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.

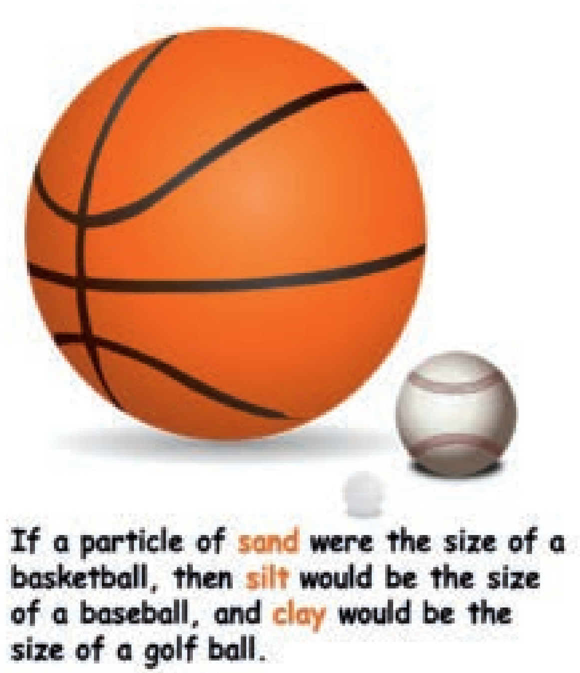


Figure 1. Relative size of inorganic soil particles (separates).

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

Figure 2. Relative comparison of different soil separate sizes.

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.

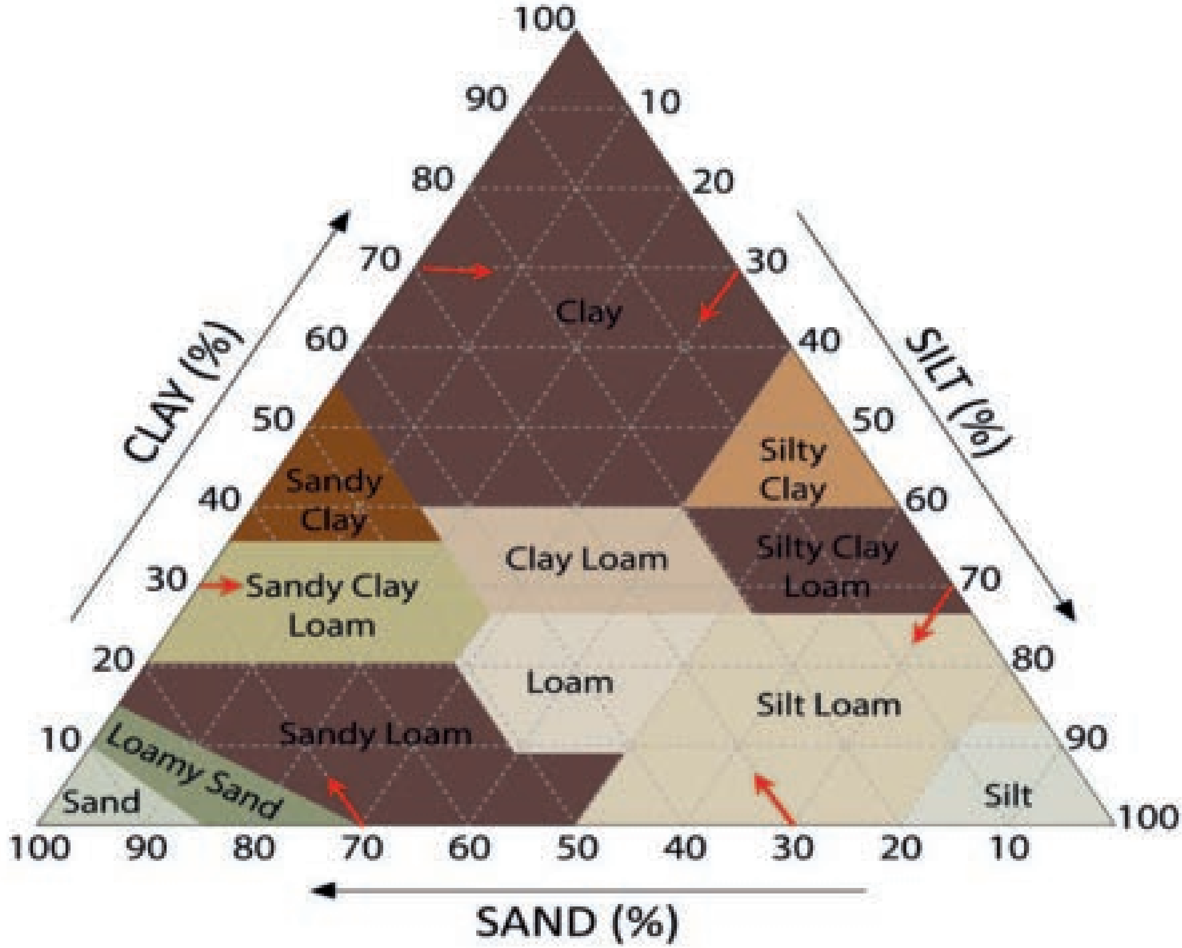


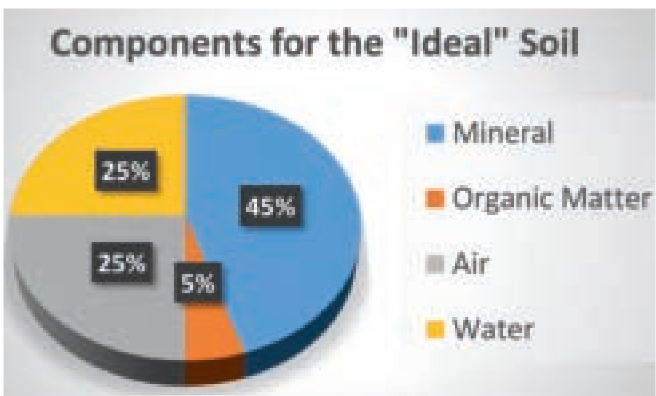
Figure 3. USDA soil textural triangle representing the percentages of sand, silt, and clay in various textural classes.

A ***soil textural triangle*** is a visual tool for determining the soil textural class. Soil 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, a line can be drawn 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*** (meaning, 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.



graphic by gale albritton

Figure 4. Graphic representation of ideal soil components.

