Assessing Root Zone Mixes for Putting Greens over Time under Two Environmental Conditions

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Executive Summary

The suitability of root zone mixtures for turfgrass growth is commonly evaluated by laboratory testing of soil physical properties, and is frequently based on United States Golf Association sponsored research initiated in the 1950's. Initial soil physical properties are measured in the laboratory and used as a critical estimate of future performance in the field. Very little information is available, however, regarding changes in soil physical properties of root zone mixtures as turf matures on recently constructed golf putting greens.

The objectives addressed in this report include,

1. Determination of initial laboratory soil physical properties (K_{sat}, porosity, bulk density) of root zone mixtures differing in amendment source,
2. Determination of soil physical properties of root zone mixtures collected from field plots of the same materials,
3. Quantification of the changes in field soil physical properties from the initial laboratory results, and
4. Assessment of the impact of field soil physical properties on turf performance.

Physical property changes occurred in root zone mixtures within two growing seasons after turf establishment in the field. K_{sat} and air-filled porosity of the mixtures decreased; whereas, capillary porosity increased. The presence of roots in root zone samples was likely responsible for the shift in pore size distribution; however, other, not yet, identified factors may also contribute.

Plots having an average seasonal turf quality rating of 7 and higher (9=best) were associated with a laboratory measurement of root zone capillary porosity of 25% or greater. Capillary porosity of root zone samples collected from these same filed plots 1999 was 27% and higher. Thus, higher turf quality has been observed on root zone mixtures that possess higher water holding capacity.

Saturated hydraulic conductivity (K_{sat}) of field samples has decreased for all root zone treatments compared to the initial K_{sat} value measured in the laboratory; however, amendment root zone treatments had K_{sat} values greater than 30 cm/hour (12 inches/hour). It should be noted that air encapsulation in root zone samples was minimized before the measurement of K_{sat} in these tests. Thus, the K_{sat} values reported may appear rather high compared to those values reported by commercial laboratories. See 1998 summary of research reported in Atlanta for more information on this issue.

Microenvironment influenced plant rooting response within two growing seasons; less root mass was observed in the enclosed (lower) microenvironment. Lower root mass in the enclosed microenvironment was associated with higher bulk density and lower total porosity in the root zone. Changes in soil physical properties will continue to be monitored. It is expected that changes in soil physical properties will continue. These changes may be important for long term performance of bentgrass grown as putting green turf.

Additional data for the amendment and sand size distribution studies are being summarized and will be reported in 2001.

INTRODUCTION

The suitability of root zone mixtures for turfgrass growth is determined by laboratory testing of soil physical properties, and is based on United States Golf Association sponsored research conducted in the 1950's. Kunze (1956) correlated Bermudagrass (*Cynodon dactylon* L.) and Howard (1959) correlated Bentgrass (*Agrostis palustris* Huds.) performance to soil physical properties. This work led to the first golf putting green construction recommendations in 1960 (USGA Green Section Staff, 1960). Since the original recommendations, there have been three revisions. The latest revision (USGA Green Section Staff, 1993) includes soil physical property specifications based on Kunze and Howard's research. Some critical specification values are: Saturated Hydraulic Conductivity (K_{sat}) at a rate of 15-30 cm^{-1} for the normal range, and 30-60 cm^{-1} for the accelerated range and porosity measurements: Total porosity - 35-55%, Air-filled porosity - 15-30%, Capillary porosity - 15-25%. Laboratory testing is conducted to determine if a particular combination of sand size distribution and amendment material will conform to these soil physical property ranges and will then be suitable as a root zone media for turfgrass growth. The original laboratory soil physical properties are used as the critical determinate of field performance, however very little information is available about changes in soil physical properties of root zone mixtures once turf is established on newly constructed golf greens. More information is needed concerning how soil physical properties of root zone mixtures change over time and impact turfgrass performance.

OBJECTIVES

1. Determine initial laboratory soil physical properties (K_{sat}, porosity, bulk density) of root zone mixtures differing in amendment source.
2. Determine soil physical properties of root zone mixtures collected from field plots of the same materials
3. Track changes in field soil physical properties from the initial laboratory results
4. Assess the impact of field soil physical properties on turfgrass performance

MATERIALS AND METHODS

Rootzone Mixtures

- Commercially available quartz sand (grade 313) acquired from US Silica
- Sand meets USGA recommendations for particle size distribution:

Table 1. Particle size distribution of US Silica 313.

Particle	USGA Size(mm)	%
Fine gravel	2.0 – 3.4	1.6
Very coarse sand	1.0 – 2.0	3.8
Coarse sand	0.5 – 1.0	20.7
Medium sand	0.25 – 0.5	52.2
Fine sand	0.15 – 0.25	18.7
Very fine sand	0.05 – 0.15	3.0
Silt and Clay	< 0.05	0.0

- Sand was combined with organic, inorganic and silt loam soil amendments for initial soil physical properties measured in the laboratory and construction of sand-based root zone plots in the field. The amendments and volume addition of amendments are listed in table 2.

