SLOPING GREEN RESEARCH UPDATE 2002

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Introduction

The United States Golf Association (USGA) introduced guidelines for constructing putting greens over thirty years ago and since then the USGA green has become the standard for golf course putting greens. The concept behind the USGA recommendations for putting green construction is to build a green that provides a measure of resistance to compaction in the rooting zone and drains quickly to an optimum soil moisture level. If greens lacked slopes there is little doubt that most, if not all, USGA greens would perform well. However with the slopes present on putting greens today, the USGA greens do not always perform ideally. Two problems that have commonly been encountered on greens are "Localized Dry Spot" (LDS) and "Black Layer". These problems are primarily associated with extremes in soil moisture in the rootzone of the green (Wilkinson and Miller, 1978; Tucker et al., 1990; Cullimore et al., 1990; Berndt and Vargas, 1992).

Specifications for a USGA putting green require that the sandy rootzone mixture be placed at a uniform depth of 30 cm (12"), across the entire surface of the green. However, 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.

Objective:

Research was initiated in 1998 at the Hancock Turfgrass Research Center to investigate whether or not 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.

Materials and Methods

In 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 rootzone type) have a rootzone mix with a uniform 30 cm (12") depth (standard 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 (Figure 1). The trenches were filled with gravel to cover the tiles and each tile was connected to a solid pipe that discharges at the lower end of each slope to a rain tipping bucket. 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 factor 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 2002, data were collected on soil moisture, leaf surface temperature, turfgrass quality and color, rootzone gases, and quantity of drainage water from various regions of the green. Turfgrass quality, color, and leaf surface temperatures were taken from five locations per green (toeslope North, backslope North, summit, backslope South, and toeslope South). Soil moisture readings were collected for four different ‘dry down cycles’ during the summer using a TRIME portable TDR unit for the 0 to 10 cm depth. A TDR100 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 (TDR location 1), summit (TDR location 2), and at two locations in the Southfacing toeslope (TDR locations 3 and 4) (Figure 1). Sampling point chambers to measure rootzone gases were installed in the north toeslope of the green. Chambers were buried to allow sampling in the USGA and modified greens at depths of 0-10, 10-20, 20-30, and 30-40 cm. With the use of 60 rain tipping buckets it was possible to quantify all of the water draining from the green at five locations (Figure 1). Data from the rain tipping buckets were collected throughout 2002 and data are currently being analyzed to determine water drainage patterns from the green.

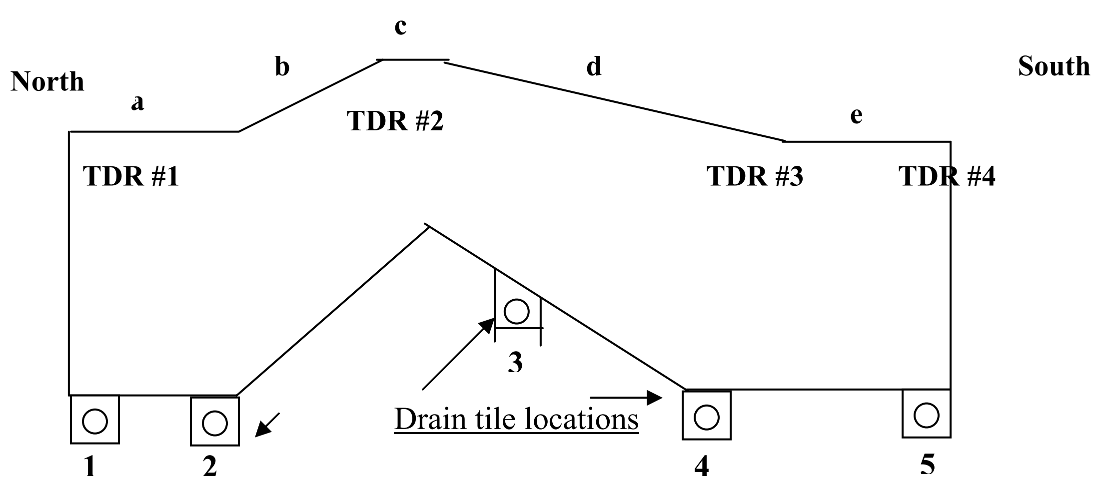

Figure 1. Cross section through plots with variable rootzone depth and different locations for measurements: (a) toeslope North, (b) backslope north, (c) summit, (d) backslope South, (e) toeslope south.

