RE|SEARCH

Alec Kowalewski, Ph.D.
Clint Mattox
Brian McDonald, M.S.
Brian Daviscourt
Carmen Magro, CGCS

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Relationship between distribution uniformity and soil moisture content

Tests on a sand-based green showed a weak relationship between distribution uniformity and soil moisture content, suggesting that soil moisture measurements and hand watering are critical to mitigating localized dry spot.

Providing a putting surface with uniform playing conditions and aesthetics is a critical component to successful golf course management. A condition that regularly disrupts putting green uniformity is localized drying or localized dry spot (also known as LDS) (3). A major factor that contributes to localized dry spot is variation in irrigation distribution (5). Industry standards suggest a minimum distribution uniformity of 70% or better (1), but changes in water pressure and flow rate, wind and irrigation equipment wear can greatly reduce this uniformity (2). Although uniform irrigation is a critical component to maintaining a uniform putting surface, other variables such as variations in surface slope, traffic, shade and organic matter accumulations have been cited as contributors to localized drying.

The objectives of this study were to evaluate the distribution uniformity of a putting green and then to assess correlations between differences in irrigation distribution uniformity and the soil wetting and drying cycle of a sand-based putting green. Exploring these correlations will help further explain the localized drying often observed on putting surfaces with relatively uniform irrigation. The hypothesis of this research is that irrigation distribution uniformity is weakly correlated to soil-moisture wetting and drying cycles because variability in surface conditions (that is, surface slope, traffic, organic matter, etc.) contribute substantially to variability in soil moisture.

Materials and methods

Field research was initiated July 15, 2014, and concluded July 25, 2014, on an annual bluegrass (*Poa annua*) putting green located at Lewis-Brown Horticulture Farm in Corvallis, Ore. The green was constructed using the California method, where 12 inches (30.48 centimeters) of straight USGA-recommended sand was placed on top of a soil subgrade. Irrigation pipe and flat tile drainage were installed on the subgrade before the sand was installed. Annual bluegrass (*Poa annua*) sod was laid in early May 2009. The putting green was 10,368 square feet (963.2 square meters), divided into three 3,346-square-foot (310.85-square-meter) irrigation zones (or replications). Irriga-

Catch cans (4 inches × 4 inches) were placed across a sand-based putting green every 10 feet × 10 feet to determine the average precipitation rate, low quarter average and distribution uniformity of the irrigation system at Lewis-Brown Farm, Corvallis, Ore. **Photo by Brian McDonald** tion heads were Hunter I-20 rotors positioned 27 feet (8.23 meters) apart using square spacing for head-to-head coverage.

Evaluating distribution uniformity

Distribution uniformity was assessed using the Lower Quarter Distribution Uniformity (LQDU) process where collection cups (catch cans) (4 inches × 4 inches [10 centimeters × 10 centimeters) were placed on 10-foot (3-meter) centers (48 cups per irrigation zone × 3 zones × 2 runs). The irrigation was run for 50 minutes, providing an average irrigation rate of 0.25 inch (6.35 millimeters) (Figure 1) (4). The water collected in each cup was measured using a graduated cylinder and then converted to irrigation depth (inches of irrigation). The lowest 25% of the 288 collection cups were averaged and divided over the average of volume in all of the cups and multiplied by 100 to get a percentage of distribution uniformity (Table 1).

Findings from this project determined that the putting surface being assessed had irrigation rates ranging from 0.007 inch (0.17 millimeter) to 0.67 inch (17 millimeter) and a distribution uniformity of 60%. While these findings are substantially less than 80%, which is a common target in the turf industry, the industry standards set by the Association Water Management Committee classify this distribution uniformity as good (AWMC classifications are: exceptional, >85%; excellent, 75-84%; very good 70-74%; good, 60-69%; fair 50-59%; poor, 40-49%; fail, <40%) (4). Irrigation best management practices consider the minimum operational uniformity for a rotor system to be 70% LQ-DU (1). United States Environmental Protection Agency Water recommendations for a new single-family home suggest a distribution uniformity of 65% or better at installation (6).