Table 2. US Silica 313 sand amended root zone treatments for original laboratory testing and construction of in the field.

Amendment Source	% Amendment Addition by Volume
Sand alone (Check)	0
Silt Loam (Loam)	2.5
Silt Loam (Loam)	5
Silt Loam (Loam)	20
Sphagnum Moss Peat (Sph)	5
Sphagnum Moss Peat (Sph)	10
Sphagnum Moss Peat (Sph)	20
Dakota Peat (Dak)	5
Dakota Peat (Dak)	10
Profile (Pro)	10
ZeoPro (Zeo)	10

Laboratory Physical Property Measurements

- ASTM F-1815-97 procedures were used to measure K_{sat}, water retention at 1, 2, 3, 4, 5, 6, 7, 8 10, 33, 100, 200 kPa tension, and bulk density

Field Plots

- Field plots constructed in 1997 in two micro-environmental locations: An "Open" micro-environment with full exposure to sunlight and adequate air circulation (Figure 1) and an "Enclosed" microenvironment with partial shading and limited air circulation (Figure 2).
- Plots constructed to USGA recommendations with 4" of gravel underlying 12" of root zone mixture except for an additional Loam5% treatment constructed with 12" of root zone mixture placed directly on soil subgrade base (Loamsub5%).
- Plots seeded to 'L93' creeping bentgrass on 31 May 1998
- 3.0 lbs. N/1000 ft applied in 1998
- Cutting height reduced to 1/8-inch on 25 May 1999
- 4.6 lbs. N/1000ft applied in 1999
- Irrigation applied at 50-75% of pan evaporation; supplemental irrigation applied to individual treatments to avoid stress
- Plots compacted weekly with water filled roller to simulate compactive stresses

Soil samples from field plots

- 3-inch x 3-inch diam. core samples taken from plots in Oct. 1999 for soil physical property assessment
- Full plot depth root samples taken from plots in Oct. 1999

RESULTS AND DISCUSSION

Original laboratory physical properties

- The original laboratory physical properties are listed in table 3. All root zone mixtures fall within the recommended ranges for K_{sat} and porosity values.

Field physical properties and bentgrass response

- Total porosity, bulk density, bentgrass root mass, and bentgrass quality were affected by the micro-environmental location (Table 4). There was less root mass in the enclosed microenvironment than in the open microenvironment (Table 5). This response is likely due to the more stressful environmental conditions in the enclosed location. The lower root mass resulted in a tighter packing arrangement of the root zone mixture and a greater bulk density in the enclosed microenvironment (Table 5). As bulk density increases total porosity decreases. There was less total porosity for field samples in the enclosed microenvironment than the open microenvironment (Table 5).

Changes in physical properties over time

- K_{sat} decreased in field samples compared to the original laboratory properties for all root zone mixtures (Table 6). There is not a strong relationship between decreased K_{sat} and decreased air-filled porosity (Table 6 and Table 7).
- Root mass in the surface 3" likely contributes to the overall decrease in air-filled porosity, however, there is not a strong relationship between decreased air-filled porosity and root mass in the surface 3" inches among different root zone treatments. This indicates that other factors, such as the accumulation of organic matter, are also contributing to the decrease in air-filled porosity.
- Capillary porosity increased in the field samples compared to the original laboratory samples for all treatments except for Dak10% (Table 7). The decreases in air-filled porosity and increases in capillary porosity from original laboratory samples to field samples indicate that a shift towards finer pores is occurring in the field.
- Higher turf quality is not strongly related to field porosity measurements (Table 7). The different amendment sources affect the available fertility of the root zone mixture, which may be impacting turf quality independently of the soil physical properties.

Conclusions

- Physical property changes occur in root zone mixtures within two growing seasons of initial establishment in the field. K_{sat} and air-filled porosity of the mixtures decrease while capillary porosity increases. The presence of roots in the root zone mixtures is likely contributing to the shift in pore size distribution.
- Micro-environmental location influences plant rooting response within two growing seasons. The rooting response affects the bulk density, which in turn affects the total porosity.

- Changes in soil physical properties will continue to be monitored. It is expected that changes in soil physical properties will continue. These changes may be important for long term performance of bentgrass grown as putting green turf.

References

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Table 3. Initial laboratory K_{sat}, porosity, and bulk density of sand/amendment root zone mixtures.

