Research *You Can Use*

Geography Affects How Rootzone Amendments Conserve Irrigation Water

Research at The Ohio State University demonstrates how geography can save irrigation water.

BY ED McCOY AND KEVIN McCOY

Peat and soil are commonly used amendments in high-sand rootzone mixes for putting greens. Extensive research has shown measurable increases in water and nutrient retention from the addition of modest quantities of peat, soil, or both to a specified sand.[1,2,4,5,7] For 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.

Increasing the available water capacity (AWC) of a sand-based rootzone through use of amendments would rationally provide a means of irrigation water conservation. Yet, employing an amended rootzone alone will not result in irrigation water savings. Golf course superintendents must also adjust irrigation practices, specifically using a protocol that employs available water information and adjusts irrigation accordingly.

A widely recognized irrigation scheduling protocol that employs soil-available water information is deficit-based irrigation.[6] Deficit-based irrigation employs rainfall and evapotranspiration (ET) information together with estimates of available water capacity within the rootzone 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 finely tuned to use actual daily rainfall and ET measurements. This study was conducted to quantify irrigation water savings that could be realized by employing peat alone, or both peat and soil as amendments to a high-sand-content putting green rootzone, and by employing a deficit-based irrigation protocol.

Table 1

Field estimates of available water contained within a 300mm deep rootzone overlying a gravel drainage blanket. Available water is defined as the depth of water removed by ET after a heavy rain or irrigation to the first indication of turf wilt (footprinting).

	Available Water	
Rootzone	**Year 2000**	**Year 2001**
	mm	
Finer Sand	23	23
Finer Sand + 10% Peat	32	33
Finer Sand + 10% Peat + 10% Soil	ND*	ND
Coarser Sand	23	23
Coarser Sand + 10% Peat	29	31
Coarser Sand + 10% Peat + 10% Soil	38	40

*Not determined because the actual rootzone mix did not meet the soil amendment target.

ROOTZONE AVAILABLE WATER CAPACITY

Climatic conditions that generate rainfall and control ET vary greatly across the U.S. with time of year and reflect year-to-year variability. Thus, estimates of water savings due to amendment use in rootzones must employ a wide range of locations, all seasons of the year, and span a sufficient period of time to address year-to-year variability. For this reason, long-term weather data from diverse regions of the U.S. were employed in the water savings estimation.

Central to water budgeting using deficit-based irrigation is an estimation of available water capacity within the rooting depth. However, the standard definition given as the volume of water retained in the soil from the soil's field capacity to permanent wilting point does not address the fact that a superintendent would apply irrigation long before the permanent wilting point is reached. Also, this definition is based on laboratory measurements of a soil sample and does not consider the

layering of soil media characteristic of a modern putting green.

We redefined available water capacity as would be appropriate for a modern putting green. This redefinition was based on results from a two-year field study wherein a complete water balance was performed on experimental greens supporting a bentgrass turf maintained under putting green conditions. The experimental greens consisted of a 300mm (12") deep rootzone placed above a 100mm (4") thick gravel drainage blanket, all contained within a non-weighing lysimeter. The study employed six rootzones: two containing pure sand, two containing sand +10% (vol./vol.) sphagnum peat, and two containing sand + 10% peat + 10% (vol./vol.) topsoil. Two different sands were used, one being slightly finer and one being slightly coarser, but both containing about 74% medium and coarse particles.

This field research recorded all rainfall and irrigation inputs, all drainage losses, and calculated daily turf ET from daily soil moisture measurements. For one instance each during years 2000 and 2001, irrigation was withheld to impose drought stress on the turf to the point where first wilt or "footprinting" became visually apparent. These dry-down periods were initiated with a heavy irrigation or rainfall. By 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.

Following the procedure above, AWC for a pure sand rootzone, a sand + 10% peat rootzone, and a sand + 10% peat + 10% soil rootzone was 23mm (0.9"), 31mm (1.2"), and 39mm (1.5") of water, respectively. These values represent the amount of water (expressed as depth) available for turf uptake within a 300mm (12") deep rootzone characteristic of a modern green.

THE WEATHER DATA

Due to climate diversity within the U.S., water savings estimates were conducted individually for six metropolitan locations across the country. Selection of the specific cities was further based on a map of soil moisture regimes of the U.S.[3] to ensure a wide span of possible climatic conditions. The six locations chosen were Phoenix, Ariz.; Sacramento, Calif.; Boulder, Colo.; Houston, Texas; Miami, Fla.; and Columbus, Ohio.

For each location, daily weather data, including precipitation, maximum and minimum air temperature, solar radiation, dewpoint, and wind speed, were required to conduct the analysis. A 20-year span of daily weather data was chosen as 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 ET (ET_0) recommended in 2000 by the ASCE Task Committee on Standardized Evapotranspiration Calculations.

A factor was needed to convert ET_0 values corresponding to the 4-inch clipping height of the reference grass to comparable values for closely mowed putting green turf. The value of this conversion factor came from our two-year water balance study wherein

Research at Ohio State investigated quantifying irrigation water savings by using peat or both peat and soil as amendments to high-sand-content putting green rootzones. The experimental greens were constructed using wading pools, and the various rootzone mixtures were evident as the plots were grown in.

measured values of putting green turf ET 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 ET for the six metropolitan locations.

