Plant, Soil and Water Relationships

The relationship between soil (growing media), air, and water is one of the least understood aspects in production and maintenance of plants. As a result, a significant amount of plant loss may be related either directly or indirectly to an improper match between these natural elements as they relate to plant growth. A basic understanding of the factors that influence success in this relationship can be valuable in developing good management practices.

Soil Physical Characteristics

Soil is composed of inorganic material, organic matter, water, air, and living organisms. Differing amounts of these materials define the soil's properties and therefore, the plant growth it can support. ***Inorganic material*** in the soil is formed from the weathering of bedrock or ***parent material*** and determines a soil's mineral properties. ***Weathering*** is the process by which rocks are broken down. *Physical weathering* occurs on rocks and other sediments through processes such as freezing and thawing, wetting and drying, and shrinking and swelling, leading to their breakdown into finer and finer particles. *Chemical weathering* is the chemical alteration or decomposition of rocks and minerals as they become exposed to oxygen, water and weak acids near the surface; this action further destabilizes the parent material. *Biological weathering* is the effect of living organisms such as plant roots and soil organisms on the breakdown of rock. Different rocks are composed of different minerals, and each mineral has a different susceptibility to weathering. Different minerals contribute to variation in soil characteristics.

Organic matter comes from decaying plant and animal life, excrement and other living organisms. Organic matter improves water and nutrient holding capacity, aeration and soil granulation. It also supports soil bacteria, fungi and algae that aid in continuing decomposition.

Water and air are contained in the spaces between soil particles. ***Water*** contains small quantities of dissolved minerals that serve as nutrients for plants. ***Air*** takes up the part of the open space not occupied by water. Nitrogen, carbon dioxide and oxygen are the primary natural gases found in the space between soil components. The oxygen is critical because it allows for respiration of both plant roots and soil organisms.

Living organisms such as plant roots use oxygen and give off carbon dioxide during respiration. The release of carbon dioxide by plant roots can lead to the formation of carbonic acid which contributes to chemical weathering of rocks and sediments helping to turn them into soils. Millions of microbes, such as bacteria and fungi, live in the soil and exist mainly on plant and animal residue; these beneficial ***microorganisms*** help breakdown complex organic compounds into simpler chemicals and make nutrients available for plant use. They also help groups of small soil particles stick together, making them more stable and resistant to erosion.

There is a whole range of weathering processes continuously at work near the surface of the earth, acting together to break down rocks and minerals during soil formation. As rocks and sediments are eroded away, more of the solid rock beneath becomes vulnerable to weathering and breakdown. The natural processes of nature, in the form of wind, rain, snow and ice, start to have their effect on these exposed rocks and sediments. Once the process begins, other physical, chemical and biological processes also start contributing to the breakdown of rocks, leading to formation of soil essential in the support of plant life.

Figure 1. Relative size of inorganic soil particles (separates).

Soil Texture

Texture is one of the most important soil characteristics because it influences many other properties such as water intake, water storage, ease of tilling, amount of aeration and soil fertility, all of great significance to plant growth. ***Soil texture*** refers to the proportionate size and distribution of mineral (inorganic) soil particles found in natural soils. These soil particles (or soil separates) include sand, silt and clay. Soil separates have specific ranges of particle size. The smallest particles are ***clay,*** classified as having diameters of less than 0.002 mm. Clay particles are plate-shaped instead of spherical; this provides an increased surface area and makes them very effective holding water and nutrients in the soil. The next larger soil separates are ***silt*** particles with diameters between 0.002 mm and 0.05 mm. The largest soil separates are ***sand*** particles with greater than 0.05 mm diameter. Furthermore, the range of sand particles can be described as coarse, medium and fine.

Name of soil separate	***Particle size (mm)***
Clay	less than 0.002
Silt	0.002–0.05
Very fine sand	0.05–0.10
Fine sand	0.10–0.25
Medium sand	0.25–0.50
Coarse sand	0.50–1.00
Very coarse sand	1.00-2.00

Soils are grouped into ***textural classes*** based on the percentages of sand, silt, and clay. Soils within each textural class have similar properties; the class name reflects the relative influence of each soil separate on the properties of that soil. For a soil to be called a sand, it must contain over 85% sand, but soil must contain only 40% clay in order to be classified as a clay. ***Loams*** have properties resulting from about equal influences of sand, silt and clay, but the loams contain more sand and silt than clay.

