Using Et_o
To Improve Irrigation Efficiency

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Water is a valuable resource in the arid Southwest. Therefore, it is in the best interest of turf and landscape managers to practice irrigation scheduling that leads to wise water use. Fine tuning irrigation scheduling can maintain acceptable aesthetic quality, eliminate luxury consumption by plant material, reduce disease susceptibility and save money.

Water vs. Aesthetics

How much water needs to be applied to maintain acceptable aesthetic quality and function or to meet a competitive standard? The turf manager can calculate water needs with currently available formulas.

Ideally, the amount of water required by turfgrass can be quantified by the equation:

$$Et_{crop} = Et_o \times K_c$$

In the above equation, Et_{crop} is the actual turfgrass water use, Et_o is the reference water use and K_c is the crop coefficient. The last step in determining irrigation quantity is to divide Et_{crop} by the irrigation system distribution uniformity (DU):

$$\text{irrigation need} = \frac{Et_o \times K_c}{DU} = \frac{Et_{crop}}{DU}$$

Basically, as the distribution uniformity (DU) decreases, more irrigation water will need to be applied, though the water used by the turfgrass has not changed.

Reference Water Use

Et_o, reference evapotranspiration, is an estimate of the amount of water used by a healthy stand of cool-season turfgrass four to six inches in height. Reference ET values can be obtained from different sources, such as CIMIS (California Irrigation Management Information Service) and AZMET in Arizona. These programs use an equation (modified Penman model) to convert recent weather data into Et_o values, which can be retrieved by irrigation managers using a modem. Some central irrigation controllers have the ability to perform Penman calculations with on-site weather data.

Reference ET can also be estimated from pan evaporation and atmometers. Certain irrigation controllers can be connected to atmometers to facilitate ET-based scheduling. Some turf managers also schedule irrigation with the help of soil moisture sensors. Moisture sensors, such as tensiometers, gypsum blocks or granular matrix sensors, can be interfaced with some irrigation controllers to interrupt irrigation when soil moisture is adequate for plant needs.

Crop Coefficients and Crop Water Use

University research over the past two decades has yielded monthly crop coefficients or plant factors (K_c) to facilitate ET-based irrigation scheduling of warm- and cool-season turfgrasses. These coefficients were developed under coastal California conditions and can differ slightly in other regions of the country. When multiplied by Et_o, crop coefficients provide a relatively accurate estimate of ET_{crop} or ET_{turf}, the amount of water (depth) used or required by the turfgrass.

Crop coefficients can be averaged to yield quarterly, semi-annual or annual crop coefficients. Averaging crop coefficients reduces monthly precision. Ideally, managers should employ monthly, or at least quarterly, crop coefficients in their calculations for turf water requirements. Table 1 provides monthly, quarterly and semi-annual cool- and warm-season crop coefficients. Historical data on crop coefficients is available in some areas.

Water Use vs Requirement

Distribution uniformity (DU) of an irrigation system is a measure of how uniformly a system applies water to a crop surface. Rainfall, in most cases, would be considered 100 percent uniform. Many irrigated sites have a DU ranging from 50 to 70 percent.

DU is important because it influences the amount of required irrigation, even when Et_{crop} remains unchanged. To make sure the turf receives the required amount of water, as calculated by multiplying the Et_o by the crop coefficient, you need to divide by the DU (i.e., 60 percent = 0.60). By dividing by a number less than one, the amount of water required to satisfy plant water use increases. Poor irrigation uniformity increases the irrigation requirement. Irrigation systems with high DUs can apply less water and still satisfy plant water needs.

Poor irrigation uniformity increases the irrigation requirement.

Determining Run Times

Once a recommended water quantity is determined for a particular turfgrass, a series of calculations are required to convert this quantity to an actual run time on an irrigation controller.

The first step calculates how many inches of water need to be applied. To do this, you multiply Et_o for the region at the particular time of year by the crop coefficient (K_c) for your particular turfgrass. The result is then divided by the irrigation system distribution uniformity.

$$\frac{Et_o \times K_c}{DU} = \text{water need in inches for period}$$

For example:

$$\frac{6.2 \text{ in. (monthly } Et_o) \times 0.94 \text{ (July } K_c)}{0.60 \text{ (distribution uniformity)}} = 9.7 \text{ in.}$$

This "depth" of water is converted to an actual run time (minutes) for the period by dividing the system precipitation rate (inches per hour) and then multiplying by 60. The final step is to calculate run time for the period by the number of irrigation events for the period.

$$\frac{9.7 \text{ in. (depth of water)}}{1.5 \text{ in. (precipitation rate/hour)}} = 389 \text{ min.}$$

Catch Can Test

Two variables are required for this calculation. They are distribution uniformity and system precipitation rate. Both can be obtained by conducting a catch-can test.

