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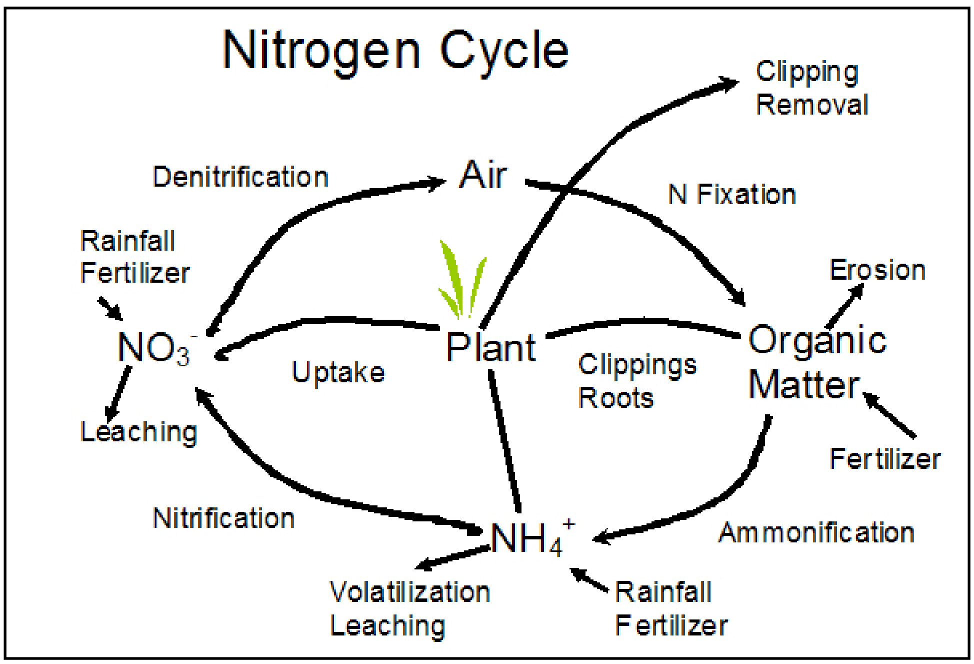

The complexity of the nitrogen cycle in turfgrass and other crops has hindered efforts to develop a reliable soil test for nitrogen. A research project was conducted at The Ohio State University, The University of Minnesota, and Virginia Polytechnic Institute and State University to determine the spatial variability of amino sugar nitrogen on golf course fairways. Fairways from an 85-year-old golf course and an 8-year-old course were sampled.

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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***.

Sampling a Turfgrass System with the Illinois Soil Nitrogen Test

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SUMMARY

A research project was conducted at The Ohio State University, The University of Minnesota, and Virginia Polytechnic Institute and State University to determine the spatial variability of amino sugar nitrogen on golf course fairways. Fairways from an 85-year-old golf course and an 8-year-old course were sampled. The study found:

- The two fairways from the newer course displayed a greater degree of spatial heterogeneity than the two fairways from the older golf course at all sampling depths.
- Although the amino sugar N concentrations measured on the four sampled fairways varied, the spatial correlation present would allow for traditional soil sampling techniques to be used to assess the soil amino sugar N concentration within an area such as a golf course fairway.
- There was also enough variability within an area that the sampling technique used would permit the identification of areas with higher and lower amino sugar N values on a golf course fairway and allow for the potential development of site-specific application of nitrogen fertility.
- To further develop site-specific N fertilizer applications, our data suggests bulking soil from 4 or 5 locations within a 100-m section of each fairway.

Turfgrass fertilization continues to be scrutinized and regulated due to environmental concerns and public perception. Phosphorus and potassium fertilizer recommendations are usually based on the results of soil tests. However, neither plant tissue nor soil testing is routinely used to evaluate nitrogen fertility needs (3) due to the complexity of the N in the soil (Figure 1). Soil nitrate nitrogen is both spatially and temporally variable because of mineralization, immobilization, nitrification, leaching, denitrification, and plant uptake. These processes are further influenced by soil-water content, soil temperature, and plant growth (3). The current practice when growing turfgrass is to apply nitrogen fertilizer based either on a predetermined schedule, regardless of actual need, or on a visual assessment of turfgrass quality.

