Nitrogen and Phosphorus Losses from Turf

By Dr. Wayne R. Kussow, *Department of Soil Science, University of Wisconsin-Madison*

Introduction

A six year study was conducted at the university's O.J. Noer Turfgrass Research and Education Facility to determine the quantities of nitrogen (N) and phosphorus (P) lost from Kentucky bluegrass established on disturbed soil. The basic soil disturbance conditions simulated were subsoil compaction and topsoil layering over the subsoil. These conditions are common in landscaped urban areas and on golf courses. Two remedial actions were tested. One was chisel plowing of the compacted subsoil. The other was tilling of half the topsoil into the subsoil to disrupt the topsoil-subsoil interface.

Methods

The study was established on an 800-foot long slope from which the topsoil in the study area was stripped off, the remaining soil graded with a bulldozer to provide a nearly uniform slope of 6% and the subsoil compacted in selected areas with a vibrating roller before replacing the silt loam topsoil. The area was then seeded to a 4-way blend of Kentucky bluegrass cultivars. Once grown in, plots measuring 32 x 8 feet were bounded with plastic lawn edging and runoff water and leachate collection devices installed. The number of runoff plots totaled 18, which were grouped into 3 side-by-side blocks. Volume of runoff water was measured throughout the six years and subsamples analyzed for nitrate + ammoniacal N and water soluble orthophosphate. At no time did the runoff water contain measurable amounts of soil sediment. Percolate was collected from April to December each year, the volume measured and subsamples analyzed for nitrate-N after determining that less than 1 % of the N was in the form of ammonium.

The turf was maintained according to university recommendations. Four pounds of N/1,000 ft2 were applied each year in 1.0 lb increments during the periods of May 1 to 15, July 1 to 15, September 1 to 15, and after the last mowing for the year, which generally fell in the period of October 15 to 30. The grass was mowed at a 2.5-inch height every 4 to 7 days, depending on growth rate. The area was watered for 30 minutes (approximately 0.43 inches of water per irrigation) whenever the turfgrass turned bluish-green, a sign of moisture stress. Weed control consisted of a single broadleaf weed herbicide applied in September of each year.

Summary Results

The mean annual precipitation over the 6 years of the study was 32.00 inches, which is 3.6% above the 30-year norm of 30.88 inches for Madison, WI. Annual deviations from the 30-year norm ranged from +11.15 to –5.07 inches. The mean annual irrigation water applied was 3.11 inches, but ranged from zero to over 5 inches, depending on rainfall amounts and distribution during the growing season.

Over the 6 years, runoff water accounted for 3.54% of the mean annual water input (precipitation + irrigation) while the percolate accounted for 45.56%. The remainder, 45.84%, is attributed to evapotranspiration(ET) loss, which would have averaged 0.086 inch per day based on a 28-week season. According to limited data (Beard,1973; Taylor et al., 1987), this mean daily ET rate is typical for turfgrass in the upper Midwest.

The 6-year means for quantities of N and P in the runoff water were 0.37 and 0.32 lb/acre/year (0.0085 and 0.0073 lb/M*/year), respectively. For the mean annual runoff volume of 1.25 inches, this amounts to 0.30 lb N/inch of runoff and 0.26 lb P/inch of runoff. Runoff and N and P losses were dominated by what occurred when the soil was frozen. This runoff resulted primarily from snowmelt, but in some years included rainfall on frozen soil. Over the 6 years, runoff from frozen soil accounted for 70% of the total amount of runoff water collected. This runoff water contained 61% of the N and 72% of the P detected.

Treatment Effects

Treatments superimposed on the 3 blocks of runoff plots were changed every 2 years. The first two years examined the effects of soil disturbance and remedial actions prior to turfgrass establishment on N and P losses via runoff water and N leaching. The next 2 years were devoted to testing the effects of fertilization and mowing practices. The treatment variable during the last 2 years of the study was type of fertilizer N carrier applied.

