Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

Ohio State University researchers constructed putting greens in elevated tables to investigate the effect of slope, rootzone profile, and rootzone mix on the drainage characteristics of water applied at high rates. Due to the slope and subsequent lateral water movement, they concluded, among other findings, that perched water may not reliably serve as a reservoir for turf water use across an entire surface of sloped greens.

Volume 2, Number 4
February 15, 2003

PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 215 projects at a cost of $21 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
904 Highland Drive
Lawrence, KS 66044
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

USGA Turfgrass and Environmental Research Committee

Localized Drought on Sloped Putting Greens with Sand-Based Rootzones

Guy Prettyman and Ed McCoy

SUMMARY

Gentle contouring and sloping surfaces are common features of putting greens. The effects of slope and putting green construction methods on soil water status and turf response was studied by withholding irrigation on experimental greens for a 10-day period. Some of our findings include:

- Putting green drainage continued for an extended period following heavy irrigation.
- As time progressed, green slope became an increasingly important factor influencing the soil water status of the experimental greens.
- Rootzones containing finer sand with both organic and topsoil amendments exhibited drought avoidance throughout the study duration.
- Turf drought stress was observed for coarser sand rootzones regardless of profile design, but only at upslope locations for greens at 4 % slope.
- Turf drought stress was associated with water contents less than 10 % (by volume) throughout a substantial rootzone depth.
- Perched water may not reliably serve as a reservoir for turf water use across an entire green surface.
- Rootzone amendments appear to play an important role in maintaining higher water contents and avoiding slope-induced drought stress.

Gentle contouring and sloping surfaces are common features of putting greens. These slopes in conjunction with a high sand content rootzone lead to lateral, subsurface flow of water (1, 2). This lateral subsurface flow, approximately one day after a heavy rain, can result in upwards of 10 % difference in soil water content across a 20-ft distance within the green.

There is also an interaction of slope-induced water contents with putting green profile design early in the drainage process. In this case, a one-tier (not containing a gravel drainage layer, Fig. 1) green design shows a greater lateral difference, and a two-tier (with a gravel layer, Fig. 1) green design shows a reduced lateral difference in water content.

These effects of green slope, rootzone composition and profile design were observed over two days following a simulated, heavy rain. Even with these differences, however, the overall soil water status of the green remained adequate, during this period, to avoid turf drought. Thus, even though treatment differences were observed, there appeared to be little short-term detrimental consequences from these differences. Yet the questions remain: will these differences persist over longer periods and how may these differences impact turf water relations after longer periods of time? Thus we conducted a longer duration study employing many of the factors of our previous work to help address these questions. We also sought any lessons to be learned that may help refine putting green construction steps.

The experimental greens

This research employed the experimental putting greens described in detail by Prettyman and McCoy (1, 2). Briefly, the study employed

Figure 1. Cross-section diagrams of the soil profile for a one-tier and two-tier putting green.

GUY PRETTYMAN received his M.S. degree from Ohio State University and ED MCCOY, Ph.D., is an Associate Professor of Soil Science at Ohio State University.

USGA Turfgrass and Environmental Research Online 2(4):1-8.
TGIF Record Number: 85739

Figure 2. The experimental putting greens used in this research. Shown are four of the 12 individual greens.

four soil profile and rootzone mix treatment combinations consisting of i) a one-tier soil profile containing a 9:1 (by volume) sand:sphagnum peat rootzone, ii) a one-tier profile containing a 6:2:2 (by volume) sand: biosolids compost: topsoil rootzone, iii) a two-tier soil profile containing the 9:1 sand: sphagnum rootzone, and iv) a two-tier soil profile containing the 6:2:2 sand: compost: topsoil mix.

Both rootzones met the particle size and physical property criteria for a USGA putting green (3). The 9:1 sand: sphagnum rootzone had an initial permeability of 20.8 in h^{-1} and the 6:2:2 sand: compost: topsoil root zone had a permeability of 12.6 in h^{-1}. Hereafter, these rootzones will be referred to as the higher permeability (HP) and lower permeability (LP) rootzones, respectively.

