CIR1085

UNIVERSITY OF FLORIDA
IFAS EXTENSION

Soil Plant Water Relationships[1]

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Florida is classified as having a humid subtropical climate. The average annual rainfall for most of Florida is somewhere between 50 and 60 inches. This is more than any crop uses during a growing season. However, the typically erratic distribution of rain and Florida's predominantly sandy soils make frequent irrigation necessary in order to avoid plant stress during drought conditions. To understand why irrigation is necessary in Florida one must understand soil-plant-water relations. A proper understanding of these concepts is important to encourage wise use of irrigation systems and promoting water conservation.

PLANT WATER

Water is essential in the plant environment for a number of reasons. Water transports minerals through the soil to the roots where they are absorbed by the plant. Water is also the principal medium for the chemical and biochemical processes that support plant metabolism. Under pressure within plant cells, water provides physical support for plants. It also acts as a solvent for dissolved sugars and minerals transported throughout the plant. In addition, evaporation within intercellular spaces provides the cooling mechanism that allows plants to maintain the favorable temperatures necessary for metabolic processes.

Water is transported throughout plants almost continuously. There is a constant movement of water from the soil to the roots, from the roots into the various parts of the plant, then into the leaves where it is released into the atmosphere as water vapor through the stomata (small openings in the leaf surfaces). This process is called transpiration. Combined with evaporation from the soil and wet plant surfaces the total water loss to the atmosphere is called evapotranspiration.

One of the openings (stoma) is shown on the leaf crossection in Figure 1. Guard cells which are found on both sides of the stoma control its opening and closing (Figure 2). Stomata can be found on one (typically underside) or both sides of a leaf depending on plant species.

Well-watered plants maintain their shape due to the internal pressure in plant cells (turgor pressure). This pressure is also necessary for plant cell expansion and consequently for plant growth. Loss of

1. This document is CIR1085, one of a series of the Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date January 1993. Reviewed June 2003. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
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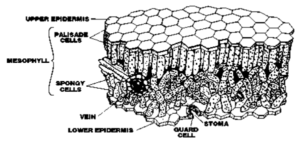

Figure 1.

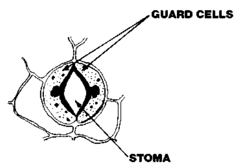

Figure 2.

this pressure due to insufficient water supply can be noticed as plant wilting.

The schematic effects of water stress on plant growth are presented in Figure 3. The major economic consequence of insufficient water in agricultural crops is yield reduction. When too little water is available in the root zone, the plant will reduce the amount of water lost through transpiration by partial or total stomatal closure. This results in decreased photosynthesis since the CO_2 required for this process enters the plant through the stomata. Decreased photosynthesis reduces biomass production and results in decreased yields.

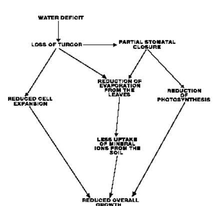

Figure 3.

SOIL-WATER RELATIONSHIPS

The role of soil in the soil-plant-atmosphere continuum is unique. It has been demonstrated that soil is not essential for plant growth and indeed plants can be grown hydroponically (in a liquid culture). However, usually plants are grown in the soil and soil properties directly affect the availability of water and nutrients to plants. Soil water affects plant growth directly through its controlling effect on plant water status and indirectly through its effect on aeration, temperature, and nutrient transport, uptake and transformation. The understanding of these properties is helpful in good irrigation design and management.

The soil system is composed of three major components: solid particles (minerals and organic matter), water with various dissolved chemicals, and air. The percentage of these components varies greatly with soil texture and structure. An active root system requires a delicate balance between the three soil components; but the balance between the liquid and gas phases is most critical, since it regulates root activity and plant growth process.

The amount of soil water is usually measured in terms of water content as percentage by volume or mass, or as soil water potential. Water content does not necessarily describe the availability of the water to the plants, nor indicates, how the water moves within the soil profile. The only information provided by water content is the relative amount of water in the soil.

Soil water potential, which is defined as the energy required to remove water from the soil, does not directly give the amount of water present in the root zone either. Therefore, soil water content and soil water potential should both be considered when dealing with plant growth and irrigation. The soil water content and soil water potential are related to each other, and the soil water characteristic curve provides a graphical representation of this relationship (Figure 4).

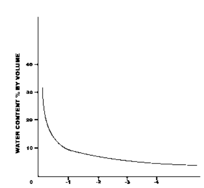

Figure 4.

The nature of the soil characteristic curve depends on the physical properties of the soil namely, texture and structure. Soil texture refers to the distribution of the soil particle sizes. The mineral particles of soil have a wide range of sizes classified as sand, silt, and clay. The ranges of sizes for those particles are presented in Table 1 . The proportion of each of these particles in the soil determines its texture.

All mineral soils are classified depending on their texture. Every soil can be placed in a particular soil group using a soil textural triangle presented in Figure 5 . For example a soil with 60% sand and 10% clay separates is classified as a Sandy loam (see point A in Figure 5).

