

Turfgrass Soil & Water Relationships

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Drought Stress Symptoms

Water is the primary constituent in turfgrass plants and makes up over 80 % of the plant mass under good growing conditions. Limited uptake of water may result from: a) lack of rainfall or irrigation to replenish soil moisture, b) low water content in soil, c) high soil salinity that restricts water uptake, or d) a shallow root system that limits the volume of soil that a plant can obtain water for uptake. Turfgrass drought stress has a major influence on quality and persistence of the stand.

As a plant is exposed to drying conditions and soil moisture is not replaced, drought stress symptoms will be exhibited (Figures 1 and 2):

- First, growth rate decreases. This is most noticeable in terms of shoot growth, but rhizome, stolon, and root growth rates are all reduced.
- Wilt symptoms may follow, which is shown as leaf folding or rolling; a bluish-green color; and foot-printing ---the lack of turgidity by the shoot tissues result in plant tissues being pressed down and leaving an impression when stepped upon.
- Leaf firing follows, which is chlorosis [yellowing] of the turf as chlorophyll pigments in the plant decline and eventually tissue desiccation. Desiccation may start as leaf tip injury and progress down the leaf, especially of young tillers.
- As tissues desiccate, the turfgrass stand starts to turn tan as dead leaves become dominant. As these symptoms progress, the grass normally will go into a dormant state, where the only living tissues are the crown, rhizomes, stolon stems, and some of the roots. If a grass is not drought resistant or tolerant (drought hardy), it may not have sufficient time to physiologically adjust into a dormant state. Instead, all or most of the tissues die, leaving little live material for recovery once the drought is over.
- The grass tissues that remain alive going into dormancy may run out of stored food reserves before sufficient rain occurs to bring about regrowth of leaves which can then produce food for further growth. If food reserves are depleted, the remaining tissues start to die. How long a grass can remain in a summer dormancy state depends on its health going into dormancy, the length of dormancy, and the temperatures during dormancy---high temperatures deplete food reserves more rapidly. Drought resistant tall fescue, a cool-season grass, developed for Georgia conditions (Southeast cultivar), has survived 10 to 13 weeks of dormancy. Other cool-season grasses would be expected to survive for shorter periods of time, while most warm-season grasses will survive within this same time frame or somewhat longer. Zoysiagrass may not survive as long as other warm-season grasses in Georgia.

Figure 1: Meyer zoysiagrass under minor moisture stress (left) and severe drought stress (right).

Budget Concept of Soil Water

A useful way to visualize turf water management is to consider the Budget Concept approach, similar to a bank checking account. Certain additions (inputs) of moisture are made and there are losses (outputs) of moisture from the plant environment. At any point in time, the plant has available to it a certain reserve of available water. The objectives of a wise turfgrass manager are to maximize inputs, minimize outputs, and maintain a large reserve.

Figure 2: Severe drought stress resulting in summer dormancy on a cool-season turfgrass.

Inputs of moisture are precipitation, overhead irrigation, dew, and capillary rise of moisture from below the root system. Precipitation and overhead irrigation are the major inputs. Normally, capillary movement to turfgrass roots from below the root zone is minor except where a water table is within 2 to 4 feet of the roots.

Outputs or losses include runoff, leaching beyond the root zone, evaporation, and transpiration. Runoff can be a problem on sloped sites and can be increased by fine-textured soils, thatched turf, compacted soils, and applying water faster than the soil can receive it. Runoff causes not only a dry site but also an excessively moist site. Reducing runoff requires correcting the above situations through cultivation, thatch control, or proper irrigation application rates.

Leaching or water movement beyond the root system is often an unrecognized water loss. Irrigators whose watering is based on the driest site often over irrigate other areas. Irrigating slightly beyond the existing root is acceptable because it provides a moist zone for further root extension. To reduce leaching losses, the irrigator must know the depth of rooting and depth of moisture penetration after applying a specific quantity of water. Well-designed irrigation systems that apply water uniformly reduce leaching losses. Also, proper zoning of irrigation heads is important. Heads in similar areas should be zoned together. Poor zoning, with heads on slopes and low spots zoned together, results in poor uniformity.

