Irrigation Management in Summer: timing, amount, syringing, and water quality

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ABSTRACT

Creeping bentgrass (*Agrostis stolonifera*) grows best when the average temperature is about 20°C. During the summer in most parts of Japan, the average temperature is more than 25°C. In such high temperatures, bentgrass greens must be supplied with just the right amount of water, at the right time. Any prolonged deficit or excess of water in the rootzone is likely to result in severe damage to the grass. Turfgrass quality is improved, and bentgrass root systems tend to be more extensive, when the soil moisture content is maintained at a low level. The timing of irrigation is less important than is the amount of water applied. Wilting grass has a very high surface temperature, but transpiring grass has a surface temperature similar to the air temperature. Syringing greens does not have a meaningful impact on surface temperatures. In addition to the quantity of water applied, it is important to know what is in the water. Specifically, the salinity and the sodium adsorption ratio (SAR) should be known, so that any potential problems can be managed before the grass is damaged.

Irrigation management is one of the most important greenkeeping jobs. In the hot summer weather, bentgrass supplied with too little water will fail rapidly. Bentgrass supplied with too much water will fail rapidly also. Ensuring that the grass is supplied with just the right amount of water is a crucial component of summertime greenkeeping.

We should always remember that grass gets its water from the soil. So when we are irrigating (Figure 1), we are really managing the amount of water in the soil. If we succeed in maintaining the optimum amount of water in the soil, the grass will respond well. The maximum amount of water the soil can hold is called **field capacity**. This is the amount of water in the soil shortly after a saturating rain or irrigation, when excess water has drained by gravity.

There is also a **wilting point**, the level of soil moisture at which the grass will wilt. Even at the wilting point, there is still some water in the soil, but it is held tightly in the small soil pores and is not enough to meet the grass demand for water. In most situations, we try to maintain the soil moisture somewhere above the wilting point, but at or below field capacity.

Figure 1: Summer irrigation of the 9th green at Golden Cross CC, Chiba-ken

On putting greens, the roots, and consequently most of the water uptake, tend to be at a depth of about 10 cm. I usually consider the rootzone to be the top 10 cm of the soil. The amount of water in the soil is often expressed in terms of volumetric water content (VWC) and given as a percentage. In 100 L of soil, for example, there may be 20 L of water. The VWC in that case is 20%. As another example, if we took completely dry soil with a volume of 500 cm^3, and then we added 100 cm^3 of water, the VWC of that soil would also be 20%.

The amount of water used by the grass through transpiration, combined with the amount of water evaporated from the surface, is called **evapotranspiration** and is often abbreviated as ET. This is expressed in mm. The ET is essentially the consumptive water use of an area. It is useful to remember that 1 mm of water spread over 1 m^2 has a volume of 1 L.

Irrigation Timing and Amount

Let's consider a few ways we might apply irrigation. Imagine that we have a putting green with a field capacity of 27% and a wilting point of 10%. The soil will never hold more than 27% water, and we want to always keep the soil at more than 10% water. In Figure 2, we see what the VWC would be

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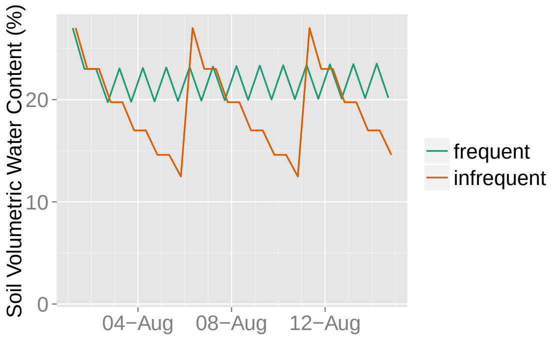

Figure 2: Calculated rootzone (10 cm depth) volumetric water content (VWC) for the first 14 days of August, assuming there is no rain, the daily evapotranspiration (ET) is 4 mm, the VWC on 1 August is at the field capacity (FC) of 27%, the frequent irrigation regime applies just enough irrigation to prevent the VWC from dropping below 18% on the next day, and the infrequent irrigation regime applies enough water to return the soil to FC when the VWC is predicted to drop below 11% on the next day.