Gravel selection for the drainage layer of the two-tier greens and for the drainpipe trenches of the one-tier greens were based on the particle sizes of the respective rootzones corresponding to USGA guidelines for two-tier greens construction (3). The four profile design:rootzone mix treatment combinations were replicated three times for a total of 12 experimental greens. The profile design:rootzone treatments were housed in experimental greens that consisted of 4 x 24 ft wooden boxes supported by a legged, metal framework (Fig. 2). This allowed for slope adjustment by simply jacking and blocking one end of each experimental green to the desired height. Subsurface drainage was through drain pipe trenches placed into each unit at 2 and 17 ft from the downslope end, for an effective drain spacing of 15 ft. The experimental greens were seeded to ‘Penncross’ creeping bentgrass in July, 1996 and thereafter maintained at a mowing height of 3/16th inch.

Profile	Rootzone	Slope	Drainage rates 4 days	Drainage rates 10 days
		%	------- liter day^{-1} -------	
One tier	Higher permeability	0	1.4	0.10
		4	1.7	0.12
	Lower permeability	0	1.9	0.52
		4	5.1	1.41
Two tier	Higher permeability	0	0.4	0.04
		4	1.6	0.13
	Lower permeability	0	1.1	0.14
		4	4.0	0.27
Mean s.e.			0.4	0.10

Table 1. Mean drainage rates from the experimental greens after 4 and 10 days without irrigation.

The research approach

Our research on the effect of slope and greens construction method on soil water status and turf drought was conducted during the summer months of 1998 and 2000. In 1998, all greens were randomly adjusted to either 0 or 4 % slope and in 2000 this ordering of slopes was reversed so all greens were tested at both slopes. In each year following slope adjustment, the greens were given sufficient irrigation to completely fill the soil pore space. The greens were then allowed to drain for two days.

From day 3 to day 10, drainage outflow from the down slope drainpipe was measured daily. The outflow data was used to determine daily drainage rate from the experimental greens. Soil water content at 3 depths (3, 6 and 9 inches) and 5 locations (2, 7, 12, 17 and 22 ft from the downslope end) were also measured daily for each green. Finally, a photographic record of turf drought stress was collected throughout the study period. The greens did not receive any rainfall or irrigation throughout the experimental period.

Only a portion of the data collected in the study will be presented here. Specifically, we will present drainage rate and the soil moisture data for days four and ten. Turf response will also be shown for times later in the study where treatment effects were visually apparent.

