# Nitrogen and Phosphorus Fate in a 10 Year Old Kentucky bluegrass Turf

Kevin W. Frank, Jeff Bryan and Erica Bogle
Michigan State University

## Introduction

Extensive research has been conducted on nitrate-nitrogen ($NO_3$-N) leaching in turfgrass systems. The majority of research has indicated that turfgrass poses little risk to the environment from nitrate leaching. Research conducted at MSU by Miltner et al. reported that the majority of $^{15}$N labeled urea nitrogen applied to Kentucky bluegrass never reached the soil. The majority of applied nitrogen was taken up by the plant, immobilized in the thatch layer, or lost to volatilization. Only 0.23% of the $^{15}$N labeled urea was collected in the drainage water of lysimeters 1.2 m below the soil surface over a three-year period following application.

Research has also shown that turfgrass builds organic matter for a period of about 10 years following establishment and then reaches equilibrium where no further net N immobilization occurs. The question under investigation is whether or not after an extended period of time, 10 years, will the amount of nitrate-nitrogen leaching from a turfgrass system change. The research is important because it will indicate if the amount of nitrate nitrogen leached from a mature turf occurs at a level where an alteration in fertilizer practices needs to be considered.

## 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 m in diameter and 1.2 m 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 L glass jugs. The leachate is collected when the jugs are approximately ½ full. For complete specifications of lysimeter construction, see Miltner et al. (1996).

### <u>Treatments: 1998-2002</u>

The lysimeters and surrounding plot area have received continual fertilizer applications and cultural practices to maintain high quality turfgrass since lysimeter construction. This research was initiated in 1998 and will last until at least 2008. The experimental design is relatively simple. Two 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 2 application dates. The application dates were May 1 and October 15. Lysimeter percolate was collected periodically, volume measured, and a subsample collected for N analysis. The turf was mowed twice a week at 7.6 cm and clippings returned. Irrigation was used to return 80% potential evapotranspiration weekly.

In the fall of 2000, 90 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 17th 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 7 sampling dates. Soil and roots samples were partitioned into depths of 0-5, 5-10, 10-20, and 20-40 cm.

Harvest dates for the microplots to date were:

November 1, 2000 (15 **D**ays **A**fter $^{15}N$ **T**reatment)
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 from fertilizer being moved to 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.

## Treatments: 2003-2007

The amount of nitrogen applied was 98 and 196 kg N $ha^{-1}$ split over four applications. Nitrogen application dates were in May, June, September, and October. For the May 2003 fertilizer application, $^{15}N$ labeled urea was applied to the lysimeters and microplot area at 24 and 49 kg N $ha^{-1}$. Microplots were harvested in June of each year to determine nitrogen allocation among clippings, verdure, thatch, soil, and roots. Phosphorus from triple superphosphate (20% P) was applied at two rates, 49 and 98 kg P $ha^{-1}$ split over two applications (May and September). The phosphorus application dates coincided with the nitrogen application dates in May and September.

## Results

### 1998-2002

For the 98 kg N $ha^{-1}$ rate (low N rate), $NO_3$-N concentrations ranged between 1.0 and 8.0 mg $L^{-1}$, well below the EPA standard for drinking water of 10 mg $L^{-1}$ (Figure 1). $NO_3$-N concentrations in leachate for the low N rate were typically below 5 mg $L^{-1}$. Flow weighted means of $NO_3$-N, for the low N rate from 1998-2002 ranged from 2.6 to 4.8 mg $L^{-1}$ (Table 1).

For the 245 kg N $ha^{-1}$ rate (high N rate), $NO_3$-N concentrations ranged between 10.0 and 40.0 mg $L^{-1}$ (Figure 1). 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 $L^{-1}$. Flow weighted means of $NO_3$-N, for the high N rate from 1998-2002 ranged from 5.0 to 25.3 mg $L^{-1}$ (Table 1).

The average total labeled N recovery among turfgrass clippings, verdure, thatch, soil, and roots for the low and high N rates was 78 and 74%, respectively. Over approximately two years, 1 and 11% of labeled fertilizer-N (LFN) was recovered in leachate for the low and high N rates, respectively (Figure 2). 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. (1996). Miltner's results found less than 0.25% of labeled nitrogen in leachate over a two year time frame.

### 2003

Leachate analysis for 2003 indicated that $NO_3$-N concentrations for the high nitrogen rate had not declined from previous levels and there had been only a slight elevation in $NO_3$-N concentration for the low nitrogen rate (Figure 3). In the first year of reducing the high N rate from 245 to 196 kg N $ha^{-1}$, the flow weighted mean concentration of $NO_3$-N leached increased from 25.3 mg/L in 2002 to 29.7 mg/L in 2003.

