This research was funded in part by the USGA.

RESEARCH

Nitrogen leaching from a sand-based green

During a three-year study of a floating green, NO_3-N concentrations in leachate were always far below EPA limits.

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Environmental concerns of the turfgrass industry and the public have promoted the development and implementation of best management practices (BMPs) for golf courses. A significant concern on golf courses is the application of fertilizer to potentially highly leachable sand-based putting greens.

Nitrogen leachate studies have been conducted previously (2-4,6-9), and a current golf course study using suction lysimeters in Rhode Island is measuring nitrogen concentration on golf greens (10). With two notable exceptions (5,10), leaching studies tend to be carried out on small-scale university research plots under controlled conditions and may not accurately represent golf course management and playing conditions.

A different study

The research presented here is unique because no study monitoring leachate flow and concentration had taken place on an entire golf course green receiving play. In addition, the golf course superintendent followed regular maintenance practices on the green throughout the three years of the study. By accurately monitoring flow through the root zone and sampling the leachate to obtain nitrogen concentrations, the total quantity of nitrogen being leached could be determined.

The overall goal of this study was to provide scientific data for the development of BMPs for sand-based turfgrass systems. To accomplish this, we measured flow through a sand-based putting green, under ordinary golf course management and play conditions, and measured the nitrogen concentration and quantity in the leachate and grass clippings.

The floating green: a massive field laboratory

The 15,000-square-foot floating island including the green used in this study was constructed in 1990 at the Coeur d'Alene (Idaho) Resort Golf Course. Buoyancy was provided by approximately 100 polystyrene-filled concrete cells (30 feet by 10 feet by 3.5 feet) staggered in two layers. To minimize weight, the green contours (subsurface grade) were constructed of plastic foam sections.

KEY points

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- **Contamination by nitrogen** leaching from fertilizer applied to sand-based greens on golf courses has long been a concern.
- **The floating green at Coeur d'Alene Resort GC** provides an opportunity to study nitrogen leaching under actual golf course management conditions.
- **Nitrogen** leaching increased following fertilizer applications.
- **During the three-year study period,** 59% of the applied nitrogen was recovered: 48% in grass clippings and 11% in leachate.

The 7,000-square-foot putting green has a USGA-recommended root zone with 14 inches of sand above a 4-inch layer of pea gravel. The putting surface was sodded to Penncross creeping bentgrass (*Agrostis stolonifera* L.). The green was irrigated with water pumped directly from Lake Coeur d'Alene. Because the lake is a large body of water (approximately 25,000 acres), as expected, lake water concentrations of NO_3-N and NH_4-N fluctuated little during the study. NO_3-N was present at 40 parts per billion (ppb) (0.04 milligrams/liter) and NH_4-N at 80 parts per billion (0.08 milligrams/liter).

Monitoring flow and sampling leachate for nitrogen

Downward flow of leachate into the plastic foam was prevented by an impermeable liner placed above the plastic foam sections and beneath a herringbone drainage system connected to two 850-gallon storage tanks located under the front and rear bunkers. The putting green drainage was isolated from the surrounding area by a vertical liner. All leachate passing through the putting green soil profile flowed through a small trapezoidal flume (Plasti-Fab, Tualatin, Ore.) attached to the main drain and then flowed into the rear storage tank. When the rear tank was nearly full, leachate was pumped via a 4-inch flexible tube to an onshore drainage field.

A leachate sample was collected daily from the flume, and flow was recorded every 30 minutes. Leachate samples were stored in an auto-

Photo courtesy of Jeff Nus

The self-contained floating island green at Coeur d'Alene (Idaho) Resort GC provides an ideal opportunity for studying leachate from a putting green.

mated sampler at 34 F to ensure sample stability, transported to Washington State University, and frozen until nitrogen analysis was formed with an Alpkem flow solution analyzer.