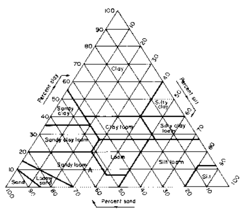

Figure 5.

In addition almost all soils contain some organic material, particularly in the top layer. This organic material, together with the fine soil particles, contributes to aggregate formation which results in the improvement of the soil structure. Soil structure refers to the arrangement of soil particles into certain patterns. The structural pattern, the extent of aggregation, and the amount and nature of the pore space describe the structure of the particular soil. No structure is usually present in the Florida's sandy soils, however the presence of the organic matter can improve the water holding capacity of the soil.

The size, shape, and arrangement of the soil particles and the associated voids (pores) determine the ability of a soil to retain water. It is important to realize that large pores in the soil can conduct more water more rapidly than fine pores. In addition, removing water from large pores is easier and requires less energy than removing water from smaller pores.

Sandy soils consist mainly of large mineral particles with very small percentages of clay, silt, and organic matter. In sandy soils there are many more large pores than in clayey soils. In addition the total volume of pores in sandy soils is significantly smaller than in clayey soils (30 to 40% for sandy soils as compared to 40 to 60% for clayey soils). As a result, much less water can be stored in sandy soil than in the clayey soil. It is also important to realize that a significant number of the pores in sandy soils are large enough to drain within the first 24 hours due to gravity and this portion of water is lost from the system before plants can use it.

To study soil-water-plant relationships it is convenient to subdivide soil water into water available to the plant and water unavailable to the plant. After the soil has been saturated with water one can observe a vertical, downward movement of water due to gravity. In Florida soils, this drainage process happens quickly. Usually 24 hours is sufficient to remove most of the gravitational water in sandy soils. The exact time depends on the soil type; the drainage of the gravitational water generally takes a little longer for clayey soils. Most gravitational water moves out of the root zone too rapidly to be used by the plants. The remaining water is stored under tension in the various size pores. The smaller the pore the greater the tension and the more energy required to remove its water. As a result plants have the ability to remove water only from the certain size pores. The removal of water from very small pores requires too much energy and consequently, this water is not available to the plant. There is also some water which is very closely bound to soil particles. This water is called hygroscopic water. It is also very difficult to remove, and is not available to the plants.

The range of water available to plants is between field capacity (FC) and the permanent wilting point (PWP). The soil is at field capacity when all the gravitational water has been drained and a vertical movement of water due to gravity is negligible. Further water removal for most of the soils will require at least 7 kPa (7 cbars) tension. The permanent wilting point is defined as the point where there is no more water available to the plant. The permanent wilting point depends on plant variety, but is usually around 1500 kPa (15 bars). This means that

in order for plants to remove water from the soil, it must exert a tension of more than 1500 kPa (15 bars). This is the limit for most plants and beyond this they experience permanent wilting. It is easy to see that soils which hold significant amounts of water at tension in the range plants are able to exert (up to 1500 kPa (15 bars) of tension) will provide better water supply for plant growth (Figure 6).

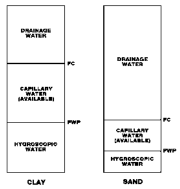

Figure 6.

Unfortunately, Florida has very sandy soils which do not provide good water storage. The pores in sandy soils are generally large and a significant percentage drain under the force of gravity in the first few hours after a rain. This water is lost from the root zone to deep percolation. What remains is used very quickly and the state of PWP can be reached in only a few days.

Ranges of available water for various soils are presented in Table 2. For a typical sandy soil found in Florida this value is approximately .75 in/ft. This means that only .75 in of water available to plants can be stored in one foot of root zone. The amount of water available to the plant depends on the depth of the root zone. Naturally, a plant with a deeper root zone will have more water available than a seedling with roots only 2 to 3 inches deep. That is why root depth is so critical in irrigation scheduling and young plants with a shallow root zone require more frequent, light application of water. To learn more about irrigation scheduling the reader is referred to the IFAS Bulletin 249 "Basic Irrigation Scheduling".

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Table 1.

Table 1. Particles sizes for various textural groups.

Textural group	Particle size (mm)	Particle size (in)
Gravel	> 2.0	>0.08
Silt	0.002 - 0.05	0.00008 - 0.002
Clay	< 0.002	< 0.00008
Sand		
coarse sand	0.5 - 1.0	0.02 - 0.04
medium sand	0.25 - 0.5	0.01 - 0.02
fine sand	0.10 - 0.25	0.004 - 0.01
very fine sand	0.05 - 0.10	0.002 - 0.004

Table 2.

Table 2. Available water for various soil types.

	Available water	
Type of Soil	range(in/ft)	average (in/ft)
Sands and fine sands	0.4 - 1.00	0.75
Moderately coarse-textured sandy loams and fine	1.00 - 1.50	1.25
Medium texture very fine sandy loams to silty clay loam sandy loams	1.25 - 1.75	1.50
Fine and very fine texture silty clay to clay	1.50 - 2.50	2.00
Peats and mucks	2.00 - 3.00	2.50