A New Way of Looking at an Old Problem

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Some of you may recall sitting in those wonderful wooden chairs (ingeniously designed to keep you awake) in the Soil Science building and learning about the specifics of nitrogen leaching from Dr. J.R. Love, Dr. Wayne Kussow, Dr. Jerry Tyler, or maybe Dr. Nick Balster (who currently teaches Soil Science 301 at UW-Madison). We learned that fertilizer is normally applied in the ammonium form which is quickly converted to nitrate by microbes. Nitrate has a negative charge, and because soils also have a net negative charge, there is no mechanism for nitrate to be retained like there is for the positively charged nutrients like ammonium, potassium, calcium, and others.

Therefore, nitrate is highly susceptible to leaching losses and the recipe for disaster includes: 1) a large application of soluble nitrogen fertilizer, 2) bare soil, or a field with plants too small to absorb most of the nitrogen, and 3) excessive rainfall to transport the nitrate to the groundwater. These three conditions are not uncommon in agricultural settings where soluble fertilizer is the only economically viable choice and logistics usually prevent fertilization when the crop is actively growing. Of course we never quite know what Mother Nature has in store for us in the spring when these applications are typically made.

As we know, turf management is very different from traditional agriculture and for the past three decades studies about nitrogen leaching

from turfgrass have found that nitrogen leaching losses from turf fertilization are minor. Perhaps this finding is not surprising because turfgrass fertilization often involves spoon feeding and slow release fertilizers. We also apply our fertilizer to actively growing, nitrogen deficient turf. That means that we are missing conditions #1 and #2 from this list above. There simply isn't much nitrogen hanging around in a turfgrass soil at any given point in time. As a Master's student under Dr. Kussow, I recall applying soluble urea to my sand-based research green and watering it in with irrigation water that contained about 10 ppm of nitrate. When we collected the drainage water, it was almost always less than 2 ppm nitrate. The turf roots absorbed the nitrogen out of the irrigation water as it passed through. My conclusion from that work was that nitrogen leaching is not a major avenue for when typical fertilization programs for putting greens are used. There are dozens of studies that have reached a similar conclusion.

But recently our ideas about nitrogen leaching from turf have begun to change based on some work from Michigan State and Colorado State Universities. In Michigan, Dr. Kevin Frank has observed substantial amounts of nitrogen leaching from a mature fertilized lawn (Figure 1). By mature, I mean it had been fertilized normally for a period of 20 years. There were two interesting aspects to his findings. First, the fact that high levels of nitrate were found at all was surprising given decades of prior work that found the opposite – in fact in the early 1990s scientists at Michigan State studied these same plots and found minimal nitrogen leaching (Miltner et al, 1996). What happened between 1991 and 2001? Why did the nitrogen start to leach?

To answer that, we need to start with the nitrogen cycle. Keep in mind that I am attempting to distill a highly complex situation into a few generalized sentences. When you apply fertilizer to corn and track where it ends up, you often find that about half of the application makes it into the corn plant.

