Long–Term Diet

Research at Michigan State University provides evidence that fertilizing more than the turf can use results in unwanted nitrate leaching.

BY JEFF NUS

At the start of each year, many of us feel compelled to make New Year's resolutions, and it is not surprising that one of the most common resolutions is to lose weight. Perhaps we need a long-term diet?

Maybe that should be the view for fertilizing turf as well. Long-term research at Michigan State University (MSU) suggests that as turf sites age, it may be necessary to reduce the amount of nitrogen (N) fertilizer to lower the risk of nitrate leaching. Golf course superintendents have a responsibility to protect the environment, including the quality of surface and ground water surrounding and beneath the golf course. If fertilizer rates are higher than the turf and soil microbes can use, the threat of nutrient runoff or leaching increases substantially.

Between 1989 and 1991, four large (3.75 ft. diameter by 4 ft. deep) lysimeters were constructed and installed at Michigan State University's Hancock Turfgrass Research Center. After installation, the area was sodded with a blend of Kentucky bluegrass cultivars including Adelphi, Nassau, and Nugget. From July 1998 through 2002, turf growing over the lysimeters was treated annually with urea at a low nitrogen (N) rate of 2 lb./1,000 ft^2 (0.5 lb. N/1,000 ft^2 per application) or a high N rate of 5 lb. N/1,000 ft^2 (1 lb./1,000 ft^2 per application). Application dates were in May, June, September, and October. As of 2011, the turfgrass area has been under continual fertilization practices for 21 years.

Michigan State University scientists analyzed leachate for nitrate-nitrogen (NO_3-N) since 1998 and gained a good understanding of the dynamics of turfgrass nitrogen use as Kentucky bluegrass turf matures over several years. Figure 1 shows concentrations (ppm) of NO_3-N measured in the leachate from fertilized plots from 1998 through 2009.

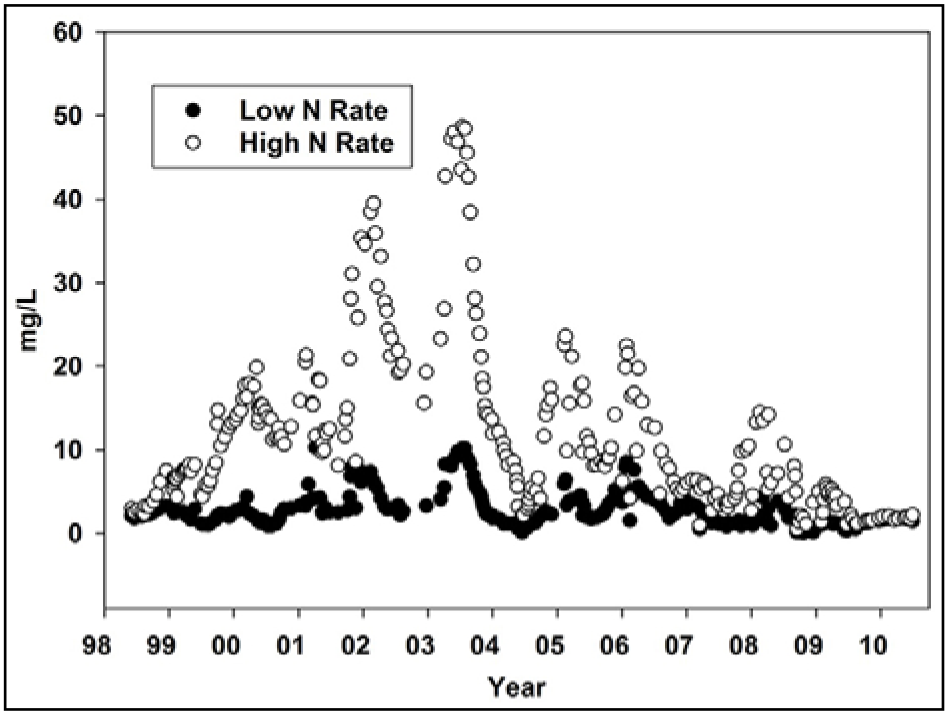

Figure 1. NO_3-N concentrations of leachate collected from lysimeters at Michigan State University under Kentucky bluegrass. The high rate of N (5 lbs. N/1,000 ft^2 per year) was reduced to 4 lb. N/1,000 ft^2 per year in 2003. The low N rate (2 lbs. N/1,000 ft^2 per year) was kept consistent throughout the experimental period.