Extended duration greens drainage rates

Throughout the study period, all the exper-

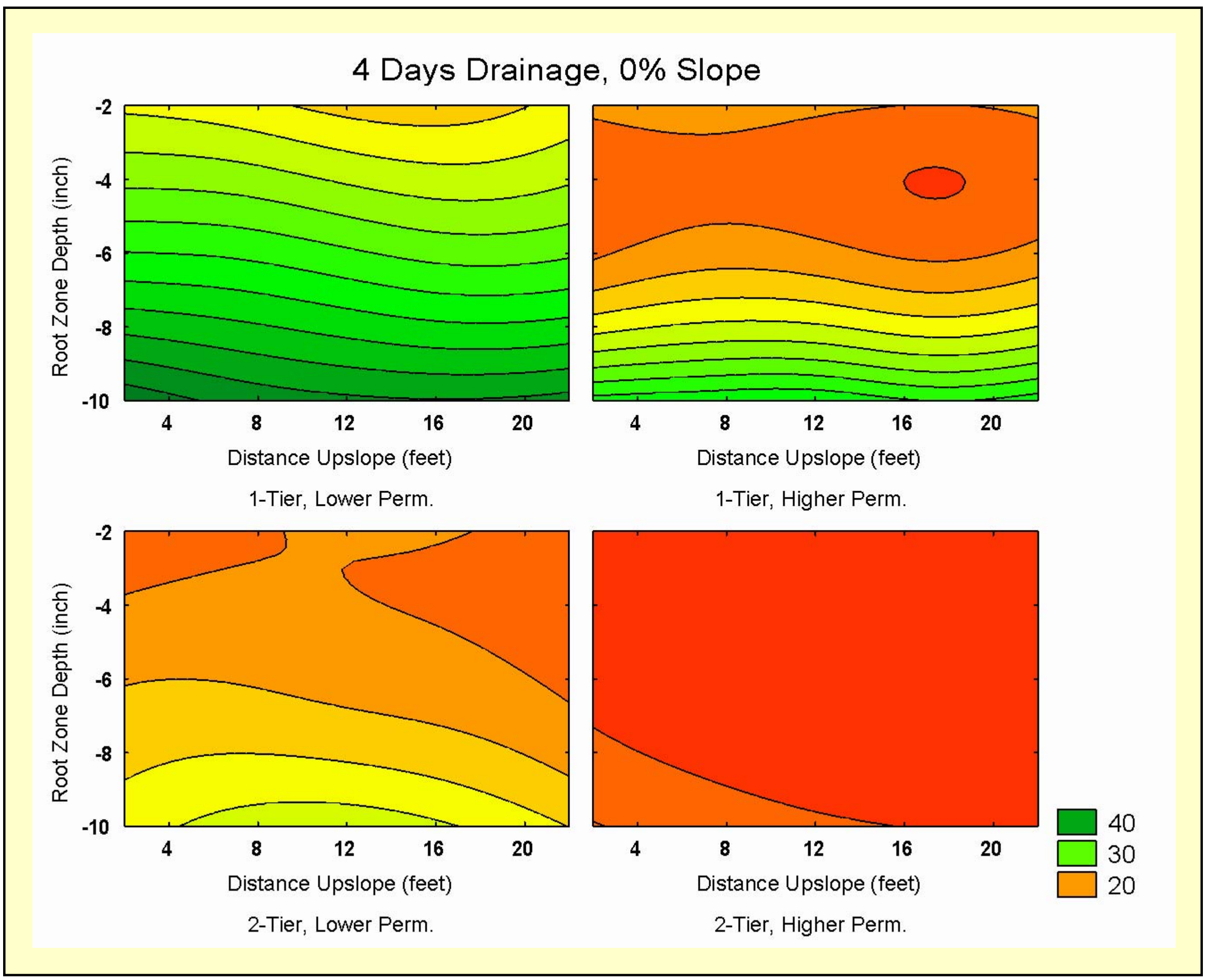

Figure 3. Mean water content (% by volume) of the experimental putting greens after 4 days of drainage and oriented at 0 % slope.

imental greens continued to drain from the downslope drainpipes (Table 1). Although these drainage rates were much less that those observed by Prettyman and McCoy (1), they were sufficient to yield treatment differences.

As expected, drainage rates declined throughout the study period with values for day 10 almost four times less than those at day 4. Yet, both the 4- and 10-day drainage rates showed similar treatment effects. The slope and rootzone permeability contrasts equally contributed to drainage rate such that the LP rootzones with 4 % slope consistently exhibited higher drainage rates. Both the increased driving force for water flow at 4 % slope and the overall increased water contents of the lower permeability rootzones are used to explain this result.

Also, the one-tier greens had higher drainage rates than the two-tier greens, again due to the overall larger water contents of the one-tier greens. Finally, drainage losses for all greens on day 4 were estimated to range from 0.1 to 0.8 mm per day, so that in some cases, drainage losses may contribute with ET to yield a measurable water loss from these soils for nearly a week after rainfall.

Rootzone water contents after drying

Green slope, rootzone permeability and profile design effects on soil water contents (% by volume) for days 4 and 10 are shown in Figures 3 to 6. In the individual figures, isobands of soil