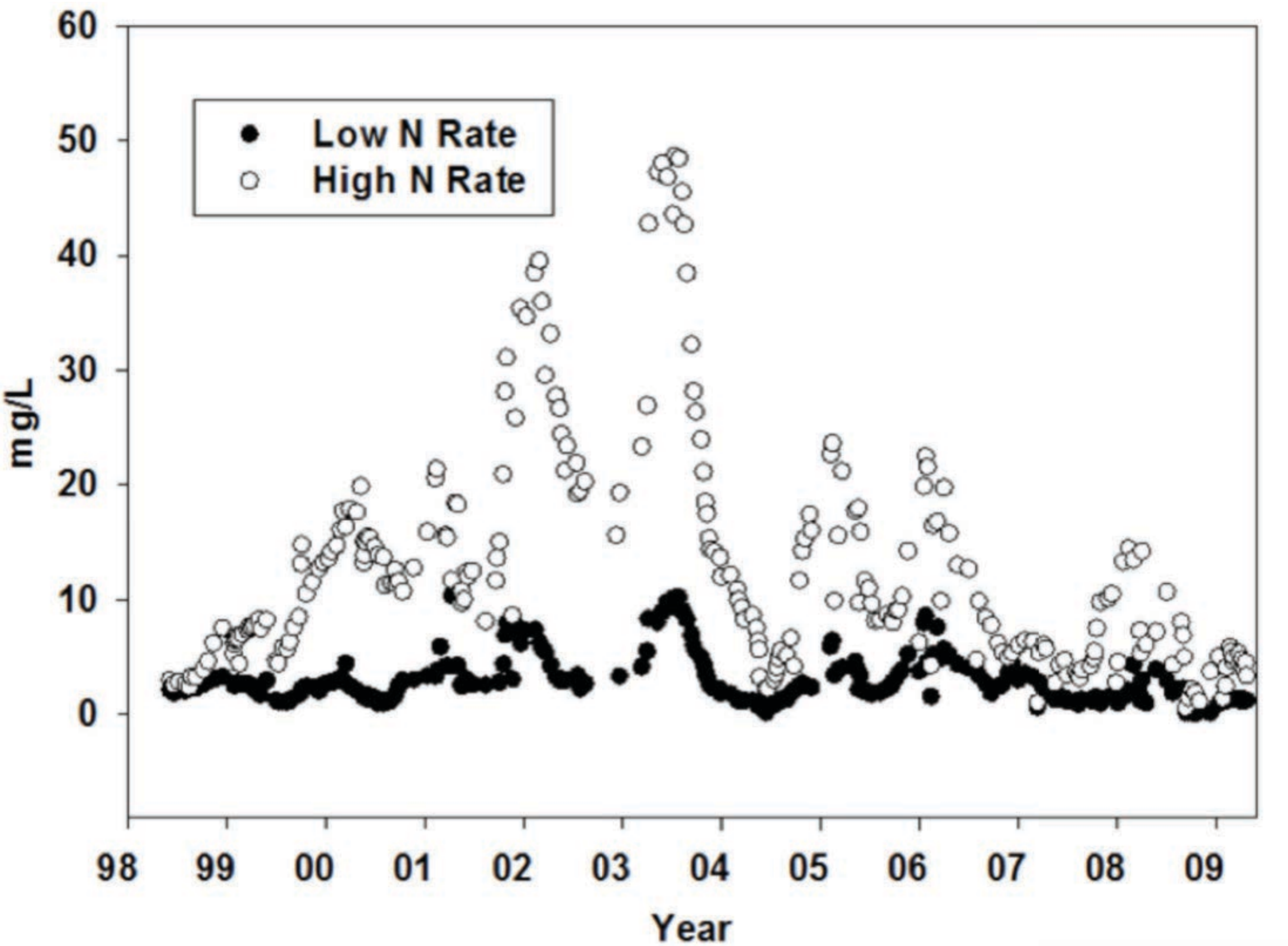

Figure 1. Concentration of nitrate in the drainage water from two mature lawns, one fertilized yearly with approximately 2 lbs N/M (low rate), and the other at about 5 lbs N/M (high rate). The leaching follows a distinct pattern, with high concentrations of nitrogen in the drainage through the late fall, winter, and early spring, with the lowest concentrations found during times of active turf growth. Normally, in conventional agriculture spikes in leaching will coincide with timing of fertilizer application and rain events, that pattern is not evident at all in the turf setting shown above, indicating a different mechanism of leaching is responsible. Graph courtesy of Dr. Kevin Frank, Michigan State University.

Most of the rest ends up in the drainage water as nitrate, with a small amount converted into the gas that makes up 70% of the air we breathe. When we track the nitrogen applied to turf, we find that about half of it ends up in the plant (like corn), but almost none in the drainage water (unlike corn), and a small amount converted to nitrogen gas. The missing portion ends up in the soil as organic matter. This organic matter accumulation can go on for a long period of time, but eventually will taper off because there is a limit to the amount of organic matter a soil can store. At this point, the nitrogen cycle changes, and the nitrogen that used to accumulate in the soil as organic matter will now begin to end up in the drainage water.

Researchers at Colorado State University published a paper that used a computer model to describe what is happening to soil organic matter over time in fertilized turf (Figure 2). If we just focus on the upper most line in the figure, which represents a lawn fertilized at 3 lbs N/M/yr with the clippings mulched, you can see that soil organic matter accumulates rapidly for about 30 years, then starts to stabilize. It is at this point in time when we would expect leaching to start to become an important process. During the accumulation phase, the extra nitrogen in the system is stored in the organic matter, but afterwards it has nowhere else to go. Figure 3 is a graph from the same computer simulation shown in Figure 2, but now shows the expected nitrogen leaching associated with the various management systems. You can see that after about 30 years, the 3 lbs N/M/yr plot begins to show significant nitrogen leaching. None of the other management scenarios do because they are still in the accumulation phase.

So what does this mean? First, this is a major departure from the way we normally talk about nitrogen leaching. Under this new system, nitrogen

leaching is predicted to occur when the soil becomes saturated with organic matter, regardless of the rainfall or the timing of the fertilizer application.

