil were taken from a 4000 sq ft turfgrass area at the Iowa State University Horticulture Research Station. Undisturbed soil columns were used because the influence of macropores is negated when experiments are done using dried, sieved, and repacked soil columns (Evert, 1989).

The area had been established with Premium Sod Blend® (Parade, Adelphi, Rugby, and Glade) Kentucky bluegrass (*Poa pratensis L.*) and maintained at golf course fairway mowing height (1"). The columns measured 8" in diameter and were excavated to a 20" depth. A 12" heating duct pipe was placed around the column, leaving 2" between the soil column and the pipe. Mortar was poured between the pipe and soil. The undisturbed soil columns were then transported to the greenhouse.

More than 99% of nitrogen has an atomic weight of 14, and less than 0.5% has an atomic weight of 15. Nitrogen-15 is a stable, nonradioactive isotope that has been used for years as a tracer of fertilizer nitrogen applied in agricultural settings. Surface applied nitrogen with a higher concentration of synthetic nitrogen-15 can be used to measure the fate of applied nitrogen. A mass spectrometer is used to determine the atomic weight of the nitrogen present in the soil, plant material, or soil column leachate.

Urea N (46% N), labeled with 5% nitrogen-15, and phosphorus were applied to the surface of the Kentucky bluegrass turf. The pesticides pendimethalin (herbicide), MCPP (herbicide), 2,4-D (herbicide), dicamba (herbicide), isazofos (Triumph, insecticide), chlorpyrifos (Dursban, insecticide), and metalaxyl (Subdue, fungicide) were also applied. The experimental treatments included two irrigation regimes. One treatment consisted of watering the column with 1" of distilled water immediately after the fertilizer and pesticides were applied. The second treatment included a 0.25" application immediately after the fertilizer and pesticide application, and three additional 0.25" applications at 42-hour intervals, yielding a total 1" irrigation spread evenly over a 7-day period. The experiment ran for 28 days. A similar experiment to investigate the fate of nitrogen and phosphorus was conducted over a 7-day period. The goals of our research were to investigate the fate of fertilizers and pesticides applied to turfgrass, and to determine if irrigation practices can be used to affect pesticide and fertilizer movement through the soil profile.

A glass trap system was used to collect volatilized N in the form of ammonia (NH_3). Leachate was collected from the bottom of the columns at various times and immediately frozen. Clipping, verdure, and thatch mat samples were taken from each column, and the soil was excavated in 4" layers at the end of the test period. The soil was then dried, placed in plastic bags, thoroughly mixed, and sampled for analysis of pesticides, ^{15}N, and phosphorus concentrations.

Results

Analysis of the pesticide data is still underway and will be reported on in a later article. Initial observations from the fate of nitrogen and phosphorus research are: a heavy irrigation increases nitrogen transport compared to a light irrigation; macropores may play a role in transport of surface-applied nitrogen through soil profiles; volatilization of liquid urea was less than 3% when followed with irrigation and is reduced to less than 1% under a heavy irrigation; and the irrigation rate does affect P transport after a 7-day period.

The macropore structure found in an undisturbed soil can have a major impact on water and solute distribution in the profile (Thomas and Phillips, 1979). About 10% of the applied nitrogen under the heavy irrigation was collected in leachate within a few hours of the fertilizer application and can be attributed to macropore flow. The heavy irrigation caused some ponding to occur on the soil surface, filling the macropores and allowing rapid flow through the soil profile.

Volatilized nitrogen was less than 3% of the applied nitrogen under either irrigation regime, which agrees with research conducted by Bowman et al. (1987). Applying irrigation immediately after a nitrogen application reduces volatilization by transporting the applied nitrogen slightly below the soil surface, where N is more likely to be adsorbed. The heavy irrigation transported more of the surface-applied N below the soil surface compared to the light irrigation, thereby further reducing N volatilization.

Starrett et al. (1994) reported that phosphorus was found in leachate from 20" undisturbed soil columns covered with Kentucky bluegrass under a heavy irrigation during a 7-day test period (Table 1). Also, 35% of the phosphorus was transported below 8" under the heavy irrigation regime.

What Does This Mean to the Golf Course Superintendent?