The total amount of LFN recovered in leachate was 2 and 1.8% for the low and high N rate, respectively (Figure 4). The range for the low N rate was 0.01 to 0.60% LFN and for the high N rate was 0.01 to 0.50 % LFN. Interestingly, the amount of LFN recovered in leachate for the low N rate was higher in 2003 than for the two year period of 2000-2002.

The total amount of Ortho phosphorus recovered in leachate for the low and high phosphorus treatments was 0.81 and 0.84 mg/L, respectively. The range for the low rate was 0.05 to 0.08 mg/L and for the high rate was 0.05 to 0.09 mg/L.

**2004**

Leachate analysis for 2004 indicated that $NO_3$-N concentrations for the high nitrogen rate declined significantly from 2003 levels (Figure 5). The flow weighted mean $NO_3$-N concentration in leachate in 2004 for the high N rate was 8.8 mg/L. This is a decline of 20.9 mg/L from 2003. Overall, for the high N rate the amount of $NO_3$-N leaching declined drastically, but there was a slight elevation in the amount of $NO_3$-N leaching in the autumn. For the low N rate the flow weighted mean $NO_3$-N concentration declined from 6.3 mg/L in 2003 to 2.6 mg/L in 2004.

The total amount of ortho-phosphorus recovered in leachate for the low and high phosphorus treatments was 1.33 and 1.22 mg/L, respectively. The range for the low rate was 0.01 to 0.14 mg/L and for the high rate was 0.05 to 0.08 mg/L.

**2005**

Leachate analysis for 2005 followed the trend of 2004 (Figure 6). The flow weighted mean $NO_3$-N concentration in leachate in 2005 for the high N rate was 11.6 mg/L. This was a very small increase in $NO_3$-N leaching from 2004. For the low N rate the flow weighted mean $NO_3$-N concentration also increased slightly from 2.6 mg/L in 2004 to 3.6 mg/L in 2005. $NO_3$-N concentration in leachate from 1998 – 2005 is presented in Figure 7.

The concentration of ortho-phosphorus detected in leachate remains very low regardless of treatment. The mean concentration of phosphorus detected in leachate in 2005 for both the low and high phosphorus rates was 0.05 mg $L^{-1}$.

**2006**

Leachate analysis for 2006 followed the trend of 2004 and 2005 (Figure 7). The flow weighted mean $NO_3$-N concentration in leachate in 2006 for the high N rate was 12.5 mg/L. This was a very small increase in $NO_3$-N leaching from 2004 through 2005. For the low N rate the flow weighted mean $NO_3$-N concentration also increased slightly from the previous years to 5.0 mg/L. $NO_3$-N concentration in leachate from 1998 – 2006 is presented in Figure 8.

The concentration of ortho-phosphorus detected in leachate remains very low regardless of treatment. The mean concentration of phosphorus detected in leachate in 2006 for both the low and high phosphorus rates was 0.02 mg $L^{-1}$.

**2007**

Leachate analysis for 2007 continued on the trend observed from 2004-2006 with even lower concentrations of $NO_3$-N in leachate from both the low and high N rate treatments (Figure 8). The flow weighted mean $NO_3$-N concentration in leachate in 2007 for the high N rate was 4.9 mg/L. This was a decrease in $NO_3$-N leaching from 2006 of approximately 7 mg/L. This was the lowest mean $NO_3$-N concentration in leachate for the high N rate since data collection began in 1998. The only collection date when the mean $NO_3$-N concentration in leachate was 10 mg/L or higher was the Dec. 3 sampling. This follows the recent trend indicating that the highest concentrations of $NO_3$-N leaching are during the dormant winter periods when the turfgrass is not actively taking up nitrogen.

For the low N rate the flow weighted mean $NO_3$-N concentration also decreased from the previous years to 1.7 mg/L. This was the lowest mean $NO_3$-N concentration in leachate for the low N rate since data collection began in 1998. $NO_3$-N concentration in leachate from 1998 – 2007 is presented in Figure 9.

The concentration of ortho-phosphorus detected in leachate continues to remain very low regardless of treatment. The mean concentration of phosphorus detected in leachate in 2007 for the low and high phosphorus rate treatments was 0.01 and 0.02 mg $L^{-1}$, respectively.

