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# 1999 RUTGERS TURFGRASS PROCEEDINGS

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The first section includes lecture notes of papers presented at the 1999 New Jersey Turfgrass Expo. Publication of the New Jersey Turfgrass Expo Notes provides a readily available source of information covering a wide range of topics. The Expo Notes include technical and popular presentations of importance to the turfgrass industry.

The second section includes research papers containing original research findings and reviews covering selected subjects in turfgrass science. The primary objective of this section is to facilitate the timely dissemination of original turfgrass research for use by the turfgrass industry.

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Dr. Ann B. Gould, Editor
Dr. Bruce B. Clarke, Coordinator

# UPDATE ON ROOT ZONE MIXTURE RESEARCH FOR PUTTING GREENS

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The USGA guidelines for construction of golf putting greens are often difficult and expensive to achieve due mainly to limited availability and relatively high cost of suitable materials. As a result, there is a need to understand the consequences of implementing various construction specifications that may or may not conform to USGA guidelines. Moreover, the microenvironment in which a putting green is constructed is likely to affect turf performance. This research project was designed to increase our understanding of these issues by assessing the changes that occur in root zone performance over time. A better understanding of root zone performance also will provide the information needed to develop future studies of management practices directed towards minimizing resource and maintenance inputs.

The overall goal of this research project is to assess the potential of various root zone mixes to reduce management and resource inputs through the monitoring of the physical, chemical, and biological changes that occur as root zones (greens) mature. Our objectives are to investigate aspects of root zone construction that affect putting green performance in two microenvironments. These aspects include 1) pore size distribution (sand particle size distribution) and depth of root zone mix, and 2) organic (peat, compost) materials, inorganic materials, soil, and other additives commonly used for amending sand root zones.

## MATERIALS AND METHODS

- Preliminary evaluations of root zone mixes were conducted in the laboratory.
- Field plots were constructed in two locations (microenvironments) in 1997 (four replications per location).
- Six sand sizes, conforming to and finer than USGA guidelines, were amended with sphagnum peat at a 9:1 volume ratio (Table 1) and a seventh sand was used unamended. The three coarsest sands were used to construct root zone plots with depths less than 12 inches.
- A silt loam and two organic and two inorganic materials were used to amend a USGA-sized sand at varying volume ratios in both microenvironments (Table 2).
- In the poor air circulation microenvironment (lower location), an additional four organic and four inorganic amendments were studied (Table 6).
- All plots were seeded on 31 May 1998 with L-93 creeping bentgrass at 1 lb/1000 ft$^2$.
- Mowing was initiated on 4 July 1998 and maintained at 1/2 inch for 1998. A mowing height of 1/8 inch was achieved on 25 May 1999.
- Plots were aerated with 3/8 inch hollow tines in April 1999.
- Plots were fertilized for 1999 as presented in Table 3.
- Irrigation was applied based on Class A pan evaporation and root zone water content.
- Curative applications of pesticides permitted the evaluation of low to moderate pest activity.

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- Data were collected for visual quality, disease activity, root zone fertility, clipping nutrient content, root zone physical properties, and irrigation requirements.
- Evaluation of root zone mixes in the field was accomplished using an experimental layout of randomized complete block design with four replications in two locations (microenvironments). The microenvironments varied primarily with respect to evaporative demand (air circulation).

## RESULTS AND DISCUSSION

### Turf Quality

*Location (Microenvironment) Effect*

- Monitoring of wind velocity, soil temperature, and evaporation from a Class A pan indicated that the lower location had lower wind velocities and evaporation of water and higher soil temperatures than the upper location (data not shown).
- Plots in the lower (poor air circulation) location had better turf quality than the upper location in May and June (Tables 4 and 5). This response reversed in August and September; plots in the upper location had better quality than plots in the lower location. The initial decline in quality in the lower location relative to the upper location was observed in late July when the detrimental effects of poor air circulation would be expected.
- It is apparent from the quality data that the environmental conditions in the lower location enhanced spring performance of the creeping bentgrass. Presumably, this is due to warmer soil temperatures in the lower location that create better growing conditions in winter and early spring relative to the upper location.
- This relatively sudden (over one month) reversal in performance between open and enclosed microenvironments may be a contributing factor to the difficulties experienced by many superintendents in managing enclosed putting greens. During the initial part of the growing season, enclosed putting greens may appear healthier and more vigorous than openly exposed putting greens. Good performance during this time may encourage greens committees and turf managers to delay the implementation of important management practices that could minimize stress on these greens later in the season.

*Sand Size Distribution Study*

- The two finest sands in the sand size distribution study had the best performance during 1999 (Table 4). These finer sands do not conform to the sand size guidelines of the USGA Green Section.
- The more coarse sand size distribution treatments usually resulted in poorer turf performance.
- Reduced root zone depth generally improved turf performance; this response was most evident as the sand size distribution became coarser.