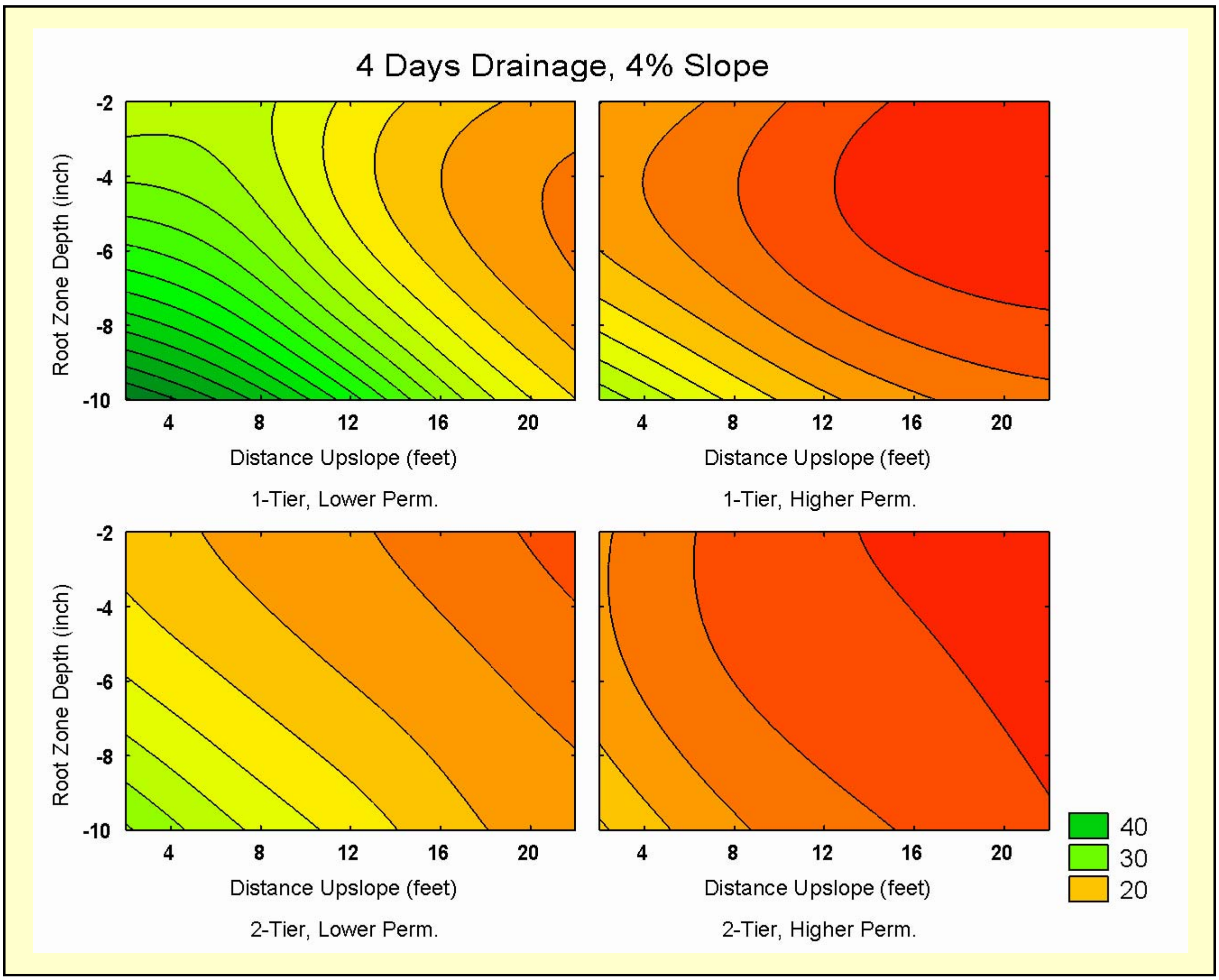

Figure 4. Mean water content (% by volume) of the experimental putting greens after 4 days of drainage and oriented at 4 % slope.