A weather station (Coastal Environmental, Seattle) was installed at the site to record environmental parameters. Probes measuring soil moisture potential and temperature were placed 39 inches in from the outside edge of the green and 5 inches below its surface.

Fertilizer applications

A foliar fertilizer, 24-0-24 Nitro-K Plus II at 0.1 pound nitrogen per 1,000 square feet (1.75% ammoniacal nitrogen, 3.0% nitrate nitrogen, 19.3% urea nitrogen), was applied by the maintenance staff every seven to 10 days during the growing season. In addition, Ferromec (15% urea nitrogen) was added to the foliar fertilizer at a rate of 1 ounce per 1,000 square feet. The total nitrogen applied annually to the green ranged from 3.4 to 4.2 pounds per 1,000 square feet.

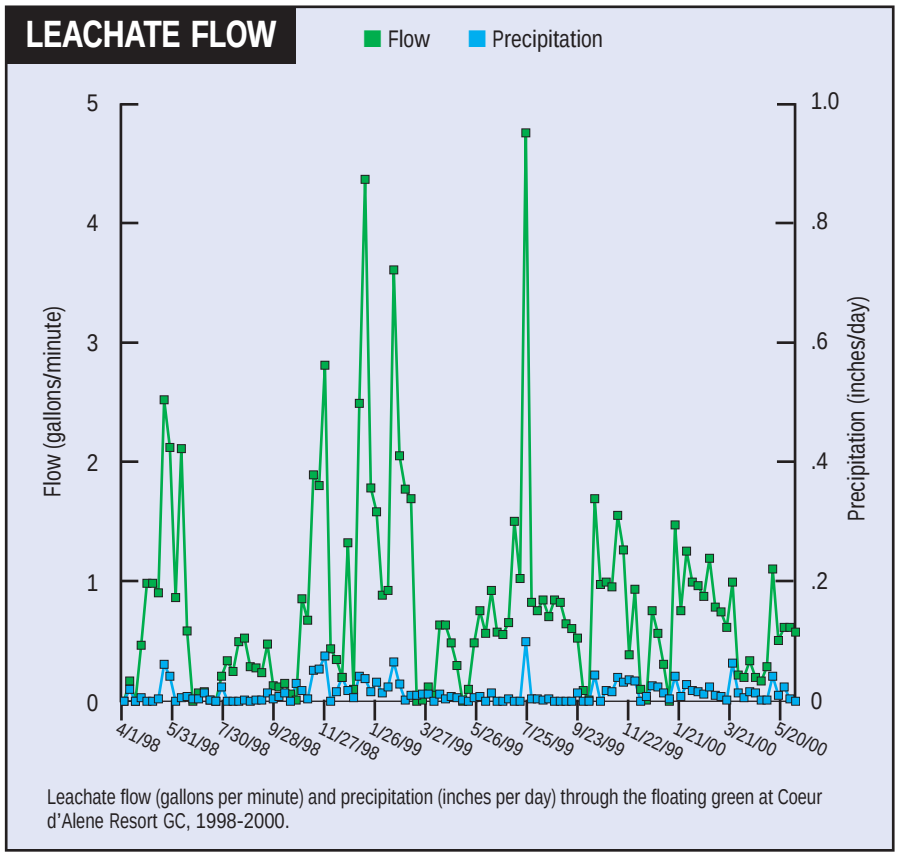
Nitrogen was increased to 0.3, 0.6, 0.7, 0.9 or 1.2 pounds per 1,000 square feet, one application at each rate, to observe the effects of higher nitrogen rates. Nitro-K Plus II was applied at 0.3 or 0.6 pound nitrogen per 1,000 square feet on Aug. 5 and Sept. 4, respectively. Scotts 26-4-13 with minor elements (0.6% ammoniacal nitrogen, 9.9% urea nitrogen, 10.8% water-soluble organic nitrogen and 4.7% water-insoluble nitrogen) was applied at 0.9 pound nitrogen per 1,000 square feet on April 8, 1999. On Sept. 17, 1999, 0.7 pound nitrogen per 1,000 square feet was applied as Scotts Starter Fertilizer 19-25-5 (4.3% ammoniacal nitrogen, 7.4% urea nitrogen, 6.3% water-soluble organic nitrogen and 1.0% water-insoluble nitrogen). In 2000, 1.2 pounds nitrogen per 1,000 square feet was applied on May 2 as Scotts 17-3-17 (3.3% ammoniacal nitrogen, 6.9% urea nitrogen, 3.9% water-soluble organic nitrogen and 2.9% water-insoluble nitrogen).