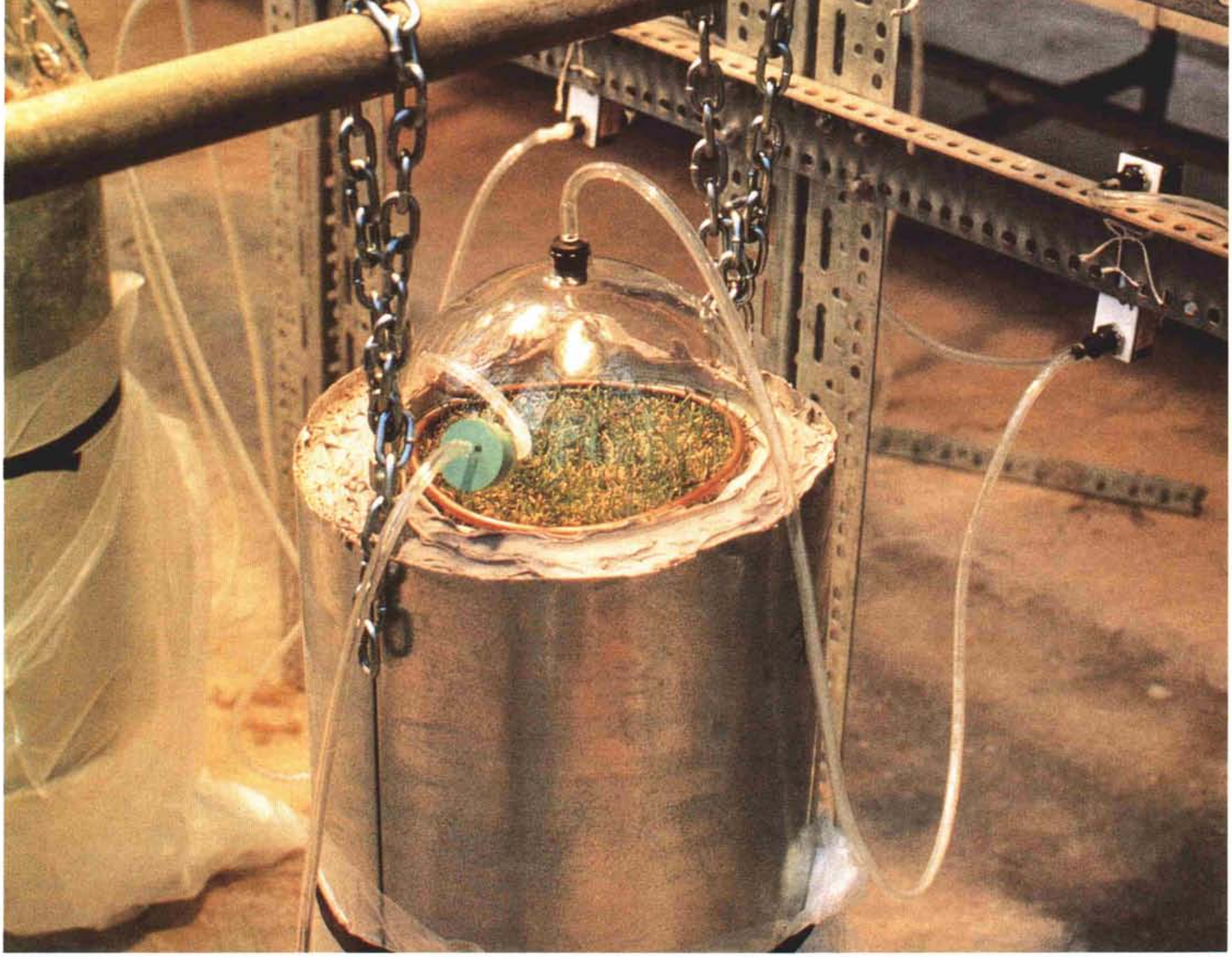
Golf courses can be managed in such a way that even phosphorus, which is known to be fairly immobile, can be moved through a 20" soil profile and potentially into the groundwater. However, there are management practices that the superintendent has control over that can minimize the potential movement of fertilizers through soil profiles. Among these practices is the control of fertilizer application rates. Excessive application rates promote more nitrogen and phosphorus being lost to volatilization and leaching, and less of the applied nutrients being absorbed by the turfgrass. Application timing is important with regard to preventing applied nutrient losses. Applying nutrients just before a heavy rainfall would cause greater losses due to leaching through the soil profile in comparison to light irrigation after applying nutrients.

Proper irrigation practices can also help to reduce nutrient losses. Nitrogen volatilization losses from liquid N fertilizers can be reduced to negligible amounts by lightly watering immediately after application. Also, losses due to leaching can be reduced by irrigation practices. In our study, a 1" irrigation versus four 0.25" irrigations after a surface application of nitrogen increased the amount of nitrogen that leached 20" into the soil profile by 40 times. Careful consideration should be given to these practices before making any management decisions. It is clear that when care is taken in applying fertilizers to golf course turf, losses can be kept to an absolute minimum.

Table 1
Available Phosphorus Concentrations (ppm) in the Soil and Total Phosphorus in the Leachate (mg)[1]

Category	Heavy Irrigation Mean	Heavy Irrigation Std. Dev.	Light Irrigation Mean	Light Irrigation Std. Dev.	Probability[2]
Thatch Mat	18.5	2.9	27.5	8.3	0.073
0-4 in.	6.7	1.5	6.4	1.6	0.735
4-8 in.	2.7	1.0	2.4	0.5	0.502
8-12 in.	2.3	0.8	1.4	0.5	0.031
12-16 in.	2.4	1.3	1.6	1.1	0.208
16-20 in.	3.0	1.6	2.0	1.7	0.288
Leachate[3]	1.0	1.0	<0.1	<0.1	0.024

[1]Values from 7 replications
[2]Probability that a difference exists (lower the value, more likely different
[3]Total P found in leachate (mg)


A glass trap system collects volatilized N in the form of ammonia (NH_3).

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