Probing Turfgrass Irrigation Saving Strategies for the 21st Century

By F. C. Waltz and L. B. McCarty

As water conservation and usage become more important issues, golf course superintendents and other turf managers will be forced to make more judicious use of water resources. Turfgrass managers will have to justify the use and volume of water and forgo the days of indiscriminate irrigation.

Since the soil in the rootzone acts as a storage reserve for water, an understanding of the soil moisture status is essential for efficient irrigation practices.

For years, superintendents have used many means to guide turfgrass irrigation. Some methods are more qualitative and adapted to quick field adjustments, while others are more time consuming but provide quantitative information. Water conservation and turfgrass quality issues will dictate that the positive attributes of all these methods be accentuated.

Watering by feel

The most commonly used method of assessing moisture status is through experience with visual determinations. Early detection of moisture stress is the observation of "wilt," a physiological condition that occurs when the cells within the turfgrass plant lose turgor pressure.

One of the earliest physical characteristics of turfgrass "wilt" is a change in color. As moisture becomes limiting, plants will change from a healthy green to a bluish hue and eventually a purplish black color. In the case of severe moisture stress, the turf will take on a brown straw color. If detected early and sufficient irrigation is applied, many turfgrass species will regain turgor pressure and the green color will return within a few days.

In addition to color change, other characteristics of "wilt" include narrowing of the leaf blade and an increase in the turfgrass canopy temperature compared to hydrated turf.

However, in the case of prolonged drought, turfgrass may either enter into an induced dormancy (at which time growth will continue only when water is no longer limited) or the turf may die.

Other characteristics of "wilt' include narrowing of the leaf blade and an increase in the turfgrass canopy temperature compared to hydrated turf. At the onset of moisture stress, a temperature increase can be detected by placing a hand on green turf and the other hand on stressed turf, much as a parent would check a child for fever. While visual and sensual assessments are quick and relatively easy, they are purely qualitative.

Measuring water

A physical measurement of water is a quantitative assessment of the moisture status or level within the turfgrass rootzone. When this is made on a weight basis it is called the gravimetric water content (indicated as qwt). This technique requires the extraction of a plug of soil, weighing the moist plug (wet weight in grams), drying it in an oven at 105° C overnight, and re-weighing the dried plug (dry weight in grams). qwt (in g g-1) can then be calculated (Equation 1).

Equation 1

$$\grave{e}_{wt} = \frac{[\text{Wet Weight (g)}]-[\text{Dry Weight (g)}]}{[\text{Dry Weight(g)}]}$$

Other information can be determined from the removal and drying of a plug. Density is the mass of an object that occupies a given volume. In soils, bulk density (BD) is the mass (g) of dry soil, including pore space, contained in a given volume (cm-3) and is often used as a measure of soil compaction (Equation 2). As the mass of dry soil increases in a given volume, so does BD, which indicates increased soil compaction. Particle density is the density of an individual soil particle or solids and is commonly approximated at 2.65 g cm-3.

Equation 2

$$\text{Bulk Density} = \frac{[\text{Dry Weight of soil (g)}]}{[\text{Volume of soil (cm}^3)]}$$

Volumetric water content (qv) is the volume of water within a volume of soil and can be calculated (Equation 3). As roots explore a volume of soil for water, the moisture environment within the rootzone is more realistically described by qv than qwt. Also, qv values can be converted to equivalent water depths, much like measurements made with a rain gauge (Equation 4). For example, a 30-cm layer of soil with a qv of 0.20 cm3 cm-3 would contain 6 cm of water.

Equation 3

$$\grave{e}_v = (\grave{e}_{wt}) \leftrightarrow (BD)$$

Equation 4

$$\text{Depth of water} = (\grave{e}_v) \leftrightarrow (\text{depth of soil})$$

Important for turfgrass growth and development, air and water are held within the pore spaces between soil solids. Total porosity (et) is the measure of voids relative to the total volume of bulk soil and is calculated by Equation 5. Bulk density is inversely related to et, as bulk density increases the porosity decreases. United States Golf Association (USGA) specifications for root zone putting green media recommend a et of 0.35 –0.55 cm3 cm-3 (The USGA Green Section Staff, 1993).

