IRRIGATION SCHEDULING TECHNOLOGY: THE OLD and NEW

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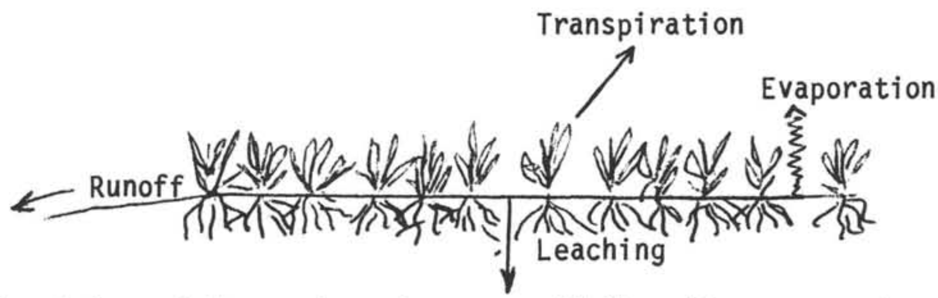
Water conservation has become a necessity for many turfgrass managers. Proper irrigation scheduling is a strategy available to all growers to reduce turfgrass water use.

To visualize how water can be conserved by good irrigation scheduling, we can consider the ways in which water is wasted. In the following figure



water can leach beyond the root system, run off the site, evaporate into the atmosphere, or be taken up by the plant and transpired. Only the water that is taken up by the plant is beneficial since it is water that is utilized in the various biochemical processes in plant cells, transportation of nutrients, and cooling the plant via transpiration.

If irrigation water is correctly applied, it will recharge the water depleted from the rootzone without causing runoff or leaching. Also, by maintaining a deep, extensive root system, several days may elapse between irrigation events, which greatly reduces the evaporation losses. Evaporation can never be totally eliminated, thus, the water used to grow a plant is considered the sum of transpiration plus evaporation -- i.e. evapotranspiration (ET).

For irrigation to be applied at the correct time, the grower must rely on some way to inform him of the timing. Three sources of information are -- the soil, the atmospheric conditions, and the plant. We will briefly review each of these.

The Soil

Monitoring the soil water content (or potential) does indicate soil water depletion. It is important to monitor water status where the turfgrass root system occurs with the realization that rooting patterns may change with the season. In most cases, soil water content will provide a good indicator of plant water needs. One exception could be on days with high evaporative demand (i.e. hot,

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dry, windy conditions) where afternoon wilting and possibly high temperature injury or desiccation can occur on sensitive grasses, such as creeping bentgrasses. Methods of monitoring soil water status are:

(a) Feel and look of the soil. Would require an auger to check at several depths. Is time consuming and accuracy depends on experience of the irrigator.

(b) Resistance of the soil to a probe. An instrument, such as a screw driver is driven into the soil and moisture content estimated based on mechanical resistance. Easy to do but not very precise.

(c) Tensiometers. Measures soil matrix potential, which equals soil water potential except on salt-affected soils. Normally, two tensiometers are used at different depths (2 to 4 inches deep, and 6 to 12 inches deep). Whenever either reaches a critical reading, irrigation is initiated and is terminated when the shallowest tensiometer reads saturation. These work well on flat, uniform sites. They measure water content only at a point source, which must be representative of the site. Tensiometers are accurate only in moist soils (0 to -0.75 bar soil water potentials) and must be removed during freezing conditions. Examples are Irrometer[2] and Tensimeter.

(d) Heat sensors. These measure soil matrix potential by determining the rate of temperature change (dissipation) after a heat pulse. They are accurate over a wider range of soil moisture than are tensiometers, determine water status at a point in the soil, and are relatively expensive. Examples are Watertech and Moisture Control Systems, Inc. sensors. The Hydrovisor sensor works on a somewhat different principle but still relates temperature response to soil matrix potential. Unfortunately, the Hydrovisor is advertised as a tensiometer but works on a much different principle. Hydrovisor sensors are factory set for only limited moisture ranges.