Soil disturbance effects:

1. During the 1992 and 1993 *growing seasons* subsoil compaction had no influence on the amount of runoff water, but did increase runoff N and P losses by 125 to 133 %. Subsoil compaction effects on runoff N and P losses disappeared when the topsoil- subsoil interface was eliminated. Chisel plowing of the compacted subsoil had little influence on N and P loss.
2. When observed *over the entire 24 month period*, subsoil compaction and topsoil layering did not significantly influence the quantities of runoff water collected or the amounts of N and P detected. The effects of subsoil compaction, treatment of that compaction, and topsoil layering or mixing with the subsoil were inconsistent.
3. The various soil disturbance treatments had no statistically significant effects on the amount of percolate, its N content or its nitrate-N concentration. Among the soil treatments, the layering of topsoil rather than mixing half of it with the subsoil had the general effect of increasing the mean annual amount of N leached from 1.68 to 2.41 lb/acre and the nitrate-N concentration from 1.88 to 2.39 mg/L (ppm).

* M = 1,000 ft^2

Fertilization and clipping management effects:

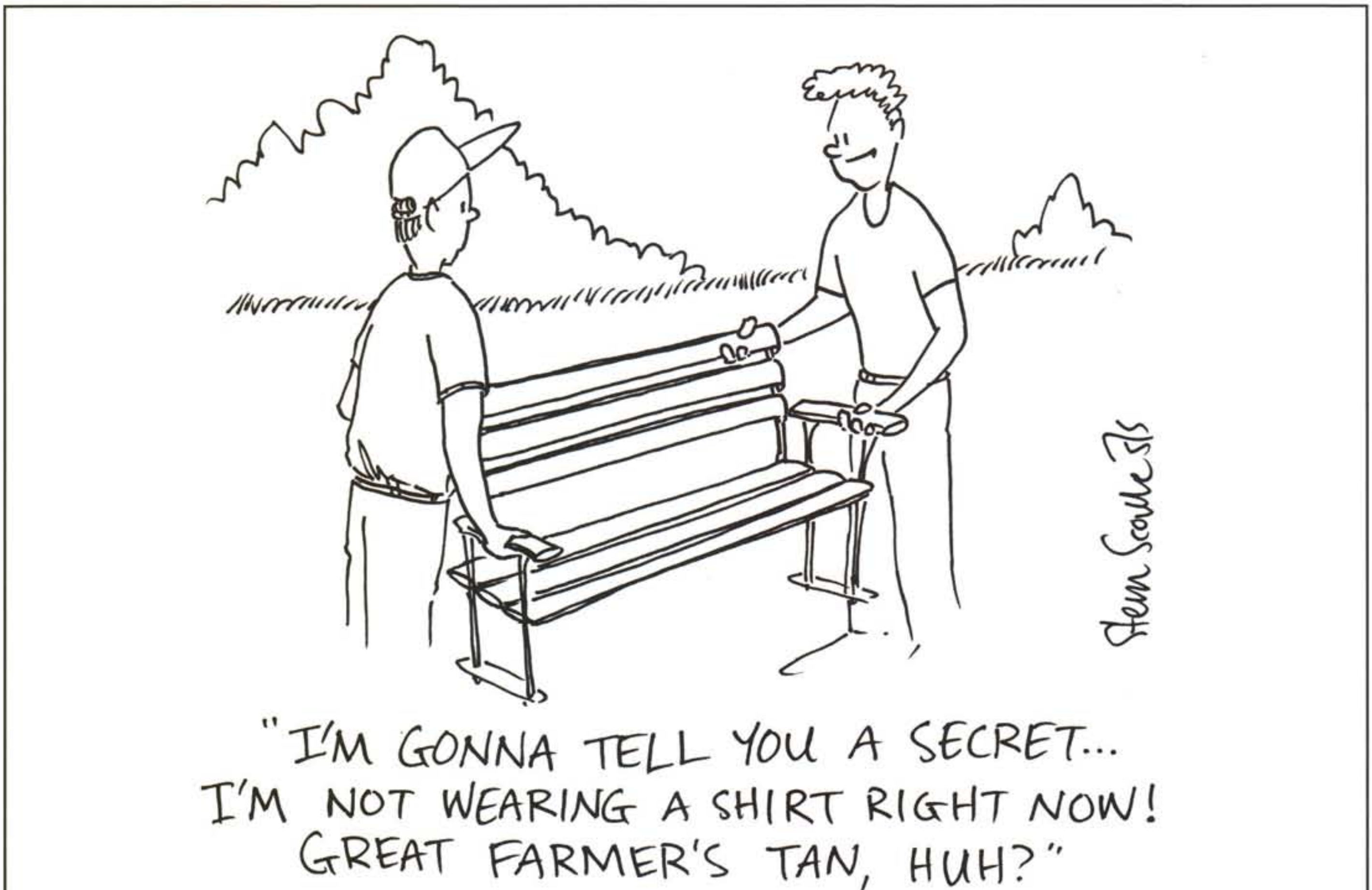
Three fertilization treatments were tested—none, application of a natural organic fertilizer (Milorganite 6-2-0), or application of a synthetic fertilizer (Scott's Turf Builder 19-3-4). The turf receiving these fertilizer treatments was subjected to both clipping removal and mulch mowing.