*Amendment Study Over Two Locations*

- There was a significant interaction between location and root zone treatment throughout the season (Table 5). The interaction in April indicated that all sphagnum-amended plots, the non-amended sand, and the 10% reed sedge amended plots had better quality in the lower location than in the upper location. All other treatments were similar between the two locations. Other interactions in the spring reflected better performance of some root zone treatments in the lower location compared to the upper location. The interaction in August indicated that two treatments, the non-amended sand and the 5% sphagnum amended plots, were capable of maintaining good turf quality in the lower location as well as the upper location; turf quality for the other treatments declined in the lower location.
- Identifying this variation in turf performance due to microenvironment and root zone construction is important because putting greens are built in widely varying microenvironments. A better understanding of the variation in turf performance over location will help both turf managers and golf competitors struggling with

inconsistencies in turf quality on putting greens.

- Turf performance among root zone treatments was more consistent in the upper location in August and September compared to the lower location, although treatment differences did exist in the upper location. More uniform treatment performance in the upper (exposed) location is likely due to the better growing environment of this location. The greater stress conditions of the lower location caused a more definitive separation of treatments.
- Amendment rate effects on turf performance were only significant in the lower location during August and September and indicated that higher rates of soil and sphagnum peat decreased quality. The quadratic rate response observed with reed sedge peat indicated that amending with reed sedge peat at both the 5 and 10% rate produced lower turf quality than the non-amended sand.
- Root zones amended with 20% soil and 10% Profile in the lower location had the poorest turf performance by August and September of 1999 (Table 5).
- The inorganic amendments ZeoPro and Profile did not produce a performance advantage over organic amendments in 1999. In fact, when differences were evident these amendments had lower turf quality than other amendments.

*Amendment Study In Lower Location*

- As mentioned above, the amendment study in the lower location included another four organic and four inorganic amendments. The performance ranking of all amendment treatments in the lower location is listed in Table 6.
- Two of the top five ranking amendment treatments, 20% AllGro with AT Sales sand and 10% Kaofin, do not conform to USGA guidelines.
- The 100% soil treatment did not produce satisfactory turf. Turf grown on the loamy soil suffered from severe scalping caused by non-uniform settling. In addition, regular hand-weeding of *Poa annua* was required for this treatment.
- The 10% Greenschoice and 10% ZeoPro + micros treatments suffered from severe localized dry spot development that strongly detracted from turf performance.

**Pest Activity**

- The upper location had the greatest amount of dollar spot activity (Tables 8 and 10).
- Cutworm feeding damage on the sand size distribution study was greatest in the lower location (Table 8).
- Dollar spot, pink snow mold, and yellow patch were more active in the upper (exposed) location than in the lower location in 1999 (Tables 7 to 10).
- Plots amended with Profile and Greenschoice were the most severely affected by pink snow mold (Table 9). Plots amended with 20% AT Sales AllGro, 5% Kaofin, 20% sphagnum, and 100% soil had the least pink snow mold activity.
- A higher amending rate of soil, sphagnum, and reed sedge appeared to suppress disease severity of bentgrass dead spot (caused by *Ophiosphaerella agrostis*), especially in the upper location (Table 10).
- Bentgrass dead spot was most severe on 100% sand and 10% Profile plots in the upper location. The activity of this disease was higher for plots amended with ZeoPro in the upper location than in the lower location. 5% reed sedge was the only treatment to have greater dead spot activity in the lower location.
- Further evaluation is needed over time to understand the relative importance (consistency) of these interactions.

**Plan of Work for 2000**

- Samples of clippings, roots, and soil have been collected for assessment of rooting and soil physical and chemical properties in 1999. Samples are currently being processed and analyzed.

- Sampling of clippings, roots and soil will be continued in 2000.
- Monitoring of humidity, wind velocity, and air and soil temperatures will be continued in 2000.
- Turf performance data for quality, disease, stress, and other characteristics will be collected.