ANALYSIS STEPS

The analysis began with the total available water capacity available for turf use. Each subsequent day, ET removes an amount of water from this reservoir. If rain occurs, the specified amount 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.

We chose two thresholds expressed as a percent of AWC. The more conservative threshold of 50% AWC means that irrigation was initiated to refill the rootzone's water content when it was diminished to 50% of its capacity. A less conservative threshold of 70% AWC 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 for that 300mm rootzone depth. Thus, the amount of irrigation applied for each irrigation event will depend on the AWC of the specific rootzone and the depletion threshold.

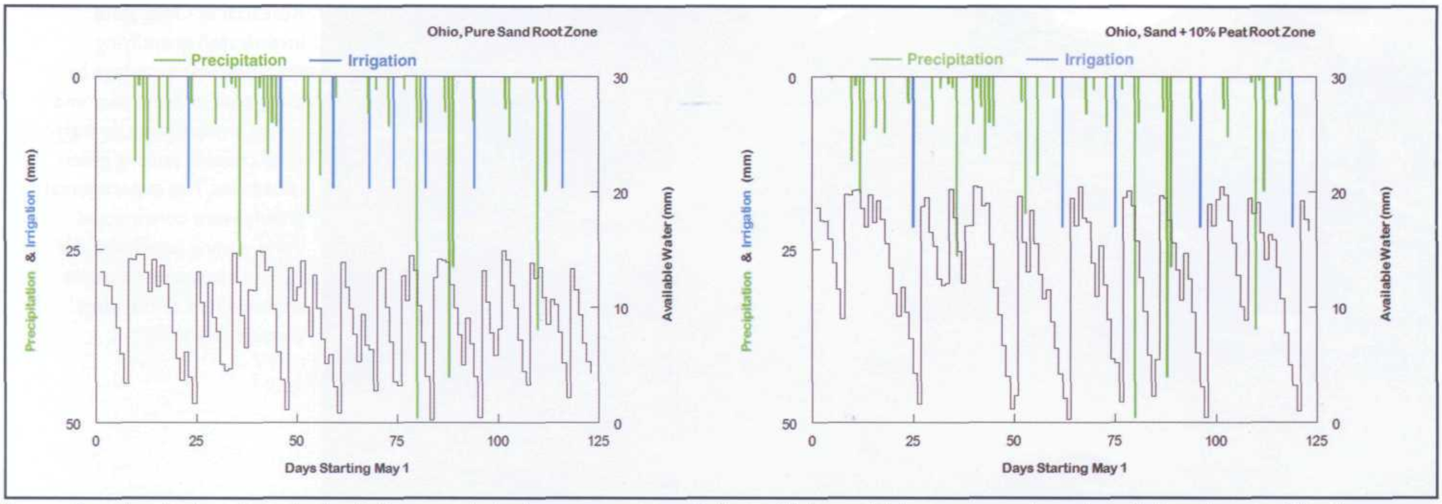
Finally, irrigation was not applied if a five-day average of the mean air temperature was below 42°F. This prevented an irrigation event from occurring when the turf was non-active due to seasonally cold weather. Subsequently, the cumulative number of irrigation events and the total depth of irrigation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

ADDING UP THE NUMBERS

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, an irrigation event was needed to refill the available water capacity and avoid drought stress. This irrigation scenario was repeated for each of the various rootzones of the study.

Examples of the analysis output are given in Figure 1. This figure shows only a small portion of the data series — 123 days starting May 1 for just one of the 20 years. Also, the graphs are paired, showing the results from a pure sand rootzone (AWC = 23mm) and a sand + 10% peat (AWC = 31mm) rootzone. A threshold of 70% AWC was used. In these graphs, precipitation and irrigation amounts extend downward from the top, as shown on the left-hand axis, and the present state of available water extends upward from the bottom, as shown on the right-hand axis.

Phoenix, Ariz., is characterized by generally large ET rates and infrequent rainfall. Correspondingly, irrigation events were frequent, particularly for the pure sand rootzone. Whereas precipitation varied in amount, as would



Research analyzed when, given the local climate, an irrigation event was needed to refill the available water capacity and avoid drought stress. The figures show the results from a pure sand rootzone and a sand + 10% peat rootzone at a threshold of 70% available water capacity (AWC). Precipitation and irrigation amounts extend downward from the top, and the present state of available water extends upward from the bottom.

be expected for natural rainfall, irrigation amounts applied were always the same, such as would occur by setting a sprinkler run time and nozzle output. Available water peaked following an irrigation event and was stepwise diminished by daily ET. Including 10% peat in the mix increased AWC such that the frequency of irrigation events could be reduced, but with a greater amount of water applied during each event.

An irrigation event could be delayed if rainfall occurred during the intervening period, refilling or partially refilling AWC. By increasing AWC using the 10% peat amendment and extending the interval between irrigations, there is an increased probability that rainfall will refill AWC and delay a required irrigation event, reducing overall irrigation requirements.