Figure 3: The Budget Concept of turfgrass water management.

Evaporation is the vaporization of water from a surface. When moisture evaporates, it removes energy (heat) from the surface. Thus, evaporation helps cool the soil and plant if free water, such as dew, is on the leaf surface. Excessive evaporation is wasteful. Growers can control the quantity of water lost by evaporation. For example, immediately after irrigation evaporation rates from the soil surface are high, but as the surface dries evaporation dramatically decreases. Thus, light frequent irrigation results in high evaporative losses contrasted to heavier, less frequent applications. Other ways to reduce evaporation are: maintain good infiltration rates to get the moisture into the soil; maintain

a dense turf to shade the soil surface; mow your turf as high feasible for your situation to insure further shading; avoid applying so much water that standing water occurs; and avoid afternoon irrigation.

Transpiration is the vaporization of water inside the plant leaf that diffuses the cuticle and through the open stomata., which are pores on the surface of leaves, where most transpiration occurs. During this process, heat is removed from the plant. In many situations more than 90 percent of the moisture taken in by a turfgrass plant is utilized for cooling purposes. Transpiration is a desirable use of water, especially in hot conditions. However, excessive transpiration can occur and thereby waste water. Over watering turf promotes excessive transpiration.

The reserve of plant-available moisture at any point in time depends primarily upon soil texture and the volume of soil occupied by the plant root system. Obviously, over a period of time, irrigation and precipitation are the sources of the reserve moisture. Soil texture and water-holding relations are detailed in the "water-holding capacity" section, but as a generalization sands do not retain as much plant-available moisture as do loam soils.

The turfgrass grower can markedly improve the moisture reserve by managing to promote development and maintenance of a good deep, extensive plant root system. A turfgrass with a 12 inch root system will have twice the quantity of plant-available moisture as one with only a 6 inch root system. Development and maintenance of a good root system will require:

- Selection of grasses that are drought resistant and capable of rooting into the hard, kaolinitic clays common in northern Georgia
- Proper mowing height
- Good irrigation practices to favor deep rooting
- Liming when needed and good fertilization
- Control of root-feeding insects
- Possibly cultivation when soils are hard or compacted

Figure 4: In both pictures are the same grass, soil, and days since the last irrigation, however, on the left is an 12 inch root system and on the right the root system is only 6 inches (the soil depths were 12 and 6 inches). Note the drought symptoms in the turfgrass on the right where wilting, blue green color, and footing printing.

With this background in soil-plant water relationships, we can now explore the major characteristics of soil that directly influence turfgrass water management.

Soil Characteristics Affecting Water Management

Because plants obtain water from soil, it is with soil that water conservation must start. Certain characteristics of soil influence water movement and retention. This section's emphasis is on important soil physical problems that the turfgrass grower may confront.

Water-holding Capacity. Soils differ in their total water-holding capacity as well as in plant-available water content (Table 1 and Figure 5). Obviously, soil texture influences water-holding capacity. Table 1 reveals that loam soils have the most plant-available water. Sands have the fewest small pores for moisture retention. Clays have a high percentage of small pores, but moisture in many is retained too tightly for plant uptake. Sometimes sand soils are amended with soil containing more silt and clay to enhance moisture-holding capacity. The red, kaolinitic soils of northern Georgia, especially the B horizon, may retain considerable water but much of it is not plant available due to retention in small micropores. If roots penetrate into the B horizon, readily plant-available water can be depleted rather rapidly. However, some moisture extraction can continue and delay dormancy of the plant and help maintain physiological activity at a reduced rate during prolonged droughts.

Table 1. Total, plant available, and unavailable water-holding capacity of different soil texture classes.

Soil texture	Water-holding capacity (inches water per foot of soil)		
	Total	Available*	Unavailable**
Sand	0.6-1.8	0.4-1.0	0.2-0.8
Sandy loam	1.8-2.7	0.9-1.3	0.9-1.4
Loam	2.7-4.0	1.3-2.0	1.4-2.0
Silt loam	4.0-4.7	2.0-2.3	2.0-2.4
Clay loam	4.2-4.9	1.8-2.1	2.4-2.7
Clay	4.5-4.9	1.8-1.9	2.7-3.0

* Available for plant uptake. Many of the red, kaolinitic clays in Georgia may contain somewhat less available moisture than the clay loams in this table.

