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Nitrogen Fate in Mature Turf

Michigan State University research demonstrates how high rates of nitrogen fertilization to mature turf can result in unacceptable levels of nitrate leaching.

BY KEVIN W. FRANK, K. O'REILLY, J. CRUM, AND R. CALHOUN

Extensive research has been conducted on nitrate-nitrogen (NO_3-N) leaching in turfgrass systems. Most research has indicated that turfgrass poses little risk to the environment from nitrate leaching.[3] Research conducted at MSU by Miltner et al.[2] reported that the majority of labeled fertilizer nitrogen applied to Kentucky bluegrass never reached the soil. Most of the applied nitrogen was taken up by the plant, immobilized in the thatch layer, or lost to volatilization, while only 0.2% of the applied nitrogen was collected in the drainage water of lysimeters 1.2 meters below the soil surface over a three-year period.

The majority of N fate research has been conducted on relatively young turf stands, ranging in age from one to seven years. However, the age of a turf stand has been proposed as an important factor in determining the fate of N. Bouldin and Lathwell[1] suggested that the ability of a soil to store organic N under relatively constant management and climatic conditions, which are typical of turf systems, would decrease with time and eventually an equilibrium level of soil organic N would be obtained.

Porter et al.[4] examined total N content in soil to a depth of 40cm in 105 turf systems ranging in age from 1 to 125 years old. The data suggest that soil organic matter accumulation is rapid in the first ten years after establishment and slowly builds to an equilibrium at 25 years, when no further net N immobilization occurs. Porter et al.[4] concluded that there is a rather limited capacity of the soil to store organic N and that after 10 years the potential for overfertilization is greatly increased.

Petrovic[3] hypothesized, based on the data of Porter et al.,[4] that older turf sites, or sites with high organic matter contents, should be fertilized at a reduced N rate to minimize the potential for NO_3-N leaching. Petrovic theorized that the rate of N applied to younger turf stands (less than 10 years) should equal the rate at which N is used by the plants, lost to the atmosphere, and stored in the soil. Older turf sites (greater than 25 years of age) lose the ability to store additional N in the soil and therefore should be fertilized at a rate equal to the rate that nitrogen is used by the turf and lost to the atmosphere.[3]

Due to the lack of long-term data on nitrogen fate in mature turfgrass stands, this research was undertaken. The research objectives were to quantify NO_3-N and ammonium-nitrogen (NH_4-N) concentrations in leachate, and determine the fate of fertilizer nitrogen among clippings, verdure, thatch, soil, roots, and leachate for a Kentucky bluegrass turf 10 years after establishment.

MATERIALS AND METHODS

Between 1989 and 1991 at the Hancock Turfgrass Research Center, Michigan State University, four monolith lysimeters were constructed. In September 1990 the area was sodded with a polystand of Kentucky bluegrass (cv. Adelphi, Nassau, Nugget) for a United States Golf Association sponsored leaching and mass balance nitrogen-fate study conducted by Miltner et al. between 1991 and 1993. Prior to the construction of the lysimeters, the area had been in turfgrass for six years. The lysimeters are constructed of grade 304 stainless steel, 0.05cm thick. The lysimeters are 1.14 meters in diameter and 1.2 meters deep. The bottom of the lysimeter has a 3% slope to facilitate leachate drainage to a tube on one side, where leachate is collected in 19-liter glass containers. The leachate is collected on a regular basis. For complete specifications of lysimeter construction, see Miltner et al.[2]

Subsequent to the Miltner studies, the lysimeters and surrounding plot have received continual fertilizer applications and cultural practices to maintain high-quality turfgrass. Leachate collection resumed again in 1998. The experimental design is relatively simple. Two of the large lysimeters and surrounding turf area were treated annually with 245kg N ha^{-1} (5 lb. N per 1,000 sq. ft.) split over five applications. The application dates were May 1, June 1, July 1, September 15, and October 15.

The remaining two lysimeters and surrounding turf area were treated annually with 98kg N ha^{-1} (2 lb. N per 1,000 sq. ft.) split over two applications. The application dates were May 1 and October 15. Lysimeter percolate was

The average total labeled fertilizer nitrogen (LFN) recovered among all sampling components (clippings, verdure, thatch, soil, roots, and leachate) for the low and high N rates were 78% and 73%, respectively. Most of the applied fertilizer nitrogen was recovered in the soil component.

