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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 350 projects at a cost of $29 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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Nitrate Leaching in Bentgrass Putting Greens

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SUMMARY

The objectives of research conducted at Auburn University were to examine the combined and separate effects of N rate and greensmix on nitrate and ammonium in leachate from bentgrass putting greens. The study's findings include:

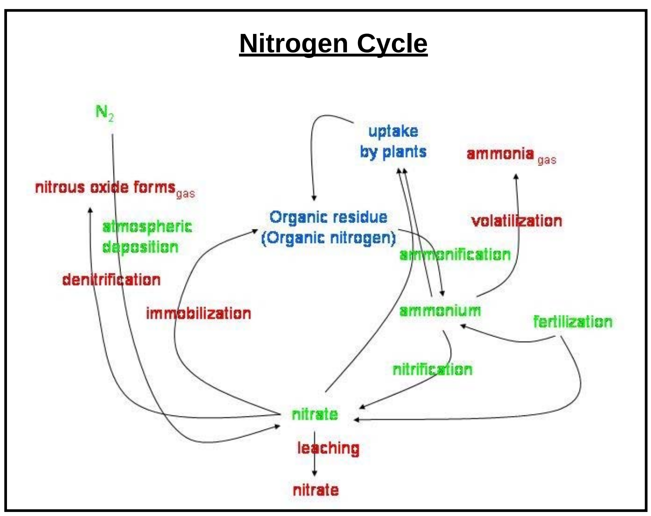
- Nitrate leaching was greatest in the initial months of the study when N was applied at high rates.
- Nitrate leaching from USGA-type greens was greater during the first 4 months after construction than from the 100% sand greens.
- Differences in nitrate leaching lessened as the greens aged and as N fertilization was reduced to maintenance levels.
- There were few differences in color or quality of bentgrass putting greens due to maintenance N rates (1/5 or 1/10 lb N/1000 ft^2/week).
- When applied at maintenance N rates, nitrate in leachate was reduced without any reduction in turf quality.

Unlike other fertilizer nutrients such as potassium (K), the availability of nitrogen for plant use is controlled by the complex and biologically-based nitrogen (N) cycle. Nitrogen is added to the N cycle via decomposition and addition of plant residues, fixation by lightning, and, most importantly in turf, fertilization with N fertilizers. Nitrogen is lost from plant availability via immobilization (N incorporated into biological organisms), denitrification (loss to the air as NO_x compounds), volatilization (loss to the air as ammonia), and leaching (loss from the rootzone as nitrate).

In turfgrass research, the N uptake/loss areas which have received most exploration are N uptake as a result of fertilization and N losses via nitrate leaching. For example, a 1990 review article on the fate of nitrogenous fertilizers applied to turfgrass cited 12 articles that studied N uptake by turf: seven examined ammonia volatilization, four examined soil storage of N, two studied denitrification, and 10 examined N leaching (11).

Leaching is the downward loss of nitrogen as the nitrate anion (NO_3^-) is moved by water from the rootzone deeper into the soil with possible movement into underlying groundwater. Nitrate leaching receives attention because: 1) there are concerns about increased nitrate in water and its effects on the populations at risk which are pregnant women, nursing mothers, and infants, 2) nitrate is a mobile anion and this path of N loss can be substantial, especially in sandy soils, and 3) unlike other N loss paths such as denitrification or immobilization, leaching is a relative easy loss path to study not requiring expensive ^{15}N-labeling techniques or specialized, expensive equipment.

In turf systems, nitrate leaching papers first appeared in the refereed literature in the late 1970s and early 1980s with continued publication in this area to the present day. Many of these



The nitrogen cycle illustrates how forms of nitrogen can be recycled through the plant, soil, and atmosphere. This study focused on leaching losses of nitrogen as affected by either rootzone (100% sand versus 80% sand/20% reed sedge peat) and nitrogen application rate (1/10 verus 1/5 lb N/1000 sq. ft/week.