** Not available for plant uptake.

Figure 5: Upper line is the field capacity and the lower line is the wilt point. Plant available water in the moisture retained between field capacity and wilt point.

Organic matter can improve the water-holding capacities of sands. Often very high sand content soils or root zone mixes benefit from the addition of 5 to 15 percent by volume of a well-decomposed organic amendment. Too much organic matter may be detrimental by reducing aeration from excessive moisture retention in the organic matter and create a soggy soil.

Another factor that can increase soil-water content is control of the water table within 2 to 4 feet of the soil surface. Water will rise above the free water table by capillary (adhesion and cohesion forces) action and this zone is called the capillary fringe. Fine-textured soils or organic soils have the greatest capillary rise, and this can be used to subirrigate turf in some situations.

A "perched" water table is one that forms due to disruption of internal drainage. Capillary rise of moisture from a perched water table can provide some water needs of turf plants.

In the USGA Green Section method for golf green construction, a perched water table is often created by the interface between a pea gravel layer and a very coarse sand layer.

Infiltration: Infiltration is the movement of water into the soil surface. Therefore, soil surface conditions are of prime interest, but other factors that influence infiltration are soil texture, structure, slope, and current soil-water content.

- Sandy soils may have infiltration rates in excess of 1.0 inch per hour while clay soils are often less than 0.1 inch per hour (Table 2).
- A well-structured soil will provide large macropores (> 0.10 mm diameter pores, also called non-capillary pores or aeration pores) for infiltration, as contrasted to a tight clay or compacted soil with few macropores.
- Organic matter often aids infiltration by providing a better-structured soil.
- Cracks that develop upon drying can markedly increase initial infiltration rates after irrigation. These are especially beneficial on heavy clay soils.
- A sloped surface will exhibit a much lower infiltration rate which complicates irrigation zoning and scheduling, particularly on rolling terrain such as golf courses.
- Thatch can reduce infiltration if it becomes hydrophobic (water-repelling) in nature. Turf managers have sometimes observed hydrophobic sands with very low infiltration rates. These are caused by organic coatings on the sand particles that repel water.
- When water is applied to a dry (or partially dry) soil, the initial infiltration rate is high and then gradually decreases as water content increases.

Table 2: Representative infiltration rates for different soil textures. Surface conditions can cause these values to vary.

Soil Texture	Infiltration rate*	
	Inches/hr.	cm/hr.
Sand - coarse	1.00 - 8.00	2.50 - 20.00
Sand - very fine	0.50 - 3.10	1.25 - 8.00
Sandy loam	0.40 - 2.60	1.00 - 6.50
Loam	0.08 - 1.00	0.20 - 2.50
Clay loam	0.04 - 0.60	0.10 - 1.50
Clay	0.01 - 0.10	0.02 - 0.25

* These values are approximate. Infiltration rates can vary widely, depending on surface conditions and water content.

Turfgrass growers have a choice of management techniques to improve in filtration rates depending upon the particular factor that limit infiltration rates:

- On soils with unfavorable infiltration rates, a good cultivation program can be very beneficial.
- Allowing the soil surface to dry between irrigations can increase the initial infiltration rates by causing soil cracking.
- On heavy clay soils, irrigators can program to apply a long burst of water initially, followed by shorter bursts with time in between for infiltration to occur. This is

- called pulse irrigation and would be in contrast to irrigating at very low rates (to match saturated infiltration rates) over long periods, or at higher rates that can cause runoff.
- Application of organic matter to the soil surface of poorly structured soils can improve infiltration. The easiest way to add organic matter is by growing a healthy plant and returning clippings. Well-digested sewage sludge, or other well-decomposed materials applied as topdressing may be useful. However, these should be applied in conjunction with a good core aeration program to prevent surface layering.
 - Breaking up any surface layer, whether from compaction, or a distinct textural change, will improve infiltration. For example, sod containing a silt-loam soil laid over a sandy root zone mix will result in slow moisture penetration since the silt loam establishes the infiltration rate.
 - If a hydrophobic sand is the cause of poor infiltration, wetting agents may be beneficial to rewet the surface.