A ***soil textural triangle*** is a visual tool for determining the soil textural class. Soil

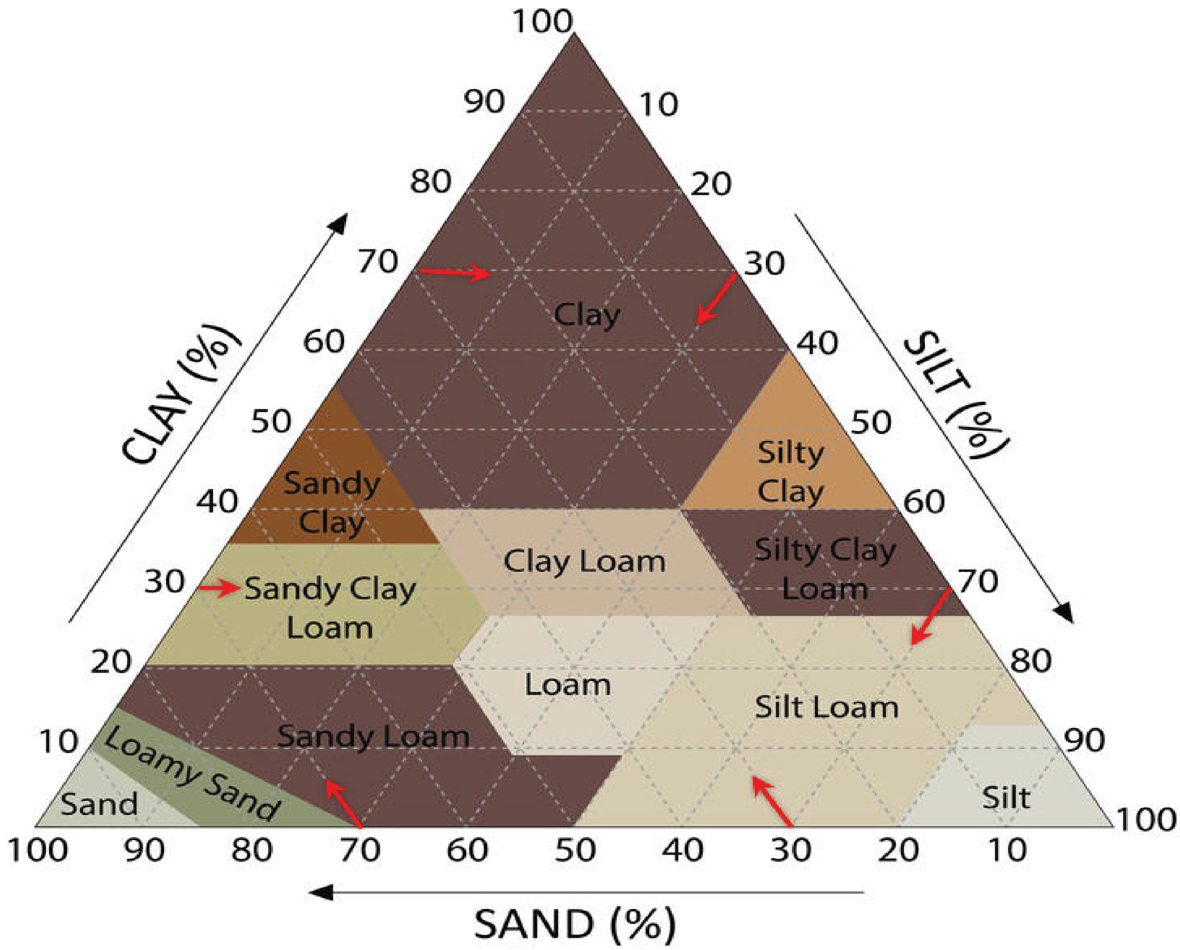

Figure 2. USDA soil textural triangle representing the percentages of sand, silt, and clay in various textural classes.

separates are measured and the percentage of each in a soil sample is calculated. Individual sides of the triangle have a scale from 0% to 100% representing the three soil separates. Using the arrows and guidelines, draw a line across the triangle at the appropriate percentage for each separate. If done correctly, the three lines will intersect at one point within a section of the triangle containing the correct textural class name. Some terms often used to describe textural classes include ***sandy*** or coarse-textured soils (for sands and loamy sands); ***loamy*** or medium-textured soils (for sandy loams, loam, silt, silt loam, sandy clay loam, clay loam, and silty clay loam); and ***clayey*** or fine textured soils (for sandy clay, silty clay, and clay). Soil textural classifications do not include organic matter in the composition.