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Table 1. Porosity and fertility of root zone treatments used in the sand size distrubution study.

| | Porosity | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sand Size | Air | Capillary | pH | P | K | Ca | Mg | O.M.[1] |
| | ----------(%)---------- | | | -----lb/acre----- | | | | |
| Coarse USGA | 29.5 | 7.3 | 6.7 | 27 | 6 | 310 | 68 | 0.4 |
| Medium USGA | 22.2 | 14.0 | 7.0 | 36 | 13 | 323 | 81 | 0.4 |
| Fine USGA | 17.5 | 17.6 | 7.1 | 33 | 14 | 278 | 77 | 0.4 |
| Extra Fine | 11.8 | 25.1 | 7.2 | 33 | 14 | 311 | 83 | 0.5 |
| Mason | 12.8 | 26.9 | 7.0 | 34 | 12 | 305 | 78 | 0.4 |
| CM 340 | 24.2 | 13.9 | 7.1 | 38 | 14 | 339 | 87 | 0.4 |

[1] Organic matter content as determined by combustion

Table 2. Porosity and fertility of root zone treatments used in the amendment study.

| | Porosity | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sand Size | Air | Capillary | pH | P | K | Ca | Mg | O.M.[1] |
| | ----------(%)---------- | | | | | ---lb/acre--- | | |
| Sand | 15.5 | 23.6 | 7.2 | 39 | 16 | 169 | 56 | <0.1 |
| Soil 2.5% | 18.2 | 21.4 | 6.8 | 55 | 19 | 198 | 60 | 0.1 |
| Soil 5% | 15.0 | 21.1 | 6.7 | 55 | 20 | 240 | 60 | 0.2 |
| Soil 20% | 13.0 | 23.1 | 6.9 | 86 | 54 | 462 | 111 | 0.4 |
| Reed Sedge 5% | 15.7 | 22.2 | 6.8 | 34 | 14 | 372 | 72 | 0.4 |
| Reed Sedge 10% | 7.4 | 32.9 | 6.7 | 31 | 13 | 601 | 93 | 0.7 |
| Sphagnum 5% | 15.0 | 21.3 | 7.0 | 44 | 16 | 245 | 72 | 0.2 |
| Sphagnum 10% | 16.7 | 24.1 | 7.0 | 42 | 15 | 336 | 92 | 0.4 |
| Sphagnum 20% | 11.8 | 33.1 | 6.8 | 33 | 14 | 474 | 132 | 0.8 |
| Profile 10% | 22.1 | 21.2 | 7.2 | 52 | 94 | 600 | 78 | 0.1 |
| ZeoPro 10% | 22.8 | 19.8 | 6.4 | 83 | 153 | 538 | 96 | 0.3 |

[1] Organic matter content as determined by combustion

Table 3. Fertilization schedule and nitrogen (N) rate used for sand size distribution and amendment root zone studies in 1999.

| Date | --------Fertilizer Analysis-------- | | | ---------N Rate--------- | |
|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | $g/m^2$ | $lb/1000\ ft^2$ |
| 7 May | 18 | 4 | 10 | 4.8 | 0.99 |
| 17 May | 16 | 4 | 8 | 1.5 | 0.30 |
| 21 May | 16 | 4 | 8 | 1.6 | 0.33 |
| 28 May | 16 | 4 | 8 | 1.6 | 0.32 |
| 1 June | 16 | 4 | 8 | 1.0 | 0.20 |
| 14 June | 16 | 4 | 8 | 0.5 | 0.10 |
| 21 June | 16 | 4 | 8 | 0.9 | 0.19 |
| 29 June | 16 | 4 | 8 | 1.3 | 0.27 |
| 12 August | 15.5 | 0 | 0 | 1.2 | 0.25 |
| 28 August | 16 | 4 | 8 | 1.0 | 0.21 |
| 10 September | 20 | 20 | 20 | 1.2 | 0.25 |
| 19 September | 15.5 | 0 | 0 | 1.2 | 0.25 |
| 25 September | 46 | 0 | 0 | 1.2 | 0.25 |
| 3 October | 46 | 0 | 0 | 0.6 | 0.12 |
| 9 October | 46 | 0 | 0 | 1.2 | 0.25 |
| 17 October | 46 | 0 | 0 | 1.2 | 0.25 |
| 22 November | 46 | 0 | 0 | 1.9 | 0.38 |
| Total N = | | | | 23.9 | 4.91 |

Table 4. Turf quality ratings of L-93 creeping bentgrass grown on root zones varying by sand size distribution in two locations in 1999.