This test can be done with any number of straight-sided containers placed in a grid across the turf area. Information is more accurate when more cans are used. Once the cans are in place, run the irrigation zone for 15 minutes. If this is not long enough, run the system for 30 minutes. Measure the amount of water in each can with a ruler. Convert the readings to inches per hour (multiply by 4 for 15-minute tests and 2 for 30-minute tests).

System distribution uniformity (DU) is determined by comparing the amount of water collected in the containers. To do this, you first need to identify the 25 percent of containers with the least amount of water. Divide the total number of containers by four. If you have 12 containers, you want to find the three that had the lowest amount of water in them. Then, determine the average depth of water in the 25 percent of the containers with the least amount of water and the average depth of water for all the containers.

$$DU = \frac{\text{mean of low quarter (volume or depth)}}{\text{overall mean (volume or depth)}}$$

Precipitation rate is the average depth of water collected in all of the cans multiplied by four (assuming a 15 minute run time). If the average measured depth is 0.25 inches, then the system precipitation rate would be 1 inch per hour.

Alternatively, precipitation rate can be calculated using the following equation:

$$\frac{\text{gpm (one head)} \times 96.25}{\text{head spacing on row (ft)} \times \text{row spacing (ft.)}} = \textit{inches/hour precipitation}$$

TABLE 1. COOL- AND WARM-SEASON TURFGRASS CROP COEFFICIENTS (Kc)

COOL-SEASON TURFGRASS					WARM-SEASON TURFGRASS				
Month	Monthly	Quarterly	Semi-An.	Annually	Month	Monthly	Quarterly	Semi-An.	Annually
JAN	0.61				JAN	0.55			
FEB	0.64	0.67	0.68		FEB	0.54	0.62	0.55	
MAR	0.75				MAR	0.76			
APR	1.04				APR	0.72			
MAY	0.95	0.96			MAY	0.79	0.73		
JUN	0.88		0.90	0.80	JUN	0.68		0.71	0.60
JUL	0.94				JUL	0.71			
AUG	0.86	0.85			AUG	0.71	0.68		
SEP	0.74				SEP	0.62			
OCT	0.75				OCT	0.54			
NOV	0.69	0.68	0.68		NOV	0.58	0.56	0.55	
DEC	0.60				DEC	0.55			

Crop coefficients are for arid Southwest. Coefficients may differ slightly in other regions.

For example, a catch can test is performed with 20 cans, spaced five feet apart. Measuring depth of water in each can, the average depth in the five lowest cans is 0.22 inch. The average depth of all 20 cans is 0.35 inch. The precipitation rate for this system is 0.35 x 4 = 1.4 inch per hour. DU is 0.22 divided by 0.35 = 0.63.

The next step is developing an efficient irrigation program to calculate run time per irrigation event. This requires knowledge of the number of irrigation events per time period. In the following example, we assume the manager wants to irrigate twice per week. Examination of a calendar shows nine irrigation events for an average month, or 35 irrigation events for a quarter. Total run time needs to be divided by this many irrigation events. Continuing with the preceding example:

run time per month (389 minutes)
number irrigation events per month (9)

= ***43 minutes per irrigation event***

This is the amount of time that will actually be programmed into the irrigation controller to apply a total amount equivalent to 94 percent Et_o, the recommended replenishment for cool-season turf in July.

Optimizing Application

Maximizing irrigation system uniformity is one of the most important steps an irrigator can take to optimize his irrigation. To illustrate, let's take the preceding example and apply it to two irrigation systems with different DUs. Notice how much more water must be applied with system 2 to achieve a similar result, compared to system 1. The less uniform a system is, the longer the sprinklers will have to run to produce a uniform turf appearance or performance over the entire irrigation area.

Irrigation system uniformity can be improved in many ways. The first is to ensure that the system operating pressure is within the manufacturer's recommended range for the head being used. Manufacturer's catalogs also list optimum operating pressures for specific heads.

High pressure causes atomization and loss of fine droplets to wind, not to mention unnecessary wear and tear on system piping and equipment. Low pressure causes insufficient diffusion of sprinkler spray patterns. Donut-shaped dry areas are the result. Operating pressure can be measured with a pitot tube held against the nozzle of a rotor or impact sprinkler head or by a gauge affixed to a pressure-regulating valve.

