3. *Evaluate post grow-in cultural practice effects on putting green long-term performance.*

Field Research. The primary objective of the 1998 growing season was to evaluate the establishment of creeping bentgrass as affected by the sand size distribution and amendment used in root zone mixes. The 37 root zone treatments constructed in either one or two microenvironments of the field research facility at North Brunswick, NJ were seeded to L-93 creeping bentgrass turf on 31 May 1998.

Location Effect. Environment (location) did affect establishment ratings for a few observation dates; however, there was not a strong influence on the establishment of creeping bentgrass in these two studies. It is expected that environment will have a greater effect on performance of turf maintained at a lower cutting height (< 5/32-inch) and receiving compaction treatment during 1999. No significant interaction between location and root zone treatment was observed during the 60-day evaluation period of bentgrass establishment.

Sand Size Distribution Study. Two finer sand size distributions (not meeting USGA guidelines) had a better rate of establishment than coarser sands. This was likely due to better moisture retention and subsequently better nutrient availability in those finer sands. The coarsest sand size established well; however, after 60 days, the performance of the plots declined. This may be an initial indication of the limitations of coarser sands.

Amendment Study. A greater affect on the establishment of bentgrass was observed in the amendment study compared to sand size distribution study. Generally, increasing the rate of amendment with soil and peat enhanced establishment. This was likely due to increased fertility and/or moisture retention in these mixes. However, establishment ratings for the 20 percent soil or peat treatments 40 days following establishment were similar to respective lower amendment rate plots. This may indicate the development of stresses associated with low air-filled porosity in the root zone. As expected, the greater fertility of ZeoPro plots enhanced establishment. Both ZeoPro and Profile (inorganic) amendments enhanced establishment up to 40 days compared to unamended sand. ZeoPro maintained high establishment ratings up to 60 days following treatment; whereas, Profile plots were more similar to the unamended sand after 40 days. Additional establishment data for all amendment treatments constructed in the enclosed environment are currently being summarized.

Laboratory Research. Research studies in the laboratory have been conducted to evaluate the influence of sample preparation on saturated hydraulic conductivity (K_{sat}). The saturated hydraulic conductivity (K_{sat}) measurement continues to be a highly variable measurement within and among USGA testing. An understanding of the source of this variability would improve testing procedures and benefit the golf course construction industry. A possible source of the variability is the phenomenon of air entrapment within 46 saturated" laboratory packed cores. Four studies assessed the influence of core diameter, antecedent moisture content prior to saturation, and saturation method on K_{sat} variability, as affected by air entrapment.

Effects on K_{sat}. Increasing core sample diameter (2- to 3-inches) resulted in higher sample densities and lower K_{sat} rates. K_{sat} rates for sand:peat and sand samples increased as the sample moisture content at time of saturation decreased. Greater sample moisture content at saturation apparently results in a sufficient amount of "pore necks" being filled with water that subsequently encloses air-filled pores during saturation (entrapped air). Conversely, a relatively dry sample provides open passages for the expulsion of air during saturation. Thus, dry sample cores did not entrap as much air during saturation and have higher K_{sat}.

Vacuum saturation procedure demonstrated the importance of removing entrapped air from core samples. Vacuum saturation of sample cores increased K_{sat} rates compared to saturation at standard air pressure. Temperature affects the solubility of gases in water. Water and room temperature can vary greatly within and between laboratories over time, and consequently could influence the air entrapment and K_{sat} of core samples. These factors are currently being evaluated for their effect on K_{sat} by varying water temperatures relative to ambient air temperatures in the lab. I

Organic Matter Dynamics in the Surface Zone of a USGA Green: Practices to Alleviate Problems

University of Georgia

Dr. Robert Carrow

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

Objectives:

1. *Determine the effectiveness of selected fall/spring-applied cultivation on enhancement of bentgrass root development, water infiltration, and soil oxygen status during spring and fall root development periods.*
2. *Determine the effectiveness of selected summer-applied cultivation, topdressing and wetting agent practices on bentgrass root maintenance and viability, water infiltration, and soil oxygen status during the summer months when root decline occurs.*
3. *The best treatments from the above objectives will be combined to develop an integrated year-round program for maximum root development and maintenance during stress periods.*

Organic matter accumulation occurs even under excellent management and regardless of specification (i.e., it is not dependent on specifications) due to the abundance of roots produced by bentgrass within this surface zone along with any thatch/mat accumulation. A considerable portion of the OM in the surface zone is as root tissue that can contribute to soil macropore plugging or sealing. Organic matter (OM) in the surface 0 to 2 inch zone of a USGA green can accumulate from an initial level of 1.0 to 4.0 percent (by weight) at establishment to 8 to 12 percent or more after two years.

