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A research team at Michigan State University led by Dr. Kevin Frank (above) investigated the efficiency of nitrogen use by mature Kentucky bluegrass when fertilized at a low (2 lb./1000 ft^2/year) and a high rate (5 lb./1000 ft^2/year). Results indicate that the high rate of nitrogen fertilization is much more than the turf needs and can result in unacceptable levels of nitrate-nitrogen in leachate.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Nitrogen Fate in a Mature Kentucky Bluegrass Turf

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SUMMARY

Research was undertaken at Michigan State University to determine nitrogen fate and nitrate-nitrogen leaching from a mature turfgrass. Research from 1998-2002, investigated the amount of nitrate leaching from two nitrogen rates, 2 and 5 lbs. N/1000 ft.^{2}/year. The research found:

- The average total labeled fertilizer nitrogen recovered among all sampling components (clippings, verdure, thatch, soil, roots, and leachate) for the low and high N rates was 78 and 73%, respectively.
- The low nitrogen rate treatment (2 lbs. N/1000 ft.^{2}/year) had low levels of nitrate leaching.
- The high nitrogen rates (5 lbs. N/1000 ft.^{2}/year) had high amounts of nitrate leaching.

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. 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 40 cm 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 ten 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

In the fall of 2000, 56 polyvinyl chloride microplots (shown above) 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.

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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. Most of the applied fertilizer nitrogen was recovered in the soil component.

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 1991-1993. 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, 0.05 cm 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. 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).

The lysimeters and surrounding plot area have received continual fertilizer applications and cultural practices to maintain high quality turfgrass since lysimeter construction. Fertilizer treatments and leachate collection began in 1998. The experimental design is relatively simple. Two

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

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.

of the large lysimeters and surrounding turf area were treated annually with 245 kg N ha^{-1} (5 lb. N/1000 $ft.^2$) split over 5 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 98 kg N ha^{-1} (2 lb. N/1000 $ft.^2$) split over two applications. The application dates were May 1 and October 15. Lysimeter percolate was collected periodically, volume measured, and a subsample collected for nitrogen analysis. The turf was mowed twice per week at 7.6 cm (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 20-cm diameter polyvinyl chloride (PVC) piping to a depth of 45 cm. 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 roots samples were partitioned into depths of 0-5, 5-10, 10-20, and 20-40 cm. Harvest dates followed by DAT (**D**ays **A**fter ^{15}N **T**reatment) 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 and Figure 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

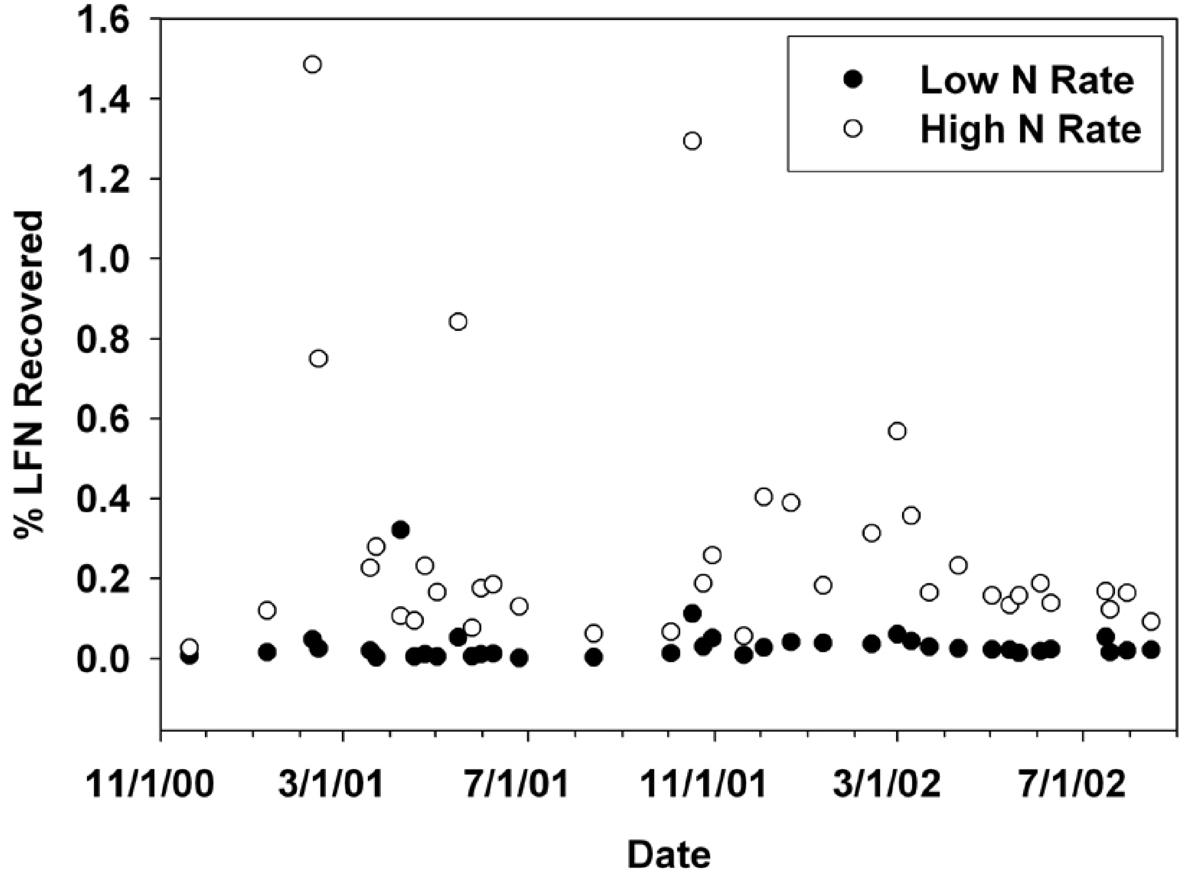

Figure 1. Percent (%) labeled fertilizer nitrogen (LFN) recovered in leachate, 2000-2002, for both the low and high rate of nitrogen fertilization treatments.

