EnviroTech Soil Solutions, Inc

Advanced soil amendment products, services & solutions

Water movement in turf: the root of soil physics

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In its most basic terms, soil physics is concerned with the delicate balance of water and oxygen in soil. Because this equilibrium is so vital to the health and appearance of turf, all sports turf managers are trained in managing soil water.

Water is released from soil three ways: through internal drainage, evaporation, and transpiration. If a field has poor drainage, it becomes more dependent on evapotranspiration to remove excess moisture. If a field remains saturated, the turf experiences stress typically referred to as "wet wilt." While extended saturated conditions can cause roots to rot, most wet wilt stress is actually caused by an oxygen deficient environment. In essence, the roots are drowning.

When we consider the life processes of the grass plant, we typically focus on photosynthesis. The plant takes in carbon dioxide, water, nitrogen, and other nutrients while the chlorophyll captures photons and through the "miracle" of photosynthesis converts light into simple sugars such as glucose. The byproducts of photosynthesis are oxygen and water vapor.

However, the life process does not end at glucose production. The sugar must be converted into energy at the cellular level in order for the organism to live. Oxygen is required to convert the glucose into energy and the byproducts of this ADP-ATP cycle at the cellular level are carbon dioxide and more water vapor. The roots are a primary gatherer of the needed oxygen but they also deposit water and carbon dioxide back into the soil.

The importance of oxygen in the soil

If soil is saturated or simply too dense, it will be oxygen deficient. In both cases there is insufficient space for oxygen diffusion, which compounds the challenges roots already face to survive. The roots are in constant competition with the microbial populations for soil oxygen. At this level, Oxygen is a depleting resource that must be constantly replenished from the atmosphere.

Bacteria and fungi need oxygen to break down—or decompose—their food, primarily organic matter. If there is insufficient free-floating O_2 in the soil, the bacteria and other microbes will pull it off of other compounds in order to live. This is a simplistic way of describing the anaerobic processes. Carbon dioxide, methane, and hydrogen sulfide are common byproducts of this anaerobic decomposition. These three gases are toxic to the turf in low oxygen environments.

A release of toxic or potentially toxic soil gases coupled with the diffusion of oxygen from the atmosphere into the soil is the process we call aeration. The evaporation of water at the surface draws water and soil gases from the soil column up toward the surface. As water and soil gases are removed from the soil through aeration, space is created for oxygen. The efficiency of the aeration process is determined primarily by a soil's physics. It is also supplemented by the turf's access to direct sunlight, which is needed for transpiration, and surface airflow, which is needed for evaporation. [NOTE: We recognize that there are other factors that affect evapotranspiration. Ambient humidity is an example.]

Soil composition affects water movement

The properties associated with soil physics are infiltration rate, total porosity (which is broken down into water porosity and air porosity), bulk density, and water holding. The composition of the soil (distribution of the sand, the gravel component, whether silt, clay, or organic matter is present) dictates the soil's physical properties. The infiltration rate measures the gravitational flow of water. It is related to saturated hydraulic conductivity, which measures the capillary rise of water to the surface. As such, the infiltration rate is an indirect measurement of capillary rise and can also give clues to the level of aeration/oxygenation.

Water does not move freely through the small spaces classified as water pores. Rather, water molecules remain inside the pores due to the water's adhesive and cohesive properties. Some pores are so small that the water is not plant available. The root hairs cannot overcome the water's adhesion and cohesion properties in many of these smallest spaces.

Water does move through the larger air pores, both gravitationally and to the surface through capillary rise. The air pores also provide space for oxygen and for root growth.

As compaction tightens the soil, many of the air pores are converted into water pores. The soil loses total porosity and permeability, as measured by the infiltration rate.

Bulk density measures compaction, but it is a "relative" value in that one must know the relative weight of the material in the soil before evaluating soil density. Some products claim they reduce compaction because they lower bulk density. However, a decline in bulk density may not be a true indicator of reduced compaction. If the product weighs less than the material comprising the rootzone, bulk density will decline due to the fact that a lighter material has been introduced. It may or may not have truly reduced compaction.

It is helpful to think of a sports field as a dynamic organism. It is constantly changing through (a) compaction, (b) the deposit of water borne contaminants that are present even in potable water, (c) the byproducts of the organisms that live in the soil, and (d) the organic matter deposited by the turf. Air pores are gradually converted to water pores with the resultant loss of permeability. The roots will prune to the surface where they will be vulnerable to multiple stressors.

Managing physical properties

A soil turf manager is a grass farmer. His or her cousin, the row crop farmer, at least in the past, tilled the fields to: (a) relieve compaction, (b) oxygenate the soil, and (c) allow water to penetrate. Sports turf managers cannot use plows but he or she can use less disruptive tools to achieve the same results. Whether the STM is managing a sand-based rootzone with internal drainage or a soil-based rootzone that is dependent on evapotranspiration, regular aerification is needed.

When it comes time to aerate, different tools are used to address different issues. Deep aeration, for instance, creates sand highways to move water from the surface but is generally ineffective in rehabilitating the soil in the second illustration. Why? Because of surface displacement. For instance, a 1-inch bit or tine on 7.5 x 7.5-inch center spacing, which is the spacing on a popular unit, displaces only 1.4% of a sports field's surface area. In contrast, 5/8 inch tines on 1.5 x 2-inch center spacing displace 10.2%.

The tighter spacing is available on a major manufacturer's walk-behind and tractor-mounted units. The smaller tines can gradually change the composition of a soil if the plugs are harvested and the holes filled with sand, but their effective depth is only 3 to 4 inches. Deep tines cannot change the soil, but they can be used to supplement the shallower tines. During the playing season, solid tines, deep slicers, and other forms of non-disruptive aeration should be used. They cannot change the composition of a rootzone but they aerate the soil and provide temporary space for water penetration, evaporation, and root growth.

An effective aerification program can address many deficiencies in a soil's physical properties but only if all of the variables are known. To use a hackneyed expression: "Knowledge is power." If you know the composition of a field's rootzone and its physical properties, you can choose the best cultural program to properly balance water and oxygen in your soil.

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