Equation 5

$$\hat{a}_t = 1 - \frac{\text{—Bulk Density}}{\text{Particle Density}}$$

While pulling a plug provides significant data, it is a destructive method requiring time to complete.

Environmental guided irrigation

Another method used to guide turfgrass irrigation is based on estimated daily turfgrass evapotranspiration (ET) rates. Evapotranspiration is the combined loss of water through plant transpiration and evaporation of water from the soil.

The concept of this technique is to use local weather information (i.e. temperature, relative humidity, wind velocities, solar radiation, etc.) in an equation, or model, which estimates the amount of moisture lost through ET. Enough irrigation is then applied to compensate for the moisture lost.

There are several models that estimate ET and are used to guide turfgrass irrigation. Fry et al. (1997) found turfgrass species, mowing height and nitrogen fertility can influence the accuracy of ET models. Also, certain models may provide more accurate estimates in one part of the country compared to another. Using ET to guide irrigation requires the input of many factors and site specific calibration.

When the proper information is used, ET can be an effective method of managing water resources, however knowledge of many variables is required for efficient use.

Probe guided irrigation

Researchers have continually shown that efficient water management is achieved by using a reliable device to guide irrigation timing. The use of instrumentation, or sensors, is yet another method of determining soil moisture status.

There are various types of instruments that measure moisture content (i.e. porous blocks, thermal dissipation blocks, tensiometers, neutron probes, dielectric constant probes, and others), with each having positive and negative attributes. Permanently buried sensors have the potential to be valuable tools in the decision process of when to irrigate and how much water to apply. Criteria for an effective moisture probe for golf course use include readings that are:

- accurate;
- independent of soil type or organic matter content, and soil compaction;
- independent of pesticide or fertilizer application (soil ionic strength);
- in a real-time manner;

• easily interfaced with a computer system;
• the probe should be relatively permanent; and
• small enough not to disturb the playing surface or required maintenance practices (i.e. pin locations and routine aerification).

Tensiometers

When compared to a set irrigation schedule, Morgan and Marsh (1965) reported on a clay loam soil, irrigation guided by tensiometers installed at two depths (5 cm and 12.5 cm) could reduce water use by 83%. On 'Tifgreen' bermudagrass (Cynodon dactylon X C. transvaalensis) managed as golf course fairways, Augustin and Snyder (1984) were able to use 42% to 95% less water using tensiometer-guided irrigations compared to plots that received daily irrigation.

Improved root vigor and depth were also observed on tensiometer irrigation guided greens, while playability did not suffer. Morgan et al. (1966) reported less compaction under tensiometer-guided irrigation compared to set irrigation schedules on a sandy loam soil with and without amendments. Also, ap-propriate irrigation practices can influence nutrient leaching. In a sandy soil, Snyder et al. (1984) observed a reduction in nitrogen leaching under tensiometer-guided irrigations.

Reduced water use, improved root vigor and depth were observed on tensiometer irrigation guided greens, while playability did not suffer.

It has been shown that irrigations guided by tensiometers can reduce irrigation frequencies, soil compaction and nutrient leaching. However, water savings have not been demonstrated on a modified sand profile construction as prescribed by the United States Golf Association (USGA). Also, tensiometers require continual maintenance, calibration, and do not fit well into an automated system.

Neutron probe

For research purposes, Aragao et al. (1997) found in situ neutron probes beneficial for scheduling irrigation on sand based putting greens. Because neutron probes use radioactive materials (radium-beryllium or americium-beryllium) to measure hydrogen ions associated with water molecules they are highly accurate (Miller and Gardiner, 1998; Evett and Steiner, 1995).

However, due to the use of radioactive materials, special licensing is required and therefore neutron probes can not be permanently imbedded in the soil (Devitt and Morris, 1997; Miller and Gardiner, 1998; Evett and Steiner, 1995).

Because neutron probes use radioactive materials to measure hydrogen ions associated with water molecules, they are highly accurate.

Neutron probes are unreliable near the soil surface (Hanks and Ashcroft, 1980; Kome, 1996; Song et al., 1998). Although highly accurate at measuring soil water content, neutron probes are not practical for golf course use due to limitations and the high cost associated with the system.