N as urea at 39.2 kg N ha^{-1} 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 (49 kg N ha^{-1} rate).

Nitrate-nitrogen Collected in Leachate

For the 98 kg N ha^{-1} rate (low N rate), NO_3-N concentrations ranged between 1.0 and 10.0 mg 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 10 mg L^{-1} (Figure 2). NO_3-N concentrations in leachate for the low N rate were typically below 5 mg L^{-1}. Flow weighted means of NO_3-N, from 1998 through 2002 ranged from 2.6 to 4.8 mg L^{-1} (Table 2).

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

The results for the low N rate were similar

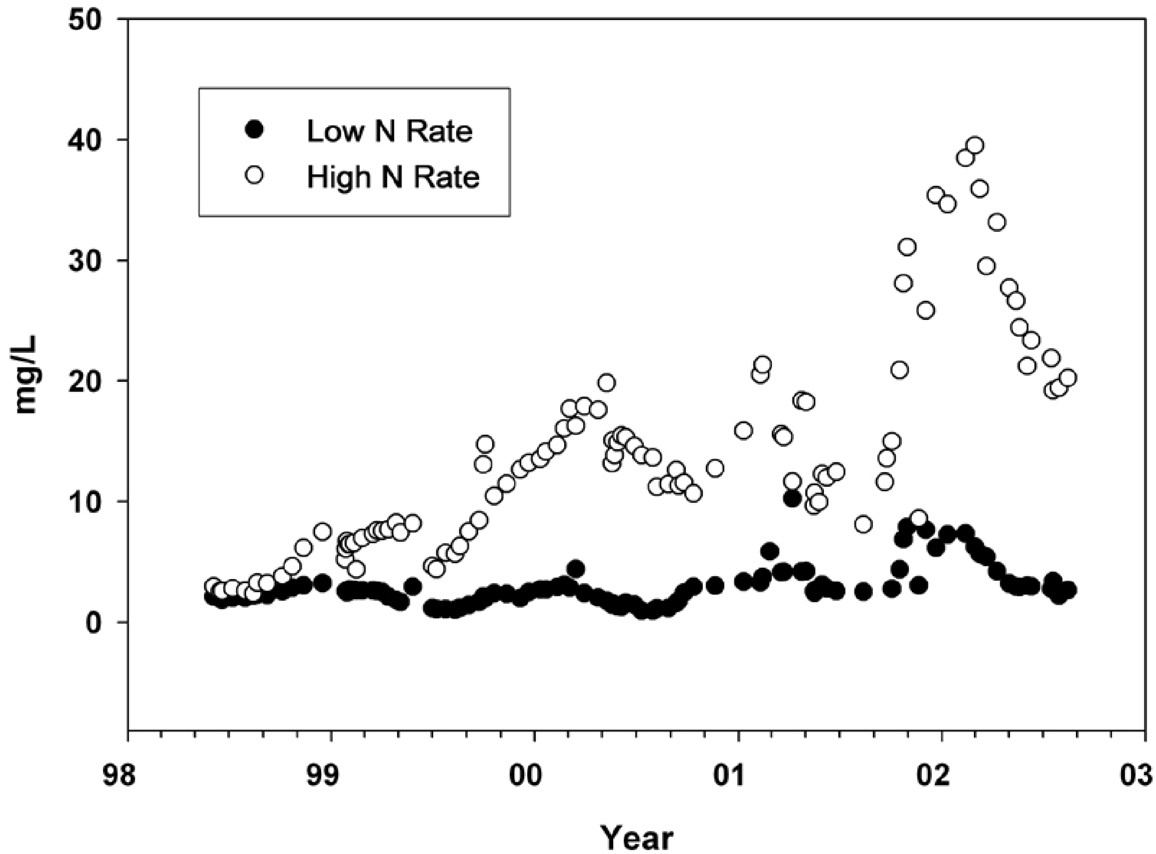

Figure 2. Nitrate-nitrogen concentration in leachate for both the low and high rates of nitrogen fertilization shown for each sampling date from 1998 through 2002.

to the results reported by Miltner et al. (2) at the same site from 1991-1993, and indicate that at the low N rate the potential for groundwater contamination is minimal. At the high N rate, 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 - 2002 was often between 20 and 40 mg NO_3-N L^{-1}.

Conclusions

This research indicates that single dose, high rate, water soluble N applications (49 kg 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 paper were from four years of data collection, albeit from a turf stand that has

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

Table 2. Mean concentration (ppm) of nitrate-nitrogen (NO_3-N) when weighted by flow rate for 1998 through 2002 for both low and high N rates of fertilization.

been fertilized for more than ten years.

The long-term N fate research at Michigan State University is on-going 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 245 to 196 kg N ha^{-1} split over four applications. The low N rate remained at 98 kg N ha^{-1}.

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 drastic 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.

Acknowledgements

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