Results and Discussion

There were no consistently significant differences observed in quality, color, or leaf surface temperatures among the treatments in 2002. At several sampling times, there were significant location x construction type x rootzone mix interactions for turfgrass quality but analysis of the three way interaction revealed no important differences among the treatments. At several sampling times, the 100% sand rootzone greens had color and quality ratings that were significantly lower than the sand/soil and sand/peat rootzone mixes.

The abundant amount of sunshine and the use of a mylar wind screen improved the reliability of the leaf surface temperature readings taken in 2002. However as in 2000 and 2001, there were no significant differences in leaf surface temperatures among the treatments.

Soil Moisture

During the summer of 2002 there were four different 'dry down' cycles during which volumetric soil moisture measurements were taken using TDR probes. Data were analyzed separately by depth for the 0-10 and 10-20 cm depths. For the purpose of this report we will report only on the data in the 0-10 cm depth. Since the 20-30 and 30-40 cm depths are not present for both construction methods at all locations on the green, statistical comparisons of these depths was not conducted.

The location x construction type interaction was significant throughout the dry down cycles. The location x rootzone mix interaction was significant at certain sampling dates but this interaction provides no information with respect to the effects of a variable depth rootzone mix on soil moisture relationships.

Location x Construction Type Interaction 0-10 cm depth

Volumetric soil moisture content data for days 1 and 4 of the three dry down cycles in 2002 are presented in tables 1 and 2, respectively. At the beginning of a dry down cycle, when the rootzone is near field capacity, the location x construction type interaction was significant on July 23 and September 28 (Table 1). For both dates at TDR location 3, soil moisture content was higher in the standard USGA construction type. Within the standard USGA construction type, volumetric soil moisture content was lowest at TDR location 2 for both the July 23 and September 28 sampling date.

Table 1. Volumetric soil moisture content for the location x construction type interaction at the 0-10 cm depth at the initiation of dry down cycles (day #1) in 2002.

		TDR Location			
Date	Construction Type	1	2	3	4
July 23	Standard	28.4 A[†]a[‡]	19.2 Ba	28.3 Aa	26.1 Aa
	Modified	22.1 Ab	22.4 Aa	19.7 Ab	20.5 Ab
Aug 25	Standard	27.8*	28.4	28.7	28.5
	Modified	27.7	29.3	27.9	26.6
Sept 28	Standard	28.6 Aa	21.4 Ba	29.4 Aa	26.7 Aa
	Modified	24.3 Aa	25.5 Aa	22.6 Ab	23.8 Aa

[†] Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

[‡] Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

* Data are not significantly different at p=0.05

At the end of the dry down cycles, day #4, the construction type x location interaction was significant at all sampling times in 2002. Within the modified construction type there were no differences in soil moisture content among locations, indicating that the modified USGA construction type had uniform soil moisture across the entire slope of the green (Table 2). Across the slope of the standard USGA construction type green, volumetric soil moisture content values were lower at the peak of the slope, TDR location 2, at all sampling times.

Comparisons of soil moisture content between construction types reveal that the modified USGA construction type had lower volumetric soil moisture content values at TDR locations 1, 3, and 4 at the August 28 and October 1 sampling dates (Table 2). Additionally, the modified USGA construction type had the highest soil moisture content at the peak of the slope, TDR location 2, for the August 28 sampling date.

Table 2. Volumetric soil moisture content for the location x construction type interaction at the 0-10 cm depth on the final day of dry down cycles (day #4) in 2002.