Collecting clippings

Grass clippings were collected from the green daily during the growing season by the maintenance staff. Clippings were weighed, subsampled and frozen. The clippings samples were later dried in a 140 F oven for three days and weighed. Clippings were separated from topdressing sand and analyzed for nitrogen using a LECO combustion autoanalyzer.

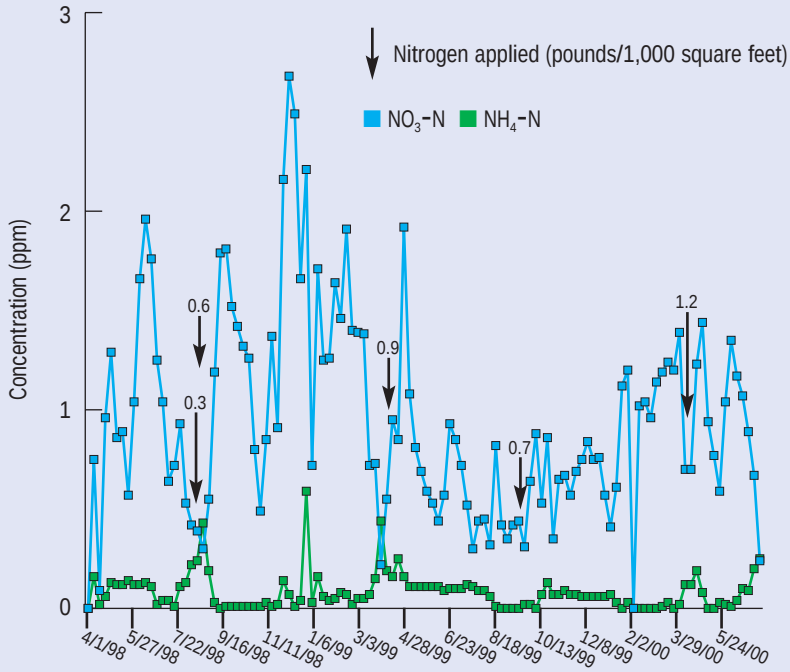
Flow (leaching) through the green

Annual precipitation during the study was 25 inches, with more than two-thirds occurring from late October to early March, a period when the golf course was generally closed (the golf course was open April 1 to Oct. 31). Precipitation and flow through the green were related; that is, as precipitation increased, the flow through the green



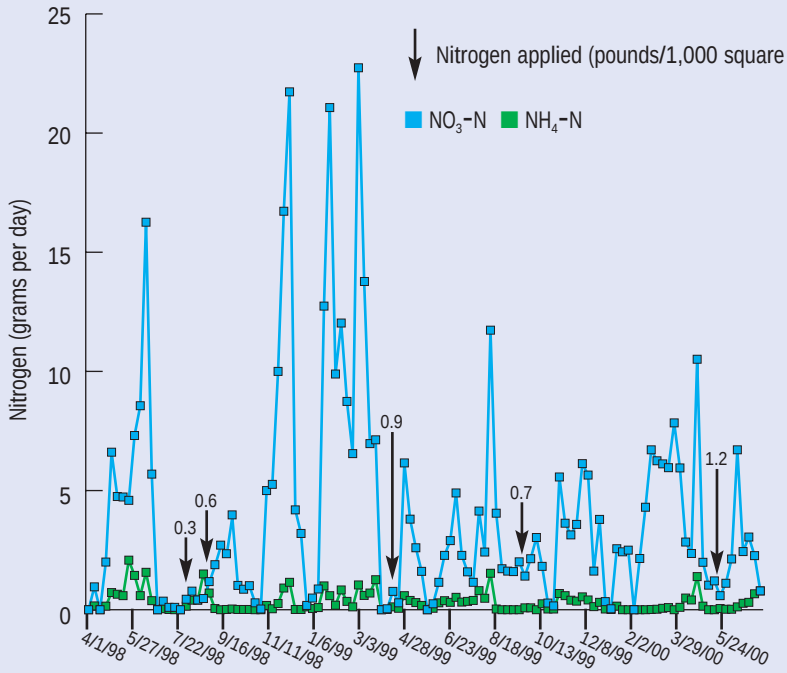
Leachate flow (gallons per minute) and precipitation (inches per day) through the floating green at Coeur d'Alene Resort GC, 1998-2000.