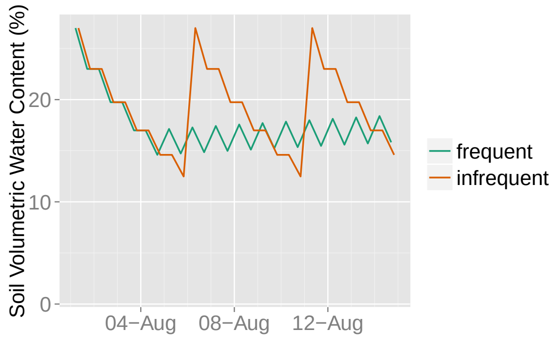

Figure 3: Calculated rootzone (10 cm depth) volumetric water content (VWC) for the first 14 days of August, assuming there is no rain, the daily evapotranspiration (ET) is 4 mm, the VWC on 1 August is at the field capacity (FC) of 27%, the frequent irrigation regime applies just enough irrigation to prevent the VWC from dropping below 14% on the next day, and the infrequent irrigation regime applies enough water to return the soil to FC when the VWC is predicted to drop below 11% on the next day.

for the first 14 days of August, assuming no rain and a daily ET of 4 mm. For the infrequent regime (orange line), irrigation is only applied to keep the soil moisture from dropping below 11%. For the frequent regime, irrigation is applied daily, but just enough to keep the VWC, on the next day, from dropping below 18%.

In the two irrigation regimes shown in Figure 2, the average VWC over the first 14 days of August are 21.9% for the frequent irrigation regime and 19.2% for the infrequent regime. In this case, the average soil moisture content is maintained at a higher level by frequent irrigation than by infrequent. But one can actually maintain a lower VWC by irrigating frequently than by irrigating infrequently. This counterintuitive result is shown in Figure 3.

This case keeps the infrequent irrigation regime the same, applying irrigation to return the soil to field capacity only to prevent the VWC from dropping below 11% on the next day. But the frequent irrigation regime shown in Figure 3 now is managed to apply just enough water to keep the VWC from dropping below 14% on the next day.

Now the average VWC for the first 14 days of August using the infrequent regime is the same, 19.2%, but the frequent (almost daily) irrigation regime has an average of 17.6%. Some advantages to the frequent irrigation regime as shown here include:

- Lower VWC, on average, which can produce firmer surfaces and fewer ballmarks
- More air in the soil
- More consistent playing conditions
- VWC never drops as low as it does in the infrequent regime, thus minimizing the chance of drought stress or the initiation of localized dry spots

Experiments to evaluate the effect of irrigation frequency have usually used an approach similar to that shown in Figure 2, namely, the soil in the frequent irrigation regime is kept very close to field capacity. In experiments in which the treatments are applied in this way (Jordan et al., 2003; Fu and Dernoeden, 2009a,b), the turf quality is better, and the roots are more extensive at the end of summer, when turf is irrigated infrequently. However, those experiments also maintain average VWC higher in the frequent irrigation treatments than in the infrequent treatments. In fact, Fu and Dernoeden (2009b) applied twice as much water to the frequently irrigated plots as they did to the infrequently irrigated plots.

A study of these experiments leads me to the conclusion that maintaining VWC at a lower level will give the best chance for improved turf quality and more extensive roots. As a practical matter, the best approach will usually be a combination of infrequent irrigation events interspersed with frequent irrigation events (Johnson, 2003). For turfgrass managers, I suggest focusing not so much on whether irrigation is applied frequently, or infrequently, but rather on applying just the right amount of water for a particular situation, and on keeping the VWC as low as possible.

Advice on the use of soil moisture meters

One can estimate how much water is in the soil, or one can measure it. Soil moisture meters al-

Figure 4: The surface temperature of 4 surfaces at 14:00 on 3 May 2013 in Bangkok when the air temperature was 38°C: a) concrete, 53.6°C; b) wilting *Zoysia matrella*, 48.8°C; c) transpiring *Axonopus compressus*, 39.2°C; d) transpiring *Zoysia matrella*, 36.2°C.

low turfgrass managers to make a precise measurement of how much plant available water is in the soil and how much water will need to be applied at the next irrigation event. Every location, because of different soil type, grass type, climate, management practices, season, desired turfgrass performance, and innumerable other factors will have a different range of VWC and optimum VWC at any time.