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.

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. In 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 or 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 flatwoods. The resulting ***hardpan*** can reduce the permeability of 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 5. 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 known as the ***water table***. For instance, sandy soils of the flatwoods are likely to be saturated with water for extended periods during most years. Yet, the sandy soils of higher, sand hill landscapes are unlikely to have high water tables even for short periods.

Organic Soils

Organic soils are composed 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 the muck soils found in south Florida.

Remember, most soils are not dominated by organic materials, but consist primarily of particles the size of sand, silt, and/or clay derived 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 6. Example of an 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, and release plant nutrients as they decompose. However, 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 from immobilization 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 1,000 square feet of area (roughly 15% to 30% by volume). Do not exceed 6.5 cubic yards per 1,000 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 one to three 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 sizes. The smaller particles fill up the pore spaces between the larger grains, making the sediment less porous.

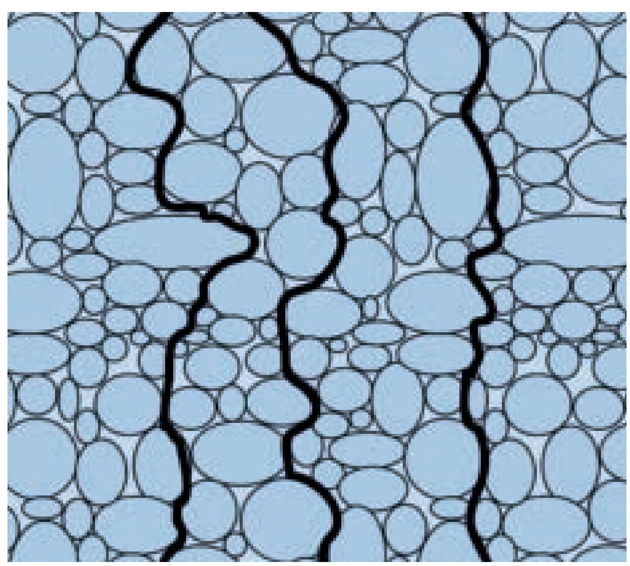


Figure 7. Pore spaces between assorted particle sizes. Small particles fill space between large particles. The black lines indicate a path of water movement through permeable soil.

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.

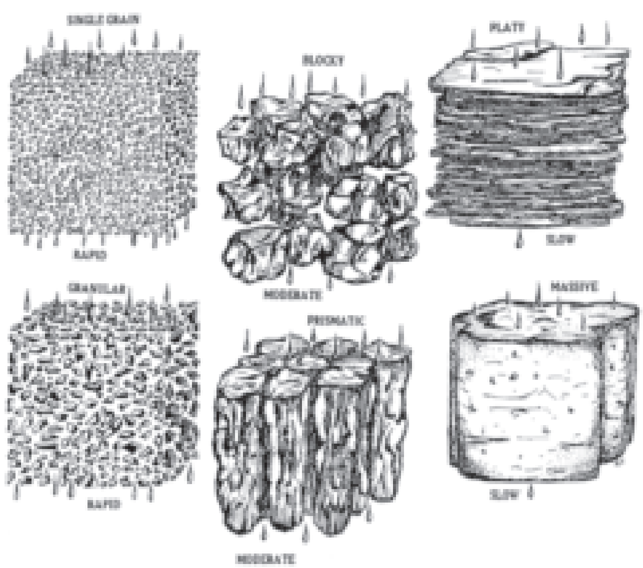


image by epa.gov

Figure 8. Common soil structure aggregates indicating permeabiliity rates of each.

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, which has low permeability, thus inhibiting the movement of water. Soil compaction also results in reduced infiltration and increased runoff and erosion.

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 60^0F, and some species require even higher temperatures. Soil temperature can be managed; however, the most common procedure is to fit the climate rather than alter it, such as by selecting crops suitable to the local environment, or delaying planting until temperatures are suitable.

Soil Air

Soils hold water that plants can use in open spaces between soil particles. Soil pores fill with water after a rain or irrigation. Water flows through these pores slowly, because it is impeded by attraction between the water and the soil particles. The ***adhesion*** between water and clay minerals becomes stronger as the soil dries. Some water is even held so tightly that plants cannot remove it.

If soil pores do not contain water, they contain air. Soil air is similar to the atmosphere above ground, except it is usually more humid and higher in carbon dioxide. Plant roots need oxygen to grow; if the soil is waterlogged for too long, respiration is impeded and plant roots die. Microorganisms living in the soil also require oxygen for respiration and metabolism. Some important microbial activities such as decomposition of organic matter, oxidation or breakdown of nutrients, etc. depend upon oxygen present in the soil air. However, there are plants and certain microorganisms adapted to oxygen shortage that are capable of surviving in the waterlogged soils of swamps and bogs.

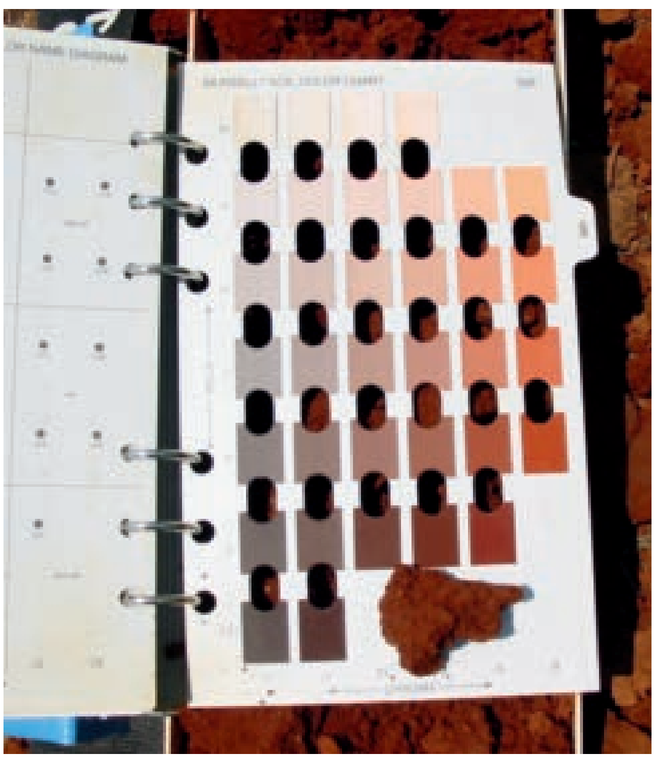


Figure 9. Soil color chart using the Munsell System that allows for direct comparison of soils anywhere in the world.