A project was initiated in late spring 1996 to investigate the influence of treatments (summer cultivation, sand topdressing, sand substitutes, wetting agents) on maintaining infiltration, soil O_2 status, and roots. This field study continued until fall 1998. It is proposed that high temperatures, especially in conjunction with high humidity, causes an increase in the rate of summer death of roots. Since many roots reside in the surface 0 to 2 inches, death of a substantial percentage of these roots in a narrow time frame. The organic matter form can change from live roots with structure to gel-like, fresh, dead organic matter that rapidly plugs surface macropores. Any water applied at this point causes a saturated zone due to a low infiltration rate, thereby inducing low soil O_2 levels as gas exchange declines. Turfgrass and soil microorganism O_2 demands are very high under hot, moist weather and severe O_2 stress (similar to wet wilt without necessarily having standing water but with a saturated surface zone) occurs. This triggers very rapid enhancement of summer bentgrass decline and further root death.

Table 3. USGA specification and treatment ranges for bulk density, total porosity, and aeration porosity.

Parameter	Surface 0-3 cm Range for Study Treatments [a]	USGA Specification Range
Bulk density (g cm^{-3})	0.61 to 0.76	1.20 to 1.60
Total Porosity (%)	66.9 to 73.2	35.0 to 55.0
Aeration Porosity (%) (-0.004 M Pa)	17.4 to 24.3	15.0 to 30.0
Moisture Retention (%) (-0.004 M Pa)	42.5 to 54.7	15.0 to 25.0

The initial field study on this problem will continue until fall 1998. Observations to date are:

a. Percent OM by weight was 9.8 percent at 30 months after initiation of treatments for the untreated Control in the surface 0 to 3.0 cm (0 to 1.2 inch) zone. The Control received light, frequent sand topdressing at 0.5 to 1.0 ft^3 per 1000 ft^2 every 3 weeks, as did all treatments but not core aeration. Core aeration (CA) with a heavy topdressing (6.2 ft^3 per 1000 ft^2) in March was the only treatment to reduce percent OM (i.e., by 25% to 7.8% OM) while all other treatments ranged from 8.9 to 10.3 percent OM. Such high OM contents in this surface zone indicates that OM controls soil physical properties more than the sand matrix. Thus, soil physical properties within this zone were substantially different from the specification ranges of a USGA root zone mix. Since OM content is the primary factor affecting these soil physical properties of the surface 0 to 3 cm zone, OM would be expected to influence soil O_2 status and water infiltration.

b. Measurement of soil oxygen diffusion rate (ODR) was made in three treatments (CA, core aeration in Mar; HJR, Toro Hydro-Ject[†] raised to create a 0.25 inch diameter hole to a depth of 4 to 8 inches every 3 weeks June through September; HJR + (Co-funded with the GCSAA), same as HJR but with wetting agent applied every 3 weeks from mid-May through September. ODR was ≤ 0.20 µg O_2 cm^{-2} min^{-1} (the ODR rate at which soil O_2 becomes limiting for roots) 38, 43, and 24 percent of readings at 2.5 cm (1.0 inch) for CA, HJR, and HJR + WA, respectively over 3 summers. At 10 cm (4 inch) ODR readings were equal or below the limiting value on 0, 14, and 14 percent of readings, respectively, over 2 summers. Thus, even with these cultivation treatments, limiting ODR values were observed at 3 to 26 hours after irrigation within the surface zone.

c. Treatments that enhanced average water infiltration (as saturated hydraulic conductivity, SHC) at 17 to 26 days after cultivation greater than the Control (128 mm hr^{-1}) were: HJR + Sand (451 mm hr^{-1}) (HJR + additional topdressing at 0.75 ft^3 per 1000 ft^2 every 3 weeks); HJR + WA (406); HJR (400); HJR + B (395) (HJR + Biostimulant, cytokinin); HJR + Sand + WA (371); HJR + Sand + WA + B (361); HJL (331) (Hydro-Ject lowered position for 0.125 inch dia. hole); and HJR + Greenschoice (269 mm hr^{-1}) (HJR + Greenschoice topdressing at 0.75 ft^3 per 1000 ft^2). The normal desirable SHC for a high rainfall region is at least 120 mm hr^{-1} with the Control and CA treatments below this value 50 and 43 percent of readings. High SHC in the summer is essential to allow rapid water movement across the 0 to 3 cm zone that controls field SHC. High SHC also prevents standing water and excessively long periods of saturation and to enhance O_2 movement into the soil.