## Conclusions

These results indicate that total yearly applications of 245 kg N $ha^{-1}$ in the form of urea to a 10 + year old Kentucky bluegrass stand with monolith lysimeters in place, resulted in elevated levels of $NO_3$-N in leachate. Nitrogen applications of 98 kg N $ha^{-1}$ resulted in low levels of $NO_3$-N leaching through the lysimeters from 1998 through 2007.

During the first year of reducing nitrogen application rates from 245 to 196 kg N $ha^{-1}$ there was no reduction in $NO_3$-N concentrations in leachate. However, after five years of annual 196 kg N $ha^{-1}$ applications there was a significant and sustained reduction in the amount of $NO_3$-N leaching.

The amount of phosphorus leaching through the lysimeters has been low for both the low and high rate fertilizer treatments.

## Literature Cited

Miltner, E.D., B. E. Branham, E.A. Paul, and P.E. Rieke. 1996. Leaching and Mass Balance of 15NLabeled Urea Applied to a Kentucky Bluegrass Turf. Crop Sci.36:1427-33.

Table 1. Flow-weighted means of nitrate-nitrogen concentration in leachate.

| Year | Low N Rate† | High N Rate |
|---|---|---|
| | ----------------------mg $L^{-1}$------------------------ | |
| 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 |
| 2003 | 6.3 | 29.7 |
| 2004 | 2.6 | 8.8 |
| 2005 | 3.6 | 11.6 |
| 2006 | 5.0 | 12.5 |
| 2007 | 1.7 | 4.9 |

† The low N rate was 98 kg N $ha^{-1}$. The high N rate treatment was 245 kg N $ha^{-1}$ from 1998 – 2002, from 2003-2007 the N rate was 196 kg N $ha^{-1}$.