Soil Color

Soil color is one of the most easily observed features of a soil. The dark color of surface layers is attributed to the soil organic matter content. The darker the soil, the more organic matter is present. Similarly, red subsurface layers are attributed to the accumulation of iron oxides. Soil colors can be interpreted to reveal processes active within the soil. For example, dark colors are a function of organic matter accumulation, red colors are a function of iron accumulation under conditions of good aeration and plentiful oxygen, yellow colors are a function of iron accumulation under conditions of less plentiful oxygen, and gray colors are a function of iron accumulation under conditions of low oxygen and poor aeration. The presence of carbonates and magnesium colors the soil white.

Soil Chemical Characteristics

The chemical properties of soils include mineral solubility, nutrient availability, cation exchange, soil pH, and buffering action. These chemical properties are more influenced by ***colloids*** (very small particles of clay and humus) than other mineral components (silt and sand). As plant material dies and decays, it adds organic matter in the form of humus to the soil. ***Humus*** is the organic matter remaining after a major portion of the residue has decomposed; it improves soil moisture retention while also affecting soil chemistry. The surface of clay and humus are negatively charged and are the sites of most chemical reactions in soils.

Carbon to Nitrogen Ratio (C:N)

Decomposition of organic matter is affected by the proportionate content of carbon (C) and nitrogen (N). Organisms that decompose organic matter use carbon as a source of energy and use nitrogen for building cell structure. The ***carbon to nitrogen (C:N) ratio*** represents the relative amount of these elements in organic matter. A material with a C:N ratio of 25:1 has 25 times as much carbon as nitrogen.

Materials with a higher cellulose content (carbon) will be decomposed rapidly by microorganisms such as bacteria and fungi in the soil. During decomposition, organic particles release the nutrients they contain. However, soil microbes absorb these nutrients and utilize them for their own growth and reproduction. This is particularly true for nitrogen, which would normally be available for plant uptake.

As organic matter continues to decay, the carbon to nitrogen ratio decreases because carbon is released during decomposition and escapes into the atmosphere as carbon dioxide (CO_2). This makes more nitrogen available to growing plants. Residues with C:N ratios 20:1 or narrower (for example, rotted manure or decomposed compost) have sufficient nitrogen both to supply the decomposing microorganisms and to release nitrogen for plant use.

Management of nutrient concentrations in growth media composed of organic material with high C:N is extremely important if optimum plant growth is to be obtained. It is common practice to add nitrogen fertilizer to potting media mixed with bark or other woody material in order to avoid nitrogen depletion and the resulting poor plant performance.

For the sake of comparison, estimated C:N ratios of several different organic matter examples are found in the chart that follows.

Organic Matter Examples	***Average C:N Ratio***
Sawdust	500:1
Wood chips	400:1
Bark	120:1
Pinestraw	80:1
Leaves	60:1
Peanut shells	35:1
Garden waste	30:1
Wood ashes	25:1
Grass clippings	20:1
Manures, composted	15:1

Figure 10. Carbon to nitrogen ratio comparisons.

Cation Exchange Capacity

Many nutrients required by plants are positively charged and thus are attracted by negatively charged sites of clay and humus. The negatively charged locations are called cation exchange sites. The ability of a soil or other growth media to retain nutrients against leaching is estimated by measuring the ***cation exchange capacity*** (CEC). ***Cations*** are positively charged elements such as ammonium (NH_4^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) that are attracted and held (***adsorbed***) to negatively charged sites on clay and humus. These cations are rather weakly held to the surface and can be replaced by stronger ***ions in solution*** like hydrogen (H^+), iron (Fe^{2+}) and aluminum (Al^{3+}). These stronger cations can compete with and often replace originally adsorbed cations, thus releasing the weaker ***exchangeable ions*** into the soil for plants to use.

The CEC of a soil indicates how well it holds cations against leaching by irrigation water or rainfall. Generally speaking, as CEC increases, soil fertility increases. Therefore, soils with a high cation exchange capacity are more fertile than those with a low exchange capacity.

Sandy soils, often present in Florida, are low in CEC, so nutrient management is difficult. In this case, the best fertilizer use efficiency can be obtained by applying nutrients more

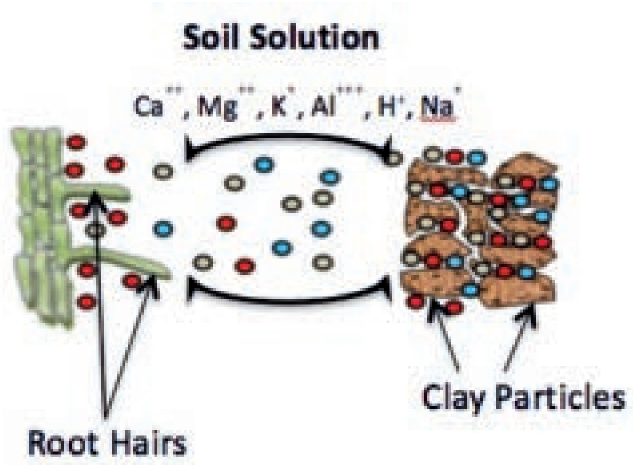


image by university of georgia

Figure 11. Nutrients entering solution after release from soil particles and available for root uptake as a result of CEC.