1. Type of fertilizer applied—all natural organic or synthetic—had no significant influence on the mean annual quantities of runoff water or its N and P content.
2. Not applying fertilizer for 2 years led to a 96% increase in the amount of runoff water when grass clipping were removed and a 63% increase when the grass was mulch mowed. With these increases in runoff, losses of N and P from non-fertilized turf averaged 48 to 146% more than from the fertilized plots.
3. Percolate volumes were not affected by the type of fertilizer applied or whether any was applied. Amounts of N leached and percolate nitrate-N concentrations were 40 to 48% lower for the natural organic fertilizer treatment than for the synthetic fertilizer or non- fertilized treatment. If one were to estimate the amount of fertilizer N leached by using values obtained by subtracting from the fertilized treatments the values for the unfertilized treatments, the results would have been 0.48% synthetic N leached and a negative 0.21% of the natural organic fertilizer N leached.

Nitrogen fertilizer carrier effects:

The nitrogen carriers tested included 100 % water soluble urea and 5 slow-release N fertilizers. The slow-release fertilizers included one natural organic and one synthetic fertilizer, both of whose N release rate is controlled by microbial action. Another product was IBDU (isobutylidine diurea) whose N release is controlled by fertilizer solubility. The last two slow-release fertilizers were coated urea products wherein N release is controlled by the rate of exit of urea solution from the coated fertilizer granules.

1. No significant treatment effects on runoff water volumes or the N and P losses were detected at any time during the two years they were applied. The N losses ranged from 0.34 to 0.85 lb/acre (0.0078 to 0.0195 lb/M). The least loss occurred



when IBDU and methylene urea based fertilizers were applied. The highest losses were in the all natural organic and polymer + S-coated urea treatments.

2. Although the annual P application rates ranged from zero to 25 lb P/acre (0.58 lb/M), there was no relationship between P application rate and the amount of P in the runoff water.
3. Quantities of N leached during the 2 years of application of fertilizers with different N carriers ranged from 1.13 lb/acre for the IBDU treatment to 2.60 lb/acre for the natural organic fertilizer treatment. Percolate nitrate-N concentrations ranged from 1.16 to 2.20 mg/L. Urea gave the highest percolate nitrate-N concentrations.

Discussion

The results of this research clearly demonstrate that in climates such as that of southern Wisconsin, runoff water from properly maintained Kentucky bluegrass turf on a 6% slope is predominantly snow melt. Water runoff when the soil was frozen contributed 53 to 92 % of the mean annual runoff and averaged 70% for the 6-year lifetime of the study. Furthermore, this runoff contained 61% of the N and 72% of the P measured. The implications of these observations are numerous. The first is that studies that measure runoff and N and P losses only during the growing season fail to capture the bulk of the losses. Depending on weather, such studies may be measuring as little as 10% of the total annual runoff and quantities of N and P lost. Therefore, the risk of arriving at erroneous conclusions from such data collected is very high.