In the fall of 2000, 56 polyvinyl chloride microplots were installed in the plot area adjacent to the lysimeters. Microplots were extracted and partitioned into verdure, thatch, roots, and soil on seven sampling dates to evaluate the fate of labeled nitrogen among turfgrass and soil components.

collected periodically, volume measured, and a subsample collected for nitrogen analysis. The turf was mowed twice per week at 7.6cm (3 inches) and clippings returned. Irrigation was used to return 80% potential evapotranspiration weekly.

In the fall of 2000, 56 microplots were installed in the plot area adjacent to the lysimeters. The microplots are constructed of 20cm-diameter polyvinyl chloride (PVC) piping to a depth of 45cm. The PVC piping was driven into the ground using a tractor and hydraulic cylinder. This process preserved the soil structure within the microplots and the surrounding plot area. On October 17, 2000, ^{15}N labeled urea was applied to the lysimeters and microplots to determine mass nitrogen balance. The microplots were extracted and partitioned into verdure, thatch, roots, and soil on seven sampling dates. Soil and root samples were partitioned into depths of 0-5, 5-10, 10-20, and 20-40cm. Harvest dates followed by DAT (Days After ^{15}N Treatment) for the microplots were:

November 1, 2000 (15 DAT)
December 1, 2000 (45 DAT)
April 19, 2001 (184 DAT)
July 18, 2001 (274 DAT)
October 9, 2001 (357 DAT)
April 20, 2002 (549 DAT)
July 17, 2002 (637 DAT)

In addition, weekly clipping samples were taken to determine the amount of nitrogen in the top-growth of the plant. The leachate from the lysimeters was monitored for nitrate-nitrogen and % ^{15}N enrichment. In addition, soil, thatch, verdure, roots, and weekly clipping samples were sampled for % ^{15}N enrichment to determine mass nitrogen balance for the system.

RESULTS: FERTILIZER ALLOCATION

The average total labeled fertilizer nitrogen (LFN) recovered among all sampling components (clippings, verdure, thatch, soil, roots, and leachate) for the low and high N rates was 78% and 73%, respectively (Table 1). The majority of applied LFN was recovered in the soil, averaging 51% and 38% for the low and high N rates, respectively. Lower amounts of nitrogen were recovered in the roots, thatch, clippings, and verdure.

Over approximately two years, 1% and 11% of LFN was recovered in leachate for the low and high N rates, respectively (Table 1). The largest amount of labeled nitrogen recovered in leachate was during the winter months. The total amount of labeled nitrogen recovered in leachate was much greater than that measured by Miltner et al.[2] On the same site as our research, from 1991 through 1993, Miltner et al.[2] applied N as urea at 39.2kg N ha^{-1} (0.8 lb. N per 1,000 sq. ft.) by either a spring or fall application schedule. Miltner et al.[2] reported 0.2% of applied LFN recovered in leachate from a fall application. For our research, leachate from the low N rate had a similarly low amount of LFN recovered. However, leachate from the high N rate had drastically different results than the Miltner et al.[2] research. Over the two years of our research, 11% of applied LFN was recovered in leachate for the high N rate (49kg N ha^{-1} rate).

Table 1

Mean labeled fertilizer nitrogen recovered from both the low and high rates of nitrogen application treatments (expressed as % of amount applied) from different sampling components of mature Kentucky bluegrass.

Sampling Component	Low N Rate	High N Rate
Clippings	1	2
Verdure	8	9
Thatch	7	7
Roots	10	13
Soil	51	38
Leachate	1	11
Total	78	73