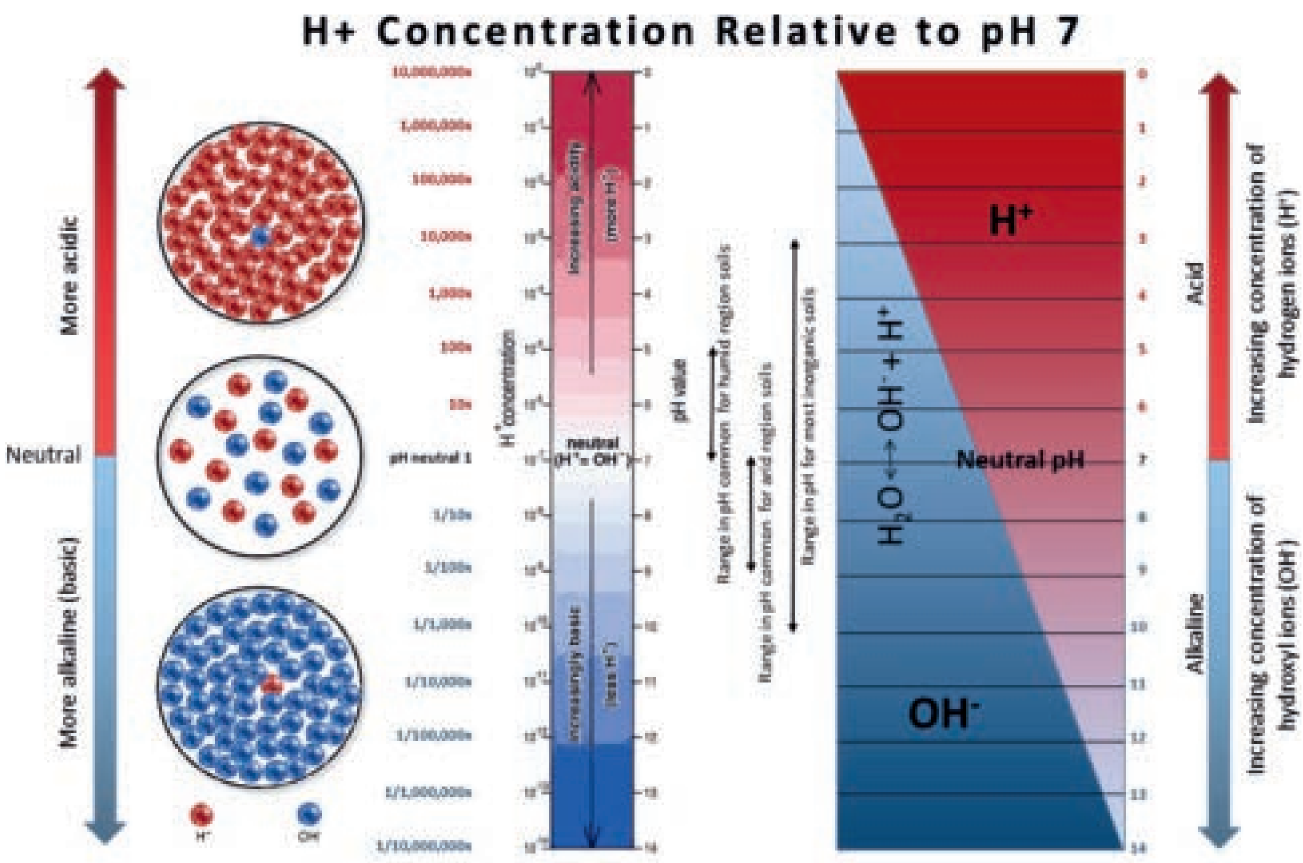
frequently and in smaller doses, particularly nitrogen and potassium that leach easily. Soil CEC can be greatly increased through the addition of organic matter. Soil organic matter has a large number of available bonding sites that hold nutrients and allow them to be released slowly over time. The risk of losing nutrients to groundwater is reduced when soil CEC is increased.

Soil Reaction (pH)

Soil reaction refers to the acidity or alkalinity of the soil and is a measure of the percentage of hydrogen ion (H^+) concentration. Soil reaction is measured as ***pH*** on a numerical scale that ranges from 0 to 14. Distilled or deionized water theoretically has a pH of 7 which is considered ***neutral***. A pH below 7 is considered ***acidic***; pH values greater than 7 are considered basic or ***alkaline***. The concentration of H^+ on the pH scale increases or decreases exponentially (by a power of 10 or 10^x). Therefore, a soil with a pH value of 5 is 10 (10^1) times more acidic than a soil with a pH value of 6 and 10 x 10 (10^2) or 100 times more acidic than a soil with a pH value of 7.

pH has a distinct effect on the availability of essential nutrients. Consequently, soil pH will affect the growth and quality of landscape plants. It does so by influencing both the chemical form of many elements in the soil and the soil microbial processes. Thus, landscape plants may exhibit nutrient deficiency or toxicity symptoms as a result of soil pH outside the optimum range.

The median pH for Florida soils is 6.1, which is characterized as slightly acidic. However, the pH of Florida soils can vary widely depending on the material from which the soil has formed. For example, well drained sandy soils that formed



graphic by gale allbritton

Figure 12. Diagrammatic representations illustrating the correlation between the relative concentration or percentages of hydrogen (H^+) ions to varying pH levels.

under pine flatwoods and organic soils can be quite acidic. In contrast, soils formed from materials high in calcium, such as limestone, marl, or sea shells, tend to be alkaline. This latter condition is common to coastal soils and the soils of south Florida. It is also common to encounter alkaline soils in the home landscape as a result of calcium-rich building materials (such as concrete, stucco, etc.) that may be left in the soil following construction. In general, alkaline soils are common in semiarid regions, while acid soils are more common in humid regions.

In acidic soils, the availability of plant nutrients such as potassium (K), calcium (Ca), and magnesium (Mg) is reduced, while the availability of potentially toxic elements such as aluminum (Al), iron (Fe) and zinc (Zn) are increased. In alkaline soils, iron (Fe), manganese (Mn), boron (B), zinc (Zn) and copper (Cu) are

