SIX-YEAR NITROGEN LEACHING AND RUNOFF STUDY ON RESIDENTIAL TURF

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Introduction

In the early 1990s, there was little research that turf professionals could draw upon to challenge allegations that lawn fertilization in the upper Midwest is a major cause of lake eutrophication and nitrate contamination of groundwater. My response was to initiate a long-term investigation of the quantities of nitrogen and phosphorus entering the environment from a simulated residential lawn.

Methods

To prepare a site for the study at the University of Wisconsin O.J. Noer Turfgrass Research and Education Facility, topsoil and subsoil were stripped off the area, which was then graded to a uniform 6% slope. The subsoil was replaced, compacted in select areas, and one-half the topsoil replaced. In some areas, the topsoil was rototilled into the subsoil. The last of the topsoil was then replaced and the area seeded to a four-way blend of Kentucky bluegrass cultivars.

Once the turf was well established, plots measuring 8x32 feet were laid out and bounded with plastic lawn edging. Each plot was then equipped with a weir, sample splitter, and a plastic pail inside a trash container to collect runoff water. Finally, each plot was outfitted with a low-tension lysimeter at an 18-inch soil depth to collect leachate.

The soil on the site is from agricultural land and contains high levels of phosphorus and potassium. Thus, plot fertilization focused on nitrogen. Throughout the study, N was applied at 4.0 lb/1000 ft^2 per season as four 1.0-lb applications during the periods of May 1 to 15, July 1 to 15, September 1 to 15, and after the last mowing of the year, which generally falls between October 15 and 30.

The turf was consistently mowed at 2.5 inches at intervals of 4 to 7 days, depending on growth rate. The plots were irrigated only when a color change in the turfgrass indicated the onset of moisture stress.

The initial objective of the project was to determine how the soil disturbances that typically occur in urban areas affect the amount of runoff water, the quantities of N and P in the water, and N leaching. There were six treatments in the study, each replicated three times. The treatments were:

(1) No subsoil compaction + layering of topsoil;
(2) No subsoil compaction + one-half of the topsoil rototilled into the subsoil;
(3) Subsoil compaction + subsoil layering;
(4) Subsoil compaction + topsoil incorporation;
(5) Subsoil compaction + chisel plowing + topsoil layering;
(6) Subsoil compaction + chisel plowing + topsoil incorporation.

Results

Data were collected for 2 full years. Analysis of the data revealed that:

1. The soil disturbances and the remedial actions of incorporating some of the topsoil into the subsoil and chisel plowing of the compacted subsoil had no significant influences on the amount of runoff, the amount of N and P in the runoff water, or in the amount of N leached.
2. Annual runoff averaged 1.35 inches, 73% of which occurred when the soil was frozen.
2. The amount of N in the runoff water averaged 0.24 lb/acre/year and 59% of this was in runoff from frozen soil.
4. Runoff loss of P totaled 0.32 lb/acre/year and 67% of this was in the runoff from frozen soil.
3. The annual average volume of leachate was 18.03 inches. This contained 2.2 lb N/acre/year and the nitrate-N concentration averaged 27.4 ppm.

Given that soil disturbances were having no significant effects on the volumes of runoff water, the objectives of the study were changed in 1995. The purpose became that of looking at the effects of fertilization practices and clipping management on water runoff and nutrient losses from a residential lawn. The treatments became:

(1) No fertilization + clippings removed;
(2) No fertilization + mulch mowing;
(3) Fertilization with a natural organic fertilizer, Milorganite 6-2-0 + clippings removed;
(4) Milorganite + mulch mowing;
(5) Fertilization with a synthetic fertilizer, Scotts Poly-S 25-3-10 + clippings removed;
(6) Scotts Poly-S 25-3-10 + mulch mowing.

Again, data were collected for 2 years and then analyzed. The principal findings were:

4. Not fertilizing resulted in 32% more runoff than from fertilized turf.
5. Nitrogen loss via runoff was 31% higher for non-fertilized versus fertilized turf and P loss was 67% greater.
6. Type of fertilizer — natural organic or synthetic — had no influence on the amounts of N and P in the runoff water or nitrate in the leachate.
7. Mulch mowing increased N leaching rates by 131%.

