TURFGRASS TRENDS

IRRIGATION AIDS

Soil-Moisture Sensors Can Help Regulate Irrigation

By Dale Bremer and Jay Ham

Competition for water is increasing between industry, the environmental and the public. The subsequent rises in irrigation costs are compelling turf managers to reduce water consumption.

In highly managed turfgrass such as golf courses, managers are under pressure to maintain green, lush turfgrass regardless of weather or other environmental conditions, which sometimes results in frequent overwatering or inefficient use of irrigation water. Often, the decision to irrigate is based on incomplete information about the water requirements of turfgrasses, evapotranspiration (ET) rates, and available water in the root zone.

New technology, which includes advances in soil-moisture sensors, could improve irrigation efficiency by providing critical information from the root zone for irrigation management decisions.

Irrigation at golf courses will likely be controlled by complex central computers that use a combination of data from soil-moisture and weather station sensors to make irrigation decisions.

Traditional methods

Traditionally, turfgrass is irrigated through the experienced eye of the turf manager. This could include but is not limited to irrigating:

- at the first sign of wilt when the turf begins to change from a healthy green to a blue, gray or purplish hue;
- turf is slow to spring back when compressed by foot traffic or wheel traffic;
- when a narrowing of leaf blades is noticed; or
- when canopy temperatures climb above that of hydrated or well-watered turf. Placing a hand on well-watered turf and then on stressed turf can often sense the latter, which feels warmer.

Although these methods are relatively quick and easy and may be somewhat effective in maintaining green turf, they are also highly qualitative and do not result in the most efficient use of irrigation water (Waltz and McCarty 2000).

Basing irrigation on ET requirements is a quantitative method that is used by a number of turf managers. This method uses environmental data collected from on-site or nearby weather stations to estimate ET. The idea is to calculate daily ET using mathematical models. This estimate of ET is technically called "reference ET."

The reference ET is usually adjusted according to the requirements of a partic-

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ular turfgrass because different species of turfgrasses use differing amounts of water. The value becomes the basis for deciding how much irrigation to apply. The goal is to reduce the overapplication of irrigation water by applying only what the turf requires, which avoids excessive runoff and leaching below the root zone.

In terms of water savings, the ET method is generally an improvement compared to watering by frequency or even by experience. However, the ET method also has its limitations. Unfortunately, even our best estimates of ET are not completely accurate. Furthermore, when using the ET method, an equal amount of water is applied on all areas of the course, meaning allowances are not made for differences in slopes, variation in soil types or differing microclimates. All of these factors affect ET rates in turfgrass.

Studies show ET rates can vary as much as 20 percent in urban environments and on a golf course. The result is that water may be overapplied or underapplied.

University studies show that ET rates can vary as much as 20 percent in urban environments and on a single golf course (Feldhake et al. 1983; Jiang et al., 1998). The result is that water may be overapplied or underapplied in some areas.

Irrigation based on sensors

For turf managers, soil-moisture sensors are useful tools in irrigation management because they provide physical, quantitative measurements of soil water in the root zone. A network of automated permanent sensors installed throughout the irrigated area can provide real-time information on moisture conditions in all irrigation zones. Soil-moisture sensors can indicate when soil has dried to the point where irrigation is required.

These sensors can also indicate when the soil profile is full of water. The latter may be most useful in greens, where overwatering is the tendency. In this way, healthy turf is maintained by avoiding plant stress caused by soil that is too dry or too waterlogged.

Soil-moisture sensors also could be coordinated with nearby sprinkler heads, so irrigation amounts could be adjusted according to different water-use rates. Consequently, the incorporation of soil-moisture sensors into an irrigation management strategy may result in the conservation of costly irrigation water (Horst and Peterson, 1990).

Although the primary benefit of sensors is water conservation, they may also result in the improvement of water quality. By preventing overwatering, less water is lost to runoff and to deep percolation into the soil. Consequently, less pesticides and nutrients are transported into streams and groundwater supplies.

The improvement in water quality is an important benefit in an era of increasing public environmental awareness and regulations.

At Kansas State University, research is under way to control irrigation automatically using dual-probe heat capacity sensors, which is a new technology that provides measurements of soil-water content near the surface (Song et al., 1998)(Fig. 1).

These sensors are wired to a central computerized control system that can be programmed to trigger and curtail irrigation when soil water content reaches specific levels. All sensors in this study were built in the laboratories at Kansas State University.

Other soil-moisture sensors are available that also may be used to control irrigation automatically. For example, time domain transmission sensors and automated heat dissipation matric water potential sensors can measure soil water content at shallow depths and could be used to control irrigation.

Several factors must be determined when using soil-moisture sensors to control irrigation in turf. For example, the soil-moisture thresholds where irrigation should begin and end must be established, and these may vary among soil types and turf species.