| | Rating Date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Source of variation | April 19 | May 18 | May 29 | June 14 | July 10 | July 21 | Aug. 6 | Sept. 4 |
| **ANOVA** | | | | | | | | |
| Location | NS[1] | ** | NS | ** | NS | NS | *** | *** |
| Treatment | *** | *** | * | *** | *** | *** | *** | *** |
| Location x Treatment | NS | NS | NS | NS | NS | NS | NS | NS |
| **Location** | Rating (9 = best) | | | | | | | |
| Lower Location | 7.4 | 7.3 | 5.6 | 7.5 | 7.8 | 7.6 | 6.2 | 6.2 |
| Upper Location | 7.3 | 7.1 | 5.8 | 7.2 | 7.7 | 7.9 | 7.5 | 7.1 |
| **Sand Size Treatment**[2] | | | | | | | | |
| Fine USGA | 7.3 | 7.3 | 5.5 | 7.4 | 8.0 | 7.6 | 7.0 | 6.3 |
| Fine USGA 10 inch | 8.0 | 7.3 | 5.9 | 7.5 | 8.1 | 7.5 | 7.3 | 7.0 |
| Medium USGA | 7.6 | 6.5 | 5.6 | 7.0 | 7.5 | 7.6 | 6.6 | 5.8 |
| Medium USGA 9 inch | 7.6 | 7.8 | 6.1 | 7.5 | 8.1 | 8.0 | 7.0 | 6.9 |
| Coarse USGA | 6.3 | 6.0 | 4.8 | 6.3 | 6.8 | 6.8 | 5.3 | 4.5 |
| Coarse USGA 8 inch | 7.3 | 6.6 | 5.6 | 7.0 | 6.9 | 7.4 | 6.5 | 6.4 |
| Coarse USGA 7 inch | 7.4 | 6.9 | 5.8 | 7.0 | 7.0 | 7.4 | 6.6 | 6.3 |
| Extra Fine | 7.9 | 8.5 | 5.9 | 8.3 | 8.8 | 8.9 | 7.1 | 7.6 |
| Mason | 7.8 | 8.6 | 6.5 | 8.6 | 8.9 | 8.6 | 7.1 | 7.3 |
| CM 340 | 7.0 | 6.8 | 5.1 | 7.3 | 7.6 | 7.8 | 6.9 | 6.6 |
| CM 4-1 | 5.9 | 6.5 | 5.4 | 6.3 | 7.1 | 7.0 | 6.8 | 7.3 |

(Continued)

Table 4 (continued).

| | ---Rating Date--- | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Source of variation | April 19 | May 18 | May 29 | June 14 | July 10 | July 21 | Aug. 6 | Sept. 4 |
| LSD | 0.5 | 0.6 | 0.9 | 0.6 | 0.6 | 0.6 | 0.5 | 0.6 |
| CV% | 6.0 | 8.2 | 14.5 | 8.3 | 7.6 | 8.0 | 6.9 | 8.8 |
| **Treatment Contrasts** | | | | | | | | |
| Fine vs. Medium | NS | * | NS | NS | NS | NS | NS | NS |
| Fine vs. Coarse | *** | *** | NS | *** | *** | * | *** | *** |
| Fine vs. Extra Fine | ** | *** | NS | ** | * | *** | NS | *** |
| Fine v.s Mason | * | *** | * | *** | ** | ** | NS | ** |
| Extra Fine vs. Mason | NS | NS | NS | NS | NS | NS | NS | NS |
| Fine vs. CM 340 | NS | NS | NS | NS | NS | NS | NS | NS |
| Fine vs. CM 4-1 | NS | * | NS | *** | ** | * | NS | ** |
| Fine 12 inch vs. Fine 10 inch | ** | NS | NS | NS | NS | NS | NS | * |
| Medium 12 inch vs. Medium 9 inch | NS | *** | NS | NS | * | NS | NS | *** |
| Coarse 12 inch vs. Coarse 7 inch and 8 inch | *** | * | NS | * | NS | NS | * | *** |
| Coarse 7 inch vs. Coarse 8 inch | NS | NS | NS | NS | NS | NS | NS | NS |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
[2] Depth of root zone is 12 inches except for specified treatments

Table 5. Turf quality of L-93 creeping bentgrass grown on amended root zones in two microenvironments in 1999.

