Rootzone Depth Affects Putting Green Performance

Research at Michigan State University demonstrates how varying putting green rootzone depth affects moisture retention.

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The United States Golf Association (USGA) introduced putting green construction guidelines 45 years ago, and since then the USGA green has become the standard for golf course putting greens. The concept behind the USGA guidelines is to build a green that provides a measure of resistance to compaction in the rootzone and drains quickly to an optimum soil moisture level.[5] Specifications for a USGA putting green require that the sandy rootzone mixture be placed at a uniform depth of 12 inches, plus or minus one inch, across the entire surface of the green. If greens lacked slopes, there is little doubt that most, if not all, USGA greens would perform well. However, with the severe slopes present on some putting greens today, USGA greens do not always perform ideally.

Putting greens constructed to USGA specifications function very well on a relatively level surface[4]; however, when the green has undulating areas, moisture extremes in the rootzone can lead to turfgrass decline.[3] Two conditions associated with moisture extremes in the rootzone are localized dry spot (LDS) and black layer. Both impair turfgrass growth and can be problematic on undulating sand-based putting greens.

Moisture variability problems on USGA putting greens could be attributed to the uniform depth of the rootzone layer. In theory, on a level surface, there is minimal lateral flow of water within the rootzone and the putting green drains at a uniform rate. However, Nektarios et al.[2] have shown that drainage in the rootzone is not always uniform. In an unsaturated putting green rootzone, water does not drain from the rootzone into the gravel layer, thereby allowing water to move laterally along the rootzone/gravel layer interface to lower elevations in the green. The resultant problems associated with this down-slope water movement are particularly evident at the higher elevations of the green, where hand watering is often necessary to prevent turf decline.

Research was initiated to investigate if altering the rootzone depth, decreasing it in high areas and increasing it in low areas, would increase the water content near the soil surface in high areas and decrease the water content near the soil surface in low areas. Our research objective was to determine if modifying the rootzone depth increases soil moisture uniformity across the slope of an undulating sand-based putting green.

MATERIALS AND METHODS

A sloped USGA putting green was constructed at the Hancock Turfgrass Research Center on the campus of Michigan State University in 1998. The putting green was designed for monitoring the down-slope movement of water in the rootzone. Time domain reflectometry (TDR) instrumentation was installed in the green to monitor soil volumetric water content (VWC).

The putting green was constructed with a summit 1.2 feet in height, with two downhill slopes of different magnitude. The peak of the summit was constructed 26 feet from the northern edge of the green and 55 feet from the southern edge. The putting green has a 7% north slope and a gradual 3% south slope. These slope gradients were chosen to represent average and extreme slopes that occur on modern USGA-recommendation putting greens.

The putting green was divided into 12 plots, 8 feet wide and 80 feet long. Six test plots were built to USGA specifications consisting of a uniform depth rootzone (12 inches). The remaining six test plots were built with a variable depth rootzone: 8 inches at the summit and gradually increasing in depth to 16 inches at the base of the slopes (toe slopes, Figure 1). Three rootzone mixes were used in the construction of both the USGA (uniform depth) and variable depth plots: sand, 85:15 sand/peat (reed-sedge), and 85:15 sand/soil. A polyvinyl chloride liner was placed between adjacent plots to prevent the lateral movement of water between plots.

Prior to construction, rootzone materials were tested for particle size distribution, organic content, and soil physical properties following USGA guidelines.[1] The sand/peat rootzone mix conformed to USGA specifications, but the sand/soil and sand rootzone mixes

Figure 1

Cross section view of the standard USGA and variable-depth construction methods. Mean percent volumetric water content for the 0- to 4-inch depth level is presented for day 3 of the dry-down period (2000-2002).

