Golfdom's PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

ENVIRONMENTAL SAFETY

Nitrogen Fertilization

Does application on the golf course cause water-quality problems?

By Thomas Rufty and Daniel Bowman

North Carolina shares the concerns felt in many areas of the United States about the quality of water supplies. This is especially acute in eastern North Carolina, where periodic algal blooms and fish kills occur. The main culprit in these environmental systems is nitrate nitrogen.

Many articles have been published in the popular press stating that golf course fertilization is a main cause of water-quality problems, but there has been little scientific basis for this conclusion.

We initiated a study several years ago to determine whether golf course fertilization might actually be an environmental problem. When the project began, it quickly became obvious that past research would not supply the answer. Many recent water-quality research projects focused on fertilizer run-off. It seemed unlikely, however, that run-off was a major problem in North Carolina river basins because best management practices (BMPs) are commonly used.

> We have found no evidence that fertilization of fairways causes an increase in nitrate in adjacent streams.

The BMPs for turfgrass fertilization were established by North Carolina State University research/extension faculty many years ago and are widely followed by turfgrass managers throughout the state. They specify that fertilizers should not be applied before anticipated rain and prescribe light watering at the time of application to ensure rapid biological use. Most superintendents are well informed and closely adhere to BMPs to minimize adverse environmental impacts and to control their own costs.

If fertilizer run-off were not a problem, then the main concern would be nitrogen leaching downward in the soil. Indeed, information coming from environmental studies with natural and agronomic systems indicated that nitrate losses occurred primarily through leaching and not surface run-off (Osmond, Gilliam and Evans, 2002).

Nitrate leaching in turfgrass systems had been addressed in research funded by the USGA, but almost all experiments were done on newly constructed plots. Because soil characteristics and the ecology of established turfgrass fairways are different from those in constructed plots, there was no way to extrapolate from the USGA project results to a landscape scale.

Continued on page 48

IN THIS ISSUE

FIGURE 1

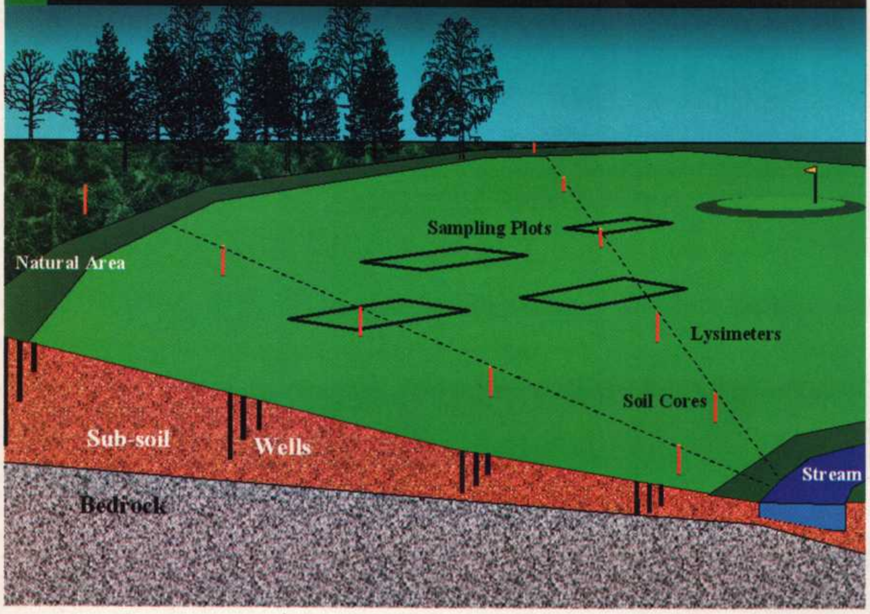


Figure 1: Experimental design for environmental studies at 10 golf courses in eastern North Carolina. Nitrogen fate was followed by analysis of samples from clippings, soil cores, soil solution, shallow wells and streams.

Continued from page 45

The research approach

To try to clear up the issue of whether North Carolina golf courses were a major cause of water pollution, we initiated an extensive field research project to follow the fate of nitrogen in bermudagrass fairways. The goal was to develop a nitrogen budget that would account for uptake by bermudagrass, retention and downward movement of nitrogen in the soil profile and any loss of nitrogen (N) into adjacent streams and lakes.

The scope of the project dictated its complexity. Detailing N movement requires crossing several scientific disciplines, including turfgrass agronomy and physiology, soil physics and hydrology, and soil microbiology. As a consequence, a group of research faculty was assembled with expertise in each of the disciplines. The large project was made possible by environmental research grants from the North Carolina legislature and the Turfgrass Council of North Carolina, which offered support even with the prospect of negative results for the turfgrass industry.