| Source of variation | April 19 | | May 18 | | May 29 | | June 14 | | July 10 | July 21 | | Aug. 6 | | Sept. 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rating Date | | | | | | | | | | | | | | |
| **ANOVA** | | | | | | | | | | | | | | | |
| Location | ***[1] | | ** | | ** | | *** | | NS | ** | | *** | | ** | |
| Treatment | *** | | *** | | *** | | *** | | *** | *** | | *** | | *** | |
| Location x Treatment | ** | | *** | | *** | | ** | | NS | * | | *** | | *** | |
| **Location** | Rating (9 = best) | | | | | | | | | | | | | | |
| Lower Location | 7.4 | | 7.3 | | 6.0 | | 7.4 | | 7.4 | 7.2 | | 5.8 | | 5.8 | |
| Upper Location | 6.9 | | 6.7 | | 5.4 | | 6.7 | | 7.6 | 7.8 | | 7.2 | | 6.7 | |
| **Treatments** | Location | | | | | | | | | | | | | | |
| | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Both (Avg.) | Lower | Upper | Lower | Upper | Lower | Upper |
| Sand | 6.8 | 6.0 | 7.0 | 5.3 | 5.8 | 4.0 | 7.3 | 5.8 | 7.1 | 7.0 | 7.5 | 6.8 | 7.5 | 6.5 | 7.0 |
| Soil 2.5% | 6.8 | 6.5 | 7.5 | 6.8 | 5.5 | 5.3 | 6.8 | 6.5 | 7.0 | 7.3 | 8.0 | 6.0 | 7.0 | 6.3 | 7.0 |
| Soil 5% | 7.3 | 6.8 | 7.5 | 6.5 | 6.8 | 5.5 | 7.8 | 7.0 | 7.5 | 6.8 | 8.3 | 5.5 | 7.8 | 5.8 | 7.5 |
| Soil 5% on Subgrade | 7.0 | 6.8 | 7.5 | 6.8 | 6.3 | 5.3 | 7.5 | 6.3 | 7.4 | 7.5 | 8.0 | 6.3 | 7.8 | 6.3 | 7.3 |
| Soil 20% | 5.5 | 6.0 | 6.3 | 7.3 | 5.3 | 6.3 | 6.8 | 7.0 | 7.0 | 6.5 | 8.0 | 4.3 | 7.0 | 4.5 | 6.8 |
| Sphagnum 5% | 8.0 | 6.5 | 7.8 | 6.3 | 6.5 | 5.3 | 7.8 | 6.3 | 7.6 | 8.0 | 7.8 | 7.0 | 7.3 | 7.0 | 6.8 |
| Sphagnum 10% | 8.5 | 7.0 | 8.0 | 6.8 | 6.5 | 5.5 | 8.0 | 6.5 | 8.3 | 7.5 | 7.5 | 6.5 | 7.3 | 6.3 | 6.3 |
| Sphagnum 20% | 9.0 | 8.0 | 8.0 | 8.0 | 7.0 | 6.8 | 8.8 | 8.8 | 8.4 | 8.0 | 8.5 | 6.0 | 7.0 | 6.0 | 6.5 |
| Dakota 5% | 8.0 | 7.8 | 7.5 | 7.0 | 6.0 | 5.5 | 7.5 | 7.5 | 7.8 | 7.0 | 8.0 | 5.8 | 7.5 | 5.3 | 7.0 |
| Dakota 10% | 8.8 | 7.8 | 7.5 | 7.8 | 5.8 | 6.5 | 8.0 | 8.5 | 8.9 | 8.3 | 8.5 | 6.3 | 7.3 | 6.0 | 6.5 |
| Profile 10% | 6.8 | 6.8 | 6.0 | 5.8 | 4.3 | 3.8 | 5.8 | 5.0 | 6.8 | 6.3 | 6.5 | 4.5 | 6.0 | 4.0 | 5.3 |
| ZeoPro 10% | 7.0 | 7.0 | 6.8 | 6.0 | 6.0 | 5.0 | 6.8 | 5.8 | 6.8 | 6.5 | 7.5 | 5.3 | 7.0 | 5.3 | 6.8 |
| LSD | | 0.5 | | 0.8 | | 0.8 | | 0.8 | 1.2 | | 0.7 | | 0.7 | | 0.7 |
| CV% | | 7.0 | | 8.2 | | 9.4 | | 8.4 | 7.7 | | 6.5 | | 7.5 | | 7.9 |

(Continued)

Table 5 (continued).

| Source of variation | Rating Date: April 19 | | May 18 | | May 29 | | June 14 | | July 10 | July 21 | | Aug. 6 | | Sept. 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Both (Avg.) | Lower | Upper | Lower | Upper | Lower | Upper |
| **Linear Contrasts** | | | | | | | | | | | | | | | |
| Soil Rate (0 to 20%) | *** | NS | ** | *** | NS | *** | NS | * | NS | NS | NS | *** | NS | *** | NS |
| Sphagnum (0 to 20%) | *** | *** | * | *** | ** | *** | *** | *** | *** | * | * | * | NS | * | NS |
| Reed Sedge (0 to 10%) | *** | *** | NS | *** | NS | *** | NS | *** | *** | *** | ** | NS | NS | NS | NS |
| **Quadratic Contrasts** | | | | | | | | | | | | | | | |
| Soil Rate (0 to 20%) | * | * | * | * | ** | ** | NS | * | NS | NS | * | * | NS | NS | NS |
| Sphagnum (0 to 20%) | NS | NS | NS | NS | NS | NS | NS | ** | NS | NS | NS | NS | NS | NS | NS |
| Reed Sedge (0 to 10%) | NS | ** | NS | NS | NS | NS | NS | NS | NS | * | NS | * | NS | ** | NS |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

