EFFECT OF ROOTZONE MATERIAL AND DEPTH ON MOISTURE RETENTION PROBLEMS IN UNDULATING USGA PUTTING GREENS

B. Leinauer, P. Rieke, R. Calhoun, T. Nikolai,
D. Karcher, and J. Crum
Department of Crop and Soil Sciences
Michigan State University

Introduction

Since 1960, thousands of putting greens have been built in accordance, or close to, USGA guidelines. These putting greens have, for the most part, performed very well when managed properly (Bengeyfield, 1989). However, two distinct phenomena that limit turfgrass perforamnce, and confound turfgrass managers have been associated with these putting greens. These phenomena, "Localized Dry Spot" and "Black Layer", are both directly related to moisture extremes in the soil module (Cullimore et al., 1990; Berndt and Vargas, 1992; Tucker et al., 1990; Wilkinson and Miller, 1978) and pose a challenge for irrigation management.

Specifications for a USGA putting green requires that the sandy rootzone mixture be placed at a uniform depth of 30 cm (12"), across the entire surface of the green. This depth increases the amount of water held at the interface between the rootzone mix and the pea gravel, while avoiding complete saturation of the rootzone following irrigation (Dougrameji, 1965). However, this optimum will only occur throughout a putting green if it is not undulating. The uniform rootzone mix depth does not account for the lateral flow of water in a sloping rootzone. Lateral flow occurs in sloping soil profiles when gravitational and surface tension forces acting on the water become larger than the attraction of water to the soil. This lateral flow causes lower water contents in high areas of the putting green resulting in dry soil conditions and susceptibility to LDS. Water flows laterally to the lower parts of the green causing higher water contents closer to the surface in the same green. This is the location where Black Layer most frequently occurs.

A study conducted at Michigan State University and partly funded by the GCSAA (Golf Course Superintendents Association of America), by the O.J. Noer Foundation and the Michigan Turfgrass Foundation has the objective of examining the effects of different rootzone materials (sand, a sand peat mix, and a sand soil mix) and different rootzone depths on the water movement in sloping and flat areas of a golf green. The hypothesis of the study is, that altering the rootzone depth, decreasing it in high areas and increasing it in low areas, will increase the water content near the soil surface in high areas and decrease the water content of the rootzone mix in low areas. This should subsequently relieve areas of elevation extremes from moisture stress and decrease the possibility of LDS or Black Layer occurrence.

Materials and Methods

During Spring and Summer of 1998, a 950 m^2 (10,000 ft^2) research putting green was constructed at the Hancock Turfgrass Research Center at Michigan State University. The entire putting green is subdivided into 12 sloping plots. 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 more gradual 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) (Figure 1). Barriers in the form of particle board dividing walls and PVC liners were placed along the length of each plot to prevent lateral movement of water between plots. Each plot received one of three rootzone mixes; sand/peat, sand/soil, or straight sand. Three plots (one of each roozone type) have a rootzone mix with a uniform 30 cm (12") depth (USGA type) and three have a rootzone mix depth varying from 20 cm (8") at higher elevations to 40 cm (16") at lower elevations (modified USGA type). Drainage tiles were placed in trenches at strategic locations across the plots: at the extreme ends of each plot as well as at the end of each slope, and in the middle of the backslope of the 3% slope. The trenches were filled with gravel to cover the tiles and each tile was connected to solid pipe that discharges at the lower end of each slope. A series of 120 Time Domain Reflectometry (TDR) probes and cables were buried in the soil to measure soil moisture in 10 cm (4") increments at several locations in every plot. The plots are arranged in a two factorial complete randomized split-block design and are replicated twice. A Rainbird irrigation system was installed to provide uniform irrigation coverage for the entire green. The green was seeded with creeping bentgrass (Agrostis palustris) cultivar L-93 in June of 1998.

In 1999 data were collected on spring green up, Dollar Spot infestation, soil moisture, leaf surface temperature, drought ratings and rooting. All data, except soil moisture and Dollar Spot counts, were taken from five locations (toeslope North, backslope North, summit, backslope South, and toeslope South) per plot. Color ratings were taken on April 6 and April 20 on a scale from one to nine with one being yellow, straw colored and nine being dark green. Dollar spot counts were taken on July 13 by counting patches on all plots. Soil moisture readings were collected on 21 days during the summer using a TRIME portable TDR unit for the 0 to 10 cm depth. A Tektronix cable tester and a series of multiplexers were used to measure soil moisture with the permanently installed probes at depths of 10-20 cm, 20-30 cm and 30-40 cm. Soil moisture measurements were taken in the Northfacing toeslope, summit, and at two locations in the Southfacing toeslope. Plant drought stress was determined by using an infrared thermometer to measure leaf surface temperature over the course of a heat stress period, and by drought ratings at the end of the stress period. Leaf surface temperature readings were taken by aiming the thermometer at the turf areas from a height of one meter at an angle of approximately 45 degrees. The average of two readings, one with the thermometer facing East, one with it facing West were taken. Drought ratings were taken on a scale from one to nine with one being lush, fully turgid turf plants and nine corresponding to dry, dead turf. Root samples have not yet been analyzed and will be presented later.