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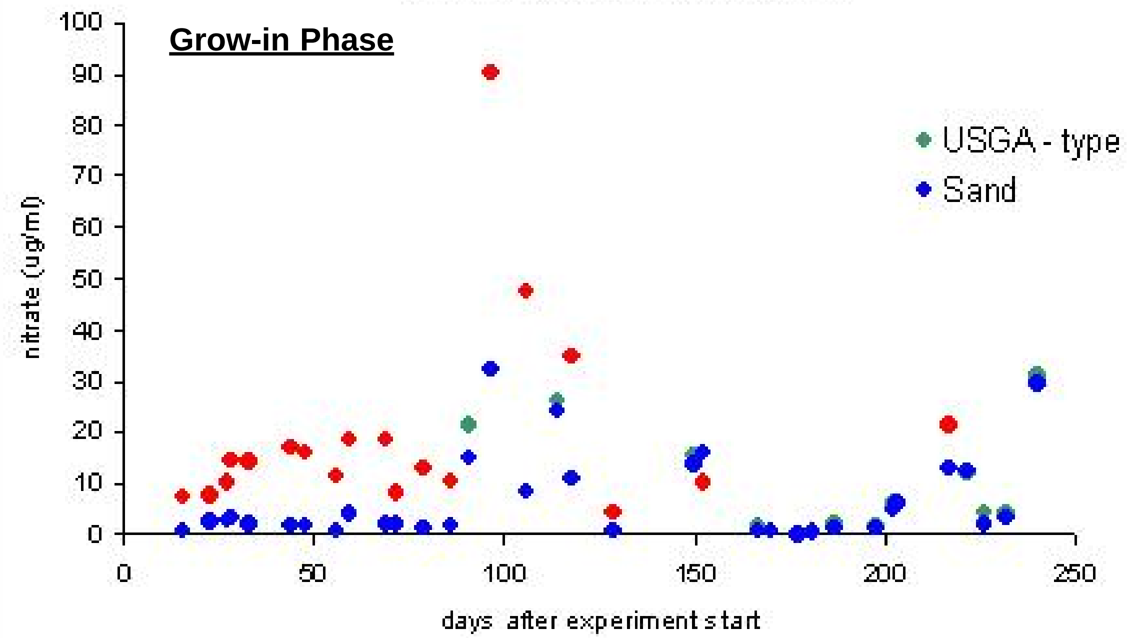

Figure 1. Effect of greens mix on nitrate leaching in a newly estqablished 'Crenshaw' bentgrass putting green, Auburn, AL. Red points indicate those sampling dates when USGA-type rootzones leached significantly higher concentrations of nitrate.

papers examined N leaching under turf managed as a lawn or fairway using species such as Kentucky bluegrass (*Poa pratensis* L.) (5, 6, 10, 12); Kentucky bluegrass/red fescue (*Festuca rubra* L.) mixtures (8, 9, 16), fairway-height hybrid bermudagrass (*Cynodon dactylon* x *C. transvaalensis* Pers.) (7, 15) and Saint Augustinegrass [*Stenotaphrun secumdatum* (Walt.) Kuntze] (4).

Studies often had N source and N rate as treatments, and, in general, concluded the following: 1) nitrate leached from high-sand soils during establishment (6) or when excessive rates (approximately 6 times the recommended rate) were applied (12); 2) nitrate leaching into the soil profile was far less likely to occur in soils with a lower sand content (12, 16); 3) N leaching from soil was reduced when a slow-release N source was used (10, 14, 15); and 4) irrigation applied at a correct frequency and rate resulted in little measurable nitrate leaching, even in a sandy soil (15). Based on this work, we have developed our general recommendations to limit nitrate leaching in turfed soils: avoid over-application of N fertilizers, consider use of slow-release N sources or split application of soluble N sources, and do not irrigate to excess following N applications.

Constructed putting greens often fit the worst-case scenarios mentioned in the preceding paragraph, as they are built with 90%, or more, sand and receive frequent inputs of N fertilizer and irrigation. Additionally, constructed greens are shallow and drain directly to an outlet, an additional potential environmental hazard. Research which examined N leaching in greens typically used small individual golf greens with the greensmix itself sometimes a treatment variable (2, 3, 13). The percentage of N lost as leached nitrate varied by study, often less than 2% of total N applied (13, 15). However, when N was over-applied at 3 times the recommended rate, leachate nitrate was as high as 23% of N applied, with greatest loss from soluble N sources (2).

