the fall of 1994 and were fitted with three lysimeters each. The nitrate concentrations in the leachate did not exceed the 10 mg L^{-1} drinking water standard for the first three years of monitoring. For 1997 the nitrogen concentrations increased in the leachate about 20 to 30 days after application. For all the years, increases in the mass of nitrogen tended to correspond with rainfall events. The concentration of nitrate and the total mass in the leachate is increasing over time. Phosphorus concentrations in the leachate were highest the first year and decreased dramatically thereafter. These initial higher concentrations were probably caused by higher phosphorous applications in 1994 during grow-in. ɪ

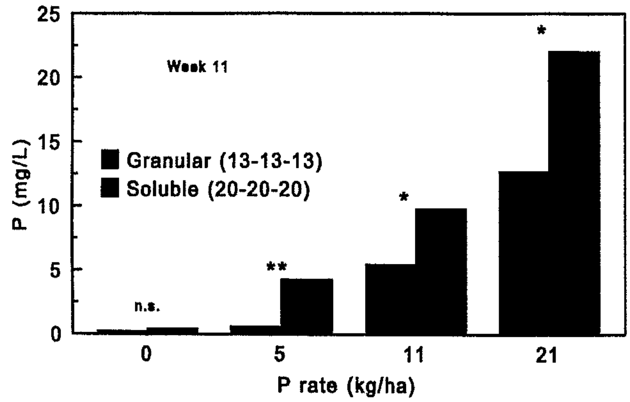

Figure 10. Concentrations of phosphorous through simulated green columns. Rates of applied were applied bi-weekly for a total of six times ceasing on week 11. *, ** indicate significance for sources at each rate (P = 0.05 or 0.01, respectively).

Innovative Water Quality Management Utilizing Wetlands Construction on a Golf Course

Purdue University

Ronald F. Turco

Start Date: 1998
Number of Years: 5
Total Funding: $125,000

Objectives:

Our objective is to evaluate the use of a "closed-loop" water in situ treatment system in terms of:

1. *Use of a golf course wetland to improve residential runoff.*
2. *Protection and improvement of a sensitive wetland environment.*
3. *Regeneration of water supplies for golf course use.*

Previous USGA-funded studies have documented the chemical makeup of water formed during golf course runoff and leaching events. Our work goes beyond monitoring to assess how innovative golf course water quality management, based around a constructed wetland, can reduce pollution from the golf course and from adjacent non-golf course sources. Not only do the wetlands accept water originating from the golf courses but also runoff from a watershed that includes a gas station, retail businesses and parking lots, over 500 residences, and two major city highways. The quality of water will be monitored throughout the system for nutrients, pesticides, salt, automobile fluids, and other possible contaminants.

Earlier results from across the country demonstrated that the quality of water originating from the golf course is expected to be good. We have established an innovative management scheme in which golf course runoff and urban runoff are passed through created wetlands and then used as the primary water source for golf course irrigation. This arrangement is designed to both reduce impacts from the golf course and commercial / residential runoff on an important wetland adjacent to the golf course and to provide a reliable source of water for golf course irrigation. This approach will provide a blueprint that allows for a reduction in golf course nutrient applications and groundwater withdrawals for irrigation.

This project is a model for any location where a golf course interfaces with natural areas or other high value property. The ability of the constructed wetland to remove contamination is being evaluated and documented. The use of the wetland system to clean and remediate roadway water and water from commercial and residential areas is also being followed. For locations where water is expensive or not available, this approach may prove to be an extremely useful way to improve water supply. This approach will add environmental value to the golf course. Roadway water that would have been directly discharged, untreated, to surface water now will be treated in the golf course wetland system before release.

Work to date has concentrated on the integration of the constructed wetland and the golf course. Purdue University's athletic department constructed the Kampen Golf Course that opened in the summer, 1998 adjacent to the new Turfgrass Research and Diagnostic Center. The Kampen Golf Course is a Pete Dye designed facility intended to display state-of-the-art environmentally sensitive golf course management as well as providing an excellent playing surface. In order to meet real and anticipated environmental problems, the Kampen golf course design includes a series of constructed wetlands between the course and the adjacent natural wetland. Moreover, the course is constructed to capture water from the adjacent city highway and residential area. The constructed wetlands will intercept and process runoff, tile water directly from the golf course, and the water captured from the adjacent urban road, commercial, and residential areas.