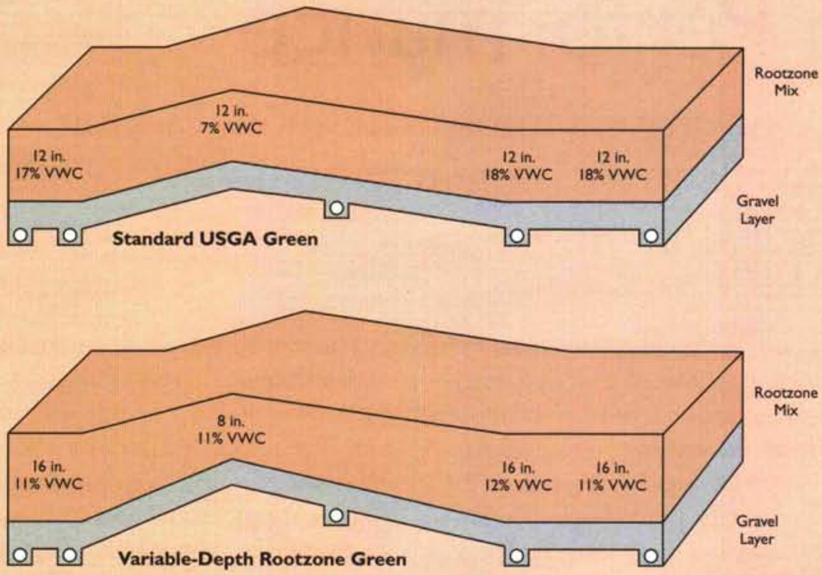

Table 1

Rootzone mix physical properties and particle size distribution.

Physical Properties	USGA Recommendation*	Rootzone Mix: Sand	Sand/Peat	Sand/Soil
Organic Matter (%)	1-5	1.20	3.20	2.00
Hydraulic Conductivity (cm hr^{-1})	Minimum 15	86.20	27.90	15.70
Bulk Density (g cm^{-3})	N/A	1.75	1.57	1.74
Particle Density (g cm^{-3})	N/A	2.64	2.35	2.66
Porosity:				
Total (%)	35-55	35.20	42.80	36.00
Capillary at 40cm tension (%)	15-25	8.90	16.70	15.80
Air Filled at 40cm tension (%)	15-30	27.30	26.10	20.20
Particle Size (mm)			%	
2.0 - 3.4†	Maximum 10	0.1	0.1	0.8
1.0 - 2.0		7.6	7.3	12.0
0.5 - 1.0	Minimum 60	26.0	25.4	24.6
0.25 - 0.50		45.4	46.6	36.8
0.15 - 0.25	Maximum 20	19.1	18.3	16.6
0.05 - 0.15‡	Maximum 5	0.6	1.1	1.3
0.002 - 0.05‡	Maximum 5	1.2	1.2	7.9
<0.002‡	Maximum 3			

*The USGA Green Section Staff, 2004
†Maximum of 3%, preferably none
‡Maximum of 10% total between the three categories

did not conform (Table 1). The sand/soil rootzone did not conform to specifications because of particle size distribution. The sand rootzone mix did not conform to USGA specifications for hydraulic conductivity and percent capillarity.

After the construction of the putting green was completed, 108 TDR probes (locally manufactured by B. R. Leinauer) were buried in the soil to measure volumetric soil moisture at four locations within each test plot: probe location 1 at the base of the north slope, probe location 2 at the summit, probe location 3 at the base of the south slope, and probe location 4 in the middle of the south toe slope (Figure 1). The TDR probes were positioned in the soil at a 45-degree angle to measure VWC at depths of 4-8, 8-12, and 12-16 inches. A hand-held TDR was used to record VWC at the four locations of the surface (0-4 inches).

After installation of the TDR probes in the summer of 1998, the putting green was seeded with L-93 creeping bentgrass. To evaluate soil moisture relationships, the putting green was subjected to "dry-down" cyles, with four cycles in each year from 2000 through 2002. Dry-down cycles were scheduled during dry periods without rainfall, and no irrigation was applied to the putting green. During each cycle, VWC was monitored daily with the TDR probes at the four locations in each plot. VWC was recorded at each location at depths of 0-4 inches and 4-8 inches. At the locations where depths were present, VWC was recorded at 8-12- and 12-16-inch depths.

Each dry-down cycle began with uniform, healthy turf across the entire putting surface. To establish near field capacity soil moisture content, irrigation (1 inch) was applied the night before each cycle, and the morning of "day 0" (0.5 inch). After the morning irrigation, TDR readings were taken at the four locations on each individual plot. The TDR readings were taken at 24-hour intervals for the length of the cycle.

\Table 2

Mean percent volumetric water content for the different rootzone types.