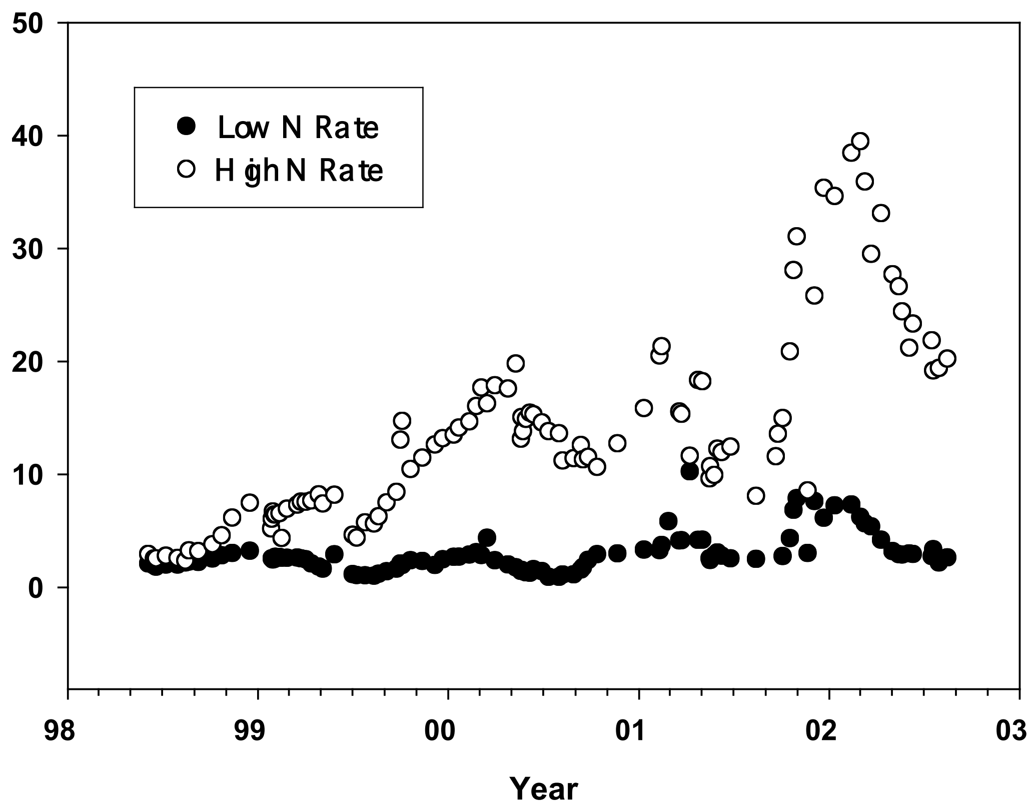


**Figure 1. Nitrate-nitrogen concentration in leachate: 1998-2002.**

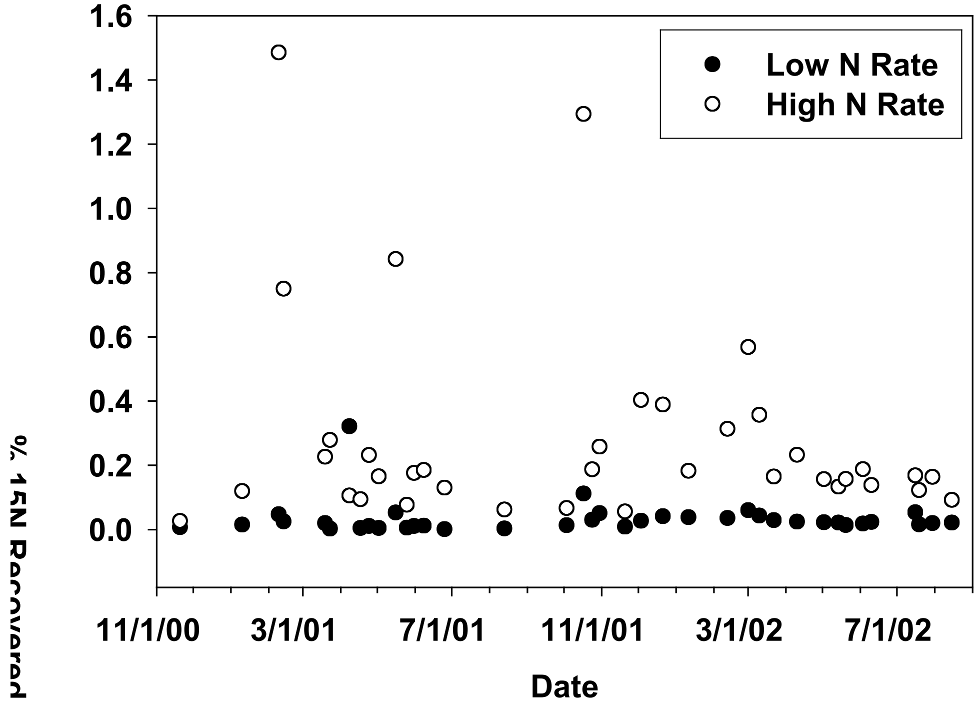


**Figure 2. Percent labeled fertilizer nitrogen recovered in leachate: 2000-2002.