Percolation is the internal drainage of water in the soil within the root zone, while drainage is considered as water movement past the root zone. Water movement within the soil can either be by saturated flow (all soil pores filled with water) or unsaturated flow (at least some pores containing air). Saturated flow in sands is high, due to many large pores. In a clay soil, saturated flow is very low since few large pores, or macropores, are present.

While saturated flow is primarily in the larger pores, unsaturated flow is water movement in the moisture films around and between soil particles. As a soil dries, the water films around particles become thinner and less continuous, thereby reducing the flow rate. Soils with predominately small pores (micropores, capillary pores) will have low unsaturated flow rates because the pores offer high resistance to flow. At the other extreme of texture, unsaturated flow in sands is very slow because of few water films and fewer points of contact for film continuity. The direction of flow will be from a moist soil area to a drier area. For example, a light rain can promote downward flow if the subsurface is drier than the surface; a water table 2 feet below the surface can result in upward movement (capillary rise) into the drier surface soil.

Internal percolation and drainage may need improvement on fine-textured soils to avoid excessive water problems such as poor aeration, soggy soils, intracellular freezing, and scald.

- Tile drainage can be used to remove subsurface water, providing an adequate outlet is available. Tile drainage is only effective on saturated soils.
- Deep cultivation can increase internal drainage by allowing rapid water penetration to the depth of cultivation.
- Soil modification with physical amendments can improve the structure of fine-textured soils and increase their internal drainage. The addition of 5 to 15 percent by volume of a well-decomposed organic matter to clay soils is especially beneficial. However, internal drainage will be improved only to the depth of mixing.

- Addition of sand to a fine-textured soil is sometimes attempted to improve internal drainage as well as infiltration. This has often been unsuccessful. Adding a solid sand particle to a clay soil essentially displaces the volume occupied by clay or silt. The same volume of clay or silt does contain considerable internal porosity composed primarily of micropores, which, under moist conditions retain water. Thus, the sand particle essentially eliminates what internal porosity has been present. It is not until sufficient sand particles are present that internal porosity (and drainage) starts to improve. This requires at least 80 percent by volume sand, and generally noticeable improvement does not occur until 85 to 95 percent sand. Amending 1 inch of a clay soil requires a minimum of 4 to 8 inches of sand, uniformly mixed.

Layered Soils. Soil layering, a common occurrence on turfgrass sites, can be of two types: a) thin layers in the soil that differ in physical properties from the overlying or underlying soil, and b) layered soils (thick layers) where the profile consists of distinctly different soils. An example would be 6 inches of sand over a silt loam soil.

Thin layers may arise from several sources. The most common causes are: a) poor topdressing, where a topdressing mix contains excessive fine particles; b) sod containing organic matter or silt laid over a sand root zone mix; c) wind deposition of silt after a windstorm; d) water-deposited silt or clay; e) improper mixing of soil amendments, resulting in discontinuous layers; f) thatch, either on the soil surface or buried; and g) soil compaction at the surface 1 to 2 inches, which acts like a layering problem.

Layered soils may be due to natural soil formation and each layer is called a horizon. On many of the Piedmont red clay soils of northern Georgia, the B horizon is often much higher in clay content than the surface A horizon and acts as a thick layer that impedes water movement and rooting (Figure 6). However, layered soils can be caused by human beings, who may, for example, bring in a topsoil distinctly different from the underlying soil. Such layers can be beneficial or detrimental, depending upon their characteristics.

Regardless of the type of layering, problems can arise in layered soils.

Figure 6: Typical Georgia red clay soil. The B horizon contains higher clay content than the surface a horizon and often impedes water percolation.