Dielectric probes

A relatively new technology to measure soil moisture is the measurement of the soil dielectric constant (DC). The DC is a unitless measurement of a solvent's ability to keep opposite charged particles apart, in this case the solvent is water (Voet and Voet, 1995). The DC of dry soil ranges from 2 to 5, while the accepted DC value for water is 78 (Rial, 1999; Miller and Gardner, 1998; da Silva et al., 1998). Due to the difference between dry soil and water, moisture content can be measured. Greater moisture contents cause higher DC values while lower DC readings indicate reduced moisture content.

There are two basic types of probes that measure DC — time domain reflectometry (TDR) probes and capacitance probes.

Time domain reflectometry is a safe technique that provides reliable, instantaneous readings that can be automated. It operates by emitting an electromagnetic pulse from a source through a wire and into two parallel probes in the soil. An oscilloscope, is used to measure the return speed of the pulse to the source. The time for the pulse to travel down the wire, through the probes, and return to the source is a function of the DC. When the soil matrix contains moisture, the return time is slowed due to the high DC of water (Devitt and Morris, 1997; Miller and Gardner, 1998).

When compared to moisture contents from neutron probes and gravimetric techniques, Hanson and Peters (1997) found good correlation with several commercially available TDR probes. In a sandy soil, Cereti et al. (1997) observed good relationship between gravimetric and TDR techniques.

In a study conducted on a golf course fairway, Kome (1996) found TDR probes to be useful in turf irrigation scheduling. When compared to weighing lysimeters in a turfgrass ecosystem, Young et al. (1997) found TDR probes measured up to 96% of the water lost through ET. However, TDR instrumentation is expensive and due to the length of the probe (30 cm or greater), it is not readily applicable for golf course use.

Like TDR, capacitance probes (CP) measure water content based on soil DC. Capacitance probes can be buried in the soil, are small (about twice the size of a golf ball), easily integrated into automated data collection systems, and are less expensive than TDR (Devitt and Morris, 1997). As a result, CP can provide real time moisture information such that turfgrass managers can quickly and accurately assess moisture in individual greens. Also like TDR, soil temperature and ionic strength can influence readings (Campbell, 1990). However, some CPs measure soil salinity and temperature along with DC, allowing for more reliable moisture readings.

Although only limited data exist for the use of CP in turfgrass, Starr and Paltineanu (1998) found CP to provide acceptable real-time sensitivity when measuring soil water moisture in field-grown corn. With further research and advancements in technology, CP may prove to be an economically justifiable tool for guiding irrigation practices on golf courses.

Other probes

Other types of probes have been used to determine soil water content. On a USGA specification rootzone media, Freeland et al. (1990) used parallel, bare wire ends to measure soil resistivity. An empirical equation was used to convert resistivity values to moisture contents. While this technique is inexpensive, rapid and useful in measuring relative moisture contents, sensors are sensitive to fluctuating soil temperatures, compaction and soil ionic concentrations.

Song et al. (1998) used a dual probe heat-pulse technique to measure soil moisture in laboratory packed columns seeded with "Kentucky 31" tall fescue (Festuca arundinacea Schreb.). The dual-probe heat-pulse technique is nondestructive, easily automated and not sensitive to soil bulk density. However, the accuracy is subject to soil temperatures and low water contents, although the authors did not feel that these limitations were of practical significance.

While this technique is inexpensive, rapid and useful in measuring relative moisture contents, sensors are sensitive to fluctuating soil temperatures, compaction and soil ionic concentrations.

Another type of probe used to measure soil moisture is thermocouple psychrometers. This technique is based on measuring the relative humidity of a sample and relating it to water potential. Unfortunately, due to temperature differentials when buried in the upper 30 cm of soil, the reliability of thermocouple psychrometers were compromised (Brown and Oosterhuis, 1992). Although very sensitive, this technique is not practical for golf course use because a calibration curve is required and the lack of reliability in shallow soils.

Conclusions

Although personal sensory methods for assessing water for turfgrass will always be used, instrumentation will become a more important part of irrigation scheduling to accurately justify the expense of irrigations.

As technology improves and water restrictions are levied, golf course superintendents will have to justify water usage and a tool that not only provides reliable soil moisture status but also allows the manager to log daily water status will be a benefit. Of the probes discussed, capacitance probes may offer an affordable option to guide water usage with a high degree of accuracy and because of their small size, do not interfere with standard cultural practices.