There is concern that turfgrass fertilization contributes to groundwater pollution (7). The majority of research has indicated that turfgrass fertilization with nitrogen poses little risk to the environment. Most of this research has been conducted on newly established turfgrass plots. However, it was recently reported that ^{15}N-labeled urea was detected in the leachate from a 10-year-old Kentucky bluegrass turf (1). This may suggest that on older turf surfaces, mineralization of organic nitrogen fractions may exceed immobilization of fertilizer nitrogen.

Therefore, turfgrass management practices that could reduce fertilizer inputs without sacrificing turfgrass quality would not only demonstrate environmental stewardship but reduce maintenance expenditures. To accomplish this task,

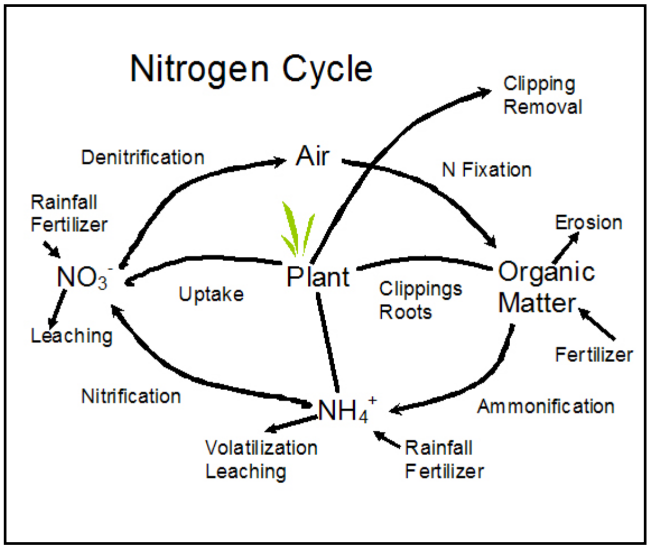

Figure 1. The complexity of the nitrogen cycle in turfgrass and other crops has hindered efforts to develop a reliable soil test for nitrogen.

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Figure 2. Hydraulic probe utilized to collect soil cores from golf course fairways in 2003 and 2004

researchers have been testing anion exchange resins to measure nitrate nitrogen in the soil (6). These vinyl strips attract negatively charged ions like nitrate, NO_3^-. Essentially, the use of anion exchange resins provides turfgrass managers a sense of plant available nitrogen at the time of sampling. To reduce nitrogen inputs, turfgrass managers need a more stable test that is not as susceptible to spatial and temporal variability.

A second method to reduce N fertilizer inputs involves utilizing stored N in the soil that will mineralize (conversion of organic N to plant-available N). Lee et al. (5) estimated that up to 3 lbs. of nitrogen per 1000 square feet could be released from mineralization of organic nitrogen in a mature bermudagrass system during a May to October growing season. However, there was a considerable difference in inorganic nitrogen release between the two soils studied.

Compared to a mature turfgrass system, recently established turfgrass with reduced organic matter accumulation would supply a lower amount of mineralized nitrogen. Use of a soil test that could measure organic nitrogen in the soil is desirable. Furthermore, over-application of N fertilizers may be reduced if estimates of mineralizable N were available. Use of a soil test could also result in more quantitative N fertility recommendations, rather than the current practice of applying based on visual appearance.

A test was developed by Richard Mulvaney of the University of Illinois, called the Illinois Soil Nitrogen Test (ISNT), which identifies sites in production agriculture that are non-responsive to N fertilizer. The test measures amino sugar N fractions in the soil organic N pool which supplies the plant with N through mineralization. Amino sugar nitrogen is relatively stable compared to NO_3^- and NH_4^+, thus making it a better predictor of season-long N fertility requirements (9).

Golf turf managers could use this information to predict soil nitrogen availability to the plant. The potential advantages of this test for golf turf management are that soil nitrogen availability could be predicted, and this information could be used to adjust fertilizer rates. Timing of soil sampling may be less important because amino sugar N fraction does not fluctuate as much as other forms of soil nitrogen.