Initially, correlations among soil-moisture, canopy temperatures and physiological stress (such as photosynthetic rates) will be investigated at Kansas State. These variables will be measured under different irrigation treatments where they are triggered at progressively lower levels of soil-moisture under turf at fairway height.

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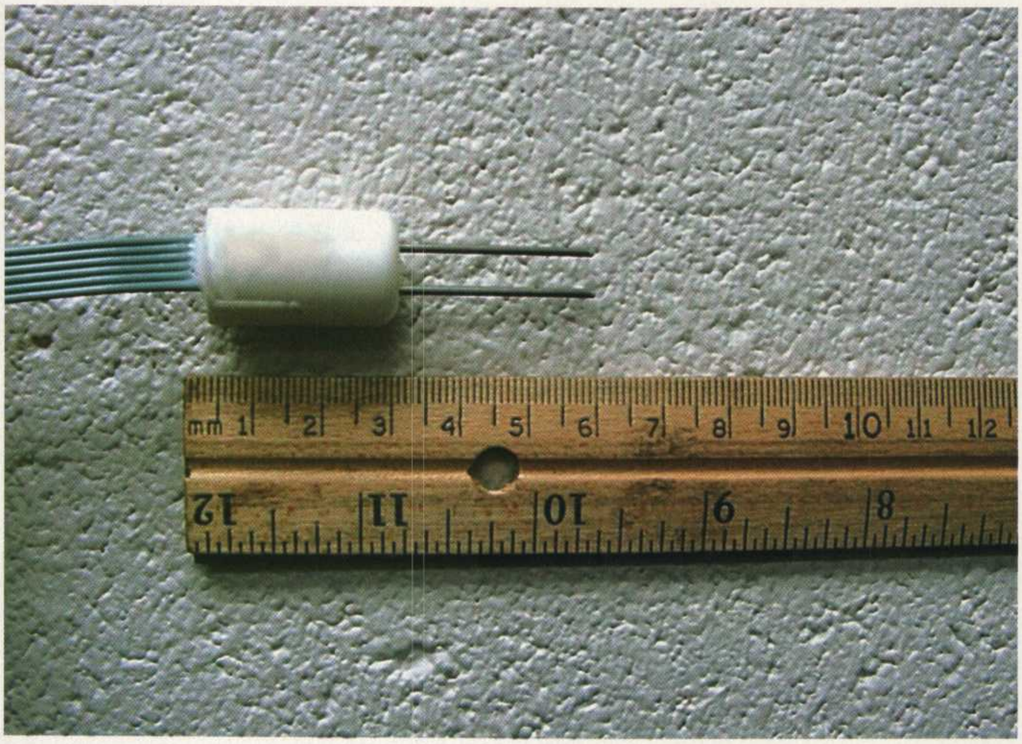

This dual-probe heat capacity sensor built at Kansas State University can help superintendents measure the effectiveness of their irrigation systems more accurately.

The effects of the various irrigation treatments on overall turf quality will also be evaluated. The goal is to determine the minimum thresholds where plants remain healthy and without stress symptoms. Delaying irrigation to this threshold may result in water savings. Furthermore, turf health should improve in the long run since the turf would be irrigated before the onset of stress symptoms.

Another consideration is the optimal depth of soil-moisture sensors. Ideally, soil-moisture sensors should be placed in the active part of the root zone where most of the water is extracted, and that depth may vary by turf species and mowing height.

For example, dual-probe data from perennial ryegrass mowed at fairway height suggest that optimum sensor placement may be at a 2-inch depth. Optimal placement may be deeper in tall fescue. Dual-probe measurements under tall fescue revealed that soil-moisture depletion was greater at 6 inches than at 2 inches or 12 inches, suggesting that 6 inches may be a better depth of placement of sensors in tall fescue (Table 1). Other practical factors may need to be considered when positioning soil-moisture sensors.

Ideally, sensors should be installed with the irrigation system during the construction of a golf course to minimize the disruption to turfgrass and to players. However, this will not always be possible. Installation in established turfgrass could cause temporary destruction of turfgrass and disruption to players, although wireless, remotely accessed soil-moisture sensors may minimize these problems.

KSU research is underway to control irrigation automatically using dual-probe heat capacity sensors -— new technology that provides measurements of soil water content near the surface.

