Nitrogen and Phosphorus Loss from Greens and Fairways

Is there a potential problem?

by LARRY SHUMAN, Ph.D.

GOLF COURSE management seems to become more complex every day. One essential practice that requires regular attention is fertilization. A golf course fertilization plan must provide a sufficient level of available plant nutrients without causing fertilizer "burn" to the turf, or salt buildup in the soil.

Today, however, there is another component in the equation: environmental protection. Golf course superintendents, as well as the public, are becoming more aware that fertilizer nutrients can cause potential environmental problems, especially if they find their way to surface water or groundwater. Fertilizer nutrients in surface waters, especially phosphorus, cause algae growth, which, in turn, causes toxins and lower levels of oxygen in the water.

Until recently, research on phosphorus fertilization and potential for movement has been conducted almost entirely on agricultural row crops. In recent years, the USGA has funded research on nutrient leaching and runoff from golf course turf. The goal of this research is to create better management practices for golf courses to reduce the potential for nutrient loading to both surface waters and groundwater. The following experiments were conducted as a result of that funding.

Tracking Nutrient Movement

Starting in 1995, we monitored nitrate (NO_3^-) and soluble phosphate in lysimeters placed in two practice greens at a golf course located in a northern suburb of Atlanta, Georgia. The lysimeters are simple stainless steel kitchen sinks with the tops placed about three inches below the green surface. The drains are connected to pipes that run to the edge of the green to collection bottles. Leachate was sampled after each major rainfall and analyzed for nitrate and soluble phosphate. The second green was removed at the end of 1998, so after that date we only have data for green one.

The phosphorus (P) concentration in the leachate was initially very high, especially for green two (Figure 1). The phosphorus decreased thereafter until 1999, when it started to increase again due to an increase in application rates. The high P concentrations in the leachate indicated that P can indeed leach, and this can be a potential problem since drainage water from putting greens may eventually lead to surface waters.

The nitrate data told a different story. The nitrate concentration in the leachate was low initially and increased to a maximum in 1998 (Figure 1). After that, levels of nitrate in the leachate decreased somewhat. We speculate that during the first several years, nitrogen (N) was being sequestered in the organic layer as it built up. Subsequently, the nitrogen started to mineralize at a rate equal to that used by microbes, and a nitrogen balance was achieved. The pattern also may have to do with different rainfall and nitrate additions for those years.

A rough estimate of the percent of applied P and N found in the leachate was calculated. Although this calculation has many assumptions, it serves as a ballpark figure. By our calculations, 27% of the applied P and 4% of the applied N were accounted for in the leachate. Thus, our concern regarding P leaching was confirmed.

Simulated golf greens were constructed in the University of Georgia greenhouse and used for studying nitrogen and phosphorus leaching through the soil

Greenhouse Studies

Simulated golf greens were set up in the greenhouse to examine nitrate and phosphorus leaching. Growth boxes (40 × 40 cm, 15 cm deep) were set on top of PVC columns that were 15 cm in diameter and 53 cm deep. Columns were filled with a rooting medium prepared according to USGA green specifications and 'Tifdwarf' bermudagrass sod was established.

Fertilizer sources used for the first experiment were a Peters soluble 20-20-20 and a Lesco micro-granular 13-13-13 that is poly- and sulfur-coated. These fertilizers represented a completely soluble source versus a slowly available nutrient source. Fertilizer rates were 0, 0.11, and 0.22 lb. P/1,000 sq. ft. and 0. 0.25, and 0.50 lb. N/1,000 sq. ft. applied every other week for a total of six treatments. Each treatment was replicated 3 times.

This experiment was carried out twice with different irrigation schemes. The first was with the 0.25 and 0.5 inches/day throughout the experiment with one large simulated rain, and the second with a lower irrigation rate per day with one large simulated rain. Leachate samples were taken weekly and analyzed for nitrate and soluble P.

As expected, the soluble fertilizer source resulted in more nitrate and phosphorus in the leachate than did the granular poly- and sulfur-coated fertilizer source (Figure 3). Lower application rates of P gave somewhat less leaching, probably due to a greater proportion being adsorbed by the rooting medium. However, similar to the lysimeter data, a much higher percentage of the applied phosphorus leached than nitrogen.

A practice that is common in green maintenance in some areas of the country is periodically flushing the green to remove salts and other materials. This was simulated in both greenhouse experiments and yielded some interesting results. Nitrogen concentrations in the leachate were not affected. The nitrogen moved through the simulated greens readily even without flushing.

Phosphorus reacted differently. Phosphorus was not detected in the leachate at all until after the flushing event; then it increased for the next several weeks before starting a long, gradual decline.