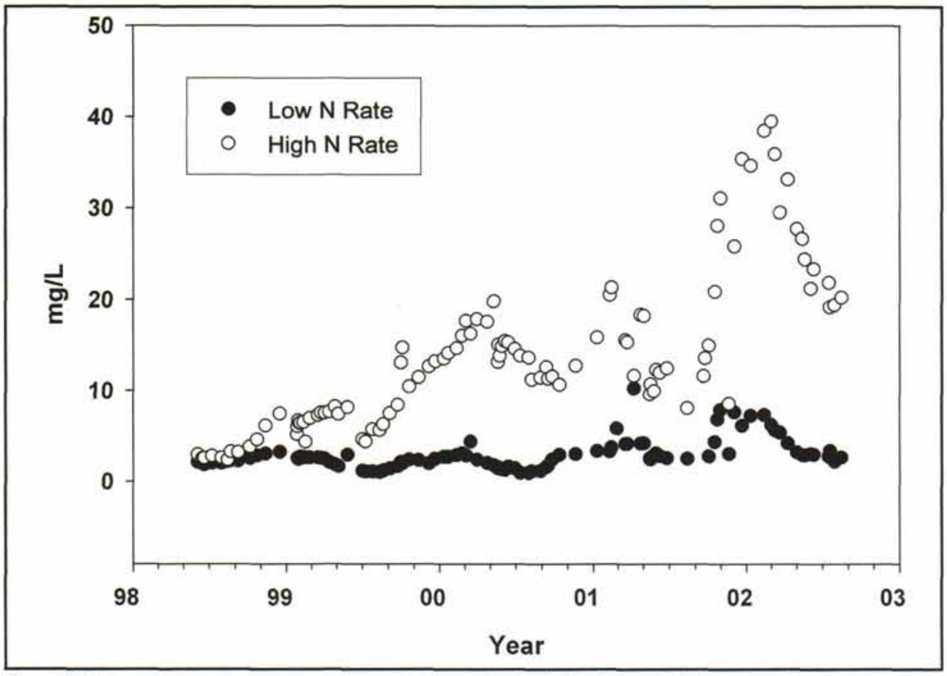

Figure 1. Nitrate-nitrogen concentration in leachate for both the low and high rates of nitrogen fertilization shown for each sampling date from 1998 through 2002.

NITRATE-NITROGEN COLLECTED IN LEACHATE

For the 98kg N ha^{-1} rate (low N rate), NO_3-N concentrations ranged between 1.0mg and 10.0mg L^{-1}. Only on one date in April of 2001 was the NO_3-N concentration equal to the EPA standard for drinking water of 10mg L^{-1} (Figure 1). NO_3-N concentrations in leachate for the low N rate were typically below 5mg L^{-1}. Flow-weighted means of NO_3-N from 1998 through 2002 ranged from 2.6mg to 4.8mg L^{-1} (Table 2).

For the 245kg N ha^{-1} rate (high N rate), NO_3-N concentrations ranged between 3mg and 40mg L^{-1} (Figure 1). On several sampling dates from 2001 through 2002, NO_3-N concentrations exceeded 30mg L^{-1}, triple the EPA drinking water standard. For the high N rate, NO_3-N concentrations in leachate were typically greater than 20mg L^{-1}. From 1998 to 2000, flow-weighted means of NO_3-N for the high N rate ranged from 5mg to 25mg L^{-1} (Table 2).

Table 2

Mean concentration (mg L^{-1}) of nitrate-nitrogen (NO_3-N) when weighted by flow rate for 1998 through 2002 for both low and high N rates of fertilization.

Year	Low N Rate	High N Rate
1998	2.6	5.0
1999	2.0	8.5
2000	2.1	14.7
2001	3.7	18.9
2002	4.8	25.3

The results for the low N rate were similar to the results reported by Miltner et al.[2] at the same site from 1991 to 1993, and they indicate that at the low N rate the potential for groundwater contamination is minimal. At the high N rate, however, the amount of LFN recovered and the concentration of NO_3-N in leachate were substantially greater than the values reported by Miltner et al.[2] At the high N rate, the NO_3-N concentration in leachate from 2000 to 2002 was often between 20mg and 40mg NO_3-N L^{-1}.

CONCLUSIONS

This research indicates that single-dose, high-rate, water-soluble N applications (49kg N ha^{-1} per application) to mature turfgrass stands should be avoided to minimize the potential for NO_3-N leaching. However, just as the original research on this site was conducted over a relatively short time frame of two years, the results presented in this article were from four years of data collection, albeit from a turf stand that has been fertilized for more than 10 years.

The long-term N fate research at Michigan State University is ongoing and future results will be reported. Upon conclusion of the 2002 research season, the USGA opted to fund this research project for an additional five years. A future article will report on data collected from 2003 through 2007. Starting in 2003 the amount of nitrogen applied for the high N rate was reduced from 245kg to 196kg N ha^{-1} (4 lb. N per 1,000 sq. ft.) split over four applications. The low N rate remained at 98kg N ha^{-1} (2 lb. N per 1,000 sq. ft.).

In the first year of reducing the high N rate, the amount of NO_3-N recovered in leachate did not decline from previous levels, but in 2004 and 2005 there was a dramatic reduction in the concentration of NO_3-N recovered in leachate. Future years of data collection will indicate whether the lowered high N rate results in consistently lower levels of NO_3-N leaching.

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KEVIN W. FRANK, PH.D., *Assistant Professor;* KEVIN O'REILLY, *Graduate Student;* JIM CRUM, PH.D., *Professor, and* RON CALHOUN, *Environmental Turfgrass Specialist; Department of Crop and Soil Sciences, Michigan State University, East Lansing.*