Observations made in the present study on soil disturbance effects on runoff provide an example of how data collected only during the growing season can lead to invalid conclusions. Measurements made only during the growing season supported the conclusion that an effective means for reducing urban runoff and loss of lawn N and P to surface waters is to regulate how turf is established - that subsoil compaction must be alleviated and a portion of the topsoil rototilled into the subsoil before seeding. But when the observations were extended over a full year to include runoff from the frozen soil surface, the conclusion is that in the long run subsoil compaction and topsoil layering do not significantly impact on the amount of runoff or its N and P content.

An assertion made by Barten and Jahnke (1997), who measured runoff P concentrations only during the growing season, is that the P in lawn runoff water comes from just two sources — fertilizer and soil. In the present study, 72% of the P was contained in snowmelt collected some 5 months after the last fertilizer application, there was no significant relationship between the amounts of fertilizer P applied and the quantity of runoff P, the ratio of N:P in the runoff water was 1.2:1 while the ratio of N:P in the fertilizers applied averaged nearly 15:1, and there was no loss of soil sediment that would contribute adsorbed phosphate. These observations collectively provide a substantial body of evidence that fertilizer was not one of the major sources of P in the runoff water.

There are few data that establish soil as a significant source of P in runoff water from turf. The results obtained by Barten and Jahnke (1997) clearly demonstrate that their measured concentrations of total P and "soluble reactive" P from 29 home lawns were unrelated to levels of soil test P in the lawns even though their runoff water samples contained up to 4.6 g/L of suspended solids. As pointed out previously, no soil sediment was collected in runoff water samples collected in the present study. While this does not discount soil contributing some water soluble P, the evidence available does not implicate soil as a major contributor to the P in turf runoff water.

Several researchers have identified plants and plant residues in the landscape as important sources of P in runoff water. (Burwell et al., 1975; Dorney, 1986; Sharpley, 1981; Waschbusch et al.,1999). These research reports prompted my clipping of Kentucky bluegrass to ground level from concise turf areas and leaching of the fresh or frozen and dried clippings with the equivalent of one inch of rainfall. The amounts of P leached accounted for all of the runoff P collected in this study, both during the growing season and from snowmelt. These observations are consistent with research done with tree leaves and agronomic crops and clearly implicates plant P as being a major source of the P in runoff water from turf.

The scenario wherein snowmelt dominated the annual quantities of runoff water and the N and P contained therein and the turf itself was a major contributor of P (comparable N data are lacking) provides an explanation as to why the soil treatments and turf fertilization practices tested in the present study had no statistically significant influences annual runoff losses of N and P. The question then arises as to what turfgrass culture practices might be implemented that could lead to significant reductions in the P loading of runoff water and what kind of improvements can be expected. With plant-derived P as a major source of the P in runoff water, there is a substantial baseline or natural concentration of P below which reductions are not possible without elimination of the vegetation from the landscape. The results of the present and other studies (Gross et al., 1991) suggest that maintenance of dense turf through regular fertilization and adoption of other recommended cultural practices to minimize the amount of runoff per se is quite possibly the most effective means for minimizing turf contributions of P to urban runoff water.

Numerous units of government in the upper Midwest have imposed restrictions on fertilizer phosphate use on turf with the intent of improving surface water quality. The results of the present study seriously question the value of these restrictions. Debate on further legislation should be suspended until more definitive research can be conducted. There is a dire need for innovative research that measures N and P in runoff water throughout the year and reliably partitions that N and P into its 3 most probable sources—fertilizer, soil **and plant**. Only when the contributions of each are established can effective strategies be developed to reduce N and P loads from turf.

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