Dr. Stan Brauen using a moisture probe on the treated plots to monitor the study.

Leaching of Nitrate from Sand Putting Greens

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GOLF IS PLAYED year round in the coastal Pacific Northwest. Summers are dry and often cool, yet the long, mild, wet winters may cleanse nutrients from sand profiles of putting greens and flush them into drainage systems. These conditions suggest to the public that golf course management practices are a potential threat to environmental quality because of the use of pesticides and nitrogen to maintain play, appearance, and turfgrass quality. If true, the result could be groundwater contamination. To complicate matters, golf course putting greens, tees, and other athletic turf areas in the coastal Pacific Northwest are often constructed of sand, some with coarse particle sizes and without amendments in order to reduce construction costs and improve drainage during the wet seasons.

The Problem

Among the questions we wanted to answer is whether nitrate nitrogen applied to putting green profiles constructed of sand or peat/soil-amended sand could potentially leach or move into streams, lakes, or groundwater. If it does move, what is the critical time of year when the leaching would occur, and what daily management practices would reduce the threat of further contamination? Would modified rooting mediums, efficient nitrogen fertilizer practices, minimal fertilization rates, deeper sand profiles, or efficient irrigation practices eliminate the threat while maintaining adequate turf for the playing of the game of golf? The development of this information would serve as the basis in providing guidance for its correction, reduction, or elimination. The objectives of the study were to quantify the effect of rooting medium, fertilization interval, and annual nitrogen rate on nitrate nitrogen leached from creeping bentgrass putting greens. It was thought that lighter, more frequent applications of fertilizers from slow-release sources might be helpful at mitigating potential leaching losses.

How the Studies Were Conducted

The study was carried out in 36 small lysimeters constructed in a manner similar to USGA putting greens. A lysimeter is simply a term used to describe a system that gives turf scientists the ability to closely measure the inputs and outputs of a system. In this case, the emphasis was on nitrate nitrogen leached.

The turfgrass lysimeters were located 30 miles south of Seattle, Washington, at Washington State University Research and Extension Center, in Puyallup, Washington. Each lysimeter was 32 sq ft, lined with chlorosulfonated polyethylene reinforced liner and fitted with 2" ABS drain tube so leachates that moved through the 12" rooting medium, the 3" intermediate layer, and 3" pea-sized gravel layer could be collected daily. The rooting medium consisted of pure sand (CEC 2.6 meq per 100 g, pH 6.8) or a mixture of 88% sand, 10% sphagnum peat, and 2% screened Sultan silt loam. Particle size analysis of the sand was 4.2% between 1.0 and 4.7 mm, 85.1% between 0.25 and 1.0 mm, 8.5% between 0.13 and 0.25 mm, and 2.2% < 0.13 mm. The effects of rooting medium, annual nitrogen rate, and nitrogen application interval on leached nitrate nitrogen were monitored for two years.

The nitrogen fertilizer rates were 4, 8, and 12 lb N per 1000 sq ft per year. The nitrogen was supplied in granular form as greens-grade blends of ammonium sulfate, ammonium phosphate, isobutylidene diurea (IBDU), sulfur-coated urea (SCU), and methylene urea (MU). The ammonium sulfate and ammonium phosphate quantities were equal for all nitrogen rates, and all of the increase in nitrogen rate from 4 to 12 lb was supplied as IBDU, SCU, and MU (see Table 1). Phosphorus was supplied from ammonium phosphate, and potassium was supplied from potassium sulfate. Fertilizer applications were made every 14 or 28 days in 22 or 11 applications per year. Fertilizers were applied from February through December.

After construction of the lysimeters during the summer of 1991, the area was seeded on October 3. The first rainfall occurred on October 24, 1991, and leachates were collected in plastic 5.5-gallon buckets beginning on October 25. Leachate volumes were measured daily and subsamples were collected daily, when available, for the next two years.

Table 1
Quantity of Soluble and Slow-Release N Applied at Each Fertilizer Application Interval

Nitrogen Rate	Annual Rate (lb N/1000 sq ft)		
	4	8	12
	11 Monthly Applications (lb N/1000 sq ft)		
Ammonium phosphate	0.04	0.04	0.04
Ammonium sulfate	0.20	0.20	0.20
Urea	0.02	0.07	0.13
Slow release[1]	0.10	0.41	0.72
Total Application[2]	0.30	0.72	1.09
	22 "Two Week" Applications (lb N/1000 sq ft)		
Ammonium phosphate	0.02	0.02	0.02
Ammonium sulfate	0.10	0.10	0.10
Urea	0.01	0.04	0.07
Slow release[1]	0.05	0.20	0.36
Total Application[2]	0.18	0.36	0.55

[1]Slow-release nitrogen sources consisted of methylene urea, sulfur-coated urea and IBDU supplied in quantities to provide equal parts nitrogen from each source. Potassium was supplied from potassium sulfate as a part of the mix.