However, the variability of amino sugar nitrogen over space and depth in a managed turfgrass system is not currently known. In order for the Illinois Soil Nitrogen Test to be a useful, one must be able to sample such that the spatial variability does not interfere with the interpretation of the test result. Therefore, our objective was to determine the spatial variation of soil amino sugar nitrogen in managed turfgrass systems in order to determine sampling recommendations.

Material and Methods

In order to determine the spatial variation of amino nitrogen in the soil, soil samples were collected from two fairways on each of two golf courses in Minnesota and analyzed for amino sugar nitrogen concentration. Heritage Links Golf Course is located in Lakeville, MN and is a more recently established course (approximately 10-years-old). The original farm land was significantly altered during construction of the course. Midland Hills Country Club is located in Roseville, MN and is about 85-years-old. Fairways at both courses were mowed at 1.2 cm and maintained for golf play. Annually, nitrogen fertilizer inputs ranged from 125 to 134 kg N ha^{-1} (111-119 lb./acre) for Midland Hills C.C. and 160 to 196 kg N ha^{-1} (142-174 lb./acre) for Heritage

Links G.C. Soil cores were collected on 30-ft centers to a depth of 18 inches from two fairways on each golf course using a 1.5-inch diameter hydraulic probe mounted on a utility vehicle (Figure 2). The leaf tissue and thatch were removed and each core was separated into three sections by depth: 0-6 inches, 6-12 inches, and 12-18 inches. Each section was weighed, dried, and stored for analysis.

Each sample was analyzed using the methods of Kahn et al. (3, 4). Briefly, the diffusion unit consists of a 473-mL wide mouth Mason Jar and a lid that is modified to hold a 60-mm (diam.) Pyrex petri dish (Figure 3A). A 1-g sample of soil or a 0.2-g sample of thatch was weighed into the jar. A petri dish containing 5 mL of H_3BO_3-indicator solution was suspended from the jar lid with a cable tie. The soil sample was treated with 10 mL of 2 M NaOH, then the lid placed on the jar and sealed with the screw band (Figure 3B). The jar was then transferred to a hot plate. The hot plate heat control was adjusted so that a thermometer immersed in 100 mL of water in a mason jar at the center of the plate measured 48-50°C.

After 5 hours, the jars were removed from the hot plate and the petri dish containing the H_3BO_3 solution was diluted with 5 mL of deionized water. The solution was then titrated with 0.01 M H_2SO_4 to an endpoint determined by measuring the pH of a solution of 5 mL H_3BO_3 and 5 mL deionized water (Figure 3C). Nitrogen concentration (µg N mL^{-1}) liberated by diffusion was calculated as S X T, where S is the volume of H_2SO_4 used in the titration and T is the titer (280 µg N mL^{-1} of the H_2SO_4)(3).

In order to determine the uniformity of amino sugar nitrogen distribution on the fairways, general geostatistical methods were used and maps were generated using the interpolation technique, ordinary kriging (2). To test for a spatial correlation in amino sugar N levels between depths for a given fairway, the data were analyzed using the mixed models (MIXED) procedure of the SAS software package.