(e) Electrical resistance devices. Electrical resistance (or conductivity) measurements between two probes or wires can be related to soil matrix potential. In some cases, bare, metal probes have been placed in the soil at a uniform spacing. These are sensitive to salt levels and generally give only a relative reading of soil moisture status. Another approach has been to imbed two metal wires in gypsum blocks, nylon blocks, or ceramic tipped probes. These are less sensitive to salts and are easier to directly relate to a specific soil matrix potential value. Electrical resistance devices are generally less accurate on moist soils than tensiometers but are able to monitor at drier conditions than tensiometers.

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[2]Mention of trade names are for information only and do not imply endorsement, nor is the list of products complete.

Examples are Delmhorst, Beckman, Watermark, Hydrodyne, and Hydrogene sensors.

(f) Some research devices may have irrigation scheduling applicability in the future. Several instruments are used by research scientists to monitor soil water status but are not currently useable for irrigation scheduling by growers because of cost, expertise required, safety, and/or time required for measurements. These include neutron probes, gamma-ray attenuation, soil psychrometers, and time domain reflectrometry (TDR). The latter has real potential for irrigation purposes with further refinements of current equipment. It has several very attractive attributes -- a wide soil moisture accuracy range; measures a larger area of soil (i.e. a larger "point" of soil); and can determine water status in a narrow (4 inch) to wide (4 ft) zone of soil.

It should be noted that many of the soil-based procedures can be used to estimate daily ET, assuming no leaching losses occur. Thus, it would be possible to determine total ET loss over a several-day period and then use this value as the irrigation need. Researchers have used this approach, especially in studies using bucket lysimeters. However, a grower would use moisture sensing devices much as discussed for tensionmeters, where a "dry" reading triggers irrigation and a "moist" reading ceases irrigation. The quantity of water to add by irrigation to bring the soil from "dry" to "moist" would be dependent on soil texture, rooting depth, and desired wetting depth.

The Atmosphere

Under well-watered situations, atmospheric conditions (air temperature, solar radiation, humidity, wind) control evapotranspiration. However, as soil moisture declines, soil water status may induce stomatal closure which would then control ET. Scientists have developed different procedures to estimate ET. Once ET is determined, then irrigation can be based on replacement of ET losses, while accounting for any precipitation. Procedures for estimating ET are;

(a) Mathematical procedures that calculate a potential ET (ET_p) based on climatic data. These are classified as energy balance methods, mass transfer or aerodynamic procedures, combinations of energy balance and aerodynamic concepts, or empirical methods with varying degrees of theoretical basis. Many different formulas have been devised but the most widespread are the Penman, Priestly-Taylor, Jensen-Haise, and Blaney-Criddle methods[3].

[3]For detailed discussion refer to: Burman, R. D. et al. 1983. Techniques for estimating irrigation water requirements. In D. Hillel (ed.) Advances In Irrigation, Volume 2. Academic Press, N.Y., N.Y. pp 336-394.

Some considerations when using these methods are:

*no universal equation has evolved for all climatic conditions.

*climatic data should be collected on the site.

*these procedures estimate ET_p which is "the evaporation and transpiration from an extended surface of short green crop (i.e. grass) which fully shades the ground, exerts little or negligible resistance to the flow of water and is always supplied with water[3]". Two sources of considerable error between estimated ET_p versus actual crop evapotranspiration (ET_c) are 1) if soil moisture depletion is sufficient to cause ET_c to be less than under well irrigated conditions, the estimated ET (i.e. ET_p) will not accurately reflect actual water use. A correction factor for limiting soil moisture conditions can be used, especially if calibrated for local soil conditions. 2) if the turf is thin where the soil surface is not shaded, the evaporation component greatly increases and causes inaccurate estimates.