[2]Pounds of nitrogen applied per 1000 sq ft per application.

When Nitrate Leached

During the first fall and spring following seeding and when the creeping bentgrass was very immature, nitrates did leach from the lysimeters. The concentration of nitrate nitrogen in the drainage water increased with annual nitrogen rate applied. Very little nitrate was leached at the 4 lbs per 1000 sq ft rate. Nitrate was present in drainage water until late December and declined to low levels in January and February.

The concentration of nitrate percolating from the lysimeters during the first fall, winter, and spring following construction and seeding was considerably different from the concentrations of nitrate leached during the second fall, winter, and spring after the turf had matured. These nitrate patterns are shown in Figure 1. The differences shown emphasize the changes that occur in the ability of turfgrass to trap nitrogen as the turf matures. Note the large differences in nitrate concentrations from November to June of 1991-92 when lysimeters were fertilized with the 12 lbs N per 1000 sq ft per year rate versus the lower rate of 8 lbs N per 1000 sq ft in 1992-93.

During the first fall, when the turf was young, there were few grass roots and no thatch, and there was no organic matter in the pure sand rooting medium. This resulted in free movement of nitrates through the rooting medium and into the drainage water. Pure sand rooting systems are very susceptible to nitrate leaching immediately after construction. Everyone would have expected this to be the case. As a consequence, nitrates in relatively high concentrations were lost at the highest rate of nitrogen application even though the nitrogen sources were primarily ammonium sources. Little nitrate was leached at the lowest application rate.

The frequency of nitrogen application (14 or 28 days) and the makeup of the rooting medium (pure sand versus organic matter modified sand) were big factors in controlling the quantity of nitrate leached during the first fall and winter when the turf was young. The average monthly nitrate-N concentration of leachate from the pure sand rooting medium was significantly greater than the leachate concentration from the modified sand rooting medium during November 1991 to June 1992.

By the second fall, the turf had become well established. Roots were well defined and a surface thatch had developed. The rooting medium and the frequency of fertilizer application were less important in reducing nitrate movement. Then, the quantity of nitrogen applied was the main factor responsible for nitrate movement into the drainage water.

For the most part, nitrates leached only from lysimeters that were fertilized with 12 lbs of nitrogen per 1000 sq ft per year during the second year. Rooting medium had little effect in regulating the concentration of leachable nitrate. Frequency of nitrogen application seemed to have some effect on reducing nitrate leaching during the late fall and early winter period. Nitrates could be detected during periods when excessive rainfall was experienced following the heaviest nitrogen applications. Periods when this occurred were when nitrogen applications above 0.4 lb N per 1000 sq ft were applied followed by periods of slow precipitation over the next seven to 10 days and after the rooting medium temperature had declined 33° to 40°F. Under these conditions, halving the rate of nitrogen application and applying on a more frequent interval reduced nitrate movement. As long as the 2" temperature of the rooting medium remained in the above range, plant uptake appeared to be great enough to prevent nitrate accumulation in the leachates. November nitrogen fertilization at moderate rates did not result in leaching of nitrate-N.

The highest concentration of nitrates in leachates occurred in early to mid-spring growth periods. The rainfall pattern was significantly different during the winter and early spring of 1993 as compared to 1992. Precipitation occurred early in January in 1992, resulting in very low levels of nitrate concentration in leachates during January and February. Precipitation was considerably lower in March and early April in 1992 as compared to 1993, which may have resulted in a lower volume of leachates and higher concentration of nitrate-N in 1992. The differences in nitrate concentrations between these two years also may reflect the differences in the maturity of the rooting mediums and the accumulation of organic matter in the rooting medium. Organic matter in the rooting medium had increased to nearly 2% in the pure sand root zone by the end of the second year and approached 2.5% in the modified rooting medium. No nitrates were found in any treatment combination during the summer through mid-fall of either year. This would imply that the risk of leaching nitrates in summer due to unexpected heavy rain or over-irrigation is very low when turfs are fertilized on frequent intervals and the total rate of application does not exceed the moderate rates used in these studies.