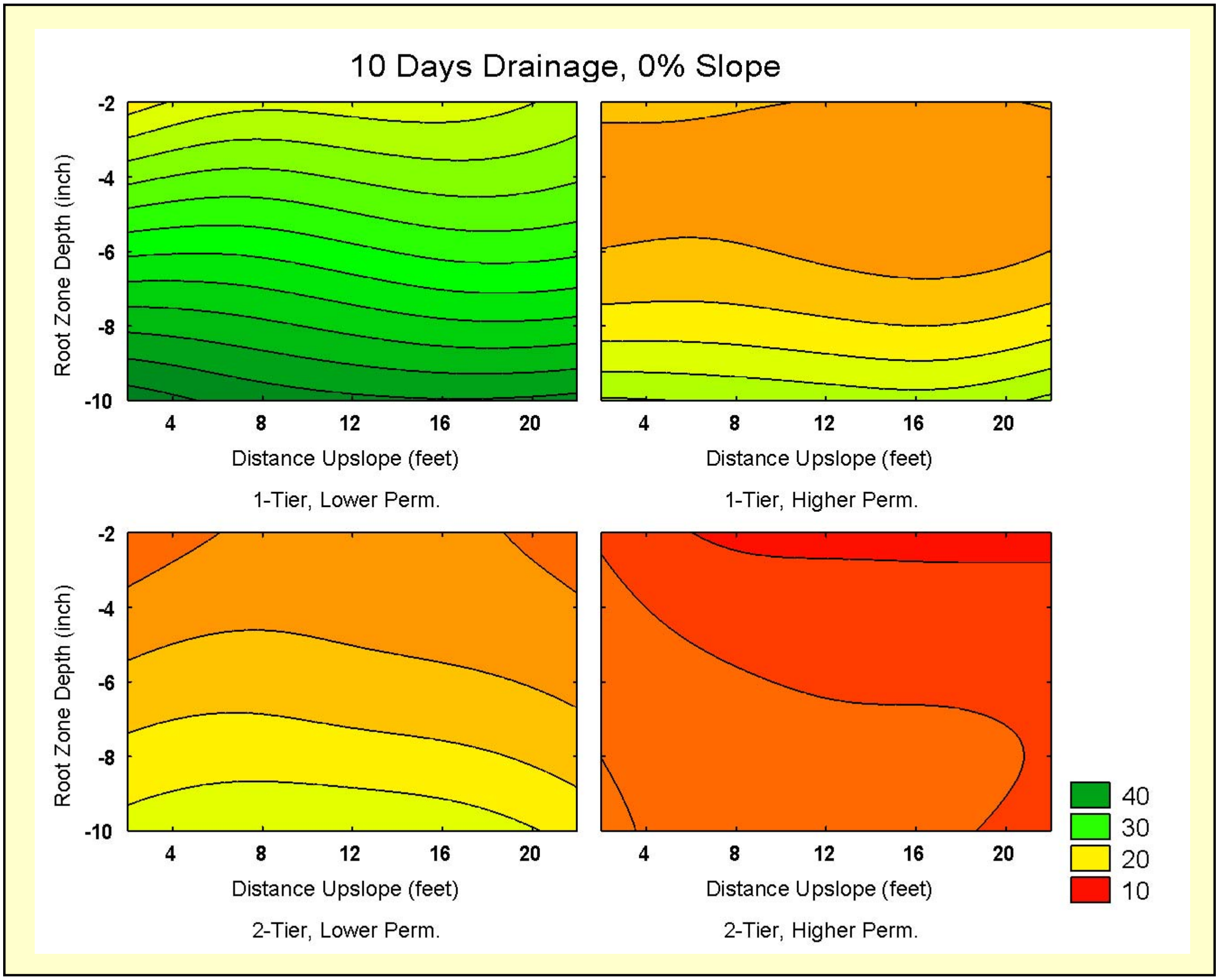

Figure 5. Mean water content (% by volume) of the experimental putting greens after 10 days of drainage and oriented at 0 % slope.

moisture are shown as a function of distance upslope (ft) and rootzone depth (in) for each of the profile design and rootzone permeability treatments. It is important to remember that although the plots are nearly square, the axis scales are different such that if drawn to scale, the plots would be about 20 times long as they are high.

Many treatment effects were apparent from the soil water content data after 4 days of drainage (Figs. 3 and 4). Profile design and rootzone permeability both contributed to retaining more or less water within the rootzone such that the one-tier, LP green overall had the wettest rootzone (water contents up to 40 %) and the two-tier, HP greens had the driest (water contents from 10 to 20 %). Also interesting were the similarity in soil moistures (particularly near the soil surface) for the one-tier HP and the two-tier LP greens, even though the permeability of these systems when constructed differed by about 10 inches per hour.

The greens at 4 % slope (Fig. 4) showed some similarity, but also strong contrasts to those at 0% slope. Particularly noticeable was the strong downslope to upslope gradient in soil water content yielding wetter soils downslope and drier soils upslope. This yielded water contents in both HP greens ranging from 10 to 15 % at the farthest upslope locations. Water contents exceeding 40 % were seen deep in the profile and dowslope for the one-tier LP green.