Over the past 30 years, fairway-based research has shown that when N is applied at the recommended rate, at the correct time of year, with appropriate irrigation, the result is minimal nitrate leaching. Studies that evaluated putting green mixes are less prevalent and were either a greenhouse trial (1, 14) or conducted on 'Tifdwarf' bermudagrass (2, 3). Given the widespread use of creeping bentgrass (*Agrostis stolonifera*) on USGA-type putting greens, the number of studies which have explored nitrate

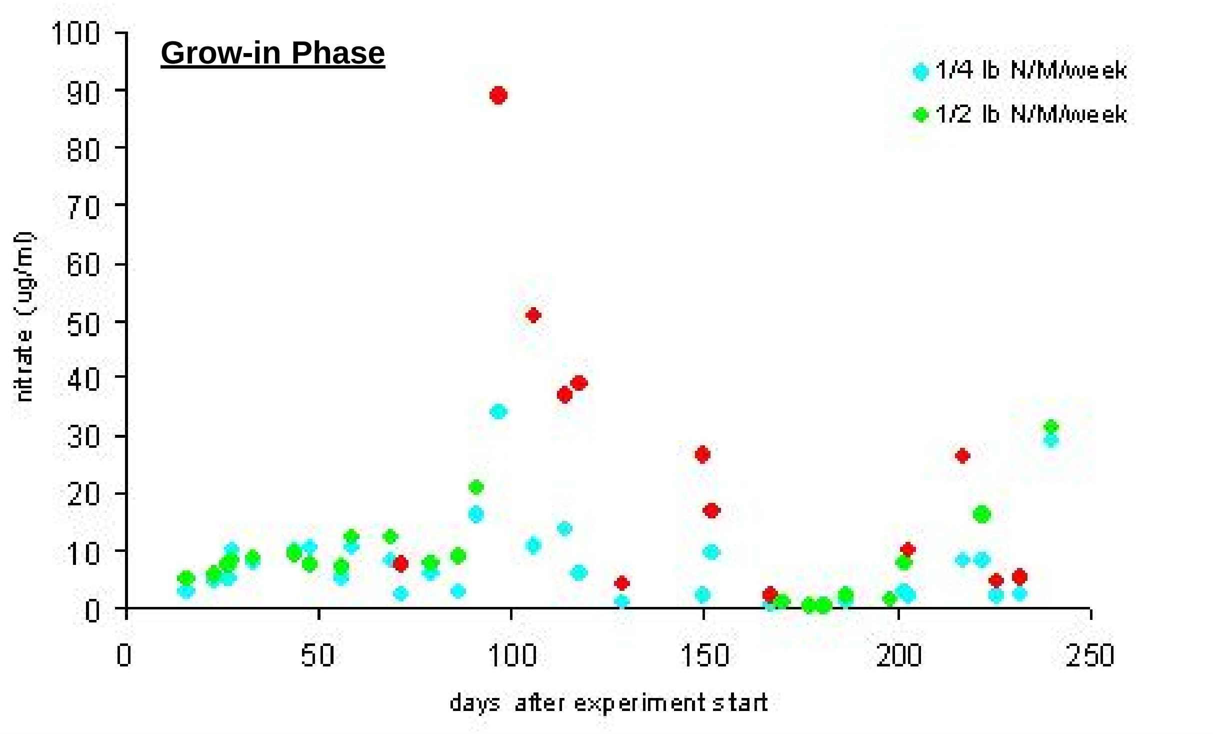

Figure 2. Effect of nitrogen rate on nitrate in leachate in a newly established 'Crenshaw' bentgrass uttting green, Auburn, AL. Red points indicate sampling dates where 1/2 lb treatments resulted in significantly higher nitrate concentrations in leachate compared to 1/4 lb/1000 sq. ft./week treatments.

losses from such a system are few (11, 13). Thus, the objective of this research project was to examine the combined and separate effects of N rate and greensmix on nitrate and ammonium in leachate from bentgrass putting greens.

Materials and Methods

The experiment was located at the Auburn University Turfgrass Research Unit (TGRU), located in Auburn, AL. The study consisted of 16 individually constructed greens, each 1 x 1/2 m (3.1 x 1.6 ft) in size. Each individual green was deep enough to hold 10 cm of gravel and 40 cm of overlying greensmix. No choker layer between the gravel and rootzone mix was used since prior analyses of the greensmix indicated that the sand would bridge. Each green drained completely into a separate collection unit, allowing all leachate from each green to be collected as needed. The greens were constructed in December 2006 using washed 'Crenshaw' creeping bentgrass sod installed in each green on January 2, 1997.

There were 4 replications of each greensmix/N rate combination. Greensmix treatments were: 1) 100% sand and 2) a USGA-type mix of 80% sand/20% reed-sedge peat (v/v). Nitrogen rate treatments were: 1) 1/4 or 1/2 1b. N/1,000 ft^2 per week for the first 8 months (grow-in phase), followed by 1/10 or 1/5 lb. N 1,000 ft^2 per week for the remainder of the test (maintenance phase). The two N rate and two greensmix treatments were arranged as a 2 x 2 factorial design with 4 replications of each treatment combination. All N was applied as a spray application on the Monday of each week using 20-5-10 as the fertilizer source with additional urea (46-0-0) used to make up the higher N rate. The experiment ended on May 5, 2000 representing three years and four months of leachate collection from the bentgrass putting greens.