It is interesting to note that, in our study, two catch cans placed adjacent to an irrigation head with a faulty nozzle received precipitation rates greater than 0.6 inch (15.25 millimeters), substantially greater than the mean irrigation depth of 0.25 inch. Faulty nozzles like this are typical on a golf course that likely has well over 1,000 irrigation heads. After this irrigation audit was performed, it was hypothesized that differences in soil moisture content across the putting green being evaluated after irrigation would be closely correlated to differences in irrigation uniformity.

Precipitation rate

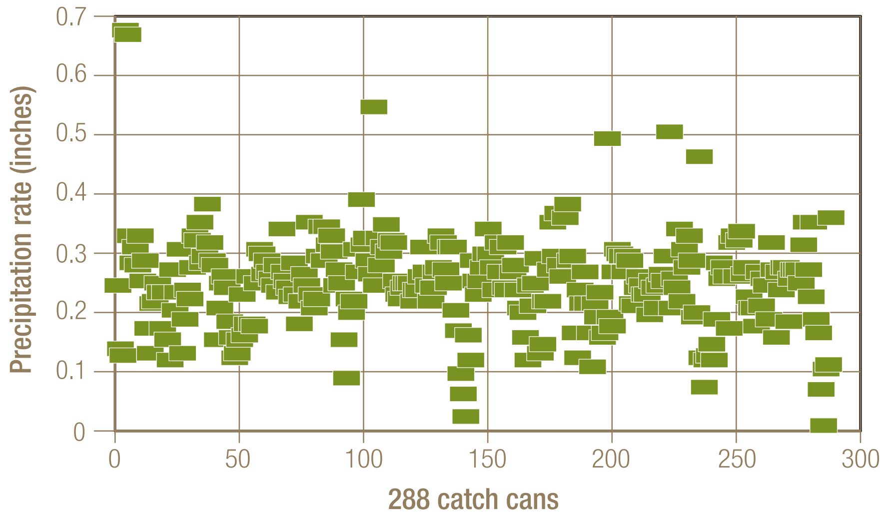

Figure 1. Precipitation rate after 50 minutes of irrigation on a sand-based putting green at Lewis-Brown Farm, Corvallis, Ore. Diamonds represent 288 data points collected across 48 catch cans, three irrigation zones and two runs.

Assessing putting green soil moisture

Soil moisture was measured using a Stevens POGO (Stevens Water Monitoring Systems) and an Apple iPad Mini. The POGO uses the Stevens Hydra Probe research-grade sensor to measure moisture (water fraction volume), salinity (electrical conductivity [EC] in decisiemens/meter [dS/m]) and surface temperature (degrees Celsius and Fahrenheit).

Samples were taken adjacent to the 48 catch cans on each of the three irrigation zones before irrigation and then, 0, 60, 90 and 120 minutes after the conclusion of the 50-minute (0.25-inch) irrigation event. This procedure was done twice for each irrigation zone; run 1 was done on July 15, 16 and 18 for zones 1, 2 and 3, respectively; and run 2 was done on July 21, 22 and 25 for zones 1, 2 and 3, respectively. The 48 locations per irrigation zone × 4 collection times (before and minutes after irrigation) × 3 zones × 2 runs resulted in a total of 1,152 data points.

Prior to irrigation, the putting green had an average moisture content of 29.8% (Figure 2). Soil moisture quickly increased to 39.3% following the conclusion of irrigation. The soil moisture then decreased, reaching 33% at the conclusion of the 120-minute (2-hour) data collection period. Irrigation run 2, conducted from July 21 to 25 had greater average moisture content than run 1, conducted from

Precipitation rate & distribution uniformity

Average precipitation rate	0.25 inch
Low quarter average (LQ) precipitation rate	0.15 inch
Low quarter distribution uniformity (LQDU)	60.0%

Note. AVR precipitation rate calculated across 288 data points; LQ precipitation rate calculated using the lowest quarter 72 data points of the 288 data points.

