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SOIL DYNAMICS and effective irrigation management

Over the past year, I have had the opportunity to become involved in the day to day management of an irrigation system installed 3 years before a newly reconstructed sports complex. I must admit that since becoming a sports field manager 25 years ago, I have never had the opportunity to become so intimately involved in irrigation management. However, on this particular field, problems had arisen which required serious consideration of all the facets of the turf management program.

Conceptually, irrigation management is simple. Just replace the water lost to evapotranspiration; the combined effects of soil evaporation and moisture loss thru turf transpiration. I was told by one employee that the previous year he had gotten daily evapotranspiration data from a local weather-related website. A basic understanding of his irrigation system allowed him the ability to use this information and program the system to apply what was required.

As I ran through the different irrigation zones on the field, I noticed some heads were not rotating, others were puddling and still others were watering in the wrong direction. Irrigation heads within the same zone were randomly fitted with different size nozzles. An irrigation audit completed by a certified irrigation auditor later reported that the system was only about 60% efficient.

Examination of the soil profile revealed major differences in soil compaction. In some areas of the field I could insert a soil probe 7 or 8 inches, in other areas only two or three. By coincidence, areas of sod replaced the year before due to fungus, coincided with these areas of heavier compaction. The areas of heavy compaction were programmed to receive the same amount of water as areas with much less compaction. Poor drainage in the heavily compacted areas was causing standing water to accumulate after irrigation. I can only assume that wet feet coupled with restricted root development had some bearing on sod loss.

In an attempt to optimize the effectiveness of the irrigation, I purchased a soil moisture meter. I did this intent on gaining a better understanding of the moisture needs of the turf. Initial readings revealed differences in soil moisture which at the time seemed counterintuitive. Areas of the field with minimal compaction showed moisture content to be around 25%. Areas of high compaction with visual signs of standing water and obvious saturation showed soil moisture content only to be around 18%. I am not the sharpest tool in the shed and came to the conclusion that these moisture readings, alone, meant absolutely nothing to me and I would need more information. I continued to take readings hoping an epiphany would suddenly make it all clear to me. It instead became clear that my efforts were in vain.

As I began to research a little deeper, it started to make sense that in order to competently program irrigation based on evapotranspiration data; it would first require a baseline soil moisture measurement or irrigation threshold. This irrigation threshold would be used as a reference point from which to determine the need for supplemental irrigation. To better understand this concept it becomes important to have a basic understanding of soil. The following information helped to clarify my confusion.

Soil is typically a mixture of inorganic and organic particles. The inorganic particles are mineral based and come from rocks that have been weathered and broken down into smaller pieces over a long period of time. The organic particles contain carbon compounds and they come from anything that was once living and has since died and decayed, including plants, microbes, insects and animals.

Soil texture is determined by the relative amounts of sand, silt and clay.

Soil structure refers to the arrangement of the sand, silt and clay particles joined together into larger aggregates of different sizes and shapes and the pore spaces that are left between them. It is in these spaces that root hairs grow and take in water and nutrients from the soil.

In heavier textured soils, soil structure favorable to turf growth is one that has stable aggregates. These aggregates result in a network of both small and large soil pores that has good aeration and drainage and allows for efficient exchange of air, water and nutrients. In sandy soils, typically having more than 85% sand, adequate pore space is primarily a product of particle size rather than soil aggregation.

The processes of root penetration, wetting and drying cycles, freezing and thawing, and microbial activity combined with inorganic and organic cementing agents produce soil structure. Soil structure can be severely compromised in many ways such as by compaction, playing on a field when it is too wet or by over tilling during construction or repairs.

After rain or irrigation, the pore space in soil typically fills with water. **Saturation** occurs when all the pores are full of water and the soil can hold no more water. This is the time when playing surfaces are generally most unstable and most vulnerable to damage caused by traffic. As moisture drains from the soil, the soil will typically become more stable. For this reason, it makes sense for the turf manager to manage soil moisture at a level favorable to turf survival yet providing a root zone stable enough to resistant damage by traffic.

Not all of the water will drain due to gravity. Some water will stay in the soil. Moisture will remain in the smaller pore spaces and as a thin coating on the outside of the soil particles. This remaining moisture held in the soil against the force of gravity is known as **capillary moisture**.

After the gravitational water has drained away, the soil is said to be at **field capacity**. At field capacity water in the pores is typically easy for the plant roots to use. Once the pore water is used up, there is normally a thin coating of moisture remaining around the soil particles. The **permanent wilting point** is defined as the point at which remaining soil moisture is held so tightly that it is unavailable to plants. Plants subjected to this level of soil moisture will not typically recover. Turf will usually exhibit signs of drought stress before the soil reaches the permanent wilting point. The amount of water held in the soil between field capacity and the permanent wilting point is called the **plant available water**. A sandy soil will typically hold less water at field capacity than a heavy textured clay soil but a larger percentage of that water is plant available water.

There are two means of identifying soil moisture content in the field. Volumetric soil moisture is measured as a percentage of the total soil volume. Soil moisture tension is a measure of how tightly water is held in the soil.

Volumetric soil moisture is a method of measurement used by many moisture meters to measure moisture in the soil and can be used as a means of monitoring irrigation requirements. Each location should be evaluated individually and the volumetric soil moisture compared to turf quality and soil conditions at the time the reading is taken. The accumulation of volumetric soil moisture data for a given location, over time, can give the turf manager the ability to correlate soil moisture readings, predict turf needs and irrigate accordingly.