Soil texture determines the rate water drains through a saturated soil. Most soils in Florida are ***coarse textured*** (sandy) soils through which water moves freely. ***Fine textured*** soils have slower water percolation and hold more nutrients than coarse textured soils. However, fine textured soils may be poor soils for growing plants due to inadequate drainage and aeration. An ideal soil for growing plants combines the drainage and aeration of a coarse textured soil with the water and nutrient holding capacity of a fine textured soil.

Generally speaking, ***sandy*** soils tend to be low in organic matter content and native fertility, low in the ability to retain moisture and nutrients, and rapidly ***permeable*** (i.e., they permit quick movement of water and air through the soil). Thick, upland deposits of such soil materials are common in the central ridge section of Florida, but also in other sand hill areas. These soils are often quite droughty, need irrigation at times during dry seasons, and are best adapted to deep-rooted crops (such as citrus, where temperatures permit). Sandy soils require good water management (generally including more frequent irrigations to fit the needs of a specific crop) and proper fertilization (meaning more frequent but lower quantities of nutrients per application).

As the relative percentages of silt and/or clay particles become greater, properties of soils are increasingly affected. Finer-textured soils generally are more fertile, contain more organic matter, are better able to retain moisture and nutrients, and permit less rapid movement of air and water. All of this is good up to a point. When soils are fine-textured enough to be classified as ***clayey***, they are likely to exhibit properties that are somewhat difficult to manage or overcome. Such soils are often too sticky when wet and too hard to cultivate when dry.

The “ideal” soil would typically have 45% inorganic (or mineral) material with a proportionate blend of large and small particles, 5% organic matter, 25% air and 25% water. These characteristics are often present in ***loam*** soils.

Figure 3. Graphic representation of ideal soil components.

Loam is not very common in Florida; but soils having sandy loam, or loam-textured surface soils, are common in the northwest portion of the state. Gray fine, sandy soils with a darker, organic-stained subsoil layer (classified as Myakka) are most extensive throughout Florida. This soil type occurs in much of the Florida peninsular on flatwood landforms, in tidal areas, depressions, and on barrier islands. It is a soil native to Florida that originates from marine deposits. South Florida soils are mostly sand with some peat and limestone aggregates. These soils are often shallow and have a high pH due to the influence of limestone parent material. Other areas in the southern part of the state tend to be peat-based and extremely fertile.

It is important to realize that texture alone does not indicate all the information about soils needed to understand and predict performance and suitability for different uses. For example, ***cementation*** is one soil attribute that can alter the effect of soil texture. A soil may be sandy throughout its depth, but the coating of sand grains by naturally-occurring materials such as organic matter and iron/aluminum oxides may lead to sand grains becoming cemented to each other and even to plugging of pores between sand grains. This phenomenon happens commonly in the layer under the surface level or subsoil of the flatwoods. The resulting ***hardpan*** can reduce the permeability of the subsoil and significantly alter the behavior of a soil. Human activities can also affect permeability. ***Compaction*** from large, heavy equipment can radically reduce soil permeability, even in sandy soils. Conversely, subsoiling or other kinds of ripping/breaking of slowly permeable soil layers can increase soil permeability.

photo by bob cook

Figure 4. Sandy, alkaline soil in south Florida with shell and limestone aggregates.

Another important influence on soil behavior is the zone of saturation where soil pores are filled with water. The upper surface of this zone is know as the ***water table***. Sandy soils of the flatwoods are likely to be saturated with water for extended periods during most years. The sandy soils of higher, sand hill landscapes are unlikely to have high water tables even for short periods.

Organic Soils

Organic soils are made up of plant and animal remains in varying stages of decomposition. These remains have accumulated in an environment where decay does not take place rapidly. Such an environment may be found in swamps, marshes, and lakes, and rarely in drier, more upland environments where the ecosystem is so productive that plant remains accumulate at extremely high rates. Muck, peaty muck, mucky peat, and peat are terms used in place of textural class names for organic soils.

Muck has very poor aeration and drainage. It is very hard to get it dry once wet and very hard to get it wet once dry. However, with managed irrigation and drainage, corn, sugarcane, rice and vegetables are grown in muck soils found in south Florida.

Remember, most soils are not dominated by organic materials, but consist primarily of sand-, silt-, and/or clay-sized particles from minerals or rock fragments. If a soil material has been designated mucky sand or other such mixed name, it indicates the soil is a mineral soil having a higher than ordinary content of organic matter (approximately 10% by weight), but not high enough to treat the soil as an organic soil (muck, peaty muck, etc.).