Table 1. Average and low quarter average (LQ) precipitation rate and low quarter distribution uniformity (LQ/AVR = LQDU) collected from 288 catch cans after a 50-minute irrigation event.

Moisture content after irrigation

Run date	Moisture (%)*
Run 1 (Aug. 15-18, 2014)	34.99 b
Run 2 (Aug. 21-25, 2014)	37.91 a

*Means represent 576 data points collected across 48 catch cans, 3 irrigation zones and 4 sampling times (minutes after irrigation). Within columns, means followed by the same letter are not significantly different.

Table 2. Effects of run on moisture content of a sand-based putting green after 50 minutes of irrigation.

Wetting and drying cycle

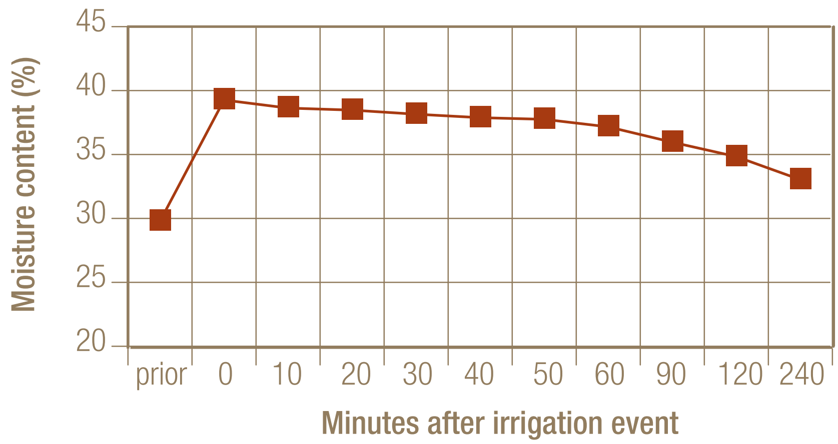

Figure 2. Wetting and drying cycle of a sand-based putting green after 50 minutes of irrigation. Mean moisture-content values represent 288 data points collected across 48 catch cans, three irrigation zones and two runs. Mean values with the same lowercase letter are not significantly different.

A POGO and an iPad Mini were used to measure the moisture content across a sand-based putting green at Lewis-Brown Farm, Corvallis, Ore. **Photo by Alec Kowalewski**

July 15 to 18 (Table 2). The difference was the result of several rain events observed between the run 2 irrigation events.

The differences between location and the interaction between location and run (data not shown) can partly be explained by the relatively weak distribution uniformity observed during the irrigation audit. Generally speaking, areas with soil-moisture-content levels reaching values of 11% or lower within the 120 minutes following irrigation frequently show symptoms of drought stress and/or anthracnose, a disease prevalent in areas of annual bluegrass that do not receive adequate irrigation. Areas that receive relatively high amounts of irrigation, and therefore have high soil-moisture-content levels, were some of the healthiest areas throughout the putting surface.

To gain a better understanding of how differences in distribution uniformity relate to soil moisture content, a series of correlation analyses were conducted. To explore wetting and then drying cycles across the putting green, correlation analyses between irrigation distribution and soil moisture content across the 48 locations and three irrigation zones were conducted for the four data collection times, minutes after irrigation; 0, 60, 90 and 120 minutes, independently (Figure 3).

As expected, trends in moisture content across irrigation depth were generally positive: as soil moisture increased, irrigation depth increased (Figure 3). However, the correlation between soil moisture content and irrigation depth was relatively weak. For instance, the strongest correlation, R^2 = 0.1124, was observed when soil moisture content was sampled at the conclusion of an irrigation event. As the time following the irrigation event increased, the relationship between soil moisture and irrigation depth decreased, with the weakest relationship observed 120 minutes after irrigation, R^2 = 0.0619. This supports the initial hypothesis that irrigation distribution uniformity is weakly correlated to soil moisture wetting and drying cycles and likely greatly affected by differences in the putting surface and use patterns. For example, the area with the two catch cans (adjacent to an irrigation head with a faulty nozzle) that received precipitation rates greater than 0.6 inch did not have the greatest soil moisture content. These two spots had soil moisture content levels just over 40%, whereas values greater than 50% were observed in areas that received substantially less irrigation.