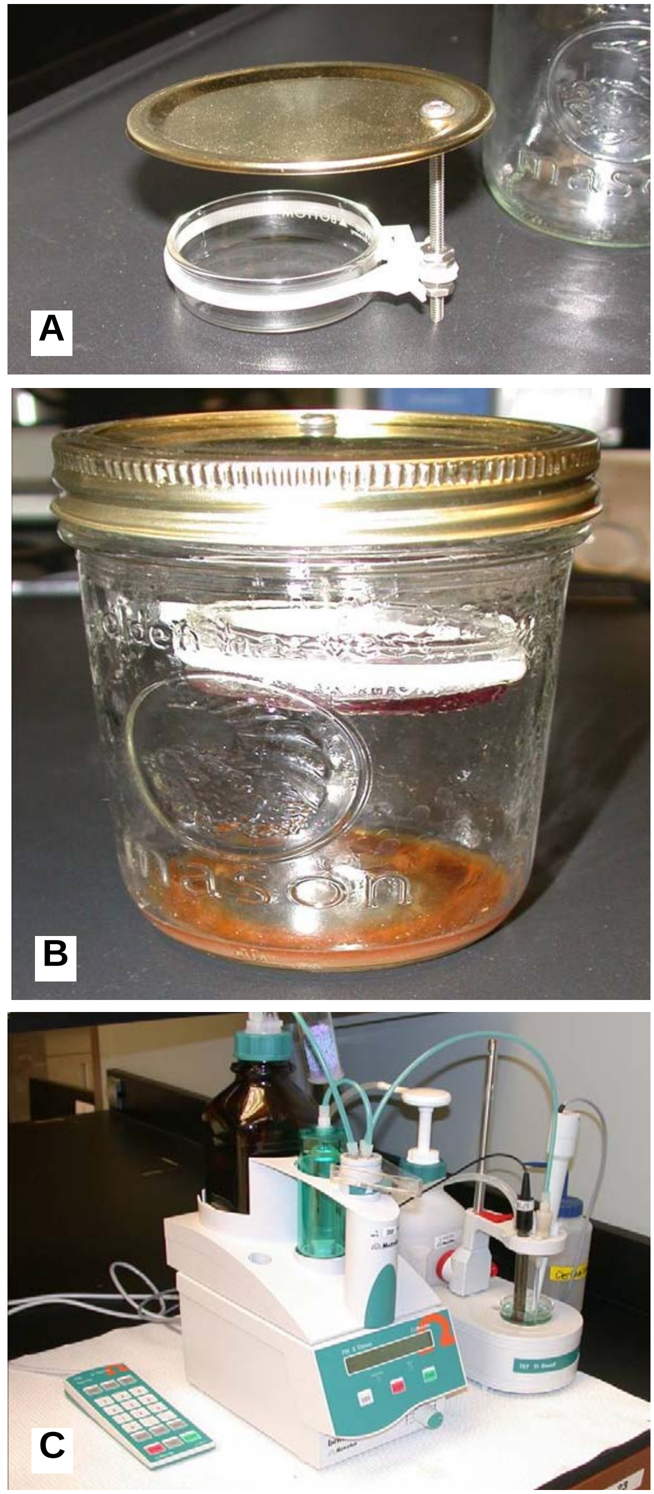

Figure 3. (A) Diffusion unit used to measure soil amino nitrogen content using the methods of Kahn et al. (3,4). One g of soil or thatch is added to the mason jar with 10 mL of 2 N sodium hydroxide. (B) A petri dish suspended from the jar lid contains 5 mL of boric acid (4% w/v). The sealed unit is placed on a hot plate at 50° C for 5 hours. (C) After heating, the petri dish is removed, 5 mL of distilled water is added, then the solution is titrated with 0.02 N H_2SO_4. Amino N content is calculated as S x T = amino N ppm, where S is the volume of H_2SO_4 and T is the titer.

