This research was funded in part by The Environmental Institute for Golf and USGA.

Putting green root-zone amendments and irrigation water conservation

Soil amendments reduce irrigation requirements, but the local climate determines how much water is saved.

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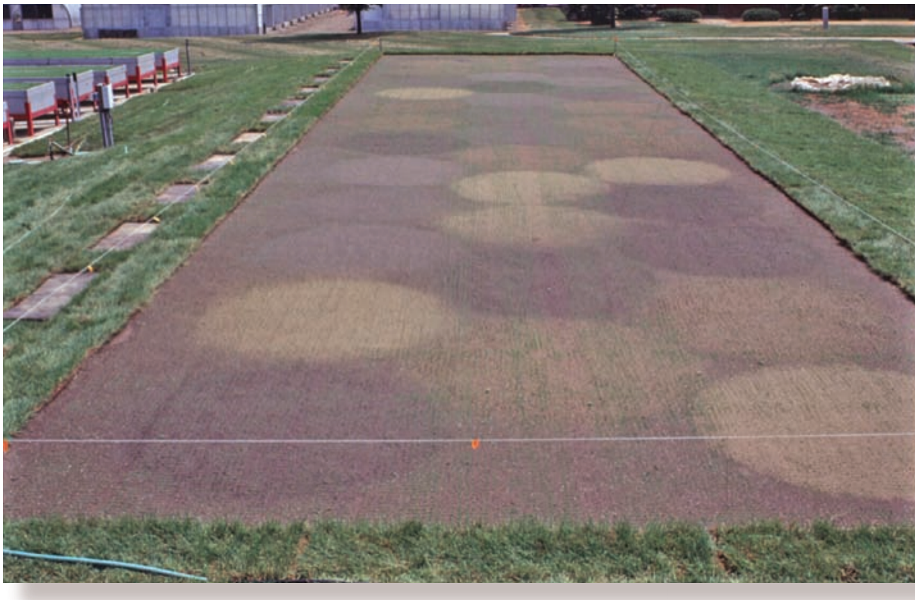
Peat and soil are commonly used amendments in high-sand-content root-zone mixes for putting greens. Extensive research has shown that adding modest quantities of peat, soil or both to a specified sand yields measurable increases in water and nutrient retention (1,2,4,5,7). For these high-sand-content mixes, the increased water retention delays the onset of injurious drought conditions between irrigations, and the increased nutrient retention maintains a stable supply of nutrients to the turf between fertilizer applications.

These amendment materials assist in the establishment and management of the turf by providing a physical and chemical buffering capacity to the sand. Consequently, increasing the available water capacity of a sand-based root zone through use of amendments would rationally provide a way to conserve irrigation water. Yet, an amended root zone alone will not conserve irrigation water. Superintendents must also adjust irrigation practices, specifically using a protocol that employs available water information and adjusting irrigation accordingly.

A widely recognized irrigation scheduling protocol that employs information about soil-available water is *deficit-based irrigation* (6). Deficit-based irrigation employs rainfall and evapotranspiration (ET) information together with estimates of available water capacity within the root zone to schedule the frequency and amount of irrigation. The procedure can be used with regional, monthly mean values of daily rainfall and evapotranspiration, or, when a local weather station is available, the procedure can be fine-tuned to use actual daily rainfall and evapotranspiration measurements. Thus, using a root- zone amendment together with deficit-based irrigation practices clearly has the potential to conserve water.

This study was conducted to quantify irrigation water savings that could be realized by employing a deficit-based irrigation protocol and by employing peat alone, or both peat and soil as amendments to a high-sand-content putting green root zone.



Photos courtesy of Ed McCoy

Figure 1. The contrasting root zones are visible at the field study site.

Climatic conditions that generate rainfall and control evapotranspiration vary greatly across the United States with time of year and reflect year-to-year variability. For this reason, we used long-term weather data from diverse regions of the United States in estimating water savings.

Available water capacity

An estimation of available water capacity within the rooting depth is central to a water budget using deficit-based irrigation. Yet, the standard definition of available water — the volume of water retained in the soil from field capacity to the permanent wilting point — is not appropriate for a putting green system because it does not address the fact that a superintendent would apply irrigation long before the permanent wilting point was reached. This definition also does not consider the layering of soil media characteristic of a modern putting green.

To improve water budgeting, we redefined available water capacity based on results from a two-year field study in which a complete water balance was performed on experimental greens supporting a creeping bentgrass turf maintained under putting green conditions.