Table 6. Performance ranking of all amendment treatments based on 1999 turf quality average of L-93 creeping bentgrass in the lower (poor air circulation) location. Except where designated, amended root zones are 12 inches deep and built over a 4 inch gravel layer.

| | Amendment Material | Amendment Rate (by volume) | Turf Quality[1] 1999 Avg. |
|---|---|---|---|
| | | (%) | |
| 1 | AllGro[2] | 20 | 8.6 |
| 2 | Kaofin | 5 | 8.3 |
| 3 | Sphagnum Peat | 20 | 7.6 |
| 4 | Sphagnum Peat | 5 | 7.5 |
| 5 | Sphagnum Peat | 10 | 7.4 |
| 6 | Reed Sedge Peat | 10 | 7.3 |
| 7 | AllGro | 10 | 7.3 |
| 8 | Irish Peat | 20 | 7.2 |
| 9 | Irish Peat | 10 | 7.1 |
| 10 | Isolite | 10 | 7.0 |
| 11 | Fertl-soil Compost | 5 | 6.9 |
| 12 | Axis | 10 | 6.8 |
| 13 | Soil on subgrade | 5 | 6.8 |
| 14 | Reed Sedge Peat | 5 | 6.8 |
| 15 | None (Sand) | 0 | 6.8 |
| 16 | Soil | 5 | 6.7 |
| 17 | Soil | 2.5 | 6.6 |
| 18 | ZeoPro in surface 4 inches | 10 | 6.3 |
| 19 | ZeoPro | 10 | 6.2 |
| 20 | Profile | 10 | 5.6 |
| 21 | Soil | 20 | 5.5 |
| 22 | Profile | 20 | 5.5 |
| 23 | ZeoPro + Micros in surface 4 inches | 10 | 4.8 |
| 24 | Greenschoice | 10 | 3.9 |
| 25 | Soil | 100 | 2.8 |
| | LSD at 5% = | | 0.4 |

[1] 9 = best turf quality; > 5 = acceptable turf quality

[2] AllGro compost mixed at 20% volume ratio with a sand that contains too much fine-sand based on USGA guidelines for root zone composition; all other amendments mixed with a medium sand conforming to USGA size guidelines

Table 7. Severity of pink snow mold and bentgrass dead spot of L-93 creeping bentgrass grown on root zones varying by sand size distribution in two microenvironments in 1999.

| Source of Variation | --------Pink Snow Mold-------- 19 May | | 28 May | | Bentgrass Dead Spot 22 July | |
|---|---|---|---|---|---|---|
| **ANOVA** | | | | | | |
| Location | NS[1] | | NS | | NS | |
| Treatment | *** | | *** | | NS | |
| Location x Treatment | ** | | *** | | * | |
| **Location** | Rating[2] | | Area Damaged (%) | | Number of Patches | |
| Lower Location | 6.8 | | 24.3 | | 1.4 | |
| Upper Location | 7.3 | | 19.1 | | 2.5 | |
| **Sand Size Treatments**[3] | ---Location--- | | | | | |
| | Lower | Upper | Lower | Upper | Lower | Upper |
| Fine USGA | 7.5 | 7.0 | 23.3 | 22.8 | 1.3 | 6.3 |
| Fine USGA 10 inch | 7.0 | 7.5 | 29.3 | 20.0 | 1.3 | 3.0 |
| Medium USGA | 6.3 | 6.8 | 35.5 | 21.0 | 2.5 | 2.3 |
| Medium USGA 9 inch | 7.0 | 7.5 | 18.3 | 18.0 | 0.8 | 1.5 |
| Coarse USGA | 6.5 | | 27.8 | | 1.0 | |
| Coarse USGA 8 inch | 6.5 | 7.3 | 19.3 | 20.8 | 0.5 | 2.8 |
| Coarse USGA 7 inch | 7.3 | 7.3 | 15.0 | 16.0 | 0.5 | 0.3 |
| Extra Fine | 6.5 | 8.3 | 28.8 | 14.0 | 0.8 | 1.0 |
| Mason | 7.5 | 7.8 | 11.3 | 14.5 | 2.0 | 1.0 |
| CM 340 | 5.5 | 6.8 | 47.3 | 20.5 | 2.8 | 3.0 |
| CM 4-1 | 7.5 | 6.8 | 12.3 | 23.8 | 1.8 | 0.8 |
| LSD | 0.8 | | 11.1 | | 2.5 | |
| CV% | 8.5 | | 35.9 | | 95.2 | |
| **Treatment Contrasts** | | | | | | |
| Fine vs. Medium | ** | NS | * | NS | NS | ** |
| Fine vs. Extra Fine | * | ** | * | NS | NS | *** |
| Fine vs. Mason | NS | NS | * | NS | NS | *** |
| Extra Fine vs. Mason | * | NS | ** | NS | NS | NS |
| Fine vs. CM 340 | *** | NS | *** | NS | NS | * |
| Fine vs. CM 4-1 | NS | NS | NS | NS | NS | *** |