If system pressure is too high, it can be reduced with an adjustable pressure regulator or a pressure-regulating solenoid valve. Pressure regulators are generally located downstream of the backflow device. One can also use a pressure-regulating master valve. A third option is installing pressure-regulating valves leading to particular zones or stations, such as low-flow zones. This provides the greatest flexibility by allowing adjustment of each zone to an optimum operating pressure.

Pressure regulation at the sprinkler head is also possible. Sprayheads can be purchased with pressure compensating devices that reduce operating pressure to an ideal range for a specific nozzle.

Shaded areas require less water than sunny areas, and so, ideally, separately valved systems should be in operation for each. Irrigation on slopes requires shorter, more frequent irrigation than other zones and should be treated as unique hydrozones.

System uniformity also can be adversely affected by low operating pressures. Remedies are more difficult than for high pressure. Check galvanized steel supply lines for corrosion and frictional pressure loss; replacing pipe might be necessary. In some cases, a booster pump can be installed to increase system pressure. A third remedy could be to divide existing zones into smaller ones to reduce flow demand by adding additional solenoid valves or index valves.

An easier solution might be to install smaller nozzles on rotor and impact heads. Smaller nozzles will reduce throw radius unless they are designed specifically for lower flow rates. If the source of irrigation water is public mains, schedule irrigation for periods when pressure is highest, usually between midnight and 5 a.m. Be aware of disease incidence caused by foliage remaining wet for long periods of time.

Assuming system operating pressure is within the recommended range, uniformity can often be improved. Rotor or impact heads provide superior uniformity to sprayheads. Nozzles for any type of head should be matched for precipitation rate. This is most important for part-circle heads.

Heads from various manufacturers can have different rotation and precipitation rates and matched precipitation can be lost. Replace damaged or worn heads and nozzles with the same brand.

Heads should be checked for vertical alignment and uniform rotation periodically. Nozzle wear and in-line filters should also be checked routinely. Irrigation should take place when wind disturbance is least.

Don't Set and Forget

Irrigation controllers should be rescheduled as frequently as possible. Run times should be changed weekly or biweekly. Water budget or global adjust features can simplify rescheduling by making percentage changes.

Remote control of irrigation, where programs can be changed via modem or radio, is becoming increasingly popular. Such features encourage frequent controller updating by making adjustments easier.

An irrigation system should be designed with hydrozones in mind. Water requirements of trees and shrubs differ from turf because the former have deeper and more extensive rooting patterns and can be watered more infrequently. The trees, shrubs and turf constitute different hydrozones and separate systems should be used for each if possible. Furthermore, shaded areas require less water than sunny areas, and so, ideally, separately valved systems should be in operation for each. Irrigation on slopes requires shorter, more frequent irrigation than other zones and should be treated as unique hydrozones.

The use of rain switches can prevent irrigation during rain events. Many new controllers have terminals into which a rain switch can easily be installed. Soil moisture sensors can also be used to prevent irrigation when soil moisture is adequate for plant needs. After all, it is the moisture in the soil available to plants that all other calculations are trying to emulate.

ET-Based Irrigation Has Arrived

Applying an amount of water which replenishes turf and landscape water use (ET) is a realizable goal that can result in significant water and monetary savings. ET-based irrigation scheduling seeks to prevent overirrigation, which leads to runoff or leaching into potable water resources. The goal is to irrigate plant materials at the recommended percentage of Et_o as infrequently as possible.

University research has shown that applying an annual average of 80 percent Et_o to tall fescue less frequently (twice per week) can result in improved visual color and quality. Keep in mind that with the longer run times associated with less frequent irrigation, water infiltration becomes a consideration and multiple cycles or lower precipitation rates might need to be used.

Acceptable turf quality and performance can best be maintained when irrigation system uniformity is optimum.

Recommendations for system uniformity include:

- **check & adjust operating pressures**
- **select appropriate heads and nozzles**
- **check head alignment and operation**
- **irrigate at times when wind is minimal**

Finally, nothing is more important than visual observation. The turf manager should inspect turf areas and irrigation systems on a regular basis. If dry areas are apparent, in spite of proper system operation, controller programs should be adjusted accordingly.

With a proficient irrigation system and frequent controller program updates, golf course superintendents should begin to see improved plant quality and performance with savings in water and energy.

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