In well-aerated rootzones, excess nitrogen is susceptible to leaching as NO_3-N, and that point is clearly demonstrated by the high N fertilizer treatment as up to 50 ppm NO_3-N was detected in the leachate during 2003-2004. It should be noted that the high rate of N was reduced to 4 lb. N/1,000 ft^2 per year in 2003 in an effort to reduce the high concentration of NO_3-N in the leachate.

Excessive nitrogen fertilization of turfgrass leads to a number of management problems, including making the turf more prone to both the occurrence and severity of various turf diseases; causing a buildup of thatch, especially on grasses that spread laterally by stolons and/or rhizomes (e.g., Kentucky bluegrass, zoysiagrass, bermudagrass); and increasing the need for supplemental irrigation since root growth is inhibited.

"Over-fertilization probably means different things to different superintendents. While some associate over-fertilization with excessive top growth at the expense of root growth, or very lush growth leading to more disease activity, over-fertilization also results in organic matter accumulation and slow, puffy greens or fairways that are ultimately more prone to scalping," says Dr. Kevin Frank, project leader at Michigan State University.

In addition to these self-imposed management challenges, over-fertilizing turf with nitrogen can have serious

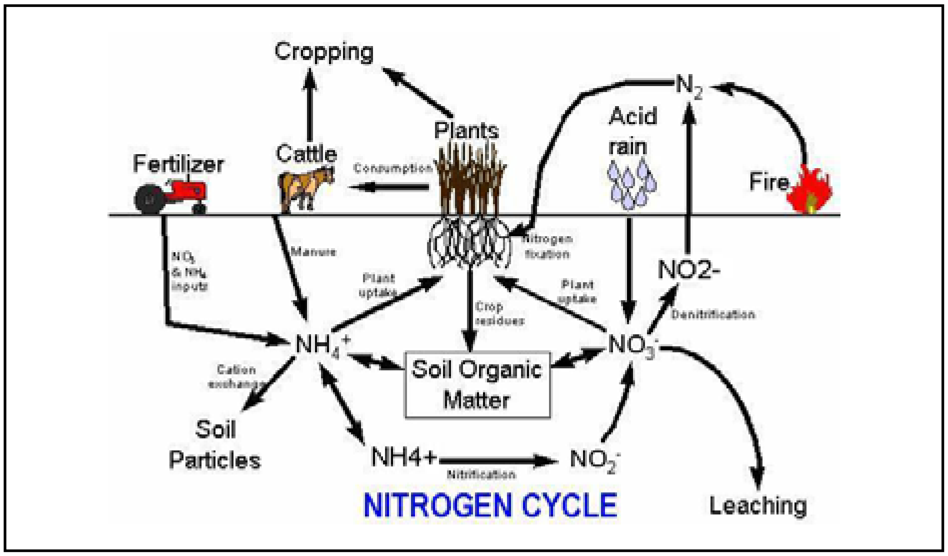

Figure 2. The Nitrogen Cycle (graphic courtesy of University of Minnesota).

environmental implications, namely nutrient transport to surface and ground water. Research has shown that runoff containing NO_3-N concentrations of more than 1 ppm or so can trigger algal blooms in surface water if other nutrients, especially phosphorus, are also present in the runoff water at high enough concentrations (0.2 ppm or above for phosphorus). Nitrate-nitrogen concentrations in ground water exceeding a federally mandated 10 ppm maximum level can result in "blue baby syndrome" (methemoglobinemia) if that water is for potable use.

The unmistakable message from MSU's research is that higher rates of nitrogen fertilizer may be acceptable for newly established sites as turf fills in and the soil microbe population increases. However, as turfgrass matures over several years, leachate data suggest that nitrogen fertilizer rates should be more conservative. Unless higher N rates that are used during the first few years following establishment are not significantly reduced, unacceptable levels of nitrate leaching will occur, especially during the winter months when turf is dormant.

To understand why this is so, it is helpful to review the nitrogen cycle (Figure 2), which diagrams the fate of nitrogen as it cycles through the atmosphere, plants (and animals), and soil. The nitrogen cycle is described by five main processes: nitrogen fixation, nitrogen uptake, nitrogen mineralization, nitrification, and denitrification. Understanding how these processes work gives us insight into why newly established turf sites need more nitrogen fertilizer and how that need diminishes with time as soil organic matter increases.

Nearly 80% of the air we breathe is nitrogen gas (N_2). Nitrogen fixation is the process by which N_2 is changed to ammonium (NH_4+) and other forms of nitrogen. Nitrogen-fixing bacteria, lightning, forest and prairie fires, as well as the production of N-containing synthetic fertilizers contribute to nitrogen fixation and nitrogen available for uptake by microorganisms and plants, including turfgrasses.

