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.

Significantly more NH_4^+-nitrogen leached from pure sand than for 20 percent (v:v) amended mixtures. Leaching losses ranked in decreasing order: pure sand > Greenschoice = Isolite > Peat > Profile > Ecolite. The most effective amendments, Profile and Ecolite, reduced NH_4^+-nitrogen leaching compared to pure sand by 75 and 88 percent, respectively.

Further studies with Ecolite and Profile had the following results. Increasing Profile and Ecolite rates from 1 to 20 percent resulted in stepwise decreases in NH_4^+-nitrogen loss. Although 20% amendment may be the most effective rate for retaining NH_4^+, it may not be economically feasible. Amendment at 10 percent significantly reduced NH_4^+-nitrogen leaching by 63 and 79 percent compared to pure sand for Profile and Ecolite, respectively.

Ecolite and Profile (10% v:v with sand) incorporated at three rootzone depths significantly decreased NH_4^+-nitrogen losses by approximately 25 percent, compared to pure sand. Again, there was a step-wise reduction of NH_4^+-nitrogen leaching reduction with increasing amendment depth. Incorporation of 10 percent amendment through the entire 30 cm rootzone resulted in the least NH_4^+-nitrogen leaching loss, with a significant difference noted between Profile and Ecolite. Losses were decreased by 65 and 80 percent for Profile and Ecolite, respectively.

Large quantities of $N0_3^-$-nitrogen(>90%), were recovered in leachate from all treatments under all experimental conditions. Peak $N0_3^-$-nitrogen concentrations of over 70 mg L^{-1} in pure sand leachate were observed. I

Grow-in and Cultural Practice Inputs on USGA Putting Greens and Their Microbial Communities

University of Nebraska

Dr. Roch Gaussoin

Start Date: 1996
Number of Years: 5
Total Funding: $100,000 (Co-funded with the GCSAA)

Objectives:

1. *Evaluate grow-in procedure effects on putting green establishment and performance, and develop criteria and recommendations for new putting green readiness for play.*
2. *Determine grow-in procedure impacts on root zone physical and chemical properties.*
3. *Evaluate post grow-in cultural practice effects on putting green long-term performance.*
4. *Determine temporal and spatial (by depth) patterns of rhizosphere community development in golf greens during accelerated and controlled grow-in of select root zone mixes and during long-term green maintenance.*

The five year project is composed of three phases, One: Construction and Grow-in, Two: Microbial Community Assessments, and Three: Grow-in Procedure Impacts on the Long-term performance of the Putting Green. Phases I and II will span three-year periods, while Phase III will involve experiments repeated over the five years of the project.

Two separate USGA-specification root zone mixtures - one composed of sand and peat (80:20 ratio) and one a combination of sand, soil, and peat (80:5:15 ratio) - were developed in 1996. Materials used for construction complied with USGA Greens recommendations for physical characteristics and organic matter content. First year greens (1997 Greens) were constructed in late summer of 1996, allowed to settle over the winter, and were seeded with Providence creeping bentgrass (1.5 lbs/1000 ft^2) in the spring (May 30) of 1997. Second year greens (1998 Greens) were constructed in the summer of 1997, allowed to settle over the winter, and were seeded with Providence creeping bentgrass (1.5 lbs/1000 ft^2) in the spring (May 27) of 1998.

Preliminary results indicate the following trends. Microbial biomass was not affected by root-zone mix or grow-in procedure on plots established in 1997. Microbial biomass increased over 200% from spring to fall and decreased 40-60% as sampling depth increased. Water infiltration from these same plots were- not affected by root-zone mix or grow-in procedure when measured in 1998.

For two consecutive years, it was found that higher inputs would initially increase cover during grow-in. However, this increase may not translate to earlier opening for play if environmental stress conditions occur that result in damage to lush, immature turf.

The root zone mix containing soil established faster and recovered from environmental stress better than a soil-less mix. A soil-containing mix also will be harder and may result in longer ball roll distance. Addition of soil to the root zone mix did not effect water infiltration during the establishment year. I

Assessing Differential Root Zone Mixes for Putting Greens Over Time Under Two Environmental Conditions

Rutgers/Cook College

Dr. James Murphy

Start Date: 1996
Number of Years: 5
Total Funding: $100,000 (Co-funded with the GCSAA)

Objectives:

1. *Evaluate grow-in procedure effects on putting green establishment and performance, and develop criteria and recommendations for new putting green readiness for play.*
2. *Determine grow-in procedure impacts on root zone physical and chemical propeties.*