NITROGEN CONCENTRATION IN LEACHATE



Leachate nitrogen concentrations (parts per million) from the floating green at Coeur d'Alene Resort GC, 1998-2000. Arrows indicate timing of nitrogen applications (pounds of nitrogen per 1,000 square feet).

NITROGEN IN LEACHATE



Nitrogen quantity (grams per day) in leachate from the floating green at Coeur d'Alene Resort GC, 1998-2000. Arrows indicate timing of nitrogen applications (pounds of nitrogen per 1,000 square feet).

increased. Low flow during winter occurred when the soil profile was frozen. When soil temperatures increased and snow melt occurred, flow increased notably. Mean flow rate through the green over the three-year study was 1,151 gallons per day. Peak flow rates can be attributed to rainfall events; for example, during the week of Aug. 4, 1999, a 2-inch rainfall occurred in a 24-hour period.

Nitrogen concentration in leachate

Analysis for NO_3-N and NH_4-N indicated low levels of nitrogen in the leachate. NO_3-N ranged from 0 to 3.1 parts per million, well below the U.S. EPA limit of 10 parts per million, and NH_4-N levels ranged from 0 to 0.6 parts per million. EPA has no standard for NH_4-N in groundwater. Low concentrations of NO_3-N in the leachate may be attributed in part to light, frequent foliar nitrogen applications, periods of high leachate flow and rapid turfgrass growth with high nitrogen uptake.

Increased nitrogen fertilizer rates increased leachate NO_3-N concentration during the seven- to 21-day period following application. Other researchers (2,4) have reported higher NO_3-N leaching as nitrogen fertilization rates increased. However, at no time during an eight-week postapplication period were NO_3-N concentrations greater than 1.9 parts per million.

Nitrogen in leachate

The highest quantity of nitrogen leached during late fall and late winter/early spring when water flow and nitrogen leachate concentrations were high and grass growth was minimal. An increase in the amount of nitrogen leached occurred seven to 14 days following fertilizer applications, but results were confounded by increased flow that also occurred during this period. Although, in general, concentration decreases as flow increases, that did not occur in this case, and the amount of nitrogen leaching increased following fertilizer applications.

Clipping dry weight and % nitrogen

Clipping dry weight variation can be attributed to mowing-height variation, periodic mowing of cleanup lap and environmental factors. Daily creeping bentgrass clipping nitrogen ranged from 2.4% to 7.3% and reflected increased nitrogen applications. Mean nitrogen in the clippings was 4.6%, which is within the range of 3% to 6% nitro-

gen on a dry-weight basis reported for turfgrass (1). The amount of bentgrass clippings removed from the green was a less accurate predictor of when nitrogen was applied than the percentage of nitrogen in the clippings. Low leachate concentrations combined with high leaf tissue (clippings) nitrogen suggest efficient nitrogen uptake by the grass.

