Ponded infiltration rates measured 20 months after turf establishment (Table 1) yielded some surprising results but were consistent with our observations reported in November, 1997. While we expected and observed greater infiltration rates from the high-permeability root zone, we also observed greater infiltration rates from the USGA profile than in the modified CA profile. Apparently, the presence of the gravel drainage blanket below the root zone in the USGA profile allowed for more rapid water infiltration regardless of the rootzone mix composition. This behavior was inferred in our previous study where a reduction in total drainage from the modified CA profile was associated with visually observed runoff that was not apparent for the USGA profile. Thus, soil profile features at 12 inches depth have an influence of water entering the soil surface in modern putting green designs.

In addition, the Phase I research showed lateral patterns of root zone moisture after 48 hours drainage. These patterns were influenced by drain line spacing in modified CA greens and slope in both modified CA and USGA greens. The question, therefore, arose whether turf drought symptoms would be observed with lateral position across these greens if further irrigation was withheld. Consequently, we conducted an initial replication of a dry-down study on the Phase I experimental units to help address this concern.

We anticipated an earlier onset of drought stress in the high permeability rootzones than in the low permeability rootzones. We also anticipated earlier drought over drain lines in the modified CA green with no slope, and at further distances up slope for both green systems at 4 percent slope. The strongest realization of these expectations was the response to slope in the high permeability modified CA and USGA greens. These greens at 10 days contained from 6 to 7 percent surface soil moisture at up slope locations and from 15 to 16 percent moisture at extreme down slope locations. This gradient in soil moisture yielded progressively increased stress symptoms from the down slope to the up slope locations. This was confirmed by our clipping yield measurements where fewer clippings were collected at up slope locations than down slope locations. Some of the more subtle turf responses to stress during this dry down study (if they exist) will require further data analysis before they are revealed.

Finally, one caveat of our Phase I results to date is that these greens were just one year old and had not experienced foot traffic. During this past year, we have applied simulated foot traffic to the greens by using a weighted roller. The roller is 4 feet in length, 8 inches in diameter and has a weight of about 325 lbs. The 'rolling factor' for this roller is about 1.2, which we estimate to simulate the heel pressure of an average human. Consequently, the water drainage and redistribution study conducted in the fall of 1997 will be repeated in the spring of 1999.

Phase II Progress. We have recently completed construction and established turf on an additional experiment to assess turf water use as influenced by root zone depth, root zone composition, and water perching in a USGA profile. The study employs six root zone mixes and two root zone depths constructed as a 2-tier USGA soil profile. Two of the root zones are 100 percent sand where the sands are relatively coarse and fine as based on USGA specifications. Two root zones are sand:sphagnum peat blends using the coarse and fine sand materials, and the final two root zones are sand:soil:peat blends again using the coarse and fine sands. Each root zone is placed in a 2-tier USGA profile with root zone depths of 9 or 12 inches. Each root zone mix and profile depth treatment combination is replicated three times for a total of 36 experimental greens.

To study turf water use, a complete accounting must be made of all water inputs and outputs from the root zone. For this reason, the greens soil profile is constructed within 6-ft diameter non-weighing lysimeters where drainage from individual greens is collected in an adjacent service pit. Additionally, TDR probes for soil moisture measurements are located at 3 and 6 inches depth for the 9-inch root zone and 3, 6 and 9 inches depth for the 12 inch profile. Use of the TDR probes will allow measurement of water loss from the turf by evapotranspiration. Water for the entire area is provided by an overhead irrigation system. The greens were seeded to Penncross creeping bentgrass in the spring of 1998.

Bacterial Populations and Diversity withing New USGA Putting Greens

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Start Date: 1996
Number of Years: 5
Total Funding: $66,667

Objectives:

1. *Determine bacterial populations associated with putting green root-zone mix materials.*
2. *Determine bacterial populations of the root-zone mixes before and after fumigation.*
3. *Compare rhizosphere bacterial populations on two different turfgrasses, bentgrass and bermudagrass.*
4. *Compare rhizosphere bacterial populations of bentgrass in two different locations, Alabama and South Carolina.*
5. *Compare rhizosphere bacterial populations of bermudagrass in two differrent locations, southern Florida and northern Florida.*
6. *Compare thatch development, rooting and bacterial population of bentgrass in relation to rootzone mix and nitrogen fertilization.*
7. *Compare soil and rhizosphere bacterial populations of root-zone mixes containing various clay sources.*
8. *Document rhizosphere bacterial population dynamics on bentgrass and bermudagrass over a four year time period.*

The overall objective of this project is to develop baseline data concerning bacterial composition (populations and diversity) of new USGA putting greens, both during and after construction. During 1996, the best methods for enumerating specific groups of bacteria were determined. These were incorporated into the research accomplished during the past two years.

University of Florida. For the project solely associated with Florida, the work completed thus far in 1998 was a repeat of the experiments carried out in 1997, with some modifications. Bacterial groups associated with putting green construction materials, prior to and after fumigation, and the bermudagrass sprigs used at planting were enumerated.