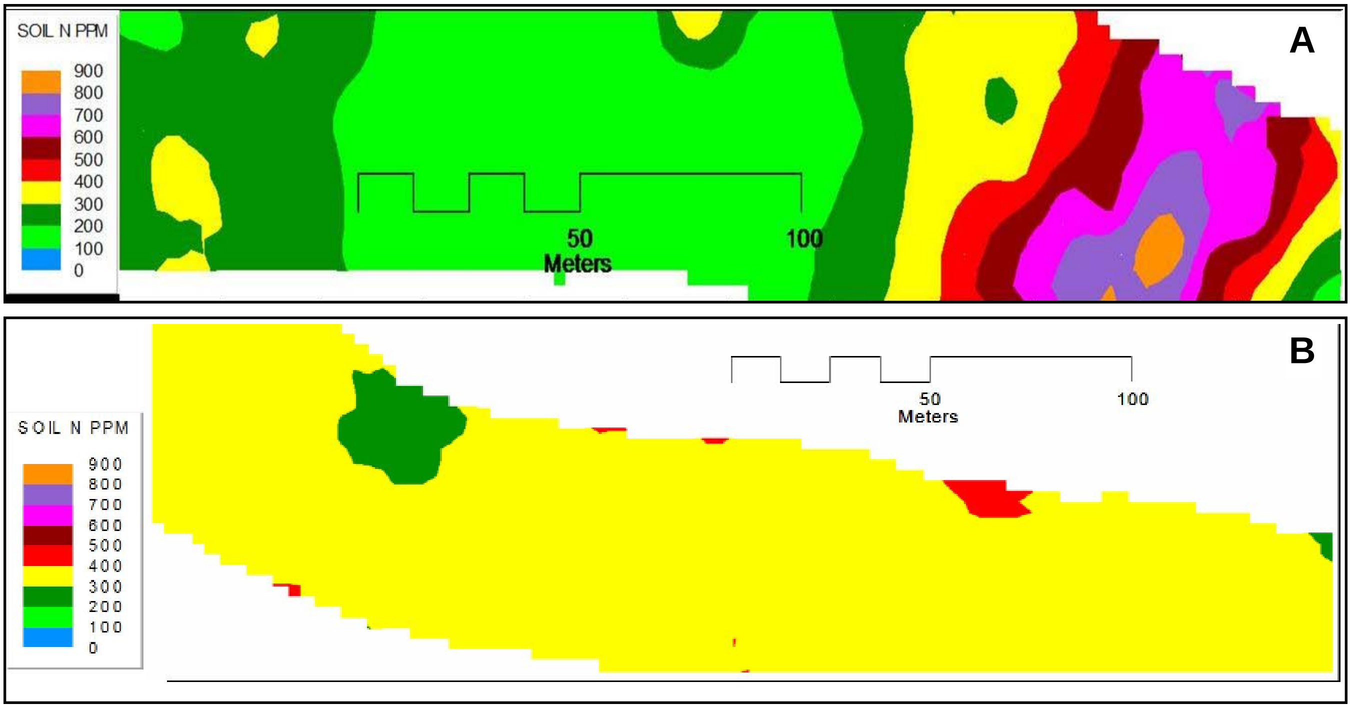

Figure 4. Spatial variability of amino sugar nitrogen on fairways of two Minnesota Golf Courses. More spatial variability and lower overall values were measured on a golf course fairway at Heritage Links (A), which is a newer golf course. Midland Hills (B) is an older course with a more uniform distribution and overall higher levels of amino sugar nitrogen.

Spatial Variability of Amino Sugar Nitrogen in Fairways

Kriged maps of the four sampled fairways in Minnesota showed that the two fairways from Heritage Links displayed a greater degree of spatial heterogeneity than the two fairways from Midland Hills at all sampling depths (Figure 4). We also found no correlation between soil depths meaning that the concentration of amino sugar N did not decrease uniformly as depth increased (Figure 5). Since certain forms of N can move through the soil profile, our goal in analyzing the different depth fractions was to determine if there had been any differential movement of N to a deeper soil depth prior to being converted to organic N. Since amino sugar N did not decrease uniformly with increasing soil depth, this may make interpretation of the test results more difficult in certain applications.

For routine use of the test, we believe that standard practices for gathering soil cores for analysis of other nutrients will be acceptable when analyzing for amino sugar N. Care will be needed to develop a specific and uniform guideline as to the depth of core to take when analyzing for amino sugar nitrogen. To further develop site-specific N fertilizer applications, our data suggests bulking soil from 4 or 5 locations within a 100-m section of each fairway.

The fairways at Midland Hills showed consistently high concentrations of amino sugar N in the samples, compared to previously published values in agriculture and our observations at other turfgrass sites. Forty-six samples from Midland Hills fairway #2 showed concentrations of amino sugar N ranging from 338-450 ppm, while 20 sampling locations interspersed throughout the fairway showed lower amino sugar N concentrations ranging from 225-338 ppm (Figure 4). Midland Hills fairway #14 had slightly lower amino sugar N concentrations than Midland Hills fairway #2.