The quantity of nitrate that leached through the greens is a function of the nitrate concentration in the drainage water and the volume of drainage water produced. The product of these two values showed that, in the first year, two periods of the year were most sensitive to nitrate leaching. These were in November, four to eight weeks after seeding, and in April and May when soil temperatures fluctuated between 45°F and 55°F. Even though the greens were actively growing during this period of the spring, the root systems still lacked sufficient maturity to be highly efficient in nitrate uptake.

The leaching collection system from the lysimeters provides turfgrass scientists the ability to closely monitor the inputs and outputs from the system. The project at Washington State University studied amended versus non-amended sands with varying N fertilization rates.

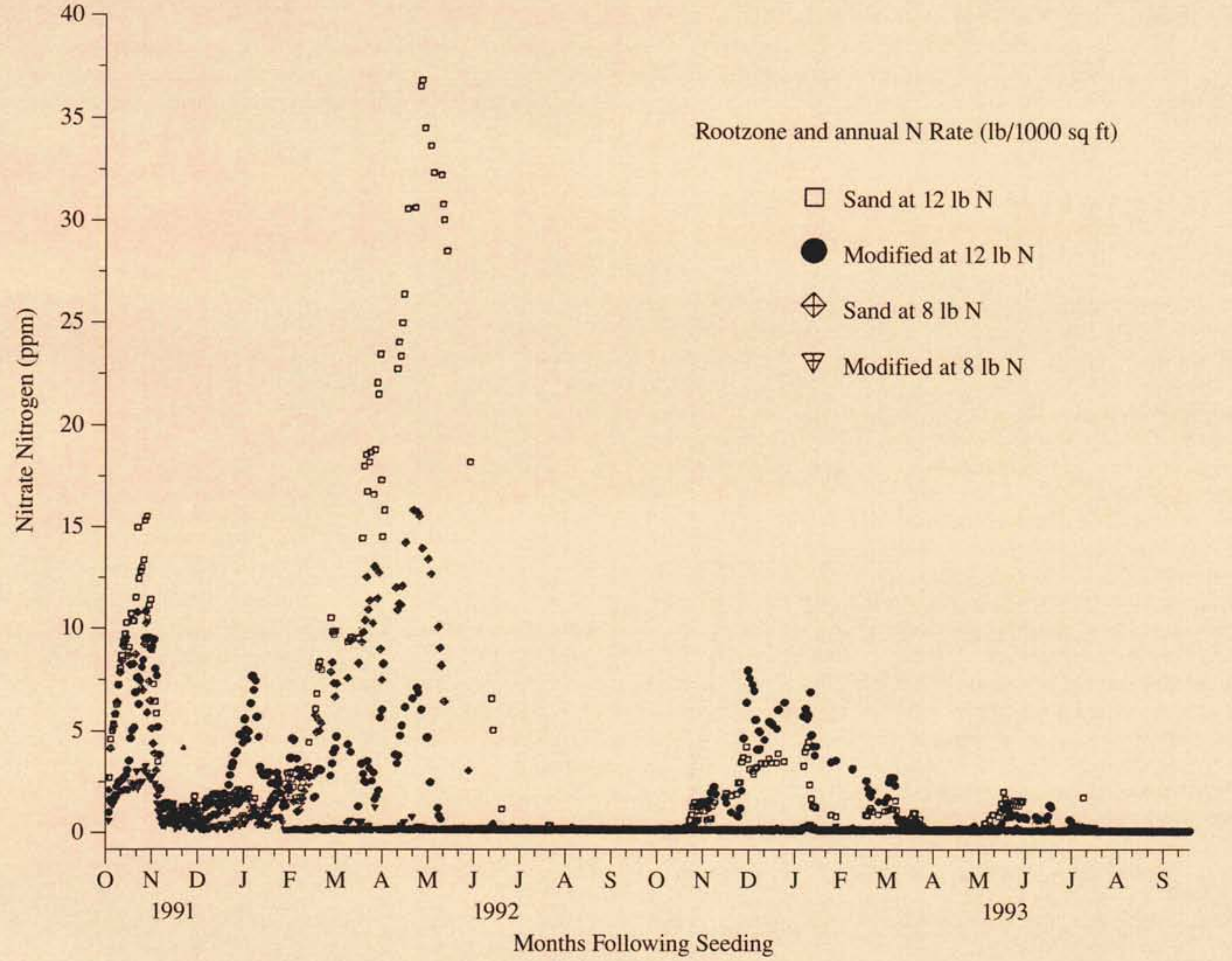
Table 2
Percent of Total Applied Nitrogen Leached as Nitrate