At least twice monthly the following was done: 1) total leachate volume from each green was collected and determined; and 2) a subsample of leachate was collected and returned to the lab

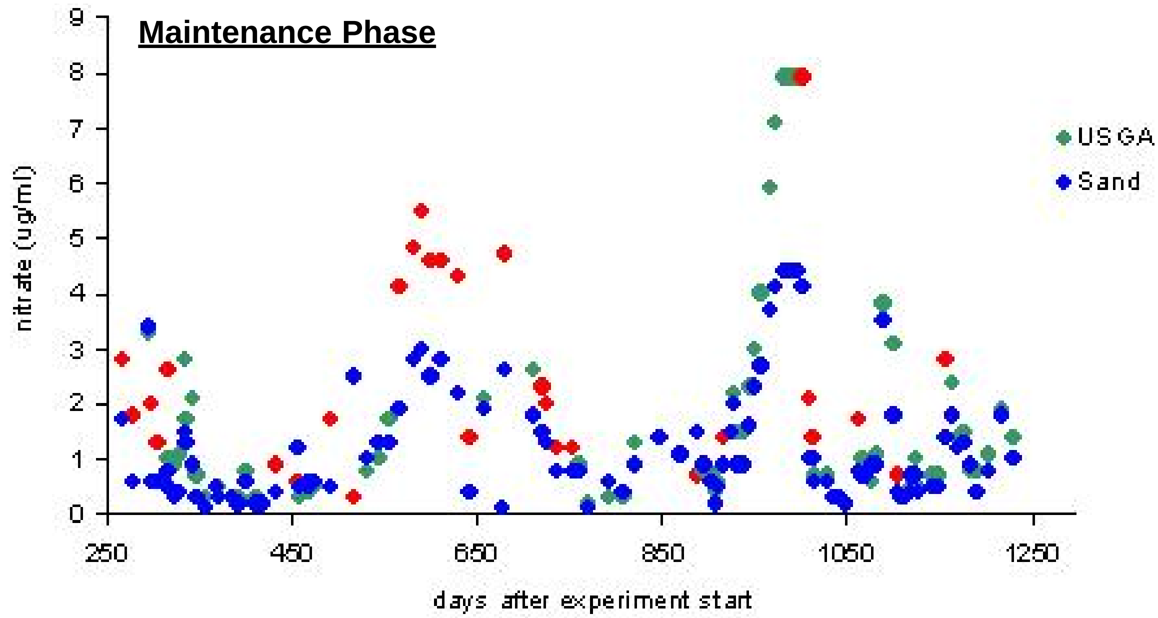

Figure 3. Effect of greens mix on nitrate leaching in a 'Crenshaw' bentgrass putting green under a maintenance regime, Auburn, AL. Red dots indicate sampling dates where USGA rootzones had significantly higher concentrations of nitrate in leachate than 100% sand rootzones.

for subsequent determination of nitrate and ammonium concentration. Nitrate and ammonium in water samples were determined via standard colorimetric techniques. If rainfall in a sampling period exceeded 1/2 inch, the leachate containers were emptied as soon as possible, regardless of the sampling time. Thus, in periods of high rainfall the collection containers were emptied frequently as needed.

Results

At most sampling dates there was not a significant N rate x greensmix interaction. The main effects of greensmix and N rate often resulted in significantly different N leaching losses. Figures 1 and 2 illustrate N lost as nitrate in the grow-in phase of the experiment when N was applied at high rates (1/4 and 1/2 lb N/1,000 ft^2/week) simulating grow-in conditions. In the Figure 1, a red dot indicates that nitrate loss from the USGA-type greensmix was significantly greater than that from the sand greensmix at that sampling date. In Figure 2, a red dot indicates that nitrate loss from plots receiving 1/2 lb N/1,000 ft^2/week was significantly greater than nitrate loss measured from the 1/4 lb N/1,000 ft^2/week treatment at that sampling date. As with previous research (2), highest N leaching was found when N was applied at rates above those that would be recommended for turf maintenance. High concentrations of nitrate in leachate were found during the establishment phase of this study. Agronomically and environmentally, such N rates were not needed to maintain newly laid bentgrass sod managed as a putting green.