*for turfgrasses, daily ET_p data is required, but current equations are most accurate over longer time periods. For example, the Penman procedure may under-estimate ET_p for the first 1 to 2 days after an irrigation, but then over-estimate ET_p -- yet, on the average over the whole time period be reasonably accurate. Modifications of current procedures (or development of new ones) and use of a correction factor for limiting soil moisture situations could potentially improve the accuracy of estimated ET_p.

*integration and calculation of the data for these methods are complex but can be programmed into computers.

While mathematical procedures for estimating ET_p has not been widely used on turfgrasses, current computerized controllers allow the use of such technology. At least one major irrigation company (Toro 8000 Monitor) is offering this approach as an option. Further refinements and use of these procedures may provide a means of substantial water conservation.

(b) Evaporation of water from a United States Weather Bureau pan (E_{pan}) can be related to ET_p of a grass, because the same climatic factors influencing ET_c also influence pan evaporation.

Some comments concerning this procedure;

*the pan should be on the site and properly placed.

*the relationship between ET_c and E_{pan} must be developed by researchers for each climatic region. Relationships have been developed in the more arid regions of the U.S.

*If the relationship between E_{pan} and ET_c has been developed for well irrigated turf, it will not be accurate under limiting soil moisture conditions. However, a correction can be incorporated for use in such situations.

*This method is easier to use in low rainfall regions but rainfall can be corrected. Also, the weather pans could be automated to measure E_{pan}, refill each day, and account for precipitation.

*Researchers may find that weather pan data can be incorporated into empirical, mathematical methods to estimate ET_p, since E_{pan} is a good integration of all climatic factors that affect ET_c.

The Plant

Since the turfgrass plant "senses" soil water status and atmospheric conditions, it should be a good indicator of impending moisture stress. This approach has the theoretical advantage of integrating soil-atmospheric-plant factors. Current irrigation scheduling approaches based on the plant are:

(a) Visual plant symptoms (wilting, foot-printing, blue-green color) are often used by growers to aid in determining when to irrigate. The major problem with this approach is that the turf is subjected to more stress than desired, especially for well-maintained sites. Over a period of time, the turf may deteriorate. Ideally, the grower wishes to irrigate before visual symptoms occur. Yet, visual plant symptoms are a very important criteria and a grower can use those areas that wilt first to be "indicator spots" for the remainder of the turf. Obviously, this approach does not lend itself to automation.

(b) Infrared thermometry allows nondestructive monitoring of turfgrass canopy temperatures which can be related to moisture needs. When a turf is under well-irrigated conditions, the canopy (leaf) temperature will be near ambient air temperature. As soil or atmospheric stress increases, so do canopy temperatures rise above air temperature. This approach was successfully used by Throssell et al. on turfgrass (Throssell, C. T., R. N. Carrow, and G. A. Milliken, 1987. Canopy temperature based irrigation scheduling indices for Kentucky bluegrass turf. Crop Sci. 27:126-131). Infrared thermometers with computer packages to perform necessary calculations are being developed by at least two companies for 1987. This approach has the potential to be adapted to remote sensors at several sites feeding back into a computerized controller.

An interesting adaptation of canopy temperature monitoring is to use the data to calculate ET on a daily basis. Some data exists that demonstrates the potential for this approach. The calculated ET (i.e. soil moisture depletion) would be used the same as ET from mathematical or weather pan methods.

(c) Other plant measurements have been used by researchers to monitor water stress - noteably, leaf water potential (activity status of the water inside the plant) and stomatal diffusion resistance (whether stomatal are open, closed, or partially closed) These do not have any practical application for irrigation scheduling because of the tedious nature of measurements and equipment needs. However, they are very useful research techniques.

Conclusion

As an aid to scheduling irrigation, the grower can use soil, atmospheric, or plant related technology. All methods have pros and cons. However, the increased emphasis on water conservation coupled with technological advances point to the utilization of some of these methods. The author anticipates the greatest advances in the next few years to be in the areas of (a) estimating ET via mathematical method and interfacing the information into computer controllers, (b) using canopy temperature data for irrigation scheduling, and (c) the development of TDR and refinement of other soil based sensors for greater use.