Different Fertilizer Sources

In a second greenhouse experiment, we compared eight fertilizer sources, all applied at 0.22 lb. P/1,000 sq. ft., and, where applicable, 0.5 lb. N/1,000 sq. ft. The 20-20-20 soluble source was included along with two other balanced granular fertilizers (10-10-10, 13-13-13). Other sources included granular 16-25-12, 9-18-18, and 19-25-5. Superphosphate was used in two treatments with two N sources (a liquid controlled-release source and a granular sulfur-coated urea). These were added every other week for a total of four treatments. Sample collection and analyses were as previously described.

The 20-20-20 soluble source and the 16-25-12 starter fertilizer produced the most leaching of phosphorus (Figure 5). The lowest leaching came from the superphosphate and 8-18-18 materials. The other sources were intermediate. These results indicate that the more soluble the source, the less should be applied at any single application since the more soluble sources are prone to leaching. Superphosphate and less soluble granulars do not leach as readily.

The nitrate results indicate less leaching. The 20-20-20 resulted in the most nitrate leached. The 10-10-10 and the liquid source were intermediate, and the coated granules were lowest in nitrate leaching. The 13-13-13 is poly- and sulfur-coated and the other coated N source was sulfur-coated urea.

Runoff from Simulated Fairways

Field runoff experiments were carried out using a facility with 12 individual plots (12 × 24 ft.) built on a 5% slope. The soil was typical of the Piedmont region of the southeastern United States, and the turf was 'Tifway' bermudagrass. A collection trough was installed in a ditch at the front of each plot to collect runoff water and direct it to a tipping bucket apparatus that measured the runoff volume and took a sub-sample of the water. Overhead sprinkler heads provided one-inch-per-hour simulated rainfall.

We applied 10-10-10 at rates of 0, 0.11, and 0.22 lb. P/1,000 sq. ft. on each plot. Two inches of simulated rainfall were added four hours after treatment (HAT) and again at 24 hours after treatment. An additional one inch of simulated rainfall was added at 72 and 168 hours after treatment. The same experiment was repeated on two different years and the results were averaged. A second experiment was carried out where the same treatments were applied, but ¼-inch of irrigation was applied to the plots to water-in the fertilizer immediately after application, and three days were allowed to elapse before the same simulated rainfall sequence was initiated.

Phosphorus concentrations in the runoff increased in step-wise fashion as P application rates increased for the first two runoff events (Figure 7). The phosphorus concentrations detected in runoff were much higher for plots receiving simulated rain on the same day as treatment (4 HAT), compared to treatments that were watered in and allowed to wait three days before the first simulated rain (72 HAT). These results show that phosphorus runoff can be significant if phosphorus-containing fertilizers are subject to heavy rain soon after application. Results also show that adding ¼ in. of irrigation immediately following fertilizer application can be very helpful in preventing phosphorus runoff.

Use Fertilizers Judiciously

Our experience has led to some general observations and recommendations. Although leaching is not considered a problem on fairways, our results indicate that it certainly can be a problem for greens. Both nitrogen and phosphorus leach readily through porous greens, although nitrogen leaches more quickly than phosphorus.

The major problem with phosphorus is that the turf does not use a great portion of it, so it eventually moves out of the rootzone into the drainage water. However, phosphorus is usually added at very low rates on greens compared to nitrogen. The only time it is used on greens in large amounts is during grow-in. Because phosphorus leaches from porous rootzones, judicious use is advised.

Supplying turf with nitrogen in a controlled fashion greatly reduces the potential for leaching and runoff. This can be accomplished by spoon feeding or using controlled-release fertilizers. These two practices help increase nitrogen efficiency use by keeping it in the rootzone where it can be absorbed by the turfgrass. Any excess nitrogen that cannot be absorbed or used by microbes will quickly pass through the green into the drainage water, which is often piped to surface outflow. Even nitrogen taken up by microbes may eventually leach as it becomes mineralized over time.

For fairways the major problem is runoff. Both nitrogen and phosphorus are readily transported with runoff water. Since turfgrass holds soil well, the water does not carry soil particles with phosphorus adhering, as is the case in agricultural row crops. Instead, phosphorus runoff from turfgrass is in the soluble form, which is the most readily available for algae growth in surface waters.

These results reaffirm the importance of applying phosphorus only according to soil test results. Also, avoid placing fertilizer on hard surfaces such as roads and cart paths. Any fertilizer on hard surfaces is washed directly into storm drains and into surface waters. As a responsible turfgrass manager, be sure to consider water quality as well as turfgrass quality in your fertilization program.

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