After 4 days of drainage, drainpipes locat-

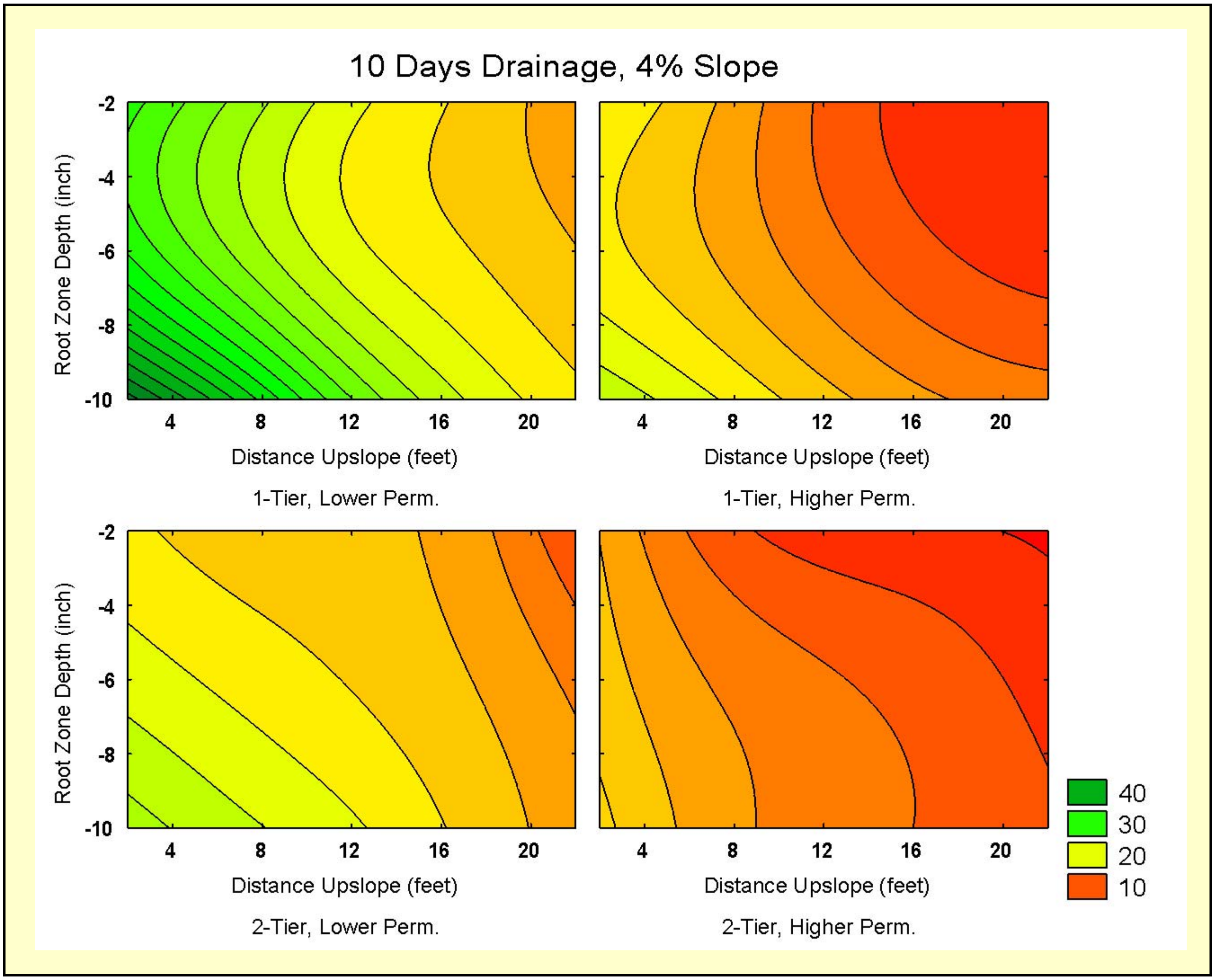

Figure 6. Mean water content (% by volume) of the experimental putting greens after 10 days of drainage and oriented at 4 % slope.

ed at 2 and 17 ft did not show a large effect in the soil moisture patterns for any of the greens at 0 % slope (Fig. 2). This contrasts with the results from earlier drainage times (2). Also in contrast with earlier drainage findings was the greater effect of slope (Fig. 4) at these later times.