These findings also illustrate the importance of site-specific soil moisture sampling when trying to minimize irrigation frequency and prevent the development of localized dry spot on a sand-based putting surface. In addition, our results indicate that an assessment of the irrigation distribution uniformity on the surface (sprinkler quality) is not necessarily a good indicator of moisture needs or availability from the turf's perspective.

Conclusion

As this research demonstrates, distribution uniformity was weakly correlated to

Turfgrass adjacent to catch cans 35 (left) and 46 (right) in plot 1 had the lowest moisture content levels (6.4% and 10.9%, respectively), as well as the poorest turf quality throughout the putting surface. **Photos by Clint Mattox**

The highest moisture content and some of the highest turf quality observed across the putting surface were seen in the turfgrass adjacent to catch can 8 (left) in plot 1 (52. 6% moisture content) and catch can 21 (right) in plot 2 (51.6% moisture content).

Moisture content

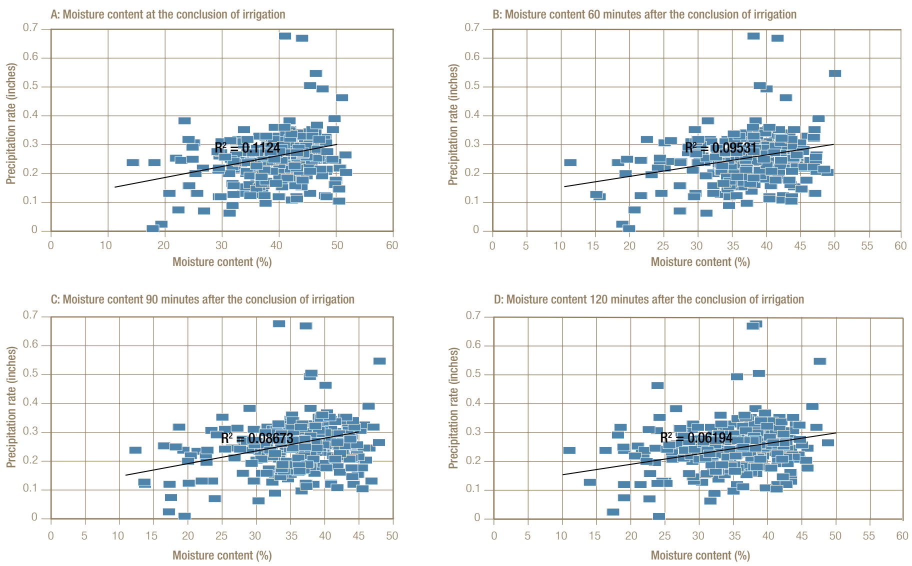

Figure 3. Trends in moisture content across precipitation rates sampled at the conclusion of 50 minutes of irrigation (A), as well as 60 minutes (B), 90 minutes (C) and 120 minutes (D) after the conclusion of irrigation in Corvallis, Ore., in 2014. ◊ = actual values. The strongest correlation (polynomial) is presented.

soil moisture on a sand-based putting green. These findings would suggest that substantial differences in soil moisture content are likely even when irrigation is uniform, necessitating the need for hand watering. Further research needs to be done to determine the influence of other key factors (for example, organic matter, slope, traffic, shade, etc.) on soil moisture uniformity. Finally, the effects of the additional variables that may have an impact on the moisture availability in the turf system including surface slope, traffic, shade and organic matter require further research.

Funding

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The RESEARCH SAYS

- This study evaluated the distribution uniformity of a putting green and assessed correlations between differences in irrigation distribution uniformity and the soil wetting and drying cycle.
- Distribution uniformity was weakly correlated to soil moisture, suggesting that even when irrigation is uniform, there are substantial differences in soil moisture content.
- This supports the importance of site-specific soil moisture sampling when trying to minimize irrigation frequency and prevent localized dry spot.
- Sprinkler quality is not always a good indicator of moisture needs or availability.