Desirable pH Ranges for Common Ornamentals and Turf

Strongly Acid (pH ≤ 5.4)	***Mod. to Strongly Acid (pH 5.5 – 5.9)***	***Moderately Acid (pH 6.0 – 6.4)***	***Slightly Acid (pH 6.5 – 7.0)***	***Slightly Alkaline (pH 7.1 – 7.8)***	***Moderately Alkaline (pH 7.9 – 8.4)***
Woody Ornamentals					
aucuba	abelia	abelia	aucuba	agave	aucuba
azalea	allamanda	allamanda	bougainvillea	aucuba	black olive
blueberry	aucuba	aucuba	camellia	black olive	Geiger tree
bougainvillea	bougainvillea	bougainvillea	citrus	Geiger tree	gumbo limbo
crape myrtle	camellia	camellia	feijoa	gumbo limbo	oleander
gardenia	citrus	citrus	gardenia	live oak	palms
holly	crape myrtle	crape myrtle	Geiger tree	oleander	trumpet tree
hydrangea	croton	croton	hibiscus	palms	wax myrtle
ixora	feijoa	feijoa	hydrangea	plumbago	
ligustrum	gardenia	gardenia	live oak	podocarpus	
magnolia	hibiscus	hibiscus	oleander	satinleaf	
podocarpus	holly	holly	palms	southern red cedar	
yaupon	ligustrum	ligustrum	pittosporum	trumpet tree	
	magnolia	live oak	plumbago	wax myrtle	
	oleander	magnolia	podocarpus	yaupon	
	palms	oleander	satinleaf	yucca	
	pittosporum	palms	southern red cedar		
	plumbago	pittosporum	sycamore		
	podocarpus	plumbago	trumpet tree		
	trumpet tree	podocarpus	wax myrtle		
	yaupon	southern red cedar	yaupon		
		trumpet tree	yucca		
		yaupon			
		yucca			
Warm Season Turfgrasses					
bahia	bahia	bermuda	bermuda	St. Augustine	St. Augustine
centipede	centipede	St. Augustine	St. Augustine		
		zoysia	zoysia		

Figure 13. Examples of common plants adapted to varying ranges of pH.

commonly deficient. Furthermore, pH affects soil bacterial and fungal activity, enhancing or inhibiting the development of soilborne plant diseases, or influencing how efficiently they function as beneficial decomposing organisms. It is also important to be aware that many pesticides and liquid forms of fertilizer perform best with a water pH of 5.5 to 8. For that reason, it is important to test water as well as soil.

Fortunately, most common landscape plants are well suited to a wide range of soil pH. For example, popular woody shrubs and trees such as pittosporum, viburnum, oaks and pines will grow well in acid to moderately alkaline soils. In addition, several common lawn grasses can tolerate wide ranges in soil pH. The ***optimum pH range*** for most plants is between pH 5.5 and 7.0. However, there are a few acid loving plants, including azalea, blueberry, gardenia and ixora that do better in acid soils with a pH of 4.5 to 5.5.

Plant pH requirements are determined from scientific experimentation or extended observation; therefore, it is wrong to assume a particular species will grow best at pH 5.5 to 7.0 simply because most plants do best in that range. It is important to know the most desirable pH range for plants being grown in the landscape or in production in order to maintain optimum growth efficiency and health.

Soil Testing Procedures

A soil test provides information about the nutritional status of a soil and may aid in the detection of potential problems limiting plant growth. The chemical status of a soil cannot be measured visually; it should always be tested using appropriate equipment before adding amendments. A number of simple chemical tests are available and accurate enough for horticultural use, so measuring pH can be done easily. A wide variety of pH meters for more precise electrical testing are also available. To assure accuracy, work closely with the local University of Florida IFAS Extension Service on soil testing both for pH and nutrients.

To test soil in the landscape, a ***composite soil sample*** should be obtained by removing subsamples from 10 to 15 small holes randomly selected throughout the sample area (for example, the front yard). Carefully pull back mulch, grass or groundcovers to expose bare soil. With a trowel or shovel, dig small holes 6-inches deep and remove a 1-inch thick by 6-inch deep slice of soil from the side of each hole. Combine and mix the subsamples in a clean plastic bucket. The soil should be spread on a nonporous surface out of direct sunlight and allowed to dry thoroughly before testing. To obtain the most reliable results, take separate composite samples from areas that have different soil types, receive different cultural practices or contain plants that have distinctly different fertility requirements. Two to three areas from a quarter to 1-acre lot will often be sampled separately.

In container production, separate media samples should be collected from blocks where plants are treated and grown under similar conditions, such as media type, irrigation, container size, etc. Collect 5 to 20 subsamples from plants within the block using a soil probe. Samples should include media from the entire container profile (depth); the top layer should be removed to avoid inclusion of any fertilizer. Combine and mix media in a clean plastic

Figure 14. Inexpensive soil test meter for the field.

bucket and allow the composite sample to dry prior to submitting for testing.

Collected samples, accompanied by completed collection and submission forms, should be sent to a university or commercial laboratory for more extensive test results. Remember that sample collection of landscape soil should precede spring fertilization by a couple of months in order to allow time for adjustments in pH if needed. Container media should be sampled more often to coincide with production schedules.

Sample collection and submission forms for soil testing are available from the local University of Florida IFAS Extension office or the UF/IFAS Extension Soil Testing Laboratory. UF publications Container Media Test Information Sheet SL-134, Producer Soil Test Information Sheet SL-135, or Landscape and Vegetable Garden Test Information Sheet SL-136 should be referenced for additional information.

Adjusting the pH of Landscape Soils

The best advice regarding soil pH is to choose landscape plants suited for the naturally occurring pH of the landscape soil. While there are soil additives that can raise or lower soil pH, the effect of these materials is often very short-lived; plus adjusting pH will probably not improve plant performance if the soil pH is within 0.4 of a pH unit of the ideal range.

Raising pH

To raise the pH of acidic soils, add a liming material like calcium carbonate or dolomite. The amount of lime application to acid soils depends largely on the initial pH and the ***buffering capacity*** (ability to resist a change in pH) of the individual soil. The Soil Testing Laboratory at UF uses a method that considers pH and buffering capacity in determining the lime requirement of individual soils. Much of the difference in buffering capacity of individual soils is related to the amount of silt, clay and organic matter present. The greater the amounts of these materials present, the higher the buffering capacity.

Crushed agricultural limestone or ***dolomite*** are the liming materials typically used to raise soil pH. Because magnesium is often deficient in Florida soils, dolomite is preferable in most locations in Florida since it contains magnesium (Mg) as well as calcium carbonate ($CaCO_3$). ***Hydrated lime*** (calcium hydroxide or $Ca(OH)_2$) may also be used to raise pH; however, the amount should be reduced by 25% because hydrated lime reacts much more quickly and can burn plants more easily than carbonate lime.

In order for lime to be effective, it should be thoroughly mixed into the top six (6) inches of the soil. This is easily accomplished before planting a garden or landscape. When applying lime to established landscapes or turf, incorporation techniques can damage plant roots. In this case, lime should be surface applied and watered in.