In the first three months after construction, plots containing the USGA-type greensmix had significantly more nitrate in leachate, regardless of the N fertilization rate (Figure 1). Initial degradation of the reed sedge peat in the greensmix was likely contributing to this N release. This higher concentration of nitrate from the USGA-type greensmix was largely depleted by four months after construction, and from that point, differences due to greensmix were largely nonsignificant (Figure 1).

Figures 3 and 4 illustrate leachate nitrate during the maintenance phase of the research. In each figure, significant differences between treatments are indicated by a red dot for the USGA-type greensmix and 1/5 lb N rate, respectively. The lower rates of N fertilization applied during

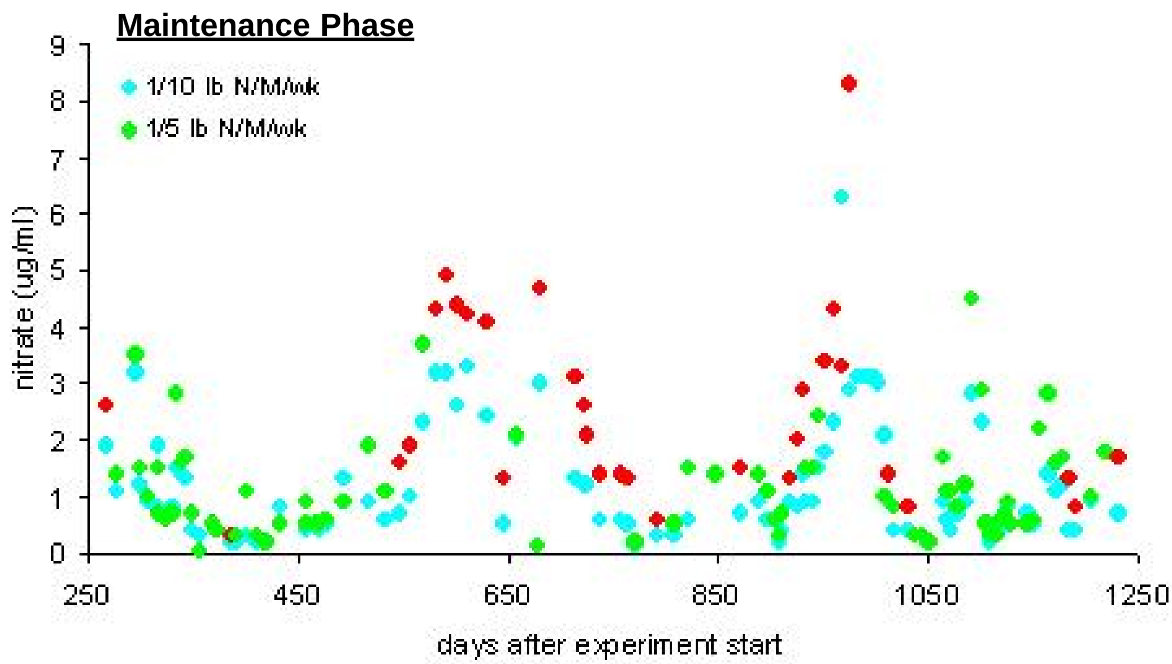

Figure 4. Effect of nitrogen rate on leachate nitrate in a 'Crenshaw' creeping bentgrass putting green managed under a maintenance regime in Auburn, AL. Red dots indicate those sampling dates where 1/2 lb treatments resulted in higher nitrate concentrations in leachate than 1/4 lb N/1,000 sq. ft./week treatments.

this maintenance period resulted in an overall reduction in leachate N, a result similar to that found in previous research. Over the length of this study, there were few times when turfgrass color or quality significantly differed due to N rate or greensmix, indicating that the lower rate of weekly N application (1/10 lb N/1000 ft^2/wk) would be adequate for a quality putting bentgrass green in the Southeast. When that rate was applied, N in leachate was typically well below 3 ug/ml (3 ppm) throughout the sampling period.

Over the two and one half years of data collection during the maintenance period, there was a cycling effect in nitrate leaching, with increased nitrate collected during July and August of each year (Figure 4). This increase did not seem to be related to unique precipitation events which were distributed fairly uniformly throughout the sampling period. It is likely that increases in nitrate during the summer were partly due to reduced rooting in the bentgrass as summer stress thinned the turf and reduced root length in the heat-stressed bentgrass. Others have shown that root architecture will affect nitrate leaching with deeper-rooted bentgrass absorbing N more efficiently than shallow rooted bentgrass (1). Although we did not measure root length or root density in this study, other bentgrass root research at the same location has shown reductions in rooting during July and August with subsequent root mass recovery by October of each year.

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