THE SLOPING GREEN: EFFECT OF ROOTZONE MATERIAL AND DEPTH ON MOISTURE RETENTION IN USGA PUTTING GREENS

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1. Introduction

Many new putting greens are constructed according to USGA specifications, which require a sandy rootzone mix over a pea gravel layer. This layered profile holds water at the interface of the rootzone mix and the pea gravel (perched water table), and provides desirable aeration, resistance to compaction, water retention, and drainage. However, two distinct phenomena that limit turfgrass vigor and confound turfgrass managers have been associated with these putting greens, particularly those with an undulating design. These phenomena, "Localized Dry Spot" and "Black Layer", can both be directly attributed to moisture extremes in the soil module: dry and very likely water repellent conditions on the elevated areas and wet, soggy conditions in the low areas of some greens.

Specifications for the rootzone mix of USGA putting greens require a sand mixture at a uniform depth of 30 cm (12") across the entire surface of the green. However, the uniform depth of the rootzone mix does not account for the lateral flow of water in a sloping rootzone. Lateral flow occurs in sloping soil profiles when gravitational forces acting on the water become greater than the capillary forces of the soil. This lateral flow leads to a lower water content in high areas of the putting green resulting in dry soil conditions and susceptibility to LDS. The water flows to the lower parts of the green causing a greater water content closer to the surface. This is the location where Black Layer most frequently occurs.

A study was initiated in summer 1997 to study the effects of different rootzone depths and materials (sand, sand/peat, and sand/soil) on water flow and soil moisture content in a sloped USGA putting green. The aim of the study was to investigate if altering the rootzone depth would increase the water content near the soil surface in high areas and decrease the water content of the rootzone mix in low areas. This would relieve areas of elevation extremes from moisture stress and thereby reduce the occurrence of LDS or Black Layer.

2. Material and Methods

A 36 m x 25 m (120' x 80') sized USGA type research green was built in spring 1998. The profile of the green (from North to South) consists of a 2.3 m (8') long flat portion (toeslope North), followed by a seven percent 5.3 m (17.3') long slope (backslope North) to the summit, followed by a three percent 12.2 m (40') long downward slope (backslope South), followed by a final 4.5 m (14.7') long flat portion (toeslope South). The entire putting green was subdivided into twelve 2.5 m x 25 m (8' x 80') plots. Four of the plots were filled with sand, four with a 80:20 sand/peat mix, and four with a 80:20 sand/soil mix. Two of each group of four plots have a rootzone mix with a uniform 30 cm (12") depth after settling and two have a rootzone mix depth varying from 20 cm (8") at higher elevations to 40 cm (16") at lower elevations after settling. All rootzone mixes overlay a 10 m (4") deep layer of pea gravel. Treatments were assigned to the plots in a randomized split-block design. Barriers were placed along the length of each plot, and each plot was lined with PVC plastic to prevent lateral movement of water from one plot to another.

The plots were seeded June 9 with *Agrostis palustris* cv. L93 at a rate of 4.8 g m^{-2} (0.8 lb/M). During establishment water and nutrients were kept at levels needed to achieve optimal shoot and root growth. During the first summer, data were collected on the soil physical properties of the mixes, on turf coverage over time (speed of grow in), and on weed and disease infestation. Soil moisture in the top 10 cm was measured on two occasions.

Particle Size Distribution and Soil Physical Properties

Prior to construction, rootzone materials were tested for particle size distribution, organic content, and soil physical properties following USGA guidelines (Hummel, 1993). Particle size analysis was conducted by separating sand particles (greater than 0.053 mm) from silt and clay through dispersion. After separation, sand particles were dry sieved through a set of sieves with a shaker and the samples were subsequently weighed. Saturated hydraulic conductivity and porosity were determined on soil cores (diameter: 7.6 cm [3"], height: 7.6 cm [3"]). Cores were filled with mixes, compacted, saturated for 24 hours and the saturated weight was recorded. For the determination of hydraulic conductivity, water flow through the saturated cores was maintained at a constant hydraulic head, collected for 20 minutes and the volume subsequently measured. Capillary porosity was calculated after extracting water from the cores at a matrix potential of -0.04 bar in pressure chambers. Particle densities were established using pycnometers and subjecting the contents to a partial vacuum. Organic matter content of the mixes was determined by loss on ignition at 440°C.

Turf Coverage

Turf coverage was estimated July 7 (four weks after seeding), July 22 and August 6 using a 0.3 m x 0.3 m (1' x 1') wooden frame with strings forming grid lines that were 5 cm (2") apart. The frame was dropped on the grass and turf coverage (0%, 25%, 50%, 75% and 100%) in each of the thirty-six 25 cm^2 (4in^2) grids was estimated. Turf coverage was determined for five locations (toe and backslope north , summit, and toe and backslope south) on each plot.