The overall patterns of water content observed after 10 days with no rain or irrigation (Figs. 5 and 6) were similar to that observed after 4 days. The principal difference between these dates was the progressive rootzone drying. Thus, within both high-permeability greens at 4 % slope, soil moistures less than 10 % were observed throughout a substantial depth of the rootzone in the upslope locations.

Turf drought response

Throughout the study, there was little visual evidence of turf drought in any of the low-permeability rootzones regardless of the green design or slope. Thus, the finer sand rootzone containing both an organic amendment and topsoil served to avoid turf drought. The high-permebility rootzone, on the other hand, showed turf drought stress for both the one- and two-tier greens, but only at 4 % slope, and then only at the furthest upslope locations (Fig. 7). Thus, there was a slope-induced gradient of drought stress symptoms with little apparent stress downslope and extreme drought stress upslope. Yet, this occurred only for the coarser sand rootzone containing little amendment addition.

Figure 7. The higher permeability, one- and two-tier putting greens oriented to 4 % slope after 10 days without rain or irrigation. Turf in the foreground (downslope) does not show drought stress where turf in the background (upslope) does.

Overall, the experimental greens avoided drought much longer than expected for actual putting greens built to the same design. This may be due to the absence of frequent foot traffic and the higher height of cut allowing deeper rooting. Regardless, the underlying cause for the observed pattern of drought stress was the soil water status that should be similar for both actual and these experimental greens. Specifically, turf drought stress was associated with soil water contents less than 10 % within the upper 4 to 6 inches of the rootzone. Only those treatment and location combinations that attained this low level of water content also yielded drought stressed turf, and this same response would be expected for greens on the golf course.

Discussion and implications

Many of the features observed by Prettyman and McCoy (1, 2) after two days of drainage were preserved throughout 10 days of drainage. The greens continued to drain, with green slope and wetter rootzones contributing to increased drainage rates. Also, green slope, rootzone composition and profile design all contributed to the distribution of soil water within the rootzone. In contrast to the earlier findings, however, drainpipe spacing effects diminished over time and the lateral gradient in water contents due to slope strengthened.

After two days of drainage, our earlier findings suggested the absence of water perching at upslope locations when two-tier greens were sloped at 4 % (2). This became clearly evident in the present study where water contents were commonly less than 20 % deep within the rootzone at upslope locations. Consequently, perched water may not necessarily serve as a reliable reservoir for water uptake by turf in naturally sloped, two-tier greens. Water perching does occur across these green after rainfall, and there is evidence that the turf can tap this reservoir. However, subsurface, lateral flow in these systems serves to drain this perched water prior to much of its use by the turf. Thus, water perching may not serve equally across contoured greens in supplying the needs of the turf.

Of course, lateral water flow occurred as well in the one-tier greens when sloped at 4 %. The result in both coarser sand greens when sloped at 4 % was the occurrence of water contents less than 10 % by volume, to a depth of 4 to 6 inches, and the associated turf drought stress. Since this occurred only in the higher permeability rootzones, it would lead one to believe that rootzone amendments play an important role in maintaining higher water contents and in drought avoidance, particularly in coarser sands. This is especially true if perching of water in the rootzone cannot be relied on, then water retention by the rootzone is the only recourse.

Acknowledgements

This research was supported in part by grants from the United States Golf Association, the Golf Course Superintendents Association of America, and the Ohio Turfgrass Foundation.

Literature cited

1. Prettyman, G.W. and E.L. McCoy. 2002. Effects of profile layering, rootzone texture, and slope on putting-green drainage rates. *Agron. J.* 94:358-364. (TGIF Record 79589)

2. Prettyman, G.W. and E.L. McCoy. 2003. Profile layering, rootzone permeability, and slope

affect on soil water content during putting green drainage. *Crop Sci.* (in press). (TGIF Record 85590)

3. USGA Green Section Staff. 1993. The 1993 revision, USGA recommendations for a method of putting green construction. *USGA Green Section Record* 32(2):1-3. (TGIF Record 26681)