Overliming or adding lime when the soil does not need it can have negative effects that can be worse than doing nothing. An approximation of the amount of agricultural or dolomitic lime needed for raising pH can be made using the *Landscape (Field) Soil pH Adjustment* table on the next page.

Figure 15. Granular dolemitic lime for raising pH.

Figure 16. Sulfur in powder form for lowering pH.

Lowering pH

Lowering the pH to acidify the soil may be desirable in some situations. However, unlike liming, lowering the pH of strongly alkaline soils is much more difficult. In fact, there is no way to permanently lower the pH of soils formed from high calcium materials such as marl or limestone, or soils severely impacted by alkaline materials used in the construction of a roadbase, fill, or foundation. Treatment with sulfur will lower the pH for a few weeks, but the pH will eventually increase.

Adding any acidifier to soils composed of high calcium materials will only temporarily adjust the pH because the acidification causes the limestone or shell to become soluble, which then neutralizes the acidifier. In landscaping, it is often better to select plants adapted to high pH conditions, rather than use plants that will need constant soil pH maintenance. If this approach is not taken, plants will have continuing nutritional problems and usually look unhealthy even after the extra effort to lower pH. To avoid artificially creating this situation, decorative limestone rocks should not be used in the landscape. Other rocks, such as river gravel, are less soluble and have little effect on pH. In contrast, if a high pH is the result of overliming, correction may be possible.

If adjustment is desired, the soil pH can be lowered by adding ***elemental sulfur***. ***Superfine wettable*** or ***dusting sulfur*** is also used to lower soil pH. The rate for dusting sulfur needed to decrease the soil pH one unit is approximately one-third (1/3) of the amount of limestone used to raise the soil pH one unit. The amount applied should not exceed one (1) pound per 100 square feet at any one application. If sulfur is being applied around living plants, the same amount should be applied; however, two separate applications should be made 60 days apart. The *Landscape (Field) Soil pH Adjustment* table below indicates rates for lime applications, but can be used to calculate the amount of sulfur needed to make pH adjustments; however, remember

Landscape (Field) Soil pH Adjustment ***Agricultural Limestone or Dolomitic Limestone to Increase pH One (1) Unit***					
Soil of ***Low*** Organic Matter Content Indicated in Pounds of Limestone per Unit					
Soil Texture	**10 sq ft**	**100 sq ft**	**1,000 sq ft**	**4 cu ft**	**1 cu yd**
Sand	0.4	3.7	37	0.3	2.0
Loamy sands	0.5	4.7	47	0.4	2.5
Sandy loams	0.6	6.0	60	0.5	3.25
Sandy clay loams	0.9	9.3	93	0.75	5.0
Soil of ***Moderate*** Organic Matter Content Indicated in Pounds of Limestone per Unit					
Soil Texture	**10 sq ft**	**100 sq ft**	**1,000 sq ft**	**4 cu ft**	**1 cu yd**
Sand	0.4	7.0	70	0.6	3.8
Loamy sands	0.8	8.4	84	0.7	4.5
Sandy loams	0.9	9.3	93	0.75	5.0
Sandy clay loams	1.1	10.9	109	0.9	5.9
NOTE*: To calculate the rate of sulfur needed to lower pH one (1) pH unit, use one-third (1/3) the rate of the figures represented above.*					

Figure 17. Recommended rates of amendments required to adjust pH of various soil textures.

photo by gale allbritton

Figure 18. An appropriate plant for site conditions should be selected to replace this lady palm suffering from iron deficiency growing in a calcareous (high pH) soil.

to use only one-third (1/3) the total amount. Make sure to monitor plants carefully after sulfur application.

Other sulfate containing materials (ammonium sulfate, iron sulfate, aluminum sulfate) can also be used to lower the soil pH. These are often included in so-called ***acid-forming fertilizers*** commonly applied to azaleas and camellias. However, be aware that not all sulfate materials, such as calcium sulfate (gypsum), magnesium sulfate (Epsom salt), or potassium sulfate will acidify soil. Alternatively, organic materials such as peat or manure also reverse the effects of alkaline soil pH on some landscape plants. Since these materials decompose with time, annual or semiannual applications are usually required.

Iron sulfate (ferrous sulfate) can likewise be used to lower soil pH, with a faster but more temporary effect than wettable sulfur. Iron sulfate helps add iron, which is often unavailable with high pH. However, it is relatively expensive, and will stain sidewalks. If used, the standard rate for iron sulfate is one (1) pound per 100 square feet. It may be necessary to reapply in 60 days, but repeated applications may reduce the amount of manganese (Mn) available in the soil. Aluminum sulfate is also effective in correcting pH, but too much aluminum can be harmful to plant growth.

Adjusting pH of Soilless Mixes

Because of the relationship between pH and nutrient availability, maintaining the correct pH in nursery and greenhouse potting mixes (soilless media) is crucial to successful production of plants. Most foliage and woody plant crops grown in the nursery or greenhouse tolerate a more acid potting mix than landscape soil; this is because the level of aluminum in soilless media is generally too low to cause problems. Container grown foliage crops perform well between pH 4.5 and 6.5 and container grown woody plants do well between pH 5.0 and 6.5. Changing the pH after plants are potted and growing is difficult. Therefore, adjustments are most easily made prior to planting.

Before Potting

Low pH levels can be raised in potting media by adding liming materials, such as ***dolomite*** or ***calcium carbonate***; high pH levels are lowered by adding ***sulfur***. The amounts of these materials needed to provide a desired pH depends on the type of organic material in the potting mix and the original pH. The materials must be carefully measured and thoroughly mixed into the media before planting.

In sandy potting media, small amounts of lime or sulfur are needed, while larger amounts are required to affect the pH of pure peat because of its higher buffering capacity. The *Container Media pH Adjustment* table (next page) serves as a guide for adjusting pH levels during potting media preparation. The table indicates modifications needed to achieve a desirable pH of 5.7 for container grown crops.