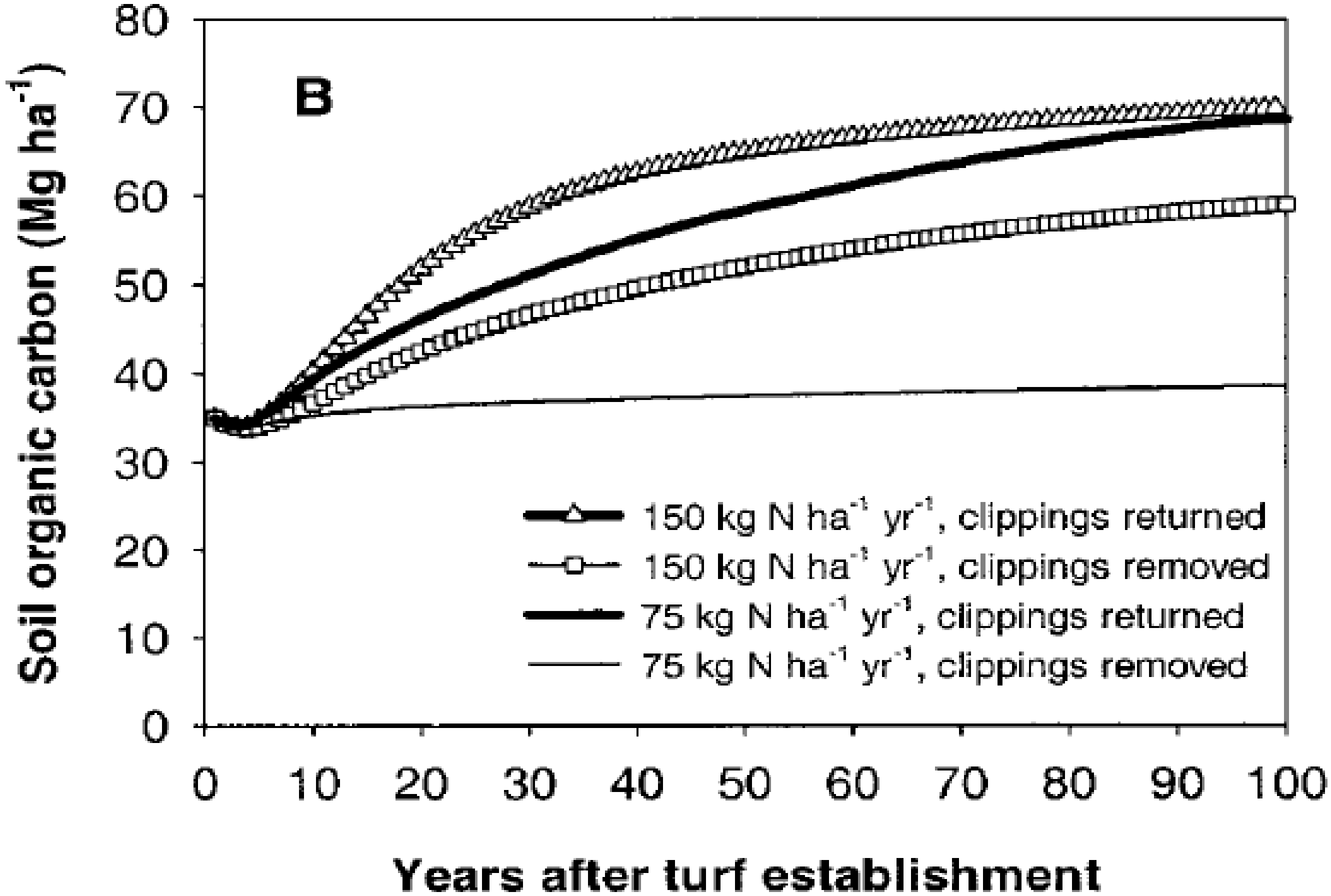

Figure 2. This computer simulation predicts how soil organic carbon (closely related to soil organic matter) changes over time under four different fertilization and clipping management programs. 150 kg N ha-1 yr-1 is approximately 3 lbs N/M. You can see that carbon (organic matter) increases most rapidly in the 3 lbs N/M program with clippings returned. However accumulation rate slows at about 30 years. Graph from Qian et al. 2006.

Second, it means that after the accumulation of organic matter levels off, nitrogen fertilizer requirements should be adjusted downward. We are still

at a very early stage in understanding all this new information. Currently there is no soil test that could determine if your soil is in the saturation phase or beyond it. However, developing such a test is now a distinct possibility that I and others are working on.

In fact, this spring Soil Science graduate student Sabrina Ruis visited a number of Wisconsin golf courses to collect soil samples and inquire about fertilization and irrigation history. She is hoping to gain some insight as to how a computer model (like the one used by the Colorado State researchers) and some soil testing information (like clay content, soil organic matter, soil organic nitrogen, pH and others) might be able to predict soil nitrogen saturation and therefore improve upon fertilization recommendations.

The Soil Science Department at the UW has a long history of improving soil testing from Emil Truog who developed the first do-it-yourself test for soil pH in 1912, to O.J. Noer who established the first soil testing lab in the US, to Dr. Wayne Kussow who comprehensively calibrated the Bray and Mehlich-3 soils tests for turfgrass. The task is tall in front of us is tall, but the Badger Soil Nitrogen Test has a nice ring to it, no?

References

Frank, K.W., K.M. O'Reilly, J.R. Crum, and R.N Calhoun. 2006. Fate of nitrogen applied to mature Kentucky bluegrass turf. Crop. Sci. 46:209-215.

Miltner, E.D. , B.E. Branham, E.A. Paul, and P.E. Rieke. 1996. Leaching and-mass balance of 15N-Labeled urea applied to a Kentucky bluegrass turf. Crop Sci. 36:1427-1433.

Qian, Y.L., W. Bandaranayake, W.J. Parton, B. Mecham, M.A. Harivandi, and A.R. Mosier. 2003. Long-term effects of clipping and nitrogen management in turfgrass on soil organic carbon and nitrogen dynamics: The CENTURY model simulation. J. Environ. Qual. 32:1694-1700.