However, there are a few things that are consistent across all of those variables. Here are some things to remember.

1. After a saturating rain, when the soil is sure to be at its maximum VWC, but after gravity has pulled any excess water from the soil, use the moisture meter to measure VWC. In practical terms, this is equivalent to field capacity for a particular soil.
2. When the soil becomes so dry that the grass starts to wilt,[1] measure the VWC just as the grass starts to wilt. In practical terms, this is equivalent to the wilting point of the grass.
3. The difference between the wilting point VWC and the field capacity VWC is the amount of plant available water in the soil.
4. If we are using a 10 cm rootzone for our calculations, then each change of 1% in VWC is equivalent to 1 mm of water and equivalent to 1 L of water per m^2.

[1] If the grass never wilts, or the grass never starts to experience drought stress, then too much water is being applied. Or, it just rains too much!

With that information, one can attempt to maintain the VWC at any desired level, or within any desired range.

Morning vs. afternoon irrigation

Is there a time of day when it is best to irrigate the turf? I think that the best time to irrigate the turf is at the time we identify that the grass requires water. Practically it may not be possible to irrigate at that time, so the best time to irrigate would then become as soon as possible.

Guertal and Han (2009) compared the effect of morning (08:00) irrigation to afternoon (16:00) irrigation on soil temperatures. They found that morning irrigation sometimes had a greater effect in cooling soil temperatures than did afternoon irrigation.

However, when fans were used, the soil temperatures were consistently lower than when fans were not used. The use of fans also increased the root length density, no matter whether irrigation was applied in the morning or afternoon.

Syringing to Cool Bentgrass Greens

For this discussion, I will consider **syringing** (or misting) to be the application of a small amount of water to the turfgrass leaves for the purpose of cooling the surface. If I were managing bentgrass greens in the summer, I would not syringe. Here's why.

Figure 5: In an experiment conducted on a bentgrass green in Chiba, ice, ice water, and 26°C tapwater were applied and the soil and surface temperature were measured.

Temperature of transpiring vs. wilting turf

Figure 4 shows the surface temperature of four surfaces on a sunny day at Bangkok when the air temperature was 38°C. When the roots cannot take up enough water from the soil, the grass wilts. And when the grass wilts, the surface temperature on a sunny day can rise much higher than the air temperature. However, when there is adequate soil moisture, the transpiring grass usually has a canopy temperature within 1 or 2°C of air temperature.

Temperature change after syringing

Given that turf supplied with adequate soil moisture will have a canopy temperature very close to air temperature, what happens when the turf is syringed? How does the temperature change? DiPaola (1984) conducted an extensive investigation and found that water application of 50 or 100 mL m^{-2} resulted in no change in canopy temperature 30 minutes after application. Adding more than 1.4 mm (1.4 L m^{-2}) resulted in a decrease of about 0.7°C in canopy temperature 30 minutes after application. By 1 hour after application, there was no change in canopy temperature between syringed and non-syringed plots, no matter how much water had been applied.

When more than 100 mL m^{-2} is applied, I hesitate to call it syringing, because most of the applied water is going to the soil rather than staying on the canopy. In that case, I call it irrigation.

I measured (Figure 5) the effect of ice, ice water (1.5°C), and tap water (26°C) on the soil and surface temperatures of a bentgrass green in Chiba.[2] This was not syringing, because the amount of H_2O applied in each treatment was equivalent to 7.8 mm. Application of ice or ice water reduced the soil and surface temperatures by a few degrees for a few hours. Application of tap water reduced the surface temperature by about 0.5°C when applied in the morning, and caused a slight increase in surface temperature when applied at sunset.

The difference in canopy temperature between transpiring turf and non-transpiring turf can be more than 10°C (Figure 4). Application of water to the turf, in the extensive studies of DiPaola (1984), has minimal to no effect on canopy temperature, unless the grass is wilting, in which case the application of water does result in a reduction of canopy temperature.