We have completed installation of sampling equipment (flow meters, samplers, and infield chemical detection systems) at five of the six sites established as part of this project on the constructed wetland. The samplers began running in September of 1998. However, we have not had a significant enough storm to allow for water collection. It is fully anticipated that most of our run off collections will be starting within the next five weeks.

Description of sample sites:

Site 1. Evaluation of the *typical* water flowing from a mature residential and light industrial setting to the golf course.

Site 2. By subtraction (site 1 from 2), water quality and quantity from a greens-fairway complex.

Site 3. The treatment ability of a single wetland cell for municipal water as well as golf course materials (site 2 from 3).

Site 4. Water quantity and quality as affected by treatment in cell series (site 1 from 4).

Site 5. Water volume and quantity for untreated conditions. By subtraction (site 4 from 5), the impact of a wetland series on the quality of discharge waters.

We are presently employing a technician on the project. To date, the funds for the technician have come from matching monies on the project. We are presently search for a student to be employed on the project. We have several excellent applications and hope to have someone in place by January of 1999.

The Effects of Turfgrass Root Architecture on Nitrate Leaching and Nitrogen Use Efficiency

North Carolina State University

Daniel C. Bowman

Start Date: 1998
Number of Years: 5
Total Funding: $97,830

Objectives:

1. *Extend our current column lysimeter study comparing six different warm-season turfgrasses for NO3 leaching and nitrogen efficiency.*
2. *Measure root architecture (depth, density, dynamics) and other root characteristics (cation exchange capacity, carbohydrate release, microbial association, viability) for the six species.*
3. *Measure the kinetic parameters of nitrogenuptake for each species.*
4. *Determine whether root architecture or uptake kinetics explains the differences between the species.*
5. *Use a state-of-the-art-flow-through nutrient solution culture system to screen germplasm for nitrogen uptake efficiency and to simultaneously determine rooting depth of the genotypes.*
6. *Use genotypes identified in objective five to validate the conclusions regarding rooting architecture vs.uptake kinetics as a primary determinant of nitrogen efficiency.*

As part of the initial phase of this study, several model systems/methodologies have been developed and tested. Large column lysimeters were constructed and installed at the NCSU Phytotron. Each is equipped with sampling hardware to permit recovery of all leachate. A preliminary study to evaluate lysimeter performance was conducted using hybrid bermudagrass sod. We hypothesized that supplementing the fertilizer with soluble carbohydrate could reduce nitrate leaching during turf establishment. This would stimulate microbial immobilization of the fertilizer, and tie the nitrogen up in the rootzone rather than having it leach.

Ammonium nitrate was applied approximately monthly for four months at a rate of 50 kg N ha^{-1}, with sucrose added at rates of 0, 50, 150 and 250 kg C ha^{-1}. Irrigation was applied to maintain a high leaching fraction and maximize leaching potential. Mass emission of nitrogen from the controls amounted to 23, 28, 9 and 7 percent of the applied nitrogen for months one through four, respectively. The reduction in loss with time corresponds to root development. Sucrose addition reduced both $N0_3$ concentration and mass emission 40 to 65 percent compared to controls (Figure 11), suggesting significant increases in microbial immobilization. Sucrose addition did not affect root distribution, which also supports the role of microbial activity in reducing leaching. These data indicate the need to better understand turfgrass soil microbiology, especially regarding nitrogen nutrition. The experiment also validated the performance of the lysimeters, which will be used to monitor root development during year two of the project.

A second objective of the research project is to compare the nitrogen uptake kinetics of several warm-season turfgrass species. We have previously characterized uptake by cool-season turfgrasses using the Classen-Barber depletion technique to quantify the kinetic parameters V_{max} and K_m. The method requires a flowing solution culture system to minimize diffusion limitations. The most common system design uses hydraulic pumps, which are expensive and often troublesome. We have designed a simplified flow-through system using the air-lift principle, which reduces both cost and complexity while maintaining rapid solution flow. Sod will be grown in culture rings until a healthy root system has developed.