After Potting

To raise the pH of a potting mix after crops are already growing, ***hydrated lime*** (calcium hydroxide or $Ca(OH)_2$) should be used, but with caution. Hydrated lime can damage plants if applied in solution at more than one (1) pound per 100 gallons per 100 square feet of surface area (pots or benches). The crop may need to be treated again four weeks later if pH has not reached the desired level. ***Calcium carbonate*** (lime), applied to the surface of the potting mix and watered in, will also raise pH. However, it may take longer for it to be effective.

If pH levels are too high in potting mixes of established crops, ***sulfur*** can be applied at the rate of 1 pound per 100 square feet of surface area to lower pH. Sulfur should not be applied more often than every four weeks because rapid pH changes may damage plants. The use of fertilizers that have a high ***acid forming potential*** (calcium nitrate, ammonium-based nitrogen, phosphoric acid, iron sulfate) can also be one of the tools chosen to help lower or maintain a lower pH in potting mixes. The acid forming potential or the acid neutralizing effect of a fertilizer is expressed in ***calcium carbonate equivalents (CCE)*** per unit weight of fertilizer. Essentially, CCE represents the pounds of calcium carbonate (limestone) it takes to neutralize one ton of a fertilizer or fertilizer component. The higher the number, the greater the acid forming potential of the fertilizer. These fertilizers should also be used cautiously to avoid plant damage.

As we have seen, there are several means available to adjust container medium pH. The specific method chosen will depend on whether or not there is a need for a quick fix or if a gradual method to control pH over time can be considered. Fertilizer management strategies, irrigation water pH, and buffering capacity of media components must also be taken into account.

Alternatives to Correcting pH

1) Select plants tolerant of existing soil pH. This is a step toward low maintenance landscaping.
2) Use a fertilizer program designed to overcome specific nutrient problems. This alternative requires considerable expertise, and may involve regular use of soil acidifiers, chelated fertilizers and foliar applications of plant nutrients.
3) Remove and replace enough soil in the planting holes to allow the plant to grow in an "island" of good soil. This method can be expensive and must be done at planting.
4) Regularly apply organic mulch to the soil surface, so that the organic content of the soil gradually increases, which gradually reduces the pH.

Container Media pH Adjustment ***The approximate amount of lime and sulfur required to adjust pH of potting mixtures***			
Dolomitic lime (pounds per cubic yard) or equivalent amount of calcium to ***raise pH*** of indicated media to 5.7			
Beginning pH	**50% Peat + 50% Sand**	**50% Peat + 50% Bark**	**100% Peat**
5.0	1.7	2.5	3.5
4.5	3.7	5.6	7.4
4.0	5.7	7.9	11.5*
3.5	7.8	10.5	15.5*
Sulfur (pounds per cubic yard) to ***lower pH*** of indicated media to 5.7			
Beginning pH	**50% Peat + 50% Sand**	**50% Peat + 50% Bark**	**100% Peat**
7.5	1.7	2.0	3.4
7.0	1.2	1.5	2.5
6.5	0.8	1.0	2.0
*Addition of more than 10 pounds of dolomite per cubic yard often causes micronutrient deficiencies. *(Adapted from Light and Fertilizer Recommendations for Potted Foliage Plants, by Charles Conover and R.T. Poole, Agricultural Research and Education Center, Apopka, FL)*			

Figure 19. Recommended rates of amendments required to adjust pH of various potting soil mixtures.

Soluble Salts

Soluble salts refer to the major dissolved inorganic solutes (ions) present in soil water. ***Saline soils*** contain excess soluble salts that reduce the growth of most crops or ornamental plants. Salts in Florida soils are commonly found in coastal areas, including landscaping at marina-centered housing developments, and where irrigation well draw-down has resulted in saltwater intrusion into the underlying aquifer. Saline soils are also found where overfertilization has resulted in excessive soluble salts in soil.

Nutrients supplied by inorganic fertilizers are usually soluble, and directly contribute to salts in the soil. High soluble salt levels reduce water uptake by plants, restrict root growth, cause burning of the foliage, inhibit flowering, and limit fruit and vegetable yields. Sensitivity to soluble salts differs among plant species, cultivars and their stage of growth. Germinating seeds and seedlings are more sensitive to salt stress than mature plants. When correct fertilizer rates are used, the salt contribution from fertilizers is low and does not adversely affect crop growth.

A ***soluble salt test*** can be useful when investigating the cause of poor plant growth, determining the suitability of a new planting site, or monitoring the quality of topsoil or compost for use on landscaped areas. Since water containing dissolved salts conducts current approximately in proportion to the amount of salt present, measurement of the ***electrical conductivity (EC)*** of a soil extract gives an indication of the total concentration of soluble salts in the soil. EC is reported in units of millimhos per centimeter (mmhos/cm), although some labs report units in decisiemens per meter (dS/m). One dS/m is equal to one mmhos/cm.

Measuring EC also provides a general indication of nutrient deficiency or excess. A high EC reading usually results from too much fertilizer in relation to the plant's needs, but inadequate watering and leaching or poor drainage are other causes. Sometimes high EC levels occur when root function is impaired by disease or physical damage. Always check the condition of the root system when sampling soil for testing. Guidelines in the *Soluble Salts Concentrations* table on the next page are useful in interpreting EC data from soil extracts using the 1:2 soil-to-water dilution method.

Many cities and towns are now using disinfected and treated effluent (reclaimed) water from sewage treatment plants. This reuse in ornamental plantings or golf courses is an excellent way to dispose of the recycled water in an environmentally sound manner and to conserve potable (drinking quality) water. While ***reclaimed water*** can be safely used to irrigate turf and most landscape plants, it may have higher levels of salts, and often contains nutrients (nitrogen and phosphorus) that should be considered part of the fertilizer regime.

Occasionally, reclaimed water contains elevated levels of salts that can harm sensitive landscape plants. Japanese plum yew (*Cephalotaxus harringtonia*) and crape

photo by gale albritton

Figure 20. Soil testing equipment used for pH and EC monitoring.