d. Percent of shoot density ratings significantly greater than the Control was highest for HJL (38% of readings), HJR + WA (29), HJR (24), and HJR + Sand + WA (24), while treatments exhibiting lower shoot density than control were LP + G (LandPride cultivation with vertical injection of Greenschoice into holes) (33%) and CA (29%). Root data are still in progress.

Stimulation of Root Development (in Spring/Fall) from the Zone of High Organic Matter Content. High OM content in the surface zone in cool weather may be due to rapid development of shallow roots. As roots developed in mid-fall to late spring, they may result in sufficient plugging of surface macropores in the surface zone to cause periods of suboptimal soil O_2 and low water infiltration. While adverse shoot responses to low soil O_2 may not be apparent in cool periods (as they are in summer where summer bentgrass decline can occur very rapidly), deep root development from late fall through late spring could be reduced, thereby limiting deep rooting going into the summer. A second project was initiated in winter 1996 to investigate the influence of selected cultivation procedures, that are non-disruptive to turfgrass shoots, on root development. Wetting agent and sand substitute treatments were also included. The objectives were to enhance SHC, soil ODR, and root development. Observations to date are:

a. Percent OM by weight in the surface 0 to 3 cm zone for the Control (received light, frequent sand topdressing at 0.75 ft^3 per 1000 ft^2 every 3 weeks as did all treatments but no core aeration) at 30 months after study initiation was 16.1 percent. Core aeration (CA) treatment in March and September with 6.2 ft^3 per 1000 ft^2 had OM of 9.3 percent while other treatments ranged from 9.8 to 16.8 percent. As in Study 1, OM in the surface dominated the physical properties of the root zone.

b. For the three treatments where soil ODR was determined, ODR at 2.5 cm (1.0 inch) was ≤ 0.20 µg O_2 cm^{-2} min^{-1} (the limiting value) 59 to 62 percent of readings in October to June and 25 to 38 percent at 10 cm (4.0 inch). The three treatments were CA, HJR + WA (Hydro-Ject Raised for 0.25 in diameter hole plus wetting agent, both at 3 week intervals); HJR + G + WA (where G = Greenschoice topdressing at 70 percent sand plus 30% G every 3 weeks at 0.75 ft^3 per 1000 ft^2 above the base sand topdressing of all treatments). Lowest ODR and SHC values occurred in December/January and May periods and values were lower than summer ODR and SHC values of an adjacent study (i.e., Study 1).

c. Maintaining high SHC across the 0 to 3 cm zone should increase soil O_2 and minimize periods of standing water or surface saturation that may inhibit rooting. Treatments that increased average SHC compared to the Control (71 mm hr^{-1}) at 24 to 41 days after cultivation were: HJR + WA (221 mm hr^{-1}); HJR (214); HJR + G + WA (183); HJR + G (152) and AW (Aerway Slicer, 100 tines, 4 inch penetration) (145 mm hr^{-1}). Lowest average SHC at 24 to 41 DAC were exhibited by QT + G (Solid quad tine of 0.25 inch dia. with Greenschoice) (53) and AW + G (63); where both of these treatments were not significantly different from the Control.

d. Treatments with 0 to 6 percent of shoot density rating less than the Control and 0 to 22 percent ratings greater than the control were AW + G, HJR, and HJR + G + WA. Treatments with highest percent of readings less than the Control were QT (28%), LP + GI (LandPride cultivation with Greenschoice vertical injection) (19), and QT + G (17). Root data are in progress.

Results from these two projects will be used in Phase II to formulate potential annual management programs (cultivation, topdressing, wetting agents, etc.) that a) would allow maximum root growth development in spring/fall without the decrease in rooting depth now observed on high sand golf greens a couple years after grass establishment, and b) would maintain root viability in the summertime and minimize summer bentgrass decline caused by low soil O_2 exchange.