% nitrogen recovered

Over the three years of this study, total recovered nitrogen was 59% (11% in leachate, 48% in clippings). Unrecovered nitrogen could be present in nonavailable forms in both the soil and thatch with some potential loss from volatilization (13,14). The nitrogen that was not recovered is not believed to be an environmental concern (6,12).

Summary

Because sand-based root zones are prone to leaching, we used the unique floating green at Coeur d'Alene GC to measure NO_3-N and NH_4-N leachate losses following applications of nitrogen fertilizer. Our study revealed that nitrogen fertilization of sand-based greens poses little potential for groundwater contamination when healthy turfgrass is maintained.

Creeping bentgrass was very efficient at taking up nitrogen, with 48% of applied nitrogen removed in the clippings. The greatest amount of nitrogen moved through the soil profile when the turf was dormant and/or in response to precipitation. An increase in nitrogen concentration and the amount of nitrogen leached occurred for seven to 21 days following fertilizer application. Tissue nitrogen was a better indicator than clipping dry weight of when fertilizer was applied. The large, sand-based floating green used in this study was a unique field laboratory that could be used in developing environmentally sound turfgrass BMPs.

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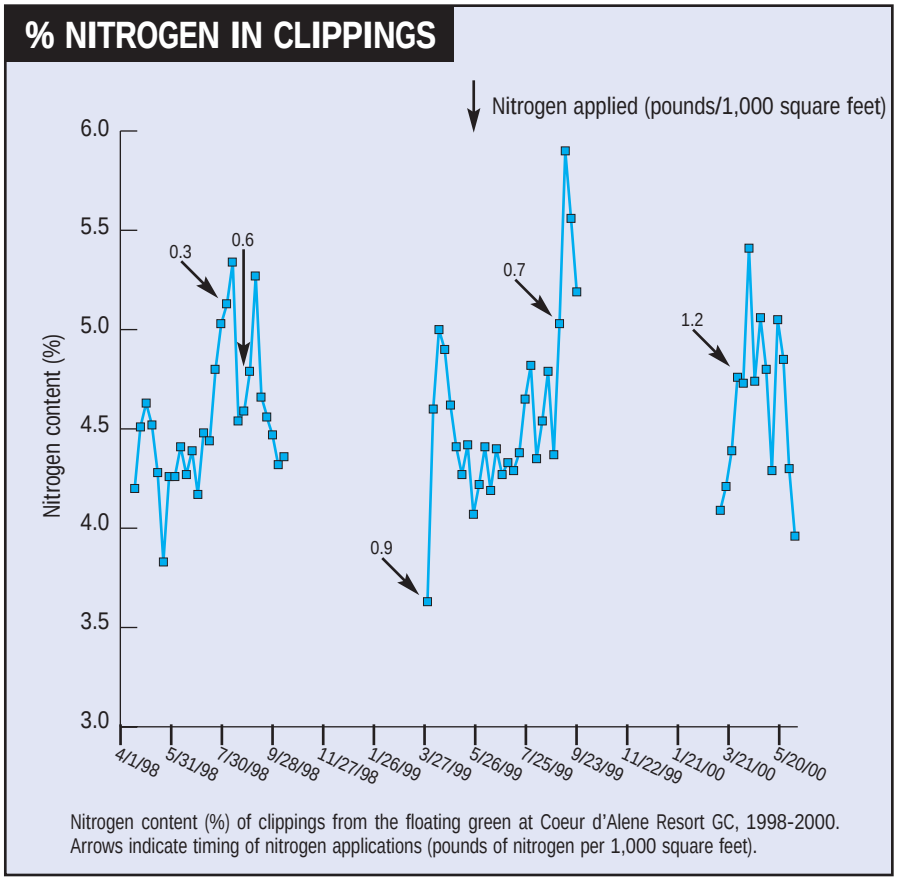

Nitrogen content (%) of clippings from the floating green at Coeur d'Alene Resort GC, 1998-2000. Arrows indicate timing of nitrogen applications (pounds of nitrogen per 1,000 square feet).