Irrigation Water Quality

When irrigation water is applied, it is important to know what is in the water. The content of the water, and the chemical properties of the water, can have an impact on turfgrass performance and on soil physical properties. These potential problems can be managed, but only if one knows what is in the water. There are two important water quality parameters.

Salinity

The first is **salinity**, which is the amount of inorganic ions (salts) in solution. Table salt is sodium chloride, which in water dissolves to be Na^+ and Cl^-. There will also be sulfate and calcium and magnesium and potassium and ammonium and nitrate dissolved in the water, along with other ions; these ions, taken together, are called total dissolved solids (TDS) and are a measurement of the amount of salt (salinity) in the water.

The TDS is reported as mg L^{-1} and is measured directly by taking 1 L of water, evaporating all the water, and weighing how much solid matter remains in the container.[3] When irrigation water with salt is applied to turfgrass, the grass uses the water, but it may not take up all of the salts, and those salts accumulate in the soil. For example, irrigation water with TDS of 1000 mg L^{-1}, applied for one month at a rate of 4 mm d^{-1}, could cause 120 g m^{-2} of salt to accumulate in the the rootzone. That is a lot! Fortunately, irrigation water in Japan rarely contains that much salt. But unless it is measured, one doesn't know how much salt is being applied to the turf.

Salinity is managed by applying more water than the grass can use. This results in leaching, and as some of the applied water leaches below the rootzone, some of the salt also leaches below the rootzone.[4]

[2] The results of these experiments were described in articles I wrote for *Golf Course Seminar* magazine in the July 2012, October 2012, and August 2013 issues.

[3] The TDS is also estimated by measuring the electrolytic conductivity (EC) of the water. An EC of 1 dS m^{-1} is approximately equivalent to a TDS of 640 mg L^{-1}.

[4] The leaching fraction with example calculations was discussed in an article I wrote in the July 2011 issue of *Golf Course Seminar* magazine.

Sodium adsorption ratio

If there is a high amount of sodium in the water compared to the amount of calcium and magnesium in the water, there can be some problems in the soil. Over time, that water applied to the soil will cause sodium to accumulate on the cation exchange sites, and as this happens, the small clay-sized soil particles can deflocculate and swell. This reduces air space in the soil and slows the water infiltration. The sodium adsorption ratio (SAR) is an indication of how the water may cause a problem with infiltration and soil structure.

One can consult various interpretation tables to evaluate how a particular SAR may be a problem; for most irrigation water in Japan, an SAR of about 6 or above would be an indication of potential problems. To manage the potential problems of high SAR, calcium is applied to the soil, or injected into the irrigation water, usually in the form of gypsum (calcium sulfate).

Additional information

- On the subject of irrigation water quality, a particularly comprehensive yet concise guide is *Interpreting Turfgrass Irrigation Water Test Results* by Ali Harivandi: http://anrcatalog.ucdavis.edu/pdf/8009.pdf
- For a clear explanation of leaching requirement to maintain soil salinity at a tolerable level, I recommend *Leaching for Maintenance* from the University of Arizona: http://ag.arizona.edu/pubs/water/az1107.pdf
- An annotated chart of soil VWC with more detail than shown in Figures 2 and 3 is available for viewing or download: http://www.flickr.com/photos/asianturfgrass/8922147839/
- During the seminar, I showed some video clips from the classic *Water Movement in Soils* movie. This film is available for purchase from the Department of Crop and Soil Sciences at Washington State University: http://css.wsu.edu/merchandise/

Figure 6 shows that new roots can develop even during the hot temperatures of summer, provided there is adequate air space in the soil. By monitoring the VWC, it is possible to supply the grass with just enough water while still maximizing air space in the soil.

In many parts of Japan, the average temperature during August is more than 28°C and creeping bentgrass is subjected to severe heat stress. Managing the soil moisture at an optimum level, so that dry spots (water deficit) are avoided, while still keeping the soil as dry as possible so that air space is at a maximum, is an essential part of successful greenkeeping during summer.

Figure 6: On 8 September 2008, the average temperature for for the previous 39 days had been 26.8°C including an average of 26.4°C in the first 8 days of September; even with these high temperatures, well above the optimum for creeping bentgrass, new roots are growing where air space had been created in the soil by a slicing treatment at the end of August.

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