Rooting Medium	Annual N lb/1000 sq ft	Year 1 Percent	Year 2 Percent	Year 3 Percent
Sand	4	5.37	0.06	2.71
	8	6.31	0.04	3.17
	12	7.55	0.70	4.28
Modified (sand/peat)	4	0.33	0.40	0.16
	8	0.91	0.02	0.17
	12	3.37	1.26	2.31

As little as 0.33% and as much as 7.55% of the applied nitrogen was leached as nitrate in the first year. The highest percent nitrate lost was from the 12 lb N per 1000 sq ft per year rate. In the second year, 1.26% was the highest quantity leached. Essentially no nitrate was leached from the 4 or 8 lb rates in the second year in either the pure sand or the modified sand greens (see Table 2). It should be noted that 4 lbs of nitrogen per 1000 sq ft per year was insufficient to support bentgrass or annual bluegrass growth in putting greens under play in the Northwest. But 0.36 lb N per 1000 sq ft (8 lbs N per 1000 sq ft per year rate) applied at two-week intervals was more favorable. At this fertilization rate each 14 days, 2.7 lbs nitrate per acre or 2.1% of the nitrogen applied was leached in the first year. In the second year, only 0.03% of the nitrogen applied was leached.

In summary, experimental putting greens that were constructed close to USGA specifications were monitored for concentration of nitrate in leachates from October 1991 to October 1993. During the first year, the concentration of nitrate nitrogen leached from their profiles was related to application rate and was strongly modified by the rooting medium and frequency of nitrogen application made to the immature turf. In this same time period, the concentration of nitrate leached from the pure sand rooting medium was much greater than the nitrate leached from the sand rooting medium modified with peat moss. Modified sand greatly reduced the

Figure 1
Daily Nitrate-N in Leachates from Sand and Modified Sand Rootzone Putting Green Lysimeters Fertilized with 8 lb and 12 lb N/1000 sq ft Annually. Values Summarized Over 14- and 28-Day Fertilization Intervals.



total quantity of nitrogen that was lost as compared to pure sand. The frequency of nitrogen application to young turf during the first year significantly affected the level of nitrate-N lost. Although the impact of this factor was much less than either nitrogen rate or rooting medium effects, it did consistently influence nitrate-N concentration in the leachate. The use of modified sand rooting medium, moderate levels of total annual N application and frequent nitrogen applications combined to reduce nitrogen lost in leachates to 2.7 to 3.6 lbs per acre and the percentage of applied nitrogen lost in leachates to as low as 3% to 5%.

In the second year, nitrate-N concentration in the leachates was greatly reduced compared to year one. A significant part of this major change was attributed to more extensive rooting, increase in thatch and increase in organic matter in the rooting medium. The leachate nitrate concentration was rate-related again, but the extent of nitrate leached was not strongly modified by the rooting medium or by how often the turf was fertilized. The nitrate concentration found in leachate from pure sand profiles was similar to that found from modified sand profiles most of the year. In addition, the reduced nitrate concentration in leachates was attributed to a greater quantity of precipitation (2.2") during early spring in 1993, as compared to 1992, resulting in dilution of leachate nitrate concentration. Nearly zero concentration of nitrates was observed in leachates in summer or early winter.

Conclusions

When putting greens were immature and fertilized with a moderate nitrogen rate, the most important factor in limiting nitrate leaching was to modify the rooting medium during construction with organic matter, in this case peat. Applying the fertilizer on 14-day intervals vs. 28 days also was important, particularly during the periods when leaching pressure was high. Managing young greens in this manner essentially eliminated nitrate movement into the drainage system. As putting greens matured and thatch and organic matter levels developed in the pure sand system, nitrogen fertilization rate was the major factor affecting nitrate leaching. Rates of 8 lbs or less nitrogen per 1000 sq ft per year resulted in little or no nitrate leaching. Applying nitrogen fertilizers with at least 70% of the nitrogen source in slow-release form on a frequent interval such as every 14 days provided excellent protection from nitrate leaching. At this point in our study, we conclude that nitrate concentration in drainage water from putting greens can be effectively limited by using appropriate nitrogen application rates, frequent and light nitrogen applications, and a modified sand rooting medium during early establishment.