The study employed six root zones: two containing pure sand, two containing sand + 10% (volume/volume) sphagnum peat, and two containing sand + 10% peat + 10% (volume/volume) topsoil (Figure 1). Two different sands were used, with both containing about 74% medium and coarse particles.

For this field research, we recorded all rainfall and irrigation inputs and all drainage losses, and we calculated daily turf evapotranspiration from daily soil-moisture measurements. Once in 2000 and once in 2001, irrigation was withheld to impose drought stress on the turf to the point where first wilt or "footprinting" became visually apparent (Figure 2). These dry-down periods were initiated by heavy irrigation or rainfall. Thus, from tracking soil-moisture changes and drainage losses during the dry-down period, a field-based estimation of water actually used by the turf from a well-watered condition to first wilt was available. This was the basis for the values of available water capacity used in this study (Table 1).

Following the procedure described above, available water capacity was 0.9 inch (23 millimeters) of water for a pure sand root zone; 1.2 inches (31 millimeters) for a sand + 10% peat root zone; and 1.5 inches (39 millimeters) for a sand + 10% peat + 10% soil root zone. These values represent the depth of water available for turf uptake within a root zone depth of 11.8 inches (300 millimeters), which is characteristic of a modern green.

Weather data

Because the U.S. climate is diverse, we used a map of soil moisture regimes of the country (3) to select six metropolitan locations for individual estimates of water-savings estimates: Sacramento, Calif; Phoenix; Boulder, Colo.; Houston; Columbus, Ohio; and Miami. For each location, we used daily weather data including precipitation, maximum and minimum air temperature, solar radiation, dew point and wind speed to conduct the analysis. A 20-year span of the daily weather data was chosen as suitably sufficient to account for year-to-year variability. The daily precipitation data for the six locations of this study were used directly in the analysis. The remaining weather data were used to calculate clipped grass reference evapotranspiration (ETo).

Figure 2. Withholding irrigation until first wilt or "footprinting" can be seen on the experimental greens indicates that the turf has depleted the available water capacity reservoir of the putting green root zone.

Finally, a factor was needed to convert ETo values corresponding to the 4-inch clipping height of the reference grass to comparable values for a closely mowed putting green turf. The value of this conversion factor came from our two-year water balance study, wherein measured values of putting green turf evapotranspiration were compared with an evaporation pan reference. Based on this comparison, a conversion factor value of 0.5 was chosen for this study. Thus, the weather data used in this study consisted of a 20-year record of daily precipitation and putting green turf evapotranspiration for the six metropolitan locations. As with the available water capacity values, these weather variables were expressed as a depth of water.

Analysis

The analysis began with the total available water capacity available for turf use. Each subsequent day, evapotranspiration removes a depth of water from this reservoir. If rain occurs, the specified depth of rainfall will partially refill the available water reservoir, completely refill the available water reservoir or refill available water with excess lost to drainage. If available water is diminished to a specified threshold, then irrigation will be required to refill the reservoir.

In this analysis, we chose two thresholds expressed as a percent of available water capacity. The more conservative threshold of 50% available water capacity means that if available water is diminished to 50% of its capacity, then irrigation would be required to refill it. A less conservative threshold of 70% available water capacity was also chosen, where irrigation would not occur until 70% of available water was depleted. The amount of irrigation applied is exactly the amount required to refill the available water capacity. Thus, the depth of irrigation applied for each irrigation will depend on available water capacity and the specified threshold.

Finally, irrigation was not applied if a five-day moving average of the mean air temperature was below 42 F. This prevented irrigation from occurring when the turf was not active because of seasonally cold weather. Subsequently, the cumulative number of times that irrigation was applied and the total depth of irrigation applied were determined for the entire 20-year weather record of each location.

AVAILABLE WATER ESTIMATES

	Available water (inches)	
Root zone	**2000**	**2001**
Finer sand	0.90	0.90
Finer sand + 10% peat	1.25	1.29
Finer sand + 10% peat + 10% soil	ND†	ND†
Coarser sand	0.90	0.90
Coarser sand + 10% peat	1.14	1.22
Coarser sand + 10% peat + 10% soil	1.49	1.57

†Not determined because the actual root-zone mix did not meet the soil amendment target.

Table 1. Field estimates of available water contained within an 11.8-inch (300-millimeter) deep root zone overlying a gravel drainage blanket. Available water is defined as the depth of water removed by evapotranspiration (ET) after a heavy rain or irrigation to the first indication of turf wilt (footprinting).