— Clint Waltz is a graduate research assistant with Dr. Bert McCarty in the Department of Horticulture, Clemson University, Clemson, SC. Clint is currently pursuing a Ph.D. in turfgrass and soil physics. Dr. Bert McCarty is a professor of turfgrass science at Clemson.

Literature Cited

Aragao, S., H. J. Geering, M. G. Wallis, C. J. Pearson, and P. M. Martin. 1997. Hydrological properties of three greens with different construction profiles. International Turfgrass Society Research Journal. 8:1136-11.49.

Augustin, B. J. and G. H. Snyder. 1984. Moisture sensor-controlled irrigation for maintaining bermudagrass turf. Agronomy Journal. 76:848-850.

Brown, R. W. and D. M. Oosterhuis. 1992. Measuring plant and soil water potentials with thermocouple psychrometers: some concerns. Agronomy Journal. 84:78-86.

Campbell, J. E. 1990. Dielectric properties and influence of conductivity in soils at one to fifty megahertz. Soil Science Society of America Journal. 54:332-341.

Cereti, C. F., E. Pettinelli, and F Rossini. 1997. Water-content measurement in fine-grained sediments using TDR and multilevel probes for turfgrass research. International Turfgrass Society Research Journal. 8:1252-1258.

Devitt, D. A. and R. L. Morris. 1997. Measuring soil moisture helps schedule irrigations. Grounds Maintenance. August:49-52.

Evett, S. R. and J. L. Steiner. 1995. Precision of neutron scattering an capacitance type soil water content gauges from field calibration. Soil Science Society of America Journal. 59:961-968.

Freeland, R. S., L. M. Callahan, and R. C. von Bernuth. 1990. Instrumentation for sensing rhizosphere temperature and moisture levels. Applied Engineering in Agriculture. 6(2):219-223.

Fry, J., S. Wiest, Y. Qian, and W. Upham. 1997. Evaluation of empirical models for estimating turfgrass water use. International Turfgrass Research Society Research Journal. 8:1268-1273.

Hanks, R. J. and G. L. Ashcroft. 1980. Applied soils physics. Springer-Verlag, New York, New York. 159 pp.

Hanson, B. and D. Peters. 1997. Update on moisture sensors. Irrigation Business and Technology. 5(6):43-45.

Kome, C. E. 1996. Time domain reflectometry and turf irrigation modeling. Ph.D. Dissertation. Michigan State University.

Miller, R. W. and D. T. Gardiner. 1998. Soils in our environment. Prentice Hall, Upper Saddle River, New Jersey. 736 pp.

Morgan, W. C., J. Letey, S. J. Richards, and N. Valoras. 1966. Physical soil amendments, soil compaction, irrigation, and wetting agents in turfgrass management I. effects on compactability, water infiltration rates, evapotranspiration, and number of irrigations. Agronomy Journal. 58:525-528.

Morgan, W. C. and A. W. Marsh. 1965. Turfgrass irrigation by tensiometer-controlled system. California Agriculture. 19(11):4-6.

Rial, W. S. 1999. Using complex permittivity to assess the volumetric water content of agronomic soil. Ph.D. Dissertation. Clemson University.

da Silva, F. F., R. Wallach, A. Polak, and Y. Chen. 1998. Measuring water content of soil substitutes with time-domain reflectometry (TDR). Journal of American Society of Horticultural Science. 123(4):734-737.

Snyder, G. H., B. J. Augustin, and J. M. Davidson. 1984. Moisture sensor-controlled irrigation for reducing N leaching in bermudagrass turf. Agronomy Journal. 76:964-969.

Song, Y., J. M. Ham, M. B. Kirkham, and G. J. Kluitenberg. 1998. Measuring soil water content under turfgrass using the dual-probe heat-pulse technique. Journal of American Society of Horticultural Science. 123(5):937-941.

Starr, J. L. and I. C. Paltineanu. 1998. Soil water dynamics using multisensor capacitance probes in nontraffic interrows of corn. Soil Science Society of America Journal. 62:114-122.

U. S. Golf Association Green Section Staff. 1993.