Rootzone Mixture	Volume	K_{sat}	Air Filled Porosity	Capillary Porosity	Total Porosity	Bulk Density
	(%)	(cm hr^{-1})	(%)	(%)	(%)	(g cm^{-3})
Sand (check)	0	109.7	16.6	22.1	38.7	1.62
Sph	5	123.8	15.1	25.0	40.1	1.59
Sph	10	104.0	12.2	28.6	40.8	1.57
Sph	20	100.3	12.9	31.5	44.4	1.47
Dak	5	93.3	12.7	26.9	39.6	1.60
Dak	10	74.8	12.0	29.4	41.4	1.55
Loam	2.5	75.2	19.9	18.8	38.7	1.62
Loam	5	61.3	20.4	18.3	38.7	1.62
Loam (Sub.)	5	63.5	20.4	18.3	38.7	1.62
Loam soil	20	47.4	19.4	18.2	37.6	1.65
Pro	10	109.6	21.5	22.2	43.7	1.49
Zeo	10	NA	22.5	19.3	41.8	1.54
$LSD_{0.05}$		4.9	1.3	0.8	0.6	0.02
C.V.(%)		6.6	7.6	3.6	1.6	1.1
ANOVA source				*P>F*		
Rep		NS	NS	NS	NS	NS
Amendment		***	***	***	***	***

*** Significant at the 0.001 probability level; NS = not significant at *P*0.05.

Table 4. Analysis of variance of K_{sat}, air-filled porosity, capillary porosity, total porosity, bulk density, surface 3-inch root mass, and 1999 seasonal turf quality rating average as affected by location and root zone mixture in the field.

	K_{sat}	Air filled porosity†	Capillary porosity†	Total porosity	Bulk Density	Surface 3-inch root mass	1999 Turf Quality Avg.††
ANOVA Source				*P<F*			
Rep(Location)	NS	NS	NS	NS	NS	NS	NS
Location	NS	NS	NS	**	**	*	*
Mixture	***	**	***	***	***	*	***
LocationXMixture	NS	NS	NS	NS	NS	NS	NS

*,**,*** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively; NS = not significant at $P \leq 0.05$.

† Air-filled and capillary porosity measured at –3kPa.

†† Rating scale 1-9; 9=best.

Table 5. Total porosity, bulk density, and surface 3-inch root mass in two micro-environmental locations in the field.

Location	Total porosity†	Bulk Density†	Surface 3-inch root mass††
	(%)	(g cm^{-3})	(mg cm^{-3})
Open Location	39.3	1.61	3.58
Enclosed Location	38.1	1.64	2.99

† Samples removed from the field and physical properties determined in the laboratory.
†† Full plot depth root samples sectioned into 4 3-inch sections; root sample depth corresponds to depth of samples removed for soil physical property testing.

Table 6. Lab and field K_{sat} and difference between lab and field K_{sat} of sand/amendment root zone mixtures.

Rootzone Mixture	Lab K_{sat}	Field K_{sat}	Diff. K_{sat}
	(cm hr^{-1})	(cm hr^{-1})	(cm hr^{-1})
Sand (check)	109.7	81.3	-28.4
Sph5%	123.8	81.1	-42.7
Sph10%	104.0	74.3	-29.7
Sph20%	100.3	63.9	-36.4
Dak5%	93.3	69.6	-23.7
Dak10%	74.8	67.5	-7.3
Loam2.5%	75.2	67.9	-7.3
Loam5%	61.3	56.2	-5.1
LoamSub5%	63.5	59.1	-4.4
Loam20%	47.4	37.5	-9.9
Pro10%	109.6	82.8	-26.8
Zeo10%	NA†	71.4	NA†
$LSD_{0.05}$	4.9	5.2	6.7
C.V. (%)	6.6	7.8	56.7

† Data not available.

Table 7. Lab and field air-filled and capillary porosity, surface 3-inch root mass and 1999 turf quality average of sand/amendment root zone mixtures.

Root Zone Mixture	Lab Air-filled porosity	Field Air-filled porosity	Diff. Air-filled porosity	Lab Capillary porosity	Field Capillary porosity	Diff. Capillary porosity	Surface 3-inch root mass	1999 Turf Quality Avg.†
	(%)	(%)	(%)	(%)	(%)	(%)	(mg cm^{-3})	(1-9)
Sand (check)	16.6	10.5	-6.1	22.1	26.5	4.4	3.15	6.6
Sph5%	15.1	11.3	-3.8	25.0	27.1	2.1	3.57	7.0
Sph10%	12.2	9.7	-2.5	28.6	29.5	0.9	3.82	7.1
Sph20%	12.9	9.2	-3.7	31.5	32.4	0.9	3.13	7.6
Dak5%	12.7	11.8	-0.9	26.9	27.2	0.3	3.49	7.1
Dak10%	12.0	10.9	-1.1	29.4	29.4	0.0	2.80	7.5
Loam2.5%	19.9	11.2	-8.7	18.8	25.6	6.8	3.54	6.7
Loam5%	20.4	10.8	-9.6	18.3	26.3	8.0	3.08	7.0
LoamSub5%	20.4	11.1	-9.3	18.3	25.9	7.6	3.02	6.9
Loam20%	19.4	10.3	-9.1	18.2	26.3	8.1	3.18	6.3
Pro10%	21.5	12.9	-8.6	22.2	27.9	5.7	3.51	5.7
Zeo10%	22.5	13.8	-8.7	19.3	26.4	7.1	3.16	6.4
$LSD_{0.05}$	1.3	1.2	1.8	0.8	1.0	1.3	0.58	0.4
C.V. (%)	7.6	10.5	29.6	3.6	26.0	31.1	17.5	3.7

† Rating scale of 1-9; 9 = best.