Results

A deficit-based irrigation scenario was generated for approximately 7,300 days for each of the six locations. This scenario indicated precisely when, given the local climate, irrigation was needed to refill the available water capacity and avoid drought stress. This scenario was repeated for the root zones.

Phoenix

Phoenix is characterized by large evapotranspiration rates and infrequent rainfall. Irrigation events were frequent (data not shown), particularly for the pure sand root zone. As expected, precipitation varied in amount, but depths of applied irrigation were always the same, as would occur by setting a sprinkler run time and nozzle output. Available water peaked following irrigation and was stepwise diminished by daily evapotranspiration.

Including 10% peat increased available water capacity, reducing the frequency of irrigation but increasing the depth of water applied during each irrigation. The rainfall pattern remained the same for root zones amended with pure sand and sand + 10% peat because the same Phoenix weather record was used for all root-zone treatments.

Irrigation could be delayed if rainfall occurred during the interval between irrigations, refilling or partially refilling available water capacity. Increasing available water capacity by using the 10% peat amendment and extending the interval between irrigations increases the probability that rainfall will refill available water capacity and delay required irrigation, thereby reducing overall irrigation requirements.

In Columbus, Ohio, the more frequent summer rainfall delivers greater depths of water, and daily evapotranspiration is less than in Arizona. As a result, few irrigations are required, and they are separated by relatively longer time intervals.

Amendment effects

A summary of the results of this study is given in Table 2, where estimated 20-year irrigation depth and irrigation counts are presented for the six locations and the three root zones considered. Scenarios for 70% and 50% available-water-capacity depletion are also shown. In all cases, incorporating peat or peat + soil reduced both the irrigation depth and the number of irrigations by increasing the available water capacity of the amended root zones. Adopting 70% depletion as compared with 50% depletion also reduces irrigation depth and irrigation count — although at a greater risk of turf drought stress.

The results also allow calculation of percentage of water savings from using 10% peat or 10% peat + 10% soil amendment in a root zone. The savings are based on the reduction in irrigation depth and number of irrigations as compared with a pure sand root zone (Table 3). Using this calculation, savings in irrigation depth from using peat ranged from a modest 4% in Phoenix to a considerable 24% in Columbus, Ohio. Savings from amending pure sand with peat + soil ranged from 7% in Phoenix to almost 40% in Columbus. These savings reflect differences in irrigation amounts based only on replenishing available water capacity. Reduction in the number of irrigations, however, was considerable at all locations, ranging from 30% to 60%. Reducing the number of irrigations may also indirectly conserve water by reducing irrigation system inefficiency losses. Finally, the amendment effect shown in Table 3 was not appreciably different between the 50% and 70% depletion scenarios.

Location effects

Location effects (Table 3) can mostly be interpreted by considering differences in rainfall frequency and evapotranspiration among locations. Because rainfall is more frequent in Columbus than in Phoenix, extending the irrigation interval using an amendment will increase the probability that rain will partially or completely replenish the available water capacity. When natural precipitation replenishes available water capacity, the subsequent irrigation event can be delayed, reducing the overall need for irrigation. Because evapotranspiration is less in Columbus than in

IRRIGATION DEPTHS AND EVENTS

	Pure Sand		Sand + 10% peat		Sand + 10% peat + 10% soil	
	Irrigation depth (inches)	No. irrigations	Irrigation depth (inches)	No. Irrigations	Irrigation depth (inches)	No. Irrigations
70% depletion†						
Phoenix	905.90	1429	866.14	1,014	842.12	783
Sacramento, Calif.	514.17	811	488.18	571	474.01	441
Boulder, Colo.	381.10	601	342.91	401	320.07	298
Houston	294.09	464	246.85	289	214.96	200
Miami	288.97	456	233.07	273	200.00	186
Columbus, Ohio	124.01	196	100.00	117	75.19	70
50% depletion†						
Phoenix	972.83	2149	912.20	1495	874.01	1138
Sacramento, Calif.	551.18	1281	516.14	846	496.85	647
Boulder, Colo.	425.98	940	385.82	633	362.20	471
Houston	350.00	772	303.14	496	253.93	331
Miami	351.18	776	294.09	481	251.96	328
Columbus, Ohio	170.07	375	129.13	211	107.08	139

†Percent depletion values correspond to management options whereby irrigation is withheld until the indicated proportion of available water is depleted by turf evapotranspiration; 50% is the more conservative approach.