**

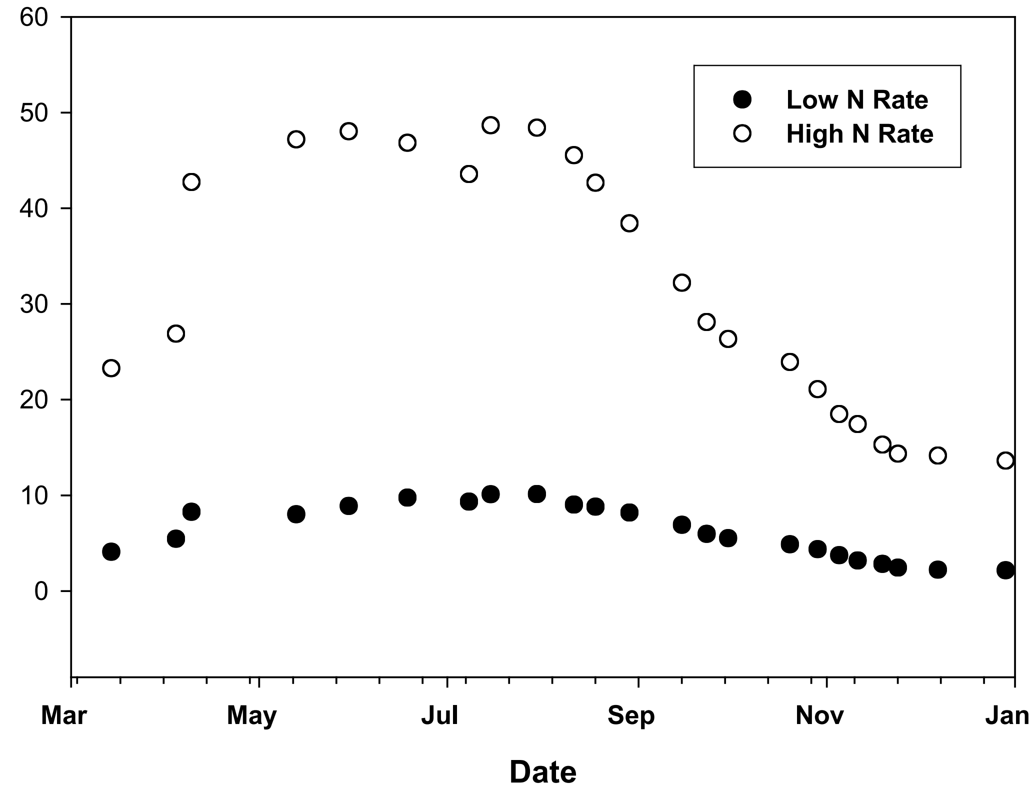


**Figure 3. Nitrate-nitrogen concentration in leachate: 2003.**

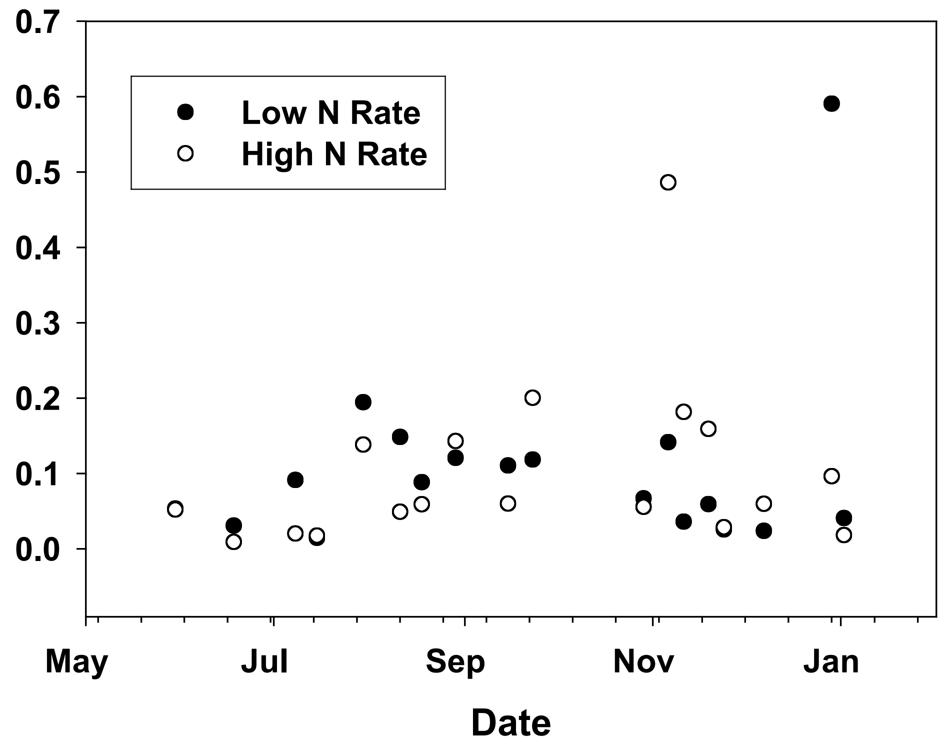


Figure 4. Precent labeled fertilizer nitrogen recovered in leachate: 2003.

