containerized greens were constructed at the Auburn University Turfgrass Research Unit, (four replications of each fertility/soil mix combination). Greens were sodded in January 1997 with washed bentgrass sod (*CRENSHAW*). Greens are 1 m long x 0.5 m wide, and each drains to an individual collection chamber. Total leachate from each green is collected as needed, volume recorded and a subsample is analyzed for NO_3-N and NH_4-N concentration.

In February, May, August and November, root and soil samples (0-4 inch depth) are collected from each green. These samples are shipped to the University of Florida, where they are subject to dilution plating and identification. Selected isolates are returned to Auburn University, where identification at the species level is conducted via GC FAME analysis. Nitrogen rates applied at the Auburn University site were originally 1 or 2 lbs. N/1000 ft^2/month (granular fertilizer source). Excessive loss of N through leachate and burning of turf at application resulted in a shift of application times and amounts to 1/5 or 1/10 lb N/1000 ft^2/week applied via a CO_2 backpack sprayer.

Year 1 analysis of nitrate and ammonium leachate indicated that both N rate and mix type affected NO_3-N and NH_4-N concentration in leachate, and there was rarely a significant N rate by mix type interaction. During Year 1 leaching of NH_4-N was greater in the pure sand green than USGA-type green. Leaching of NO_3-N from the USGA green was greater than that from the sand green, but only in the first few months after construction (January - April).

Clemson. Rhizobacteria are being evaluated for promotion of plant growth and for biological control of weeds, insects, diseases, and nematodes in a number of ecosystems. A critical research need in putting green management is to understand the bacterial interactions in the rhizosphere of turfgrasses. A database on turfgrass rhizobacteria from newly constructed bentgrass putting greens was initiated in December 1996. Each quarter, 160 bacterial isolates growing on tryptic soy-broth agar (TSBA) are randomly selected and identified by GC FAME analyses. Broad classes of rhizo-bacterial populations were successfully separated on selective media. Numerical differences of rhizo-bacterial populations in bentgrass rhizosphere over eight sampling periods were observed (Figure 1).

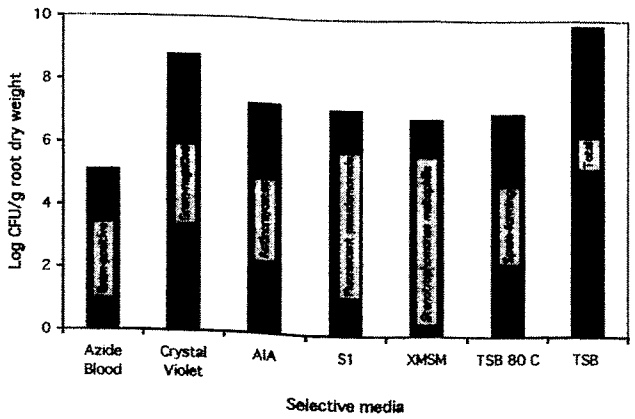

Figure 4. Rhizobacteria populations were averaged over eight sampling periods from bentgrass greens. Samples were collected from December 1996 to September 1998 from Charlotte Country Club Golf Course, NC.

In the samples of December 1996, isolates identified from bentgrass rhizosphere belonged to 23 genera and 34 species. *Acidovorax*, *Burkholderia*, and *Pseudomonas* were the major genera. However, in the samples of June 1998, isolates identified from bentgrass rhizosphere belonged to 23 genera and 43 species. *Pseudomonas* and *Arthrobacter* were the major genera. Based on the KOH method, 83% of the bentgrass isolates were Gram-negative over eight sampling periods.

Chemical and Physical Stability of Calcareous Sands Used for Putting Green Construction

Washington State University

Eric Miltner

Start Date: 1998
Number of Years: 3
Total Funding: $55,342

Objectives:

1. *To examine changes in particle size distribution, hydraulic conductivity, and calcium carbonate chemistry in calcareous sands used for putting green construction.*
2. *To qualitatively examine mineralogical properties of calcareous sands with scanning electron microscopy, both prior to and following weathering.*
3. *To survey existing golf courses of varying ages for variations in physical and chemical attributes of the greens mix.*

Calcareous sand can be defined as any sand that contains at least one-percent calcium carbonate (calcite) on a weight basis. In areas where they exist, they are often used for construction of golf course putting greens and other sand-based root zone media. Because of either perceived or real problems associated with these sands, which are not well defined or understood, their use is discouraged. In general, the types of problems that may occur are related to undesirable soil-physical properties (aeration, hydraulic conductivity, and water holding capacity) as compared to USGA recommendations. It is the objective of this research project to determine if performance characteristics of putting greens decline because of weathering of calcareous sands, and to determine the mechanism of this weathering and the subsequent performance decline. Ultimately, we hope to provide guidelines concerning suitability for use of various sands for putting green construction.