Nitrogen uptake occurs as plant roots, bacteria on roots (rhizosphere), or soil organisms absorb nitrogen as ammonium or nitrate (NO_3-) and quickly incorporate that nitrogen into proteins and other nitrogen-containing compounds. It is important to realize that soils that have a high content of organic matter have higher nitrogen contents, as well, since organic matter serves as a reservoir of stored nitrogen (and carbon).

Nitrogen mineralization is the process by which nitrogen that is incorporated into organic matter (plant roots and shoots, soil microorganisms, thatch, etc.) is converted back into inorganic nitrogen. When plants, animals, and soil fauna and flora die, the decay process releases organic nitrogen as ammonium (NH_4+). Plants can absorb the ammonium again or

Lysimeters were installed at the Michigan State University Hancock Turfgrass Research Center from 1989 to 1991. Plots have been continuously fertilized for 21 years, and leachate has been analyzed for nitrate-nitrogen since 1998. Leachate analysis revealed that levels of nitrate-nitrogen in the leachate can be reduced by lowering the application rates of nitrogen fertilizers, but such leachate reductions may take five years or more before acceptable levels are achieved.

the nitrogen after it is converted from ammonium to nitrate through a process called nitrification.

In well-aerated soils, the process of nitrification rapidly converts ammonium to nitrate. If there is an abundance of nitrogen in the soil, nitrogen runoff and leaching losses are principally from nitrate since the conversion of ammonium to nitrate is rapid and the positively charged ammonium is hydrostatically held to negatively charged surfaces of soil particles or organic matter (cation exchange). There are far fewer positively charged sites in the soil to hold the negatively charged nitrate, so nitrate is free to flow with runoff or percolate downward as leachate.

Denitrification is the last step of the nitrogen cycle and refers to the process of nitrogen oxides (NO_3-, NO_2-, NO, N_2O) being converted to nitrogen gas (N_2) and returned to the atmosphere. Denitrification counterbalances the amount of nitrogen fixed by nitrogen fixation, uptake, mineralization, and nitrification.

So why did the Kentucky bluegrass in MSU's plots need less nitrogen fertilizer as it grew older, and what was the proof that too much nitrogen was being applied? MSU researchers have been analyzing leachate for nitrate-nitrogen and phosphorus and have gained a good understanding of the dynamics of turfgrass fertilization as the turf matures over several years. As of 2011, the turfgrass area has been under continual fertilization practices for 21 years, with leachate collection for the last consecutive 13 years.

Figure 1 shows concentrations (ppm) of NO_3-N measured in the leachate from fertilized plots from 1998 through 2009. The nitrate leachate data clearly show that at the high N rate, very high rates of NO_3-N were detected in the leachate. So it was evident that nitrate uptake by the turf rhizosphere bacteria and soil microbes was insufficient to immobilize the high rate of N.

Dr. Kevin Frank (shown) and his colleagues at Michigan State University have been monitoring leaching of nitrate-nitrogen and phosphorus from turf plots at Michigan State University for more than two decades.

The critical question to MSU researchers at that point was, "How long does it take for NO_3-N leachate concentration to decrease if N applications are reduced?" Figure 1 shows this quite clearly. As noted above, the high N rate was decreased from 5 lb. N/1,000 ft^2 per year to 4 lb. N/1,000 ft^2 in 2003. Notice that the leachate concentrations of NO_3-N decreased in response to that reduction of N fertilizer, even with the seasonal fluctuations, up through 2008. Reductions in nitrate-nitrogen leaching occurred through a five-year period following the reduction of the high N rate.

As important as it is to realize that reducing leaching of mineralized N from over-fertilized areas may take a five-year period or so, it is also important to realize that the highest leaching concentrations occur during the winter, when turf is dormant.

"In most instances we observed higher nitrate-N leaching levels during the dormant winter period. It is important to remember that in our climate in Michigan there are many winters when our soils do not completely freeze, and snow, rain, and melting events result in nitrate-N leaching through the soil because the turf is not growing, so it is not going to take up any N," says Dr. Frank. "I'm not sure we can ultimately control or eliminate all potential nitrogen leaching during the dormant winter period, but it would seem the last thing we would want to do is add more N to the system late in the year, when it is subject to numerous melting events that can result in leaching."

The leachate study at Michigan State University is valuable because it demonstrates the danger of nitrate leaching in over-fertilized sites, especially as those sites age. It also shows that when over-fertilized areas are given less nitrogen, leaching will be reduced, as well. Typically, the duration of field experiments involving turfgrass is two or three years, but this project shows the value of monitoring turf over an extended period. It also demonstrates the value of a long-term diet.

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