(Continued)

Table 7 (continued).

| Source of Variation | --------Pink Snow Mold-------- 19 May | | 28 May | | Bentgrass Dead Spot 22 July | |
|---|---|---|---|---|---|---|
| | ---Location--- | | | | | |
| | Lower | Upper | Lower | Upper | Lower | Upper |
| Fine 12 inch vs. Fine 10 inch | NS | NS | NS | NS | NS | * |
| Medium 12 inch vs. Medium 9 inch | NS | NS | ** | NS | NS | NS |
| Coarse 7 inch vs. Coarse 8 inch | NS | * | NS | NS | NS | NS |

[1]NS = not significant; * = *P* < 0.05; ** = *P* < 0.01; *** = *P* < 0.001
[2]9 = least disease
[3]Depth of root zone is 12 inches except for specified treatments

Table 8. Severity of cutworm damage and dollar spot of L-93 creeping bentgrass grown on root zones varying by sand size distribution in two microenvironments in 1999.

| Source of Variation | Cutworm Damage 7 June | Dollar Spot 18 June |
|---|---|---|
| **ANOVA** | | |
| Location | *[1] | ** |
| Treatment | *** | NS |
| Location x Treatment | NS | NS |
| **Location** | Number of Damage Centers | Number of Spots |
| Lower Location | 5.1 | 0.0 |
| Upper Location | 2.8 | 6.1 |
| **Sand Size Treatments**[2] | | |
| Fine USGA 12 inch | 2.5 | 1.5 |
| Fine USGA 10 inch | 5.1 | 4.9 |
| Medium USGA 12 inch | 3.0 | 4.1 |
| Medium USGA 9 inch | 4.6 | 5.9 |
| Coarse USGA 12 inch | 2.0 | 0.0 |
| Coarse USGA 8 inch | 1.5 | 2.1 |
| Coarse USGA 7 inch | 1.6 | 1.9 |
| Extra Fine | 8.6 | 2.8 |
| Mason | 10.6 | 3.6 |
| CM 340 | 1.8 | 2.8 |
| CM 4-1 | 1.6 | 1.0 |
| LSD | 2.5 | 6.1 |
| CV% | 59.7 | 202.3 |
| **Treatment Contrasts** | | |
| Fine vs. Medium | NS | NS |
| Fine vs. Coarse | NS | NS |
| Fine vs. Extra Fine | *** | NS |
| Fine vs. Mason | *** | NS |
| Extra Fine vs. Mason | NS | NS |
| Fine vs. CM 340 | NS | NS |
| Fine vs. CM 4-1 | NS | NS |
| Fine 12 inch vs. Fine 10 inch | * | NS |

(Continued)

Table 8 (continued).

| Source of Variation | Cutworm Damage 7 June | Dollar Spot 18 June |
|---|---|---|
| | Number of Damage Centers | Number of Spots |
| Medium 12 inch vs. Medium 9 inch | NS | NS |
| Coarse 12 inch vs. Coarse 7 inch and 8 inch | NS | NS |
| Coarse 7 inch vs. Coarse 8 inch | NS | NS |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
[2] Depth of root zone is 12 inches except for specified treatments

Table 9. Severity of yellow patch and pink snow mold of L-93 creeping bentgrass grown on amended root zones in two microenvironments in 1999.

| Source of Variation | Yellow Patch 31 March | | ----------Pink Snow Mold---------- 19 May | | 28 May | |
|---|---|---|---|---|---|---|
| **ANOVA** | | | | | | |
| Location | *[1] | | ** | | NS | |
| Treatment | ** | | *** | | *** | |
| Location x Treatment | ** | | * | | *** | |
| **Location** | Number of Rings | | Rating[2] | | Area Damaged (%) | |
| Lower Location | 0 | | 7.4 | | 24.3 | |
| Upper Location | 1 | | 6.6 | | 24.0 | |
| **Sand Size Treatments** | ----------------------------------Location---------------------------------- | | | | | |
| | Lower | Upper | Lower[2] | Upper[2] | Lower | Upper |
| Sand | 0 | 0.5 | 7.8 | 5.5 | 23 | 33 |
| Soil 2.5% | 0 | 1.8 | 8.0 | 7.0 | 20 | 20 |
| Soil 5% | 0.5 | 0 | 7.5 | 6.5 | 27 | 23 |
| Soil 5% Subgrade | 0 | 0 | 7.8 | 6.5 | 15 | 22 |
| Soil 20% | 0 | 0 | 6.8 | 7.8 | 21 | 11 |
| Sphagnum 5% | 0 | 0.8 | 7.3 | 6.3 | 28 | 26 |
| Sphagnum 10% | 0 | 0 | 7.5 | 6.5 | 24 | 24 |
| Sphagnum 20% | 0 | 0 | 8.5 | 7.5 | 9 | 13 |
| Dakota 5% | 0 | 0.5 | 7.3 | 6.8 | 39 | 22 |
| Dakota 10% | 0 | 0 | 7.8 | 7.5 | 26 | 11 |
| Profile 10% | 0 | 4.3 | 5.5 | 5.5 | 49 | 44 |
| ZeoPro 10% | 0 | 4.5 | 7.3 | 6.0 | 10 | 40 |
| LSD | 2.0 | | 1.0 | | 13 | |
| CV% | 265 | | 10.3 | | 37 | |
| **Linear Contrasts** | | | | | | |
| Soil Rate (0 to 20%) | NS | NS | * | *** | NS | ** |
| Sphagnum (0 to 20%) | NS | NS | NS | *** | * | ** |
| Reed Sedge (0 to 10%) | NS | NS | NS | *** | NS | *** |