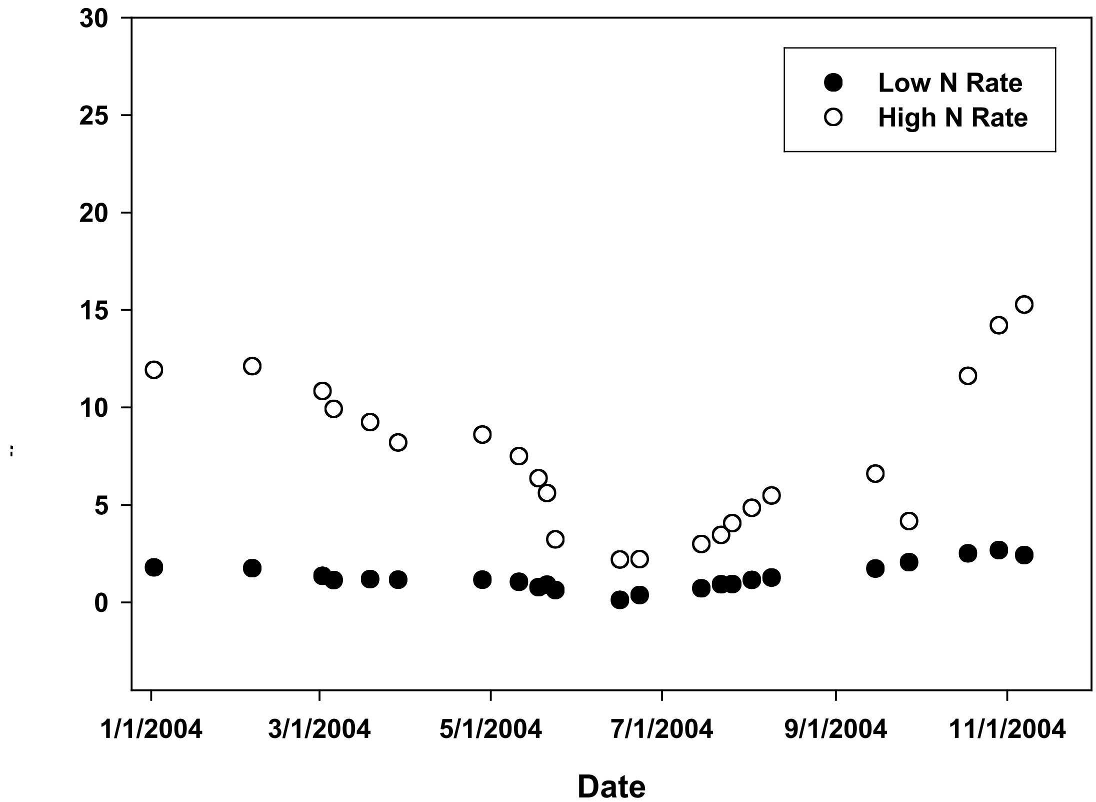


**Figure 5.Nitrate-nitrogen concentration in leachate: 2004.**

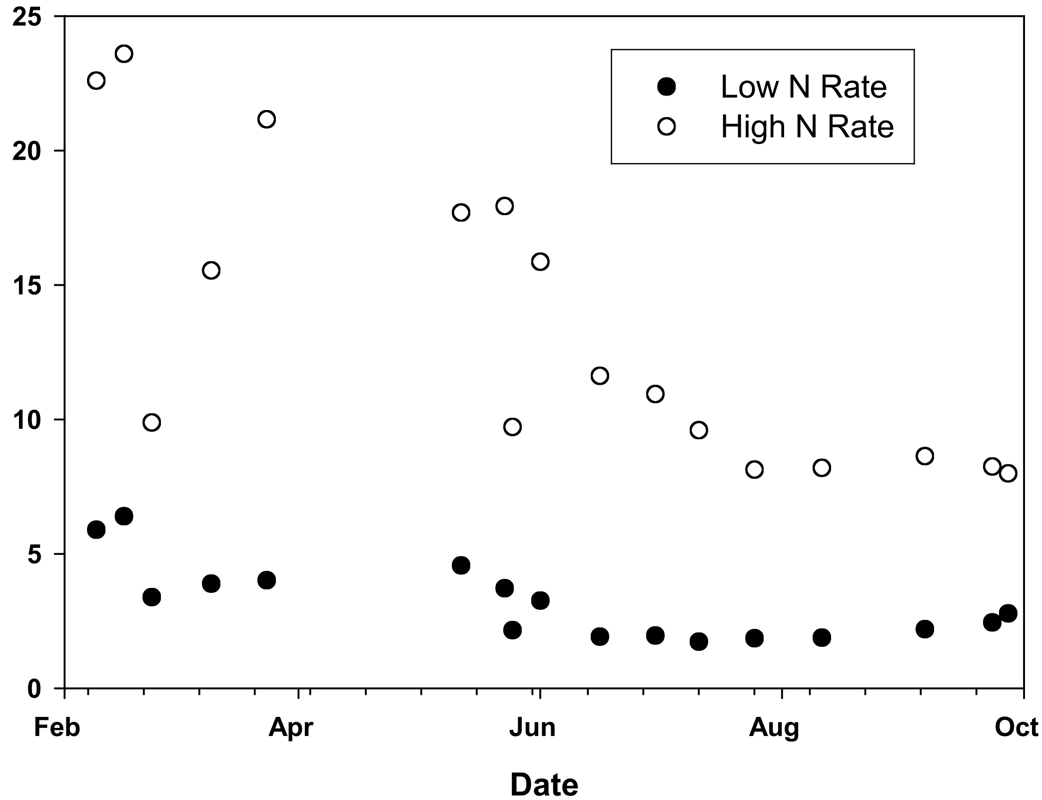