		TDR Location			
Date	Construction Type	1	2	3	4
July 13	Standard	21.0 A†a‡	11.6 Ba	22.7 Aa	22.3 Aa
	Modified	15.7 Aa	14.5 Aa	14.2 Aa	13.4 Ab
Aug 28	Standard	27.3 Aa	18.6 Bb	26.6 Aa	26.4 Aa
	Modified	20.1 Ab	21.5 Aa	19.2 Ab	19.3 Ab
Oct 1	Standard	24.4 Aa	14.8 Ba	21.4 Aa	21.0 Aa
	Modified	15.3 Ab	16.2 Aa	14.4 Ab	14.0 Ab

† Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

‡ Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Soil moisture content measurements from two dates in 2000 are presented in table 3. The results from 2002 are consistent with the results from our initial year of data collection in 2000 and indicate that the modified USGA construction type had lower volumetric soil moisture content than the standard USGA construction type at TDR locations 1, 3, and 4 on the Sept. 3 sampling date. Although the differences were not statistically significant, volumetric soil moisture content was greater at the peak of the slope, TDR location 2, for the modified USGA construction type on Aug. 31 and Sept. 3.

Table 3. Volumetric soil moisture content for the location x construction type interaction at the 0-10 cm depth at the initiation (day #1) and conclusion (day #4) of dry down cycles in 2000.

		TDR Location			
Date	Construction Type	1	2	3	4
Aug. 31 (Day #1)	Modified	17.5 A†b‡	20.8 Aa	16.2 Ab	17.6 Aa
	Standard	24.2 Aa	17.5 Ba	23.4 Aa	22.5 ABa
Sept. 3 (Day #4)	Modified	14.1 Ab	14.5 Aa	14.8 Ab	13.6 Ab
	Standard	21.2 Aa	11.3 Ba	20.8 Aa	19.1 Aa

† Means in a row (for each date alone) followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

‡ Means in a column (for each date alone) followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Rootzone Gas Analysis

In 2002, rootzone gases were sampled at several sampling times in accordance with on-going drydown cycles. Our interest in sampling rootzone gases was to determine the possible influence of a modified rootzone depth on rootzone gas concentrations. The samples were analyzed with a Soil Gas Analyzer from Soil Air Technology. One of the difficulties we experienced while collecting the data was that the instrument was not capable of reading carbon dioxide levels in excess of 5%. During the course of data collection we repeatedly withdrew samples from the rootzone that were in excess of 5% but we were not able to determine the actual values due to the limitations of the instrumentation. We have recently purchased an upgrade for the carbon dioxide sensor that will enable us to record carbon dioxide concentrations over 5%.

Data from the gas analysis is still preliminary in nature but initial results indicate higher oxygen and lower carbon dioxide concentrations in the modified depth rootzone construction method. The greatest differences were observed in the sand/soil and sand/peat rootzone mixes. For the July 11 sampling the carbon dioxide concentrations for the sand/peat and sand/soil rootzone mixes were in excess of the instruments recording ability. Using oxygen concentrations to predict carbon dioxide concentrations the predicted values were 10.1 and 9.4% carbon dioxide for the sand/soil and sand/peat rootzone mixes, respectively. These values are generally considered to be in excess of what would be favorable for turfgrass root growth.

In 2003, additional sampling of rootzone gases will occur throughout the entire season and with the aid of the new sensor technology we will be able to accurately quantify high carbon dioxide concentrations.

Drainage Water

Drainage water was quantified from the five locations throughout the summer of 2002, and data are currently being analyzed to determine water drainage patterns from the green.

Conclusions

1. A variable depth rootzone green 20 cm (8") in elevated areas and 40 cm (16") in low areas resulted in more uniform soil moisture across the entire slope of the green than a standard 30 cm (12") depth rootzone green.

2. Regardless of rootzone depth, the straight sand greens had greater extremes in soil moisture content across the slope of the green than the sand/peat and sand/soil rootzone mix greens.

References

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