Weed and Disease Infestation

Weed infestation was assessed on July 23 and August 8 by counting broadleaf and grassy weed plants on each plot. Dollar Spot mycelia on each plot were counted on September 19.

Soil Moisture

Volumetric soil moisture in the top 10 cm (4") was measured by Time Domaine Reflectometry (TDR) on September 1 and 3. September 3 measurements were taken 24 hours after a rainfall event of 17 mm (3/4"). The average of three measurements is given for each location (toeslope north, summit, and toeslope south) on each plot.

3. Results and Discussion

Particle Size Distribution and Soil Physical Properties

Particle sizes and soil physical properties of the three rootzone mixes used in the study are given in Table 1.

Table 1. Particle size distribution and soil physical properties of sand, sand /peat and sand/soil mixes

Particle diameter (mm)	USGA limits		Sand	Sand/Peat	Sand/Soil
2.0-3.4	max 3%		0.1	0.1	0.8
1.0-2.0		max 10%	7.6	7.3	12.0
0.5-1.0			26.0	25.4	24.6
0.25-0.5		min 60%	45.6	46.4	36.6
0.15-0.25	max 20%		19.1	18.3	16.6
0.05-0.15	max 5%		0.6	1.1	1.3
<0.05	max 5% (Silt)		1.2	1.2	7.9
	max 3% (Clay)	max 10%			
Organic Matter (%)	1-5		1.2	3.2	2.0
Hydraulic conductivity (cm hr^{-1})	15-30		86.2	27.9	15.7
Bulk Density (g cm^{-3})			1.75	1.57	1.74
Part. Density (g cm^{-3})			2.64	2.35	2.66
Porosity					
Total (%)	35-55		35.2	42.8	36.0
Capillary (%)	15-25		8.9	16.7	15.8
Air filled (%)	15-30		27.3	26.1	20.2

The sand/peat mix met the USGA recommendations for particle size distribution and soil physical properties. Straight sand also met the recommendations for particle size distribution, but values for capillary porosity and hydraulic conductivity were outside the range set by the USGA for rootzone mixes. Particles greater than 1 mm made up more than 10% of the sand/soil mix, but soil physical properties were within USGA limits.

Turf Coverage

On all three dates turf coverage was lowest on the sand only plots, and highest on the sand/peat plots. On July 7 and 22 the differences were significant (Table 2). Type of construction (uniform vs. variable rootzone depth) had no influence on turf coverage.

Table 2. Turf coverage on three sampling dates (July 7, July 22, and August 6) for different rootzone mixes.

Rootzone	coverage (%)		
	July 7	July 22	August 6
sand/peat	38 a†	81 a	99 a
sand/soil	27 b	70 b	97 a
sand	7 c	37 c	70 b

† values in columns followed by the same letter are not significantly different from each other (α=0.05, Tukey's test for multiple comparison of means)

Table 3. Turf coverage on three sampling dates (July 7, July 22, and August 6) for different locations on plots.

Location	Coverage (%)		
	July 7	July 22	August 6
backslope N	31 a†	70 a	93 a
backslope S	24 ab	68 a	91 a
summit	26 ab	63 ab	89 a
toeslope N	20 b	54 ab	88 a
toeslope S	19 b	60 b	83 a

† values in columns followed by the same letter are not significantly different from each other (α=0.05, Tukey's test for multiple comparison of means)

Weed Infestation

On both counting dates, total weed counts and number of broadleaf weeds were highest on the sand/soil plots, followed by the sand/peat plots (Figure 1). Grassy weed counts were always highest on the straight sand plots. Rootzone depth of the plots had no influence on weed counts.