**Figure 6. Nitrate-nitrogen concentration in leachate: 2005.**

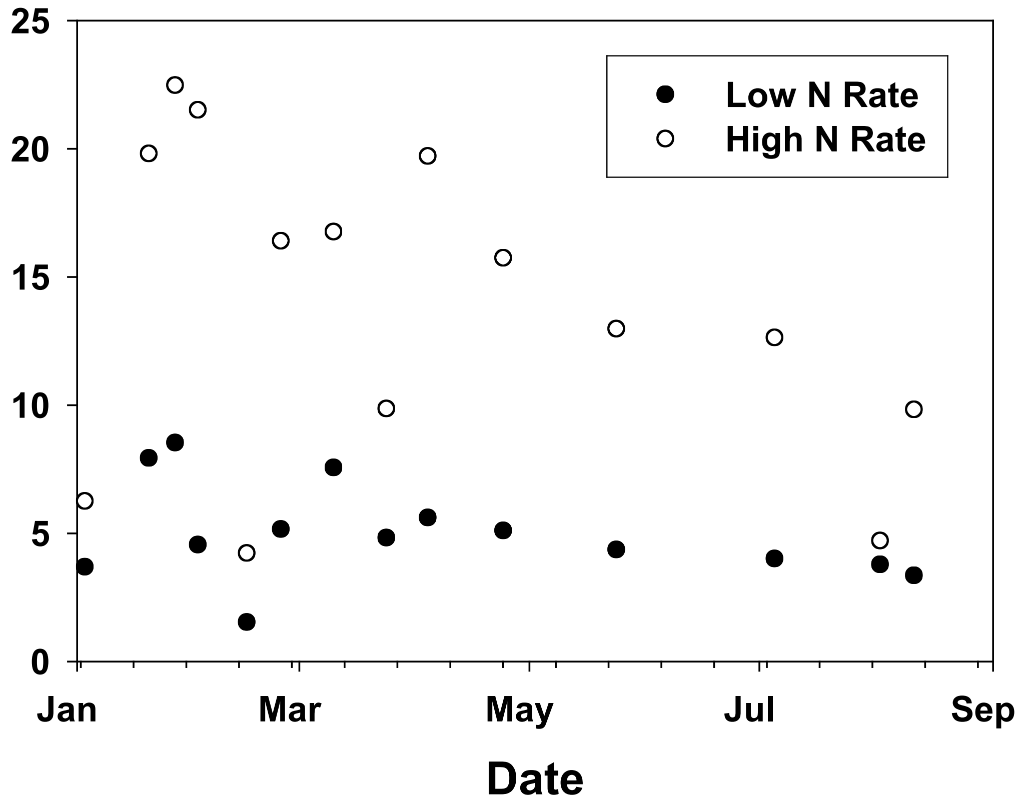


Figure 7. Nitrate-nitrogen concentration in leachate: 2006.