Trenches were dug at the FLREC for placement of 100-gallon size Lerio™ tree containers. These containers are 36-inch square and 18-inches deep. A 6-inch layer of non-calcareous washed river gravel was placed in the bottom of each container. No intermediate layer was added as the gravel and root-zone mixes met USGA specifications. Two peat materials were used to make the mixes, either sphagnum peat or reed sedge peat. The Canadian sphagnum peat was mixed with the sand to obtain an 85:15 mix. The Dakota reed sedge peat was mixed with the sand to obtain a 93:7 mix. The root-zone mixes are the two main treatments. The subplots or second factor is fumigation type. The containers are either not fumigated (control) or are fumigated with methyl bromide or metam sodium.

Samples were obtained for enumeration of seven different bacterial groups from: 1) individual root-zone components prior to blending, 2) each root-zone mix after blending, 3) prior to fumigation, 4) 9 days post-fumigation, 5) 23 days post-fumigation, and 6) each month after planting of bermudagrass for five months total. Samples were also obtained of the bermudagrass sprigs prior to planting. Only three monthly samples have been obtained to date.

The sand and sphagnum peat contained the lowest number of bacteria, with two groups not detected at all (fluorescent *Pseudomonads* and *Stenotrophomonas maltophilia*). All bacterial groups were detected in the reed sedge peat. Only *Actinomycetes* were not detected in the two root-zone mixes. For both root-zone mixes, there were significant differences within each fumigation treatment among the different bacterial groups at both sampling periods. The only consistent results obtained were: 1) the inability to detect fluorescent *Pseudomonas* in the methyl bromide treated containers 14 days after the plastic was removed; and 2) the lack of effect of the fumigants on *Actinomycetes* populations 14 days after the plastic was removed (Table 2).

All the bacterial groups were present when the *TIFDWARF* bermudagrass was sampled prior to planting. Throughout the next three months of sampling, all groups continued to be detected on plant material and in the root-zone mix. Data have not been analyzed to date concerning differences among root-zone mixes or fumigation treatments after planting.

Results this year indicate that bacterial numbers for most of the bacterial groups enumerated are actually increased by fumigation with either methyl bromide or metam sodium. Overall, the study would thus far indicate that bacteria certainly are not absent from root-zone mixes, even after fumigation, and that planting of the bermudagrass will introduce even more bacteria into the putting green.

Auburn. At Auburn University, treatments include nitrogen rate (1x or 2x normal rate) and construction materials (pure sand putting green or 80:20 sand:peat mix). Sixteen

Table 2. Bacterial groups present when materials delivered to UF/FLREC.

	Colony Forming Units per gram dry weight[y]						
Bacterial group	Sand	SP[z]	RSP[z]	SP- mix	RSP-mix	P.F	F value
Total	5.0 A e	6.6 A b	8.4 A a	5.8 A d	6.3 A c	0.0001	398.1
Fl. Pseudomonads	0.0 E c	0.0 E c	3.7 D a	1.6 D b	1.3 D b	0.0001	14.1
S. maltophilia	0.0 E c	0.0 E c	1.3 E b	2.1 CD ab	2.4 C a	0.0003	10.6
Gram positive	2.4 D b	1.2 D c	4.2 D a	0.5 E cd	0.0 E d	0.0001	18.1
Gram negative	3.4 B d	5.8 A b	6.4 C a	4.5 B c	4.5 B c	0.0001	293.4
Actinomycetes	2.7 C b	2.3 C b	7.5 B a	0.0 E c	0.0 E c	0.0001	75.3
Heat tolerant	2.7 C d	4.1 B c	7.1 BC a	3.0 C d	5.2 B b	0.0001	42.6
P>F	0.0001	0.0001	0.0001	0.0001	0.0001		
F value	456.2	43.6	70.2	37.4	75.3		

[x] Values are means of four replicate samples. Means in the same column followed by the same capital letter or means in the same row followed by the same small letter are not significantly different ($P \leq 0.05$), according to the Waller Duncan *k*-ration *t* test.
[z] SP, sphagnum peat; RSP, reed sedge peat

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).

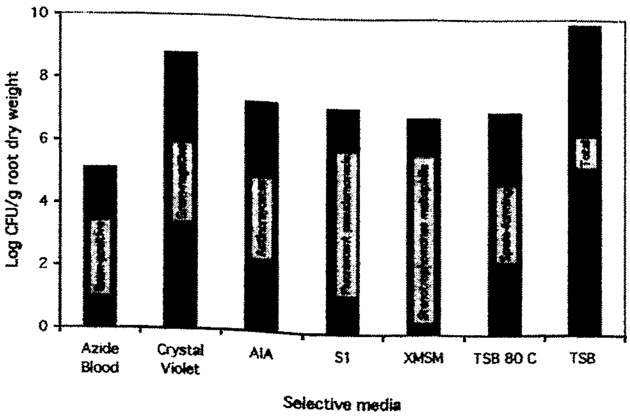

Figure 4. Rhizobacteria populations were averaged over eight sampling periods from bentgrass greens. Samples were collected from December 1996 to September 1998 from Charlotte Country Club Golf Course, NC.

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.