Figure 1 shows the results for Columbus, Ohio, where, during the summer months, rainfall is more frequent, delivers greater amounts of water, and daily ET is less than in Arizona. As a result, few irrigation events are required, and these events are separated by longer time intervals. For the period shown in Figure 1, there were eight irrigation events for the pure sand rootzone and five events for the sand + 10% peat rootzone. Again, a greater amount of water was applied for the sand + 10% peat rootzone during each irrigation event compared to the pure sand rootzone.

A summary of the results of this study is given in Table 2, where estimated 20-year irrigation depth and event counts are presented for the six locations and three rootzones considered. Also shown are results for 70% and 50% AWC depletion scenarios. The locations are ordered in Table 2 from those requiring the greatest irrigation amount to those requiring the least irrigation amount when considering the pure sand rootzone. In all cases, incorporating peat or peat + soil served to reduce both the cumulative irrigation amount and the number of irrigation events. This benefit is provided by the increased AWC of the amended rootzones. Further, adopting a 70% depletion scenario also reduces the irrigation amount and the number of irrigations, although at a greater risk of turf drought stress.

The results also allow for calculation of percentage savings from using 10% peat or 10% peat + 10% soil amendment in a rootzone. The savings in this case are based on the reduction in irrigation amount and number of irrigation events as compared with a pure sand rootzone (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. 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 solely on the basis of replenishing AWC.

Event reduction, on the other hand, was considerable at all locations, ranging from 30% to 60%. Although not specifically determined in this study, reducing the number of irrigation events may also serve indirectly to 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, LOCATION, LOCATION

The location effects of Table 3 can mostly be interpreted by considering rainfall frequency and ET differences that occur in the various locations. Because rainfall is more frequent in Columbus than in Phoenix, by extending the irrigation interval using an amendment, there is a greater probability that rain will replenish the AWC, partially or completely, reducing irrigation need. The smaller ET of Columbus compared to Phoenix performs similarly in that the increased AWC of an amended rootzone will take longer to deplete and also delay irrigation. Both increased rainfall frequency and lower ET serve in extending the irrigation interval.

Irrigation water conservation from the use of an amendment results from increasing the available water capacity of the putting green rootzone such that less frequent irrigation is required. This provides a greater probability that a rainstorm, rather than irrigation, would replenish the AWC reservoir. The climate where the putting green is located, however, dictates the actual probability of a replenishing rain to occur. Thus, the location of the putting green within the U.S. will influence the absolute magnitude of irrigation water conservation.

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Table 2

Estimated 20-year irrigation depth and event count for a 300mm deep rootzone containing pure sand, sand amended with 10% (vol.) peat, and sand amended with 10% (vol.) peat + 10% (vol.) soil. The results correspond to deficit-based irrigation practices and are generated for 6 locations from distinct soil moisture regimes of the U.S. (Soil Survey Staff, 1994). The pure sand rootzone contained 23mm of available water, the sand amended with 10% peat contained 31mm of available water, and the sand amended with 10% (vol.) peat + 10% (vol.) soil contained 39mm of available water, where available water was defined as the depth of water retained in a 300mm rootzone following drainage to the first indication of turf wilt (footprinting).

	Pure Sand		Sand + 10% Peat		Sand + 10% Peat + 10% Soil	
	Irrigation Depth	Irrigation Events	Irrigation Depth	Irrigation Events	Irrigation Depth	Irrigation Events
	cm		cm		cm	
70% Depletion*						
Phoenix, Ariz.	2301	1429	2200	1014	2139	783
Sacramento, Calif.	1306	811	1240	571	1204	441
Boulder, Colo.	968	601	871	401	813	298
Houston, Texas	747	464	627	289	546	200
Miami, Fla.	734	456	592	273	508	186
Columbus, Ohio	315	196	254	117	191	70
50% Depletion*						
Phoenix, Ariz.	2471	2149	2317	1495	2220	1138
Sacramento, Calif.	1400	1281	1311	846	1262	647
Boulder, Colo.	1082	940	980	633	920	471
Houston, Texas	889	772	770	496	645	331
Miami, Fla.	892	776	747	481	640	328
Columbus, Ohio	432	375	328	211	272	139

*The percent depletion values correspond to management options whereby irrigation is withheld until the indicated proportion of available water is depleted by turf ET, 50% being the more conservative approach.

Table 3

Estimated 20-year irrigation savings from the addition of 10% peat or 10% peat + 10% soil. Savings are based on the reduction of irrigation depth and the reduction of irrigation events as compared with a pure sand rootzone.

	Sand + 10% Peat		Sand + 10% Peat + 10% Soil	
	Irrigation Savings	Event Reduction	Irrigation Savings	Event Reduction
	%	%	%	%
70% Depletion				
Phoenix, Ariz.	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, Texas	16.1	37.7	26.9	56.9
Miami, Fla.	19.3	40.1	30.8	59.2
Columbus, Ohio	19.5	40.3	39.5	64.3
50% Depletion				
Phoenix, Ariz.	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, Texas	13.4	35.8	27.4	57.1
Miami, Fla.	16.5	38.0	28.2	57.7
Columbus, Ohio	24.2	43.7	37.1	62.9