0-4 Inches Depth	Sand	Sand/Soil	Sand/Peat
	----------------	%	----------------
Aug. 23, 2000	15B†	25A	27A
Aug. 24, 2000	14C	21B	24A
Aug. 25, 2000	13C	18B	23A
Aug. 26, 2000	12C	18B	23A
July 23, 2002	18C	25A	27A
July 24, 2002	17B	23A	27A
July 25, 2002	14B	20A	21A
July 26, 2002	12B	18A	21A
Sept. 28, 2002	20B	27A	29A
Sept. 29, 2002	16B	22A	25A
Sept. 30, 2002	18B	24A	25A
Oct. 1, 2002	13C	21B	24A
4-8 Inches Depth			
July 10, 2002	17B	20A	22A
July 11, 2002	15B	19A	20A
July 12, 2002	14B	18A	20A
Sept. 28, 2002	18‡	20	31
Sept. 29, 2002	15B	19AB	22A
Sept. 30, 2002	16	19	21
Oct. 1, 2002	15B	17AB	21A

†Means in a row followed by the same letter are not significantly different according to t-test ($p=0.05$)

‡Data not followed by letters are not significantly different

Each dry-down cycle was ended after either 3 or 4 days, at which time there were visible signs of severe turfgrass moisture stress on the sand rootzone plots at the peak of the summit.

Statistical analysis was conducted independently for each day and for the measurement depths 0-4 and 4-8 inches, as these were the only depths present at each location within each test plot. Coefficient of variation (CV) was calculated for VWC data in each plot and analyzed for treatment differences. The CV is a relative measure of variation in the data, and it was used to assess the variability of VWC across the slope of the putting green.

RESULTS

Differences in Rootzone Type

VWC for rootzone type, when averaged across the two construction types, was significantly different throughout the dry-down cycles in 2000 and 2002. For the 0-4-inch depth, for the majority of sampling days, there were no differences in VWC among the sand/soil and sand/peat rootzones (Table 2). The sand rootzone consistently had the lowest VWC. For the 4-8-inch depth, the results were similar. There were no VWC differences between the sand/soil and sand/peat rootzones, and the sand rootzone had the lowest VWC. The results indicate that regardless of construction type, the water-holding capacity of the rootzone mixes containing soil or peat is higher than the sand rootzone. Sand rootzones with peat or soil added should not see the extremes in VWC that are often encountered in 100% sand rootzones.

Among USGA greens, the sand rootzone had the highest CV, indicating that the sand rootzone green had the greatest variation in VWC across the slope of the green. Generally, for the USGA greens, there were either no differences in CV among the sand/soil and sand/peat rootzones, or the sand/peat rootzone had the lower CV. For the variable-depth rootzones, there were either no differences in CV among the rootzones or the sand rootzone had the highest CV.

Differences in Construction Type

Comparisons between the two construction types reveal that uniform-depth sand greens had a higher CV than variable-depth sand greens on almost all dates. For the sand/soil greens, there were no differences between the construction types in 2000, but in 2002, the variable-depth rootzones had a lower CV on three of four dates. The sand/peat rootzones did not have a different CV, regardless of construction type. The CV data support our hypothesis that by altering the rootzone depth, the variability of VWC across the slope of the green, especially for the sand rootzone greens, can be greatly reduced.

Mean VWC:
Construction Type and Soil Type

On day zero, the greatest difference in VWC among sampling locations for all rootzone mixes with variable depths was 4%. On day three, the greatest difference among sampling locations was still only 4%.

Differences in VWC among locations remained consistent as the green dried down. In contrast, for USGA greens (with uniform rootzone depths), the greatest difference in VWC among locations on day zero was 6% and for day three was 11%. The differences between USGA (uniform depth rootzone) and variable-depth rootzone construction types on day zero was small (2%), but by day 3 was large (7%). These data further support our conclusions that for variable-depth rootzones, VWC was more uniform across the green.

Also, the difference in VWC among the sampling locations explains the high CV of the standard-depth greens. For the uniform-depth sand greens on day 3, the range in VWC included a low of 7% at location 2 (summit of slope) and

Table 3

Coefficient of variation for volumetric water content for construction and rootzone type, 0-4 inches rootzone depth.