In contrast, the fairways at Heritage Links were considerably more variable over space, and displayed a large range of amino sugar N concentrations (Figure 4). Heritage Links fairway #3 had a sample with an amino sugar N concentration of 952 ppm and 14 samples with high amino sugar N concentrations ranging from 474-953 ppm among samples located on the easternmost (right side) of

Figure 5. Comparison of amino sugar nitrogen values from the upper 6 inches of soil and the 6-12 inch soil horizon on Heritage links fairway #13. The amount of amino sugar nitrogen in the top 6 inches of soil was not related to the amount of amino nitrogen found at lower sampling depths.

the fairway. Heritage Links fairway #13 had a sample with the lowest amino sugar N concentration measured at the 0-6 inch depth (73 ppm) (Figure 5). Heritage Links fairway #13 also had 16 sample locations on each end of the fairway with lower amino sugar N concentrations (73 -256 ppm), and these concentrations increased towards the middle section of the fairway. There were 11 samples around the middle section of the fairway with higher amino sugar N concentrations ranging from 384-512 ppm (Figure 5).

Comparing the Spatial Variability of Amino Sugar N at the Two Courses

Heritage Links is a relatively young site whereby a considerable amount of soil movement during golf course construction may be reason for the greater degree of spatial heterogeneity. Based on work by Porter et al. (8), immobilization of applied fertilizer N occurs for a defined period following turfgrass establishment. The age of Heritage Links falls into this period described by Porter et al. (8), and the amino sugar N concentrations may not have reached a point where mineralization adds inorganic N for plant uptake.

The higher overall amino sugar N values observed at Midland Hills, compared to Heritage Links, may be due to the older age of the turfgrass stand on the Midland Hills fairways and the routine fertility practices during Midland Hills' history. The relatively high concentration of amino sugar N in the samples from Midland Hills indicates a significant amount of potentially mineralizable N present in these soils. Future research will determine the effect of amino sugar N concentrations and added N fertilizer on turfgrass responsiveness.

How Does Amino Sugar Nitrogen Compare to Soil Organic Matter?

There was a correlation between amino sugar nitrogen and soil organic matter content, and this was more apparent on the more spatially variable fairways at Heritage Links. The association between amino sugar N concentration and organic matter was lower on the older, more uniform fairways of Midland Hills. However, while there was a correlation between organic matter and amino sugar N within each golf course, the course which had higher mean amino sugar nitrogen values also had lower mean organic matter values. The mean amino sugar N concentration at Heritage Links was 326 ppm and the mean organic matter content was 4.95%. In contrast the mean organic matter content at Midland Hills was 4.84% and the mean amino sugar N concentration was 393 ppm. Since soil organic matter is not uniformly mineralizable, it is possible that as a site matures and the organic matter becomes more complex, the amino sugar nitrogen content will provide a more reliable predictor of potential mineralization of nitrogen than would the organic matter content.

There seemed to be less spatial variability at Midland Hills than at Heritage Links and one possible reason is that Midland Hills is an older course and as such equilibrium has been reached over time that doesn't appear to exist on the sampled fairways at Heritage Links. Heritage Links is a younger course, and it is possible that the variability observed on these fairways is due to the age of the golf course where fairways have not had time to reach equilibrium.

Conclusions

Although the amino sugar N concentrations measured on the four sampled fairways varied, the spatial correlation present would allow for traditional soil sampling techniques to be used to assess the soil amino sugar N concentration within an area such as a golf course fairway. There was also enough variability within an area that the sampling technique used would permit the identification of areas with higher and lower amino sugar N values on a golf course fairway and allow for the potential development of site-specific application of nitrogen fertility.

To further develop site-specific N fertilizer applications, our data suggests bulking soil from 4 or 5 locations within a 100-m section of each fairway. With the exception of Heritage Links fairway 13, the rest of the fairways sampled from both golf courses showed that amino sugar N concentrations were spatially correlated over distances of 100 m or less. Our data show that if new samples were taken from these fairways, and the samples were taken from locations separated by more than 100 m, then the samples would be considered independent. More research is required to assess if this spatial structure is similar across golf courses of varying ages.

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