Figure 5. Organic soil.

Soil Amendments

Soil qualities are often not ideal for plant growth and must be modified using soil amendments. Soil amendments are added to improve physical characteristics, such as water retention, nutrient holding capacity, permeability, water infiltration, drainage, aeration and structure. Soil amendments can be organic or inorganic in nature. When modification is necessary, the goal is to select amendments that provide a better environment for roots.

Organic matter is often considered the most important soil amendment. ***Organic amendments*** will decompose over time as the organic matter is oxidized by soil microorganisms, releasing plant nutrients as they decompose. Only well-decomposed organic amendments should be incorporated into the soil; otherwise, the nitrogen present in the soil may be immobilized by microorganisms in the decomposition process and become unavailable to plants.

Organic materials recommended for soil modification include various composts, sphagnum peat, Florida peat, wood chips, pine bark, sawdust, and wood shavings. If wood products are used, a nitrogen (N) fertilizer should be present while the wood is decaying; this helps avoid N deficiencies during decomposition.

To be effective, a large volume of any organic material should be used and must be thoroughly mixed into the soil. A general guideline is to add organic soil amendments at a rate of 3 to 6 cubic yards per 1000 square feet of area (roughly 15% to 30% by volume). Do not exceed 6.5 cubic yards per 1000 square feet (approximately 35% by volume) since there may be issues with soil ***subsidence*** (gradual settling) as the organic amendment decomposes.

Organic amendments should be tilled or mixed thoroughly into the soil. If it is merely buried, its effectiveness is reduced, and it will interfere with water and air movement as well as root growth. Therefore, organic matter should be applied at a depth of 1 to 3 inches and incorporated uniformly into the top six (6) inches of the soil.

Amending a soil is not the same thing as mulching, although many types of mulch are also used as amendments. ***Mulch*** is left on the soil surface; its purpose is to reduce evaporation and runoff, inhibit weed growth, and create an attractive appearance. Mulches also moderate soil temperature, helping to warm soils in the spring and cool them in the summer. Mulches may be incorporated into the soil as amendments after decomposition. The use of organic mulches will, over time, improve soil conditions. In established plantings, the use of organic mulch is the best method of getting organic matter into the soil. Other amendments such as nitrogen, phosphorus, or lime may also need to be applied depending on existing soil conditions.

Inorganic products may also be used to help improve soil conditions. ***Inorganic amendments*** are not subject to biological degradation, and thus are considered to be more stable than organic amendments, which decompose with time. Calcined clay improves water holding capacity, and in some instances, may improve drainage and aeration. Colloidal phosphate, which consists of clay particles surrounded by natural phosphate, has also been used successfully as a soil conditioner. Vermiculite is a naturally occurring mineral composed of shiny flakes, resembling mica; it is sometimes used to increase water and nutrient holding capacity. Perlite, a naturally occurring siliceous rock, is yet another inorganic conditioner that is used to improve drainage characteristics.

Availability, cost and difficulty of applying the material must be weighed against the potential improvements when determining whether to use a soil amendment. While modification of soil characteristics may be necessary at times, the best approach is to choose plants adapted to growth in existing Florida soils. More descriptive information on organic and inorganic soil amendments follow in the section on container media.

Soil Porosity

Soil is composed of solid particles and the void space between particles. The relative proportions of different particles (the soil texture) affects many properties like structure and chemistry, but most notably, it affects soil porosity and permeability.

Soil porosity refers to the amount of pore or open space between soil particles. Porosity determines the total amount of water a soil will hold, and varies from one material to another. The greater the volume of pore spaces a material contains, the higher its porosity, and the more water it can hold. Porosity is largely influenced by factors of particle (grain) size, shape and assortment. In samples where the grains are well-rounded and fairly uniform in size, such as well-sorted medium-grained sand, the porosity is quite high. In contrast, poorly-sorted sediments contain particles of many