Experimental sites were established on 10 golf courses in eastern North Carolina. The locations were chosen based on several criteria. One was that they represented a variety of soil types, because soil texture strongly influences leaching. Secondly, we wanted to examine golf courses of different ages, thinking that older courses could have different levels of organic matter and compaction than younger ones. Thirdly, it was important that the research be located on golf courses willing to cooperate and put up with our intrusion.

As shown in Figure 1, multiple plots were established on each site for periodic collection of clippings during the bermudagrass growing season. Transects were run from adjacent natural areas, across roughs and fairways to a stream. Four transects were used at each site to allow appropriate statistical analysis of data. Soil cores were taken to a depth of 4 feet, four times a year (bracketing fertilization periods) along the transects to resolve patterns of nitrate accumulation in the soil profile.

Suction lysimeters were installed at 6-, 12-, and 18-inch depths, which allowed direct sampling of soil solution for nitrate analysis. The lysimeter samples were collected weekly. "Nests" of shallow wells, 8 feet to 20 feet deep, were installed for sampling of subsurface water flows. Water samples were collected weekly from streams at points where they entered and exited the golf course.

As implied above, this was the first comprehensive study of nitrogen fate in bermudagrass fairways in a natural setting. The experiment ran for three years, and the superintendents were asked to maintain their normal management practices throughout. The general fertilization protocol in this geographical area is to supply 2.5 pounds to 3.5 pounds of nitrogen per 1,000 square feet per year, mostly during the bermudagrass growing season from May through September.

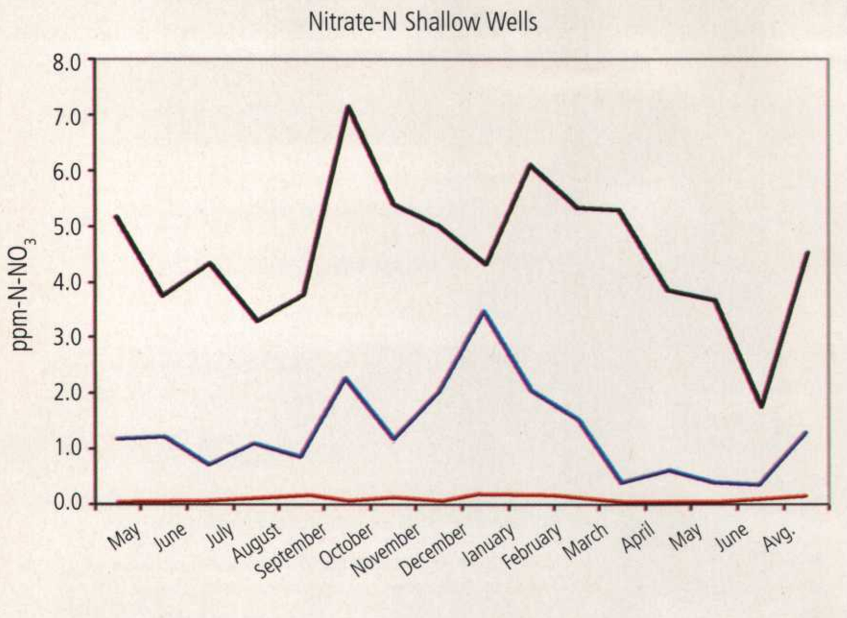
Expected results

Our initial expectation was that we would find high nitrate levels in soil solution and subsurface water beneath the turfgrass system. Consequently, there was a high potential for water pollution. This came from simple reasoning:

- The golf courses ranged from 10 years to 100 years old and, even in the youngest, soil organic nitrogen levels should have been in equilibrium or approaching equilibrium. That meant soil organic nitrogen levels were stabilized and would not increase from year to year.

Continued on page 50

FIGURE 2



Continued from page 48

■ Since clippings were not removed from any of the sites, fertilizer inputs should approximate losses. Taking into account fertilization rates and yearly rainfall (about 45 inches per year), it was estimated that groundwater should contain about 50 parts per million (ppm) to 100 ppm nitrate.

From the earliest analyses, it became evident that our initial expectations were wrong.

Nitrogen in the turfgrass/soil system

One of the initial surprises in the study was the realization that more nitrogen was being incorporated into clippings during the growing season than was being supplied in fertilizer.

Nitrogen uptake efficiency was calculated from the clipping harvests and analyses, and values generally ranged from just over 100 percent to as high as 300 percent. The calculation indicates that nitrogen was being rapidly cycled in the system. For example, fertilizer N was taken up into the grass, cut clippings were rapidly being degraded by soil microbes — releasing N back into the soil, and the soil N was being reabsorbed by the turfgrass.