(Continued)

Table 9 (continued).

| Source of Variation | Yellow Patch 31 March | | ----------Pink Snow Mold---------- 19 May | | 28 May | |
|---|---|---|---|---|---|---|
| | ---Location--- | | | | | |
| | Lower | Upper | Lower | Upper | Lower | Upper |
| **Quadratic Contrasts** | | | | | | |
| Soil Rate (0 to 20%) | NS | NS | NS | NS | NS | NS |
| Sphagnum (0 to 20%) | NS | NS | * | NS | NS | NS |
| Reed Sedge (0 to 10%) | NS | NS | NS | NS | * | NS |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
[2] 9 = least disease

Table 10. Severity of cutworm feeding, dollar spot, and bentgrass dead spot of L-93 creeping bentgrass grown on amended root zones in two microenvironments in 1999.

| Source of Variation | Cutworm 7 June | Dollar Spot 18 July | Bentgrass Dead Spot 22 July | |
|---|---|---|---|---|
| **ANOVA** | | | | |
| Location | NS[1] | ** | NS | |
| Treatment | *** | NS | *** | |
| Location x Treatment | NS | NS | ** | |
| **Location** | ----------------Number of Damage Centers---------------- | | | |
| Lower Location | 3.7 | 0.2 | 4.0 | |
| Upper Location | 2.2 | 3.6 | 5.8 | |
| **Sand Size Treatments** | ----------------------------------Location---------------------------------- | | | |
| | Both (Avg.) | Both (Avg.) | Lower | Upper |
| Sand | 0.8 | 0.6 | 7.8 | 14.0 |
| Soil 2.5% | 1.3 | 1.1 | 7.0 | 8.3 |
| Soil 5% | 2.3 | 1.9 | 4.3 | 3.5 |
| Soil 5% Subgrade | 2.4 | 2.5 | 2.3 | 4.5 |
| Soil 20% | 2.9 | 2.4 | 0.5 | 1.0 |
| Sphagnum 5% | 4.0 | 3.6 | 3.3 | 4.3 |
| Sphagnum 10% | 5.3 | 1.4 | 2.0 | 4.8 |
| Sphagnum 20% | 6.6 | 1.9 | 2.0 | 0.8 |
| Dakota 5% | 3.1 | 2.0 | 9.3 | 3.5 |
| Dakota 10% | 5.3 | 2.6 | 1.8 | 3.8 |
| Profile 10% | 1.0 | 0.5 | 5.0 | 13.3 |
| ZeoPro 10% | 0.6 | 2.1 | 3.0 | 8.3 |
| LSD | 1.9 | NS | 4.2 | |
| CV% | 64.2 | 125 | 60.9 | |
| **Linear Rate Contrasts** | | | | |
| Soil (0 to 20%) | * | NS | *** | *** |
| Sphagnum (0 to 20%) | *** | NS | ** | *** |
| Reed Sedge (0 to 10%) | *** | NS | ** | *** |

(Continued)

Table 10 (continued).

| Source of Variation | Cutworm 7 June | Dollar Spot 18 July | Bentgrass Dead Spot 22 July | |
|---|---|---|---|---|
| | ----------Location---------- | | | |
| | Both (Avg.) | Both (Avg.) | Lower | Upper |
| **Quadratic Rate Contrasts** | | | | |
| Soil (0 to 20%) | NS | NS | NS | *** |
| Sphagnum (0 to 20%) | NS | NS | NS | NS |
| Reed Sedge (0 to 10%) | NS | NS | * | ** |

[1]NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$