Table 2. Estimated, 20-year irrigation depth and event count for an 11.8-inch-deep (300-millimeter-deep) root zone containing pure sand, sand amended with 10% (by volume) peat, and sand amended with 10% (by volume) peat + 10% (by volume) soil. Irrigation depth is given in centimeters.The results correspond to deficit-based irrigation practices and are generated for six locations from distinct soil-moisture regimes of the United States (3). The pure sand root zone contained 23 millimeters of available water, the sand amended with 10% peat contained 31 millimeters of available water, and the sand amended with 10% (vol.) peat + 10% (vol.) soil contained 39 millimeters of available water; where available water was defined as the depth of water retained in an 11.8-inch (300-millimeter) root zone following drainage to the first indication of turf wilt (footprinting).

Phoenix, the increased available water capacity of an amended root zone will take longer to deplete, and irrigation will be delayed. Thus, both rainfall frequency and evapotranspiration extend the interval between irrigations.

Rainfall from a given rainstorm also contributes to location effects (Table 3). Rainstorms in Columbus generally deliver more precipitation and are more likely to fully replenish available water capacity than rainstorms in Phoenix. For example, Columbus had 330 days (11.7% of all rain days), but Phoenix only had 54 days (7.4% of all rain days) when rainfall equaled or exceeded 0.6 inch (16.1 millimeters) (70% of the available water capacity for sand). This implies that the chance that a rainstorm would completely replenish available water capacity was 60% greater in Columbus than in Phoenix. Incomplete filling of available water capacity by a given rainstorm would only delay irrigation, whereas completely filling available water capacity would allow superintendents to skip an irrigation. Of the three weather factors considered here, the increased rainfall frequency in Columbus compared to Phoenix is expected to best explain location effects.

Thus, the results (Table 3) reinforce the role of natural rainfall in influencing the magnitude of irrigation savings when amendments are used to increase available water capacity. Greater proportionate irrigation savings occur when rainfall is sufficiently frequent, allowing natural precipitation to replenish the available-water-capacity reservoir. Although increased available water capacity allows less frequent irrigation, without frequent rainfall, the differences are diminished by the system's demand for greater irrigation amounts with each application.

THE RESEARCH says . . .

- **Root-zone amendments** can translate into irrigation water savings when accompanied by appropriate irrigation scheduling.
- **The extent of** irrigation savings depends on climate, with lesser savings in generally arid climates and greater savings in humid climates.
- **The increased rainfall** frequency of a humid climate together with the less frequent irrigation requirement of an amended root zone increases the probability that rainfall rather than irrigation will replenish the available water capacity in the root zone.

Conclusion

Using a soil amendment conserves irrigation water by increasing the available water capacity of the putting green root zone so less frequent irrigation is required. This provides a greater probability that a rainstorm, rather than irrigation, would replenish the available-water-capacity reservoir. The climate where the putting green is located, however, dictates the actual probability of a replenishing rain. Thus, the location of the putting green will influence the absolute magnitude of irrigation water conservation.

20-YEAR IRRIGATION SAVINGS

	Sand + 10% peat		Sand + 10% peat + 10% soil	
	% irrigation savings	% event reduction	% irrigation savings	% event reduction
70% depletion				
Phoenix	4.4	29.0	7.1	45.2
Sacramento, Calif.	5.1	29.6	7.8	45.6
Boulder, Colo.	10.1	33.3	16.0	50.4
Houston	16.1	37.7	26.9	56.9
Miami	19.3	40.1	30.8	59.2
Columbus, Ohio	19.5	40.3	39.5	64.3
50% depletion				
Phoenix	6.2	30.4	10.2	47.0
Sacramento, Calif.	6.4	34.0	9.8	49.5
Boulder, Colo.	9.2	32.7	15.0	49.9
Houston	13.4	35.8	27.4	57.1
Miami	16.5	38.0	28.2	57.7
Columbus, Ohio	24.2	43.7	37.1	62.9

Table 3. Estimated 20-year irrigation savings from the addition of 10% peat or 10% peat + 10% soil (volume/volume). Savings are based on the reduction of irrigation depth and the reduction of irrigation events as compared with a pure sand root zone.

Funding

This research was supported by funds received from The Environmental Institute for Golf, USGA and the Ohio Turfgrass Foundation.

Acknowledgments

This article was previously published as "Putting green root-zone amendments and irrigation water conservation," by Ed McCoy and Kevin McCoy in *USGA Turfgrass and Environmental Research Online* 4(8):1-9, April 15, 2005 (http://usgatero.msu.edu/v04/n08.pdf).

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