Another consideration is the potential for sensors to be damaged by routine aeration treatments. For example, if the depth of aeration is greater the depth of the sensors, then

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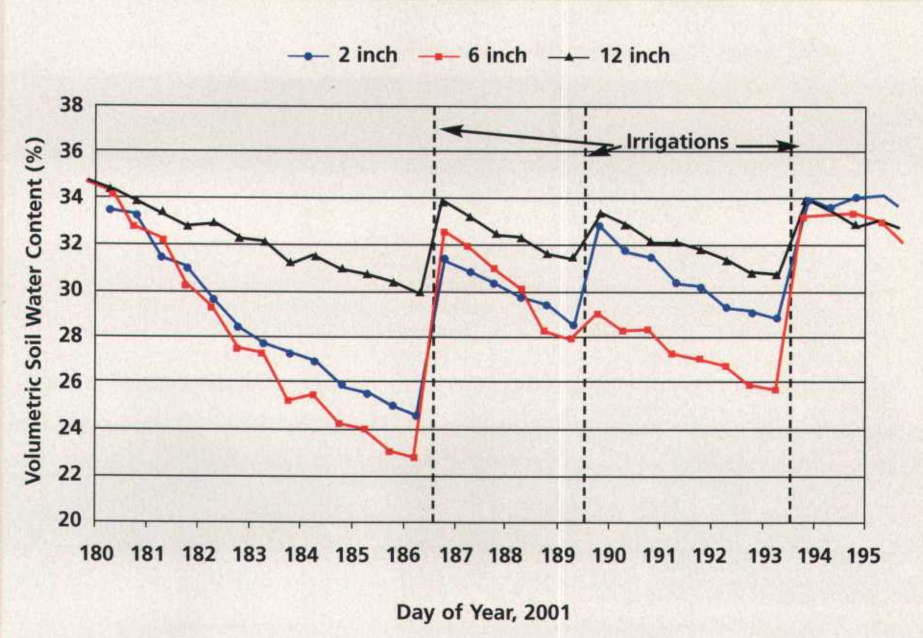
TABLE 1

Soil moisture in tall fescue



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there is potential for damage. Compaction in heavily trafficked areas also may affect the accuracy of soil-moisture sensors because the readings of a number of sensors are affected by the change in bulk density.

The rapid development in soil-moisture technology may help to overcome these challenges in the not-so-distant future. For example, remote sensing techniques are being developed to estimate soil water content in the surface layer without sensors being installed in the soil (called passive microwave; Schmugge et al. 1992). This would avoid the problem of aeration spikes or deep divots ruining soil-moisture sensors.

Another possibility may be to install soil-moisture sensors along underground irrigation pipes near each riser. Because of advances in technology, the type of soil-moisture sensor used in current studies is probably less important in the long run than the fundamental information obtained. For example, the relationships between soil-moisture levels and plant physiological stress, and the establishment of lower and upper irrigation thresholds for turfgrass are factors that will be the same regardless of the type of soil-moisture sensor used.

Although soil-moisture sensors offer much promise for automated control of irrigation in turfgrass, they won't solve all irrigation problems in turf. For example, under extremely high temperatures plants may be under stress and require light watering (syringing) even if soil-moisture levels are adequate (Beard, 2002; Huang et al., 1998). In other instances, soil-moisture sensors may initiate irrigation even when rainfall is imminent. Incorporation of weather data, in combination with soil-moisture sensors, into the irrigation control system could provide a solution to these problems.

A computer's fuzzy logic would not take control away from the operator, but would "learn" how the superintendent makes irrigation decisions.

Control systems that use fuzzy logic and

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Scotts

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The Scotts Co. and Monsanto recently resubmitted to the USDA their petition seeking deregulation of Roundup Ready Creeping Bentgrass. The petition was voluntarily withdrawn last fall to fulfill the USDA's request for additional scientific data.

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neural networks (also called artificial intelligence) are already in use by other industries and may be well-suited for controlling irrigation in turfgrass. Such systems can make accurate decisions based on uncertain or approximate inputs (Kasabov, 1996).

Looking ahead, it's quite possible to imagine that irrigation management in turfgrass in

In the future, irrigation at golf courses will likely be controlled by complex central computers that will use a combination of data to operate.

the future will be managed by automated, computerized systems that use soil-moisture sensors, weather data and an adaptive fuzzy logic control system.

Such systems would allow turf managers to override the systems for manual control if necessary, and the control system could actually "learn" from inputs provided by the superintendent. Thus, fuzzy logic would not take control away from the operator, but would actually "learn" how the superintendent makes irrigation decisions.

Conclusions

In summary, using soil-moisture sensors in irrigation scheduling will become more important as the costs of water rise and as water restrictions are imposed. Research is under way to determine fundamental relationships between soil-moisture levels and physiological stress in turf and to determine upper and lower limits for irrigation thresholds.

Although there are a number of practical limitations to using soil-moisture sensors in irrigation scheduling, new technology will likely overcome these limitations.

The benefits in water conservation and improvements to water quality will outweigh the difficulties associated with the deployment and maintenance of soil-moisture sensors.

In the future, irrigation at golf courses will likely be controlled by complex central computers that use a combination of data from soil-moisture and weather station sensors to make irrigation decisions and to make the most efficient use of irrigation water.

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