	Construction Type	Sand	Sand/Soil	Sand/Peat
2000		------- Coefficient of Variation -------		
Aug. 23: Day 0	Standard	31	12	9
	Modified	12	11	9
Aug. 24: Day 1	Standard	44A† a‡	15Ba	20Ba
	Modified	20Ab	18Aa	16Aa
Aug. 25: Day 2	Standard	38¶	16	13
	Modified	29	16	25
Aug. 26: Day 3	Standard	43Aa	19Ba	16Ba
	Modified	11Ab	17Aa	15Aa
2002				
July 23: Day 0	Standard	24Aa	24Aa	8Ba
	Modified	14Aa	10Ab	14Aa
July 24: Day 1	Standard	30	21	10
	Modified	10	12	12
July 25: Day 2	Standard	45Aa	35Ba	15Ca
	Modified	32Ab	19Bb	19Ba
July 26: Day 3	Standard	42Aa	32Ba	22Ca
	Modified	22Ab	13Bb	16ABa

†Means in a row followed by the same upper-case letter are not significantly different according to t-test (p=0.10)

‡Means in a column, for each date, followed by the same lower-case letter are not significantly different according to t-test (p=0.10).

¶Data not followed by letters are not significantly different

Table 4

Mean percent volumetric water content for the 0- to 4-inch depth, 2000-2002.

	Location 1	Location 2	Location 3	Location 4
Day 0				
USGA Sand	21	15	21	20
USGA Sand/Peat	30	26	28	27
USGA Sand/Soil	29	23	27	25
Modified Sand	16	17	18	17
Modified Sand/Peat	26	28	24	24
Modified Sand/Soil	24	26	22	22
Day 3				
USGA Sand	17	7	18	18
USGA Sand/Peat	27	20	26	25
USGA Sand/Soil	27	16	24	21
Modified Sand	11	11	12	11
Modified Sand/Peat	21	22	18	19
Modified Sand/Soil	18	19	16	15

a high of 18% at locations 3 and 4 (Figure 1). In contrast, for the variable-depth sand greens, there was only a 1% difference in VWC among the locations.

CONCLUSIONS

The USGA specifications for putting green construction, first published in 1960, were designed to improve the quality of putting greens. Although the USGA has published several revisions, most recently in 2004, the recommendation for a uniform 12-inch rootzone layer has remained unchanged. The layering of a sand-based rootzone mix over a gravel layer maintains optimum moisture across the putting green on a relatively level putting surface; however, in areas of undulation the uniform rootzone depth can result in moisture extremes at the different elevations.

Our research confirmed that the addition of peat and/or soil to the rootzone mix increased water-holding capacity. Modifying the depth of the sand rootzone improved the uniformity of VWC across the surface of an undulating putting green. When soil or peat was added to the sand rootzone, extremes in soil moisture content between the high and low elevations of the green were reduced, regardless of construction type. For greens constructed with a 100% sand rootzone, it would be beneficial to modify the depth of the rootzone (i.e., shallower in high areas and deeper in low areas) to maintain uniform soil moisture content across the surface of the putting green. Although varying the rootzone depth in this way helps even out rootzone water content, constructing greens in this way may be too impractical and is not currently part of USGA putting green recommendations.

Even if greens are not constructed with a variable-depth rootzone, this research reveals the importance of closely following rootzone depth specifications during construction. Special attention should be given to following rootzone depth specifications

Researchers at Michigan State University investigated the hypothesis that reducing rootzone depth in higher-elevation areas and increasing depth of the rootzone in lower-elevation areas of contoured putting greens may result in more even moisture distribution across the entire putting green.

during construction and not making alterations based on aesthetics. In certain situations, rootzone material unfortunately is excavated from lower areas and moved to other regions of the green to increase elevation changes. The result is that the green would have a shallower rootzone depth in low areas and rootzone depths in excess of 12 inches in higher areas, a worst-case scenario. At a minimum, this research emphasizes the importance of closely monitoring construction activities to ensure that higher points in contoured putting greens do not have rootzone depths greater than 12 inches, which would cause "hot spots," and low points do not have rootzone depths that are too shallow, which could create excessive moisture conditions.

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Editor's Note: A more complete research report on this study may be found at: http://usgatero.msu.edu/-v04/n11.pdf.

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