Two primary approaches are being used in this project. The first is a column study that investigates the weathering potential of various sands under controlled conditions. The second is a field survey that involves collection of intact cores from putting greens constructed of calcareous sands.

The column study includes three different sands. Silica sand, to serve as a control, will contain no calcite. The other two sands will have varying calcite contents so that a range of materials will exist. We have collected over thirty sands from various sources throughout the country, and have found most contain less than 10 percent calcite. Many of these samples were previously thought to be highly calcareous based on pH and reaction to acid. However, these samples had never actually been analyzed for calcite content.

We have expanded our search and are currently collecting new samples and characterizing them. One sample from Hawaii contains in excess of 85 percent calcite, but is too fine in gradation. In addition, this coral derived sand is atypical of most sands used in this country. We have recently solicited samples from suppliers in Florida that should be derived primarily from limestone, but have not yet received these. Once the sands to be used are identified, they will be subjected to acidifying conditions (as caused by fertilization) and bicarbonates (usually present in irrigation waters), both important factors in weathering of calcite. Changes in chemical and physical characteristics will be studied.

For the field survey portion of the project, cores have been collected from three golf courses to date. The first two courses, located in northern Utah, were constructed using the same sand (approximately 6% calcite). One course was built in 1989 and the other in 1993. We hope to see different physical characteristics in these samples based on their ages. Samples from a Texas course that has experienced problems that may be due to calcareous sand were also collected. These samples will be analyzed after more golf course samples are collected.

Evaluation of New Technologies in Construction and Maintenance of Golf Course Greens

North Carolina State University

Dr. Daniel Bowman

Start Date: 1996
Number of Years: 5
Total Funding: 100,000

Objectives:

1. *Survey golf courses throughout North Carolina to determine putting green aeration as a function of depth.*
2. *Develop and characterize a soil mix providing optimal moisture and aeration throughout the soil profile.*
3. *Measure the response of turf to the various mixes, and the impact of the turf on soil physical and chemical properties.*
4. *Conduct a field study examining turf response to promising soil mixes under natural environmental conditions.*

The physical properties of three sands (fine, medium, and coarse) and inorganic amendments (Ecolite, Greenschoice, Isolite, Profile, and sphagnum peat moss) were evaluated in this study. The 0, 10, and 20 percent (v:v) amendment were combined with each sand to produce nine rootzone mixtures. Also, 0, 10, 20 percent amendment (v:v) was added into the top 15 cm of the three sands. Physical properties measured included: hydraulic conductivity, bulk density, moisture retention (with depth), and pore size distributions/water retention at 0 to 200 cm tensions. Inorganic amendment evaluations included; particle size analysis, and pore size distributions/water retention at 0 to 15,000 cm tensions.

Nutrient retention of inorganic and organically amended sand rootzones was measured for 30-cm deep rootzone mixtures over 10 cm of suitable gravel. One application of 50 kg ha^{-1} of ammonium nitrate in liquid solution was applied and leached with 2.5 pore volumes distilled water. Leachate was analyzed for ammonium and nitrate by the rapid diffusion method. Four different experiments included: all amendments at 20 (v:v) material; Ecolite and Profile at 1, 5, 10, 20 percent; Ecolite and Profile at 10 percent (v:v) incorporated in the top 2.5, 15, and 30 cm depths; and an incubation study at 0, 12, and 24 hours in pure sand, 10 percent Ecolite and Profile.

Laboratory Results. The measured physical properties of three sand sizes amended with inorganic and organic amendments were as follows. Compared to pure sand, amendment addition increased total porosity, macroporosity, and water retained at 20-kPa tension. While, plant available water (water released from 4 kPa to 20 kPa) decreased with amendment addition Only fine sand and amended fine sands met USGA guidelines for total porosity, macroporosity, and capillary water retention. Medium and coarse sands and sand amendment mixtures resulted in rootzone mixtures that had excess macroporosity and lacked adequate water retention. Of the amendments tested, sphagnum peat resulted in the most water retained and had the most dramatic effect in the medium and coarse sands.

Evaluations of the inorganic amendments alone resulted in the observation that indeed these materials have a high degree of internal porosity (> 55%) and retain significant water (> 20%) even at high tensions. There were two clusters of amendment performance. Ecolite was similar to Greenschoice for water retention and release, both measured less than Isolite and Profile that were similar.

Hydraulic conductivity effect was variable between the three sand sizes and related to sand and amendment sizes. Sphagnum peat with its variety of particle sizes had the most consistent effect on K_{sat} and decreased this parameter for all three sands. At no point was a K_{sat} recorded that was less than 6 inches per hour.

Amendment addition decreased bulk density of all rootzone mixtures compared to pure sand.

Ammonium leached rapidly from all mixtures with peak concentrations occurring at approximately 0.5 pore volumes.