Soil moisture tension is a phenomenon caused by the capillarity of water. **Capillarity** is the combined effect of cohesion and adhesion. **Cohesion** is the attraction water has to itself. It is the reason water beads up on a sheet of glass. **Adhesion** is the attraction water has to another surface; in this case it is the attraction to the soil particles. Moisture adhesion to the soil is typically the stronger of these two properties. Capillarity causes some water to remain in the soil after gravitational water has drained away. Capillarity also allows for water movement thru the turf plant against the force of gravity. This movement of water against the force of gravity is called **capillary motion**. Soil moisture tension increases as the volume of soil moisture decreases. Soil moisture tension can increase to a point where moisture remaining in the soil is held so strongly, it is unavailable to the turf. This is the permanent wilting point as previously described.

Kilopascals (kPa) are units of pressure measurement used to measure soil moisture tension. Suction is a negative pressure or tension and is therefore referred to by negative numbers. Soil moisture tension is a measure of suction, and the correct way to refer to it is minus or negative X kPa. Numbers closer to zero refer to less suction and therefore wetter soils. As a soil dries out the kPa value becomes larger (and more negative).

One benefit to measuring soil moisture tension as opposed to volumetric soil moisture is that soil texture is largely irrelevant. -25kPa in clay is the same as -25kPa in sand. Turf in either of these soils is basically working the same to extract moisture.

A **tensiometer** is a hand-held device that is forced into the ground for the purpose of measuring soil moisture tension. The hollow ceramic tip of a tensiometer is porous, allowing water to move into and out of a sealed water storage 'reservoir' or tube inside the tensiometer shaft. As the soil dries out, water is sucked out of the tensiometer through the porous ceramic tip. This creates a partial vacuum inside of the tube, which is registered by a vacuum gauge. Tensiometers usually operate accurately over a range of 0 kPa to -80kPa. **Gypsum block** sensors are also available for measuring soil moisture tension and can be buried in different locations of a field to allow for soil moisture tension measurements. Gypsum is a naturally occurring porous mineral. When shaped into a block and buried in the soil, water from the surrounding soil moves into and out of the gypsum block as though it were soil.

A gypsum block sensor consists of two electrodes embedded in a block, 'tablet' or cylinder of gypsum. When water moves into the gypsum block some of that gypsum dissolves, allowing a current to move between the electrodes. As the amount of water in the block changes so does the resistance to current flow.

As the soil dries out, water leaves the gypsum block and the resistance between the electrodes increases. Conversely, as the soil wets, soil water is drawn back into the gypsum block and the resistance decreases. These resistance values are then translated into soil moisture tension readings by a meter connected to the two electrodes, which displays the soil moisture tension as units of kilopascals (kPa).

The level of soil moisture tension required to sustain turf can vary by turfgrass species, region of the country and other environmental factors. -50kPa to -80kPa may represent an approximate irrigation threshold for cool season turf above which the sports field manager could anticipate draught stress and a decline in turf quality. As always, it is the responsibility of the sports field manager to evaluate soil moisture tension readings as they compare to turf quality and use good judgment when establishing an irrigation threshold from which to initiate irrigation.

Dielectric Constant or Dielectric Permittivity Sensors use electric fields to monitor a dynamic of soil called its 'dielectric constant'. Water greatly changes a soil's dielectric constant. Dry soil has a dielectric constant of between 2 and 5. Pure water has a dielectric constant of 80. Consequently, as the moisture level in the soil changes, the dielectric constant changes accordingly.

This class of sensors uses the dielectric permittivity as a means of reporting soil moisture content. A key advantage of these sensors is that mineral particles such as salt barely affect the dielectric constant of soil so the soil moisture readings are largely unaffected.

Although each employs a different technology, thetaprobes, capacitance or frequency domain reflectometry (FDR) probes and time domain reflectometry (TDR) devices all rely on the dielectric permittivity of soil for their soil moisture measurements.

In addition to soil moisture monitoring being available as a manual method of establishing and maintaining an irrigation threshold, manufacturers of automated irrigation systems have integrated similar methods of soil moisture monitoring as means of controlling supplemental irrigation. Whether you choose to monitor soil moisture yourself or incorporate it into an automated irrigation system, your choice becomes another tool in your sports field manager's tool box.

The methods of monitoring soil moisture mentioned in this article should not be considered the only options available to the sports field manager. This article is intended only to suggest the benefits that can be realized through soil moisture monitoring and the tools mentioned are used only as examples to help better understand the principles provided.

In the past 25 years, I have attended many classes and read a lot of books and articles on the topic of soil. However, I had not seriously considered the interrelationship between soil dynamics and effective irrigation management. The positive or negative influences that in sum total contribute to an improvement or decline in turf quality warrant understanding and consideration. Knowledge acquired thru success is far less expensive than wisdom acquired thru failure.

As for the field I mentioned at the beginning of the article; a basic review of these few principles concerning soil and soil moisture gave me the ability to comprehend why and how the compacted soil I had previously identified as having 18% moisture could conceivably measure less moisture, and exhibit a higher level of saturation than other areas of the field. We look forward to having the irrigation system repairs completed in the spring and hope to be able to establish an effective irrigation threshold from which to program the supplemental irrigation needs of the turf. We will also be working to further relieve compaction across the board. ■

Jim Hermann, CSFM, is President of Total Control Inc. Athletic Field Management.