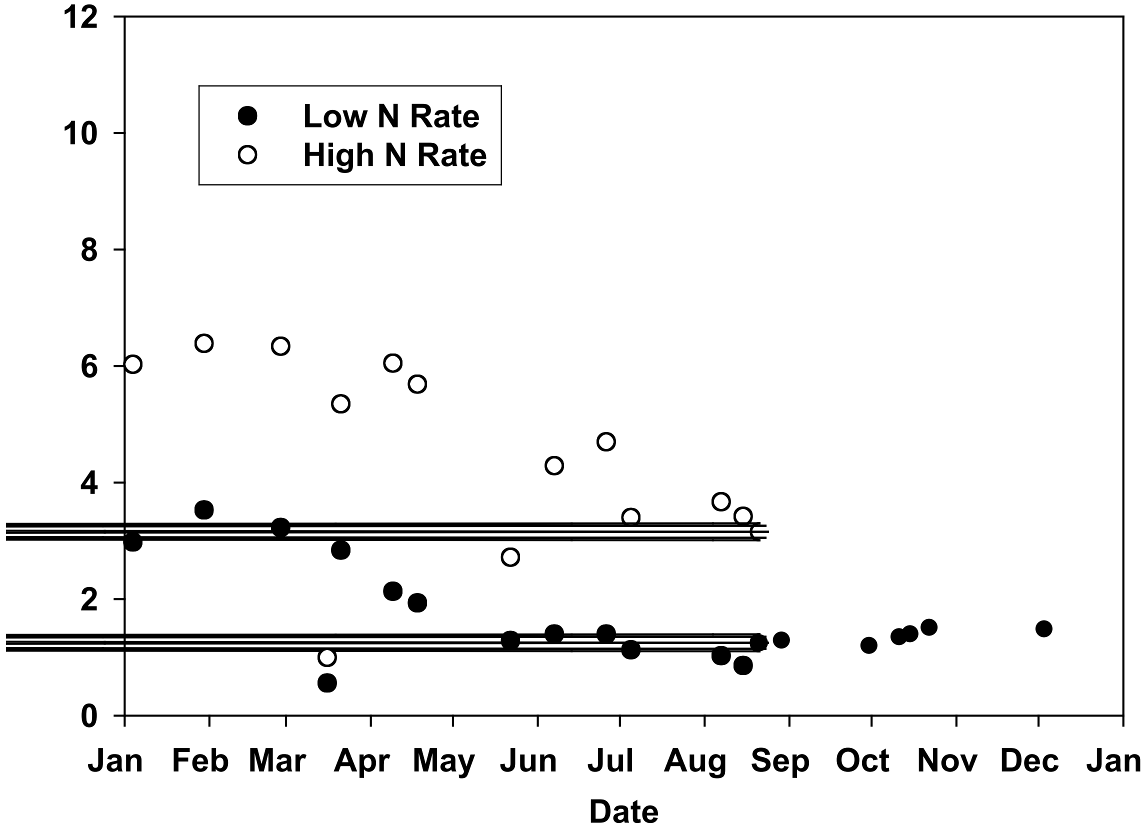


**Figure 8. Nitrate-nitrogen concentration in leachate: 2007.**

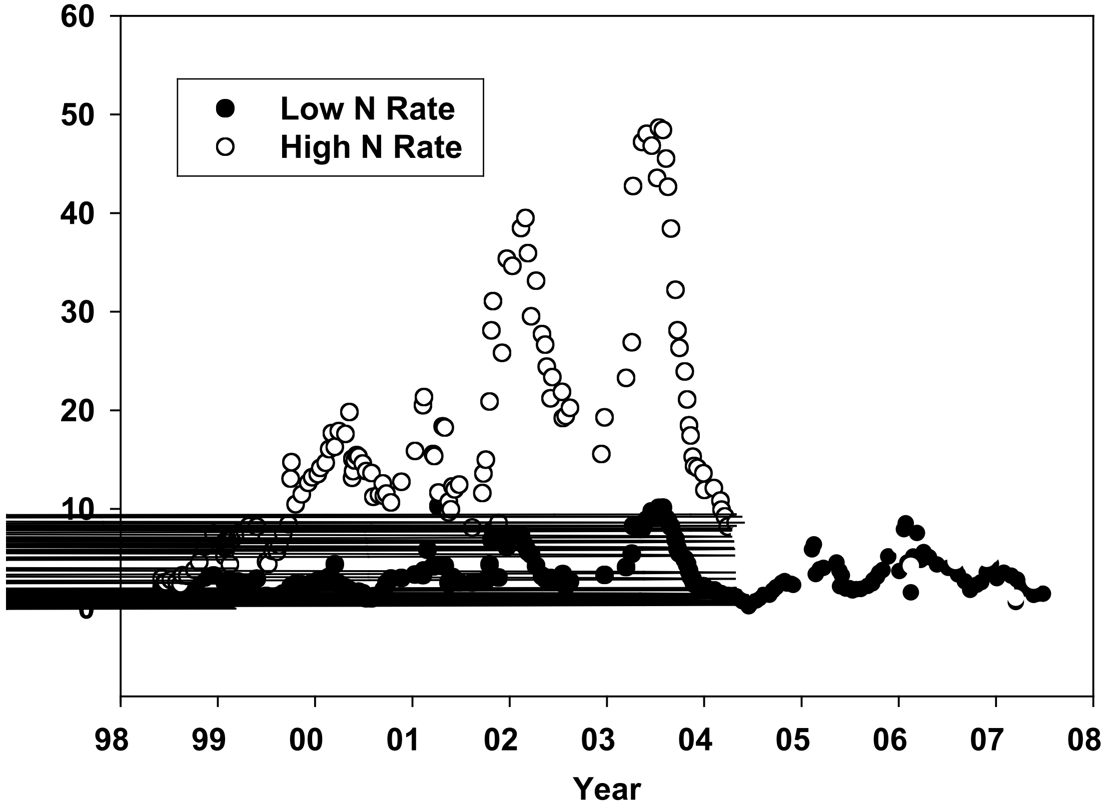


**Figure 9. Nitrate-Nitrogen concentration in leachate: 1998-2007.**