Results and Discussion

Spring Green up

On both sampling dates green up ratings were lowest on the sand only plots, and highest on the sand/peat plots. The differences were significant on April 6 for construction type (uniform vs. variable rootzone depth) (Table 1) and on both dates for type of rootzone (Table 2).

Table 1. Spring green up ratings (9=dark green, 1=straw, yellow colored) on two sampling dates (April 6 and April 20) for different locations averaged over construction and rootzone types.

Location	April 6	April 20
Toeslope North	6.5 a†	7.5 a
Backslope North	5.0 b	7.1 ab
Summit	4.3 c	6.8 b
Backslope South	4.9 b	7.4 a
Toeslope South	4.8 b	7.3 a

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

Table 2. Spring green up ratings (9=dark green, 1=straw, yellow colored) on two sampling dates (April 6 and April 20) for different rootzone types averaged over all locations and construction types.

rootzone type	April 6	April 20
sand	4.5 a†	6.6 a
sand/soil	5.2 b	7.4 b
sand/peat	5.6 c	7.7 b

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

The ratings indicated that Spring green up was more greatly influenced by soil moisture than by sunshine. Locations that were facing North and quite possibly stayed wetter longer, greened up faster than locations exposed to more sunshine. The importance of soil moisture on Spring green up was supported by the results of green up ratings for the three soil types (Table 2). The lowest rating was given to straight sand, which has the lowest water holding capacity, followed by sand/soil, then sand/peat, which has the highest water holding capacity.

Dollar Spot

Dollar spot counts were lowest on the sand plots and highest on the sand/peat plots (Table 3). The differences were statistically significant and can most likely be correlated to the occurrence of dew and guttation water. In the mornings dew and guttation sat much longer on the sand/peat and sand/soil plots than on the sand plots. Disease infestation was not influenced significantly by construction type.

Table 3. Dollar Spot patches per plot on June 13 for different rootzone types averaged over construction types.

rootzone type	Dollar spot counts/plot
sand	72 a†
sand/soil	188 ab
sand/peat	324 b

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

Soil Moisture

Soil moisture measurements were taken on 21 days in June, July, August and September of 1999. On all 21 days there was a significant location by depth interaction for soil depths from 0 to 10 cm and 10 to 20 cm. This significant interaction indicates that soil moisture in the upper 20 cm (8") in low and high areas of an undulated USGA green can be improved (decreased in low areas and increased in high areas) by altering the depth of the rootzone. Volumetric soil moisture values for two (June 21 and September 2) of the 21 days period are given in Table 4 and 5. The results obtained on all other days showed the same tendencies. Numbers in Table 4 represent a 'wet' day, as the readings were taken four to six hours after an irrigation event which applied water at rates that were 50% above the normal irrigation rate. Numbers in table 5 represent a 'dry' day, as the green was only irrigated to a minimum, and no additional precipitation had fallen for more than a week.

Table 4. Volumetric soil moisture for different construction types (modified USGA green vs. standard USGA green) at different depths (0 to 10 cm and 10 to 20 cm), different locations (summit vs. toeslope) and different rootzone types (sand, sand/soil, and sand/peat) on a 'wet' day (June 21).

		0 to 10 cm			10 to 20 cm		
Location	Rootzone	Construction type			Construction type		
		modified	standard		modified	standard	
	Sand	8.1 a†	5.0 a	*	8.1 a	3.9 a	*
Summit	Sand/Soil	15.8 b	14.7 b	n.s.	12.2 b	9.1 b	*
	Sand/Peat	19.1 c	18.9 b	n.s.	16.6 c	14.2 c	*
	Sand	8.7 a	14.4 a	*	8.1 a	16.4 a	*
Toeslope	Sand/Soil	15.8 b	20.8 b	*	12.2 b	16.6 a	*
	Sand/Peat	19.1 c	21.8 b	n.s.	14.9 c	18.0 b	*

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

* values differ significantly from each other for construction types (a=0.05, Fisher's LSD test for multiple comparison of means)

Table 5. Volumetric soil moisture for different construction types (modified USGA green vs. standard USGA green) at different depths (0 to 10 cm and 10 to 20 cm), different locations (summit vs. toeslope) and different rootzone types (sand, sand/soil, and sand/peat) on a 'dry' day (September 2).