- Infiltration is reduced if a fine-textured layer occurs at the soil surface and it may be further restricted if soil compaction occurs. This explains why a sandy root zone mix can have poor infiltration if it is capped with a fine-textured layer. Whenever soil of a distinctly different texture is applied over another soil, care should be taken to remove the sharp boundary difference.
- Percolation, internal drainage, can be markedly reduced by even a thin zone of different texture below the surface area. For example, a thin silt layer 6 inches below the surface of a sand soil can impede drainage and cause water to pond (temporary perched water table) above the layer because the hydraulic conductivity of the layer is less than that of the sand. Obviously, if the fine-

- textured layer is several inches thick, percolation can be even more affected. When water is perched above a layer, an anaerobic (low soil oxygen) zone occurs in the saturated zone and may lead to black layer.
- Even a sandy layer in a silt or clay soil can disrupt water flow. While coarse-textured sand has a highly saturated conductivity, its unsaturated conductivity is low because of few water films and poor continuity of the films. Thus, water may not easily move across the zone until sufficient water is perched above the layer to initiate water flow.
 - Poor infiltration and percolation in turfgrass soils can result in a host of problems associated with excessive water. Examples: scald; intracellular freezing; encouragement of *Poa annua* L. infestation; disease - brown patch or *Pythium* blight; poor cold, heat, or drought hardiness; poor aeration for root development; and interference with use and management of the turf because of wet, soggy soil.
 - As mentioned, poor aeration will reduce root growth, but layering has other influences on root development. A fine-textured zone at the point of root initiation and elongation may restrict growth due to mechanical resistance (only small pores for the roots to expand through) and low oxygen for respiration. Also, a root top that comes into contact with a distinctly different texture zone may grow horizontally instead of penetrating more deeply. If root growth is restricted, turf-water management becomes more difficult.

Correction of layering problems depends upon its nature. Thin layers near the surface can often be corrected with core aeration. In layers composed of fine particles cores may be removed and holes filled with sand by topdressing. Deep cultivation methods can be used to penetrate 6 to 24 inches to disrupt thick layers, such as a B horizon with higher clay content than the surface. Prevention of management practices that may create a layer is also important.

Soil Compaction. Surface or subsurface compacted zones are typical layer problems (see previous section on Layers) but will be dealt with in a separate section due to their common occurrence. Effective water management can be greatly hindered by soil compaction. High-use recreational sites are especially susceptible since these areas receive appreciable traffic. In most turfgrass situations compaction is confined to the surface 1 to 2 inches, but this narrow compacted zone can adversely affect plant growth and water movement. Another common compacted layer is at the 3 to 4 inch depth on sites where frequent core aeration with 3 inch cores has been practiced and the soil is one susceptible to compaction. Deep compacted zones may occur during construction. This is a common problem on many home sites where the soil is compacted during construction and the compaction is not alleviated by adequate cultivation before establishment of turf, trees, and shrubs (Figure 7).

Figure 7: Soil compaction during construction can occur to 12 to 24 inches. This compacted zone is often not alleviated before establishment of plants and hinders rooting and water movement.

Soil compaction reduces soil aeration and total porosity, while increasing bulk density, soil strength, and moisture retention, i.e., a shift to smaller pore sizes or micropores. These responses create an environment unfavorable for root penetration, water movement, and gas exchange, as do other types of layer problems. Infiltration and percolation rates can be greatly reduced, while soil oxygen levels become low. Reduced total root growth had been observed by many researchers

Compaction is most serious on soils high in silt or clay since these particles are pressed closer together into a more dense mass. High sand content soils resist compaction because the large sand particles provide a resistant matrix as they bridge with one another.

There are four primary approaches to eliminating or reducing soil-compaction problems:

- One is to use species and cultivars that exhibit a greater tolerance to soil compaction.
- A second practice to reduce compaction is by spreading traffic around or traffic control.
- A third cultural practice to reduce compaction is by a good cultivation program to create temporary macropores and reduce soil strength.
- The last alternative is soil modification, either partial or complete.

Conclusion

In summary, turfgrass water-use efficiency and conservation can be enhanced by adopting the Budget Concept of water management. Management practices to increase the reserve of water while reducing undesirable outputs (losses) of water will insure improved turf quality and better water use. How to maximize the inputs through effective irrigation is the topic of the web article "Turfgrass Irrigation Scheduling Techniques".