The soil cores revealed that nitrate levels in the soil profile beneath the turf were always very low, ranging from 1 to 3 milligrams (mg) per kilogram of soil. (Lee et al., 2003). The levels were similar to those found in natural areas adjacent to the course that were not fertilized, and much lower than those reported in studies with fertilized agricultural crops.

The nitrate levels were uniformly low with depth from the soil surface, so there was no indication of accumulation anywhere within the soil profile. Also, nitrate was not elevated in the days and weeks following fertilizations, probably reflecting the high uptake efficiency by the turfgrass.

Samples from the lysimeters, which were taken with greater frequency, also indicated that soil solution nitrates were low.

The placement of wells allowed sampling of subsurface water as it flowed beneath fertilized fairways from higher natural areas to low-lying streams. The subsurface flows would contain nitrates that leached downward through the soil to the water table. There were two major findings (Figure 2, see Adams 2001 for details).

First, some elevation in nitrates could be seen as subsurface water moved from unfertilized, natural areas to the fairways, but levels were relatively low, ranging from approximately 2 ppm to 8 ppm. This is much lower than the predicted 50 ppm to 100 ppm range.

Second, and more importantly, nitrates declined to almost undetectable levels (less than 1 ppm) as the flow approached streams.

From the earliest analyses, it quickly became evident that our initial expectations were wrong.

The water samples contained high levels of dissolved organic carbon (8 ppm to 20 ppm). The high carbon levels, coupled with anaerobic conditions, presumably led to denitrification. For example, transformation of nitrates to nitrogen gas that was released into the atmosphere.

In agricultural fields, leaching of fertilizer nitrates generally leads to nitrate accumulation in the soil that bleeds into adjacent streams or lakes over extended time periods. We have

Continued on page 52

Continued from page 50

found no evidence that fertilization of fairways causes an increase in nitrates in adjacent streams.

Stream nitrate levels generally were low (less than .5 ppm) and actually tended to decrease during water passage through the golf course. All the superintendents maintained vegetation along streams, which evidently absorbed a portion of the available nitrates.

Pollution potential is low

The results from the field studies are consistent among all locations, always indicating a low potential for nitrate contamination of ground and surface waters.

In the past two years, the research has been expanded to include five additional sites in other parts of North Carolina where soils and topographies are different than those in the East. Up to this time, we have not found any evidence indicating significant pollution problems.

Our findings may come as a surprise to many people working in the water-quality area, just as they were to us. Turfgrass systems have particular characteristics, however, that are atypical of the agricultural world, where almost all previous landscape-scale research has been done. One is the fertility approach. Turfgrasses are usually fertilized three or four times during the growing season with relatively small amounts of nitrogen (about 42 pounds per acre), so the system is not overloaded and predisposed to leaching. Most of the root system is fully developed when the fertilizer is added.

By contrast, a corn crop would receive the same total amount of fertilizer, but in one or two applications early in the growing season. It has been estimated that corn takes up only about 50 percent of the nitrogen applied.

A second notable difference with turfgrasses is the density of the root system. Nitrogen uptake efficiency is a function of root absorption surface. The fine roots of turfgrasses typically form a dense matrix several inches into the soil, and individual roots can extend downward as much as 2 feet to 3 feet. Nitrogen entering the root zone is rapidly taken up from the soil solution.

A third difference is the high microbial activity in the soil just beneath turfgrasses (Lee et al., 2001). The thatch layer at the soil surface provides an ideal environment for microbial communities, and microbial biomass greatly exceeds that found in natural or agricultural soils. High microbial activity and efficient uptake by the roots are key components of efficient nitrogen cycling, which causes fertilizer N to be retained within the system.

Another key characteristic of turfgrasses that is different from traditional agriculture is the large amount of carbon being deposited into the soil. With irrigation and frequent fertilizations, bermudagrass is being grown in a relatively stress-free environment. Large amounts of organic material are generated, and none is removed by harvesting. The carbon in the organic material provides an energy source for microbial activity that in turn drives degradation and denitrification processes.

The evidence that we have assembled thus far suggests that managed turfgrasses may serve a similar function as the riparian buffers being constructed to protect streams and lakes from nitrate contamination. The primary purpose of the riparian buffers is to intercept nitrate in subsurface water flows (Osmond, Gilliam and Evan, 2002). Buffers function by providing a carbon source that is used by microbes for denitrification in the anaerobic conditions close to stream banks, an effect analogous to that observed in our research. With this in mind, it is conceivable that turfgrass systems may occupy an important role in strategies to protect water supplies in the future.

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