The data collected during this 1995-96 time frame were quite consistent with previous years and from year-to-year. This prompted a decision to once again shift the focus of the study. For the 1997 and 1998 seasons, the treatment variable was N carrier. The carriers applied were a natural organic (Milorganite), urea, methylene urea, polymer-coated urea, polymer+ sulfur-coated urea, and IBDU.

During the 1997 and 1998 seasons, the summers were drier than normal. This led to a small reduction in th total annual runoff, but more importantly, resulted in over 90% of the runoff and the runoff N and P coming from frozen soil. With nearly 20% more of the runoff coming from frozen soil, the annual runoff losses of N and P increased by 45 to 115%. However, there were no significant differences among the N carriers regarding the quantities of N and P in the runoff water or in the amounts of N leached.

Discussion

The 6 years of data collected in this study raise some intriguing questions. These are:

(1) Why weren't the effects of soil disturbance, fertilization practices, and clipping management on runoff losses of N and P and leaching of N not statistically significant?

(2) What are the sources of N and P in runoff water from frozen soil?

(3) How can non-fertilized turf possibly lose more N and P than fertilized turf?

(4) How do the N and P losses from residential turf compare to those from agricultural fields?

To begin to answer these questions, we first take note of how much of the annual runoff came from frozen soil. Over the 6-year period, 80% of the runoff came from frozen soil. This, in itself, explains why soil disturbance did not significantly influence the volumes of runoff. Once soil is frozen, conditions beneath the surface have no influence on runoff.

Spring snowmelt provided nearly 75% of the annual runoff. Despite the fact that the research site was graded to a uniform 6% slope, the snow cover was by no means uniform. Blowing and drifting resulted in large variations in snow cover and where on the site snow cover was greatest varied from year-to-year. The end result was such high variability in runoff from individual plots that the differences observed were not large enough to be statistically significant.

This brings us to the issue of the sources of N and P in the runoff from frozen soil. Upon consulting the scientific literature, one finds numerous studies showing that freezing and drying of vegetation of all types greatly increases the water solubility of N and P in the plant tissues. To follow up on this information, we collected Kentucky bluegrass clippings, froze them, and then let them air-dry. This simple test showed that freezing and drying converted 20% of the tissue N and 32% of the tissue P to water-soluble forms. This solubilization of tissue N and P readily accounts for the quantities found in runoff water from frozen soil.

Not fertilizing the turf increased the amount of runoff water collected in winter as well as summer. The 32% increase in annual runoff, the fact that the increase came from through-out the year, and the fact that about 72% of the runoff N and 80% of the P was collected when the soil was frozen, adds up to an explanation of why runoff losses of N and P were greater from non-fertilized than fertilized residential lawns.

We, as turfgrass professionals, are constantly faced with drawing comparisons between residential lawns and agricultural fields regarding nutrient contributions to surface and groundwater. There are several good, long-term studies on N and P losses from agronomic crops, particularly for corn and for crop rotations common to our area. These indicate that annual runoff losses of N and P are in the range of 30 and 10 lb/acre, respectively, and the amounts of N leached range from 25 to 40 lb/acre/year. Over the 6 years of the present study, N runoff loss averaged 0.37 lb/acre/year, P runoff loss was 0.36 lb/acre/year, and leaching loss of N averaged 2.2 lb/acre/year. It is clear from these numbers that the potential for contamination of surface and groundwater is far greater for agronomic crops than for residential turf.

Conclusions

There is a unique and important feature of N and P runoff losses from residential turn in the upper Midwest. Some 70% or more of the annual runoff is likely to occur when soil is frozen. Because of this, the compaction of soil around construction sites, and the subsequent leveling and layering with topsoil for turf establishment do not result in notable increases in the amount of runoff or the N and P content of the runoff water.

Over the 6 years of this study, 81% of the P in runoff water came from frozen soil. Evidence indicates that the predominant source is the frozen desiccated turf. This being the case, not fertilizing turf with phosphorus will have little or no impact on annual runoff losses of P. Failure to maintain a dense stand of turf through N fertilization is likely to lead to increased runoff and greater losses of N and P than from fertilized turf.

With the runoff being predominantly from frozen soil and the runoff N and P coming mainly from the dormant turfgrass, there is little reason to believe that significant reductions in N and P losses can be achieved through application of a natural organic rather than a synthetic fertilizer. Likewise, changing from highly soluble to slow-release N carriers cannot be assumed to have a beneficial effect with respect to N and P runoff losses.