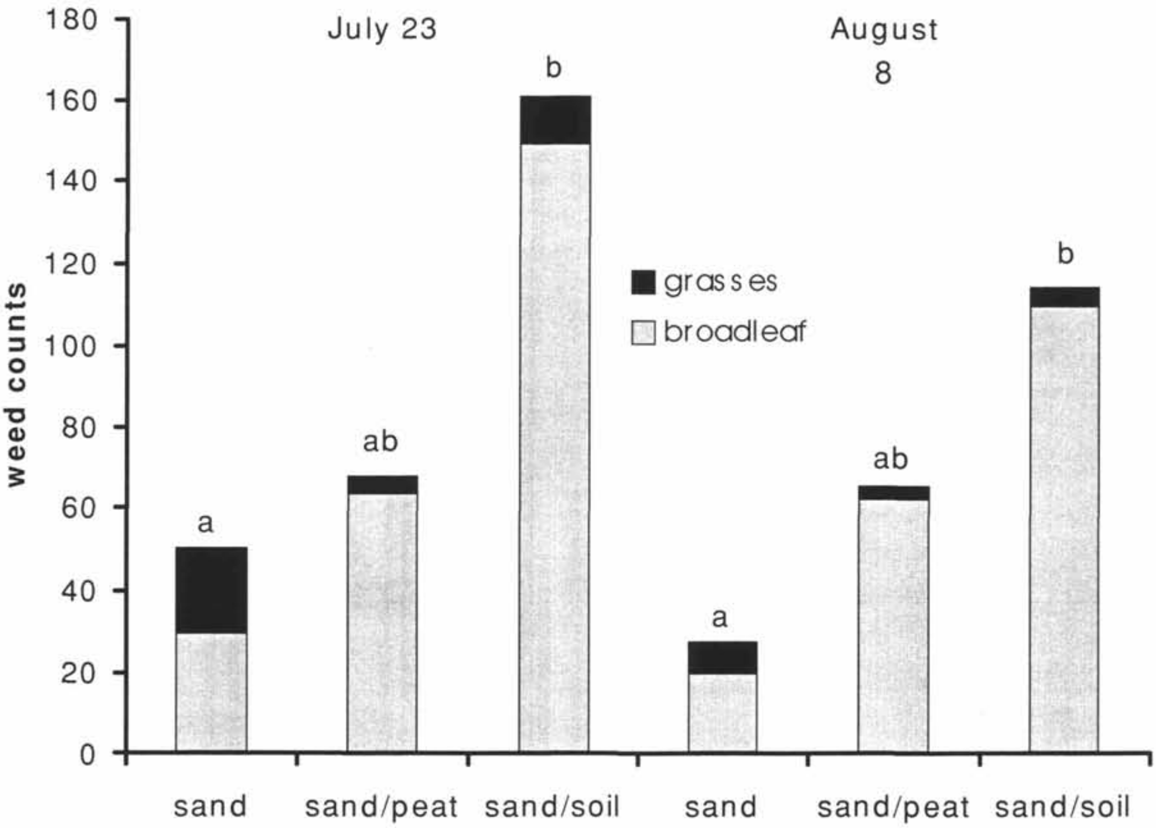

Figure 1 *Weed counts (grasses and broadleaf) on July 23 and August 8 for different rootzone mixes. Bars with the same letter on each sampling date are not significantly different from each other (a=0.05, Tukey's test for multiple comparison of means).*

Disease infestation

Dollar spot counts were lowest on the sand plots and highest on the sand/peat plots (Table 4). The differences were not statistically significant.

Table 4. Dollar spot counts for different rootzone mixes.

Rootzone	Counts
sand/peat	20
sand/soil	15
sand	4

Soil Moisture

On both sampling dates rootzone mix and depth significantly influenced soil moisture in the top 10 cm (4"). No differences in soil moisture were found between the North and South end toeslopes, therefore the data were pooled in subsequent analyses. Volumetric soil moisture for the different soil and construction types on the two sampling dates (September 1 and 3) are given in Tables 5 and 6.

Table 5. Volumetric soil moisture in top 10 cm of toeslopes and summits for different construction types on September 1 and 3

Construction type	Toeslope		Summit	
	Sept 1	Sept 3	Sept 1	Sept 3
uniform rootzone depth	13.5 a†	15.4 a	9.3 a	13.8 a
variable rootzone depth	6.9 b	11.3 b	11.0 a	15.4 b

† values in columns followed by the same letter are not significantly different from each other (α=0.05, Tukey's test for multiple comparison of means)

Table 6. Volumetric soil moisture in top 10 cm of toeslopes and summits for different rootzone mixes on September 1 and 3

Rootzone mix	Toeslope		Summit	
	Sept 1	Sept 3	Sept 1	Sept 3
sand/peat	12.6 a†	17.0 a	15.2 a	19.3 a
sand/soil	10.3 ab	14.5 b	11.3 b	17.5 a
sand	7.8 b	8.6 c	4.1 c	7.1 b

† values in columns followed by the same letter are not significantly different from each other (α=0.05, Tukey's test for multiple comparison of means)

Comparison of soil moisture in the three rootzone mixes confirmed laboratory results (Table 6). The sand/peat mix held the most water, followed by the sand/soil mix.

These preliminary results support the hypothesis that greater rootzone depths at the lower ends of sloping greens would result in significantly lower soil moisture, as demonstrated by the significantly lower soil moisture in the top 10 cm of plots with variable rootzone depths (Table 5). Furthermore, summits of plots with shallower rootzone mixes had significantly higher soil moisture in the upper 10 cm than plots with uniform rootzone mixes.

Acknowledgements:

The authors are grateful for the financial support of the Michigan Turf Foundation, Spartan Services Inc., TriTurf Inc., Rainbird, and Bruce Mathews from Design3. Without the generous support from these companies this research would not have been possible.

References

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