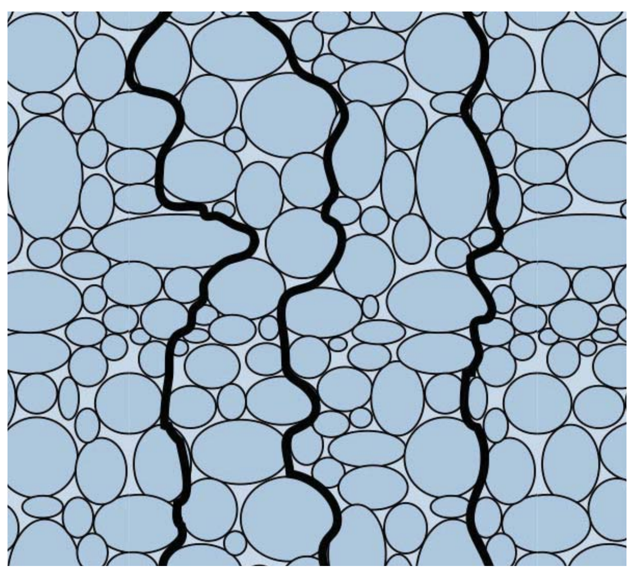

Figure 6. Pore spaces between assorted particle sizes. Small particles fill space between large particles. The black lines indicate a path of water movement through permeable soil.

sizes. The smaller particles fill up the pore spaces between the larger grains, making the sediment less porous.

Permeability is closely related to porosity in that it reflects the capacity of soil to transmit water. Fluids are able to permeate through a solid by passing through the pores it contains. Permeability is controlled by the size of pores and the degree of connectivity between soil pores. A highly permeable soil is one in which water runs through it quite readily. Coarse textured soils tend to have large, well-connected pore spaces and consequently high permeability. In general, higher porosity in a material is likely to be accompanied by higher permeability.

Soil Structure

Soil structure is the way soil particles aggregate or group together into units called peds. Soil peds come in a variety of shapes depending on the texture, composition, and environment.

Granular structure is crumbly and tends to form an open arrangement that allows water and air to penetrate the soil. ***Platy structure*** looks like stacks of dinner plates overlaying one another. Platy structure tends to impede the downward movement of both water and plant roots through the soil. Therefore, open structures tend to be better soils for plant growth.

The ***bulk density*** of a soil is calculated as the dry weight of soil divided by its volume. Bulk density increases with clay content and is considered a measure of the compactness of the soil. Greater bulk density results in more compact soil. Compact soils have low permeability, thus inhibiting the movement of water, Soil compaction also results in reduced infiltration and increased runoff and erosion.

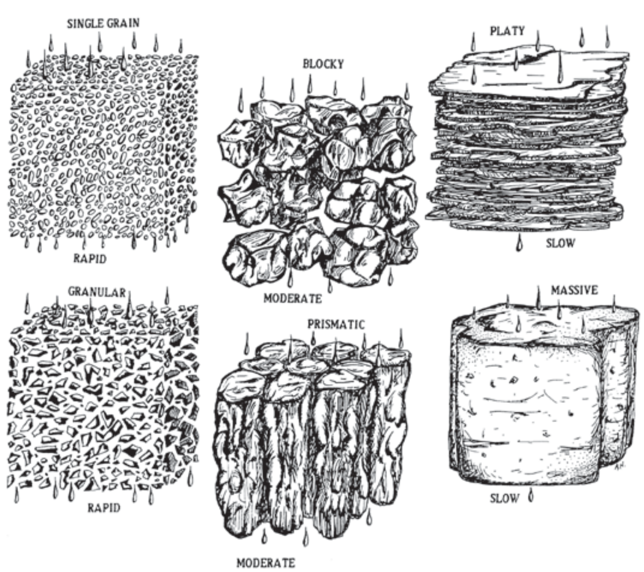

image by epa.gov

Figure 7. Common soil structure aggregates indicating permeabiliity rates of each.

Soil Temperature

Energy from the sun hits the soil surface, where it may be absorbed or reflected. All soils normally gain heat by absorbing solar energy. The heat is redistributed by conduction from the hot surface to the subsurface and the air, by evaporation of water, and by reradiation to the atmosphere and space. Daily heating and nightly cooling set up ***diurnal*** temperature fluctuations where the range of change is greatest at the soil surface and progressively less with depth.

Soil cover moderates soil temperature extremes because it blocks incoming radiation by day and impedes outgoing radiation and heat transfer in moving air at night. Soil water moderates extremes of soil temperature since water adds to the soil's heat capacity, helps heat move through the soil, and cools the soil by evaporation. In other words, water acts as an insulator. Therefore, a regular watering schedule in dry, cold weather can help protect plants from freezing temperatures and cold damage just as well as it cools soil temperatures and protects plants from heat stress in hot, dry weather.

All phases of plant growth are influenced by soil temperature. Raising soil temperature often improves seed germination and plant growth. Roots of many species function poorly at soil temperatures below 60°F, and some