		0 to 10 cm			10 to 20 cm		
		Construction type			Construction type		
Location	Rootzone	modified	standard		modified	standard	
	Sand	3.5 a†	3.5 a	n.s.	8.8 a	3.3 a	*
Summit	Sand/Soil	8.6 b	6.9 b	*	14.0 b	11.8 b	*
	Sand/Peat	13.7 c	6.3 b	*	15.7 c	15.6 c	n.s.
	Sand	10.0 a	15.3 a	*	11.7 a	16.9 a	*
Toeslope	Sand/Soil	14.8 b	19.5 b	*	15.2 b	16.8 a	*
	Sand/Peat	17.7 c	18.6 b	n.s.	17.2 c	16.7 a	n.s.

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

* values differ significantly from each other for construction types (a=0.05, Fisher's LSD test for multiple comparison of means)

Readings for the 'summit' locations showed a consistent and significant increase in soil moisture at 0 to 10 cm and 10 to 20 cm depths for sand/soil and sand/peat rootzones when the rootzone depth was reduced to 20 cm (modified USGA green). On especially dry days, the grass plants on the straight sand plots used up the available water in the top 10 cm to such an extent that altering the rootzone depth could not *compensate* for the little water holding capacity of the sand. Both construction types dried out to an equally low soil moisture content of 3.5% on the summits (table 5). The data also suggest 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 20 cm of plots with variable rootzone depths. The irrigation prior to the 'wet' day was obviously not sufficient to wet the entire soil profile: soil moisture readings for the top 10 cm on all locations were higher than readings at depths from 10 to 20 cm. But even under these circumstances the top 20 cm for all rootzone mixes at the toeslopes of the modified USGA plots was significantly drier than the top 20 cm of the standard USGA depth plots.

Drought Stress

Drought ratings taken on September 2 were significantly higher on the straight sand than on the other two rootzone mixes (table 6), but showed no significant differences between construction types. Similarly, leaf surface temperatures on summits and on back slopes did not differ significantly between construction types. However, temperatures taken on toeslope south locations were significantly higher on the modified construction type plots than on the standard USGA type plots (table 7). The higher temperatures in the low areas of the modified USGA plots are a reflection of the lower moisture contents in the top 20 cm of these plots. Of all rootzone types, straight sand had the highest surface temperature readings (table 8).

Table 6. September 2 drought ratings (9=dead turf, 1=lush, fully turgid turf) for different rootzone types averaged over all locations and construction types.

rootzone type	**Ratings**
sand	4.3 a†
sand/soil	3.4 b
sand/peat	3.2 b

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

Table 7. Leaf surface temperature (°C) at southfacing toeslope location for different construction types averaged over all rootzone types.

construction type	**Surface Temperature (°C)**
USGA	28.4 a†
modified USGA	30.9 b

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

Table 8. Leaf surface temperature (°C) for different rootzone types averaged over all locations and construction types.

rootzone type	**Surface Temperature (°C)**
sand	32.0 a†
sand/soil	28.9 b
sand/peat	29.0 b

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

Conclusion

These preliminary results support the hypothesis that greater rootzone depths at the lower ends of sloping greens would result in significantly lower soil moisture in the top 20 cm, and high areas with shallower rootzone mixes would result in higher soil moisture in the upper 20 cm compared to areas with an uniform 30 cm (12") deep rootzone mix. However, while the turf cover on elevated areas of modified USGA greens might improve substantially during periods of drought, the greater rootzone depth at the low spots could lead to a greater susceptibility to drought stress. Different rootzone depths for different climate zones in the low areas of undulated USGA greens might have to be considered. Further research is needed to determine the optimal rootzone depth, especially at the low areas of modified USGA type greens.

Acknowledgements:

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

References

Bengeyfield, W. H. 1989. Specifications for a Method of Putting Green Construction. USGA. Golf House, Far Hills, New Jersey.

Berndt, W. L., and J. M. Vargas Jr. 1992. Elemental Sulfur Lowers Redox Potential and Produces Sulfide in Putting Green Sand. Hort. Sci. 27:1188-1190.

Cullimore, D. R., S. Nilson, S. Taylor, and K. Nelson. 1990. Structure of a Black Plug Layer in a Turfgrass Putting Sand Green. J. Soil Water Conserv. 90:657-659.

Dougrameji, J. S. 1965. Soil-Water Relationships in Stratified Sands. Ph.D. diss. Michigan State University.

Tucker, K. A., K. J. Karnok, D. E. Radcliffe, G. Landry, Jr., R. W. Roncadori, and K. H. Tan. 1990. Localized Dry Spots as Caused By Hydrophobic Sands on Bentgrass Greens. Agron. J. 82:549-555.

Wilkinson, J. F., and R. H. Miller. 1978. Investigation and Treatment of Localized Dry Spots on Sand Golf Greens. Agron. J. 70:299-304.

Figure 1: Cross section through plots with variable rootzone depth and different locations for measurements: toeslope North (a), backslope North (b), summit (c), backslope South (d), and toeslope South (e)