Ratings for Soluble Salts Concentrations in Soils			
Electrical Conductivity (mmhos/cm)	**ppm †**	**Rating**	**Interpretation**
0 – 0.15	0 - 96	Very low	Plants may be starved of nutrients.
0.15 - 0.50	96 - 320	Low	If soil lacks organic matter. Satisfactory if soil is high in organic matter
0.51 - 1.25	321 - 800	Medium	Okay range for established plants.
1.26 - 1.75	801 – 1,120	High	Okay for most established plants. Too high for seedlings or cuttings.
1.76 - 2.00	1,121 – 1,280	Very high	Plants usually stunted or chlorotic.
> 2.00	> 1,280	Excessively high	Plants severely dwarfed; seedlings and rooted cuttings frequently killed.
† Multiply mmhos/cm by 640 to estimate ppm salt. More than 2.5 mmhos/cm or 1,600 ppm is unsuitable for most crops.			

Figure 21. Interpretation of soluble salt test results.

myrtles (*Lagerstroemia* sp.) are two common landscape plants that are especially sensitive to high salt levels. Higher than normal salt levels may be found in reclaimed water nearer the coast because of the influence of seawater. Any potential problems associated with using reclaimed water on landscape plants can most often be avoided by irrigating only when necessary, growing salt tolerant plant species, and minimizing the use of overhead sprinkler irrigation so that water high in soluble salt does not contact plant foliage.

Local reclaimed water providers will have data about salt levels in water. However, electrical conductivity (EC) of the water should be measured regularly to monitor soluble salt levels. If elevated readings are found, usually greater than 1.5 to 2.0 mmhos/cm, the water should be mixed with better quality water before it is used for irrigation. If mixing is not possible, this water should not be used for irrigation except by experienced water managers.

Salts may also be introduced to the soil and aquifers by catastrophic storm events such as hurricanes. Flooding induced by storm surge will directly introduce seawater onto land previously free of salinity problems. When the storm occurs near the end of an area's rainy season, it may take several months for salt removal via the natural rainfall and leaching process.

Salt effects on plants are often exacerbated during periods when drying conditions persist. During drying, water is removed by evaporation from the soil surface and by transpiration from plants. Salts are left behind that were previously dissolved in the soil water, concentrating them and increasing the adverse impact on plants.

Figure 22. Irrigating with reclaimed water in public gardens.

Most approaches to treating soils with high soluble salts (EC) involve ***leaching*** (flushing) of the soil with clean, relatively pure water. Sufficient water must be applied to dissolve any excess salts that have accumulated and cause them to percolate below the root zone. Testing initial soil salinity levels will enable a determination of how much water should be applied to reduce salt concentrations to acceptable levels. Postleaching soil salinity tests will ensure efforts has been successful.

Container Media

The purpose of a container ***medium*** or ***substrate*** is to physically support the plant and to supply adequate oxygen, water and nutrients for proper root functions. The plant must be held upright in the medium, and the medium must be heavy enough to stabilize the container and keep it in an upright position. The optimum weight of container media depends on the size and form of the plant being produced and the degree of wind in the production area. However, excess weight should be avoided since this hampers handling and increases shipping costs.

Plants can be grown in many different types of media if proper management is provided. The optimal container medium will depend upon the specific plant species or cultivar being grown, size of the container, environmental conditions in the production area (such as irrigation control, rainfall distribution, irrigation water salinity level, light intensity and temperature), characteristics and location of the markets, plus the availability and cost of growth medium components.

Selection or formulation of a container medium properly suited for a given production system is extremely important since it relates to every cultural practice in container nursery crop production. A quality, well-chosen medium is an investment that will pay great dividends in terms of plant growth and quality. Adjustment of cultural practices that become necessary due to a poorly chosen container medium may add up to several hundred dollars of hidden or indirect costs in just one cubic yard of container medium over the production period. Even larger costs can be encountered through losses in plants or reduced plant quality due to a poor container medium. It pays to purchase or formulate a container medium suited for each production system or management regime.

Additionally, Best Management Practices (BMP) goals for container production are to choose the correct container substrate; specifically, one that conserves water and minimizes leaching while providing the best possible conditions for plant growth to prevent movement of nutrients, pesticides, and pollutants from the potting area.

Figure 23. Long-term interiorscape plants in quality media.

photo by bob cook

Figure 24. An example of container media consisting of 60% pine bark and 40% peat.

Physical Properties of Container Media

Like native soils, growing medium consists of solids (such as, peat moss, bark, perlite) and pore space. The size and distribution of pores is one of the most critical factors in developing a growing medium with optimum physical characteristics.

Media Porosity

Total pore space in most soilless growing media is approximately 60% to 80% by volume. Large pores allow water to flow freely from them by the force of gravity and permit air to reenter the medium following irrigation. Small pores hold water against gravity and are a source of water for the soil environment. Since growing medium in containers holds a relatively large quantity of water, the percentage of pore space filled with air is reduced. Therefore, an adequate distribution of large and small pores is essential. On average, most mixes contain 10% to 30% air following irrigation.

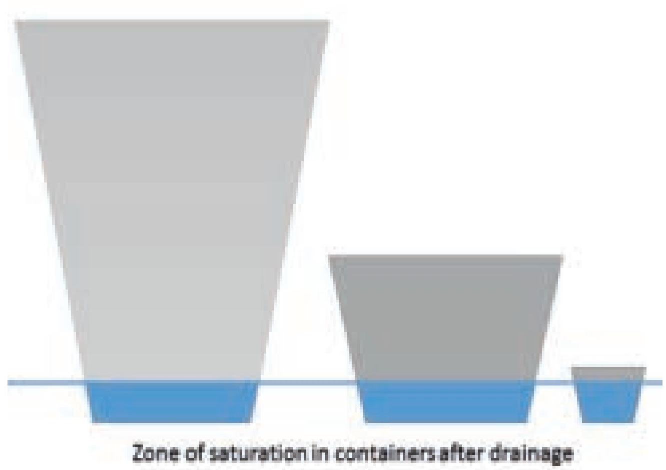
Water is also held in the pore space of a growing medium. ***Capillary action*** is important for moving water between the spaces of a porous material. Capillary action occurs because water molecules stick to water molecules (***cohesion***) and water molecules are attracted to and stick to other substances (***adhesion***). The availability of this water for plant growth is largely determined by how tightly it is held by the solid components of the medium. The closer a water molecule is to a solid, the more tightly it is held by the forces of adhesion. Therefore, a fine mix may hold more water than a coarse mix, but less of it is available to the plant because it is bound to soil particles. Pore size impacts capillary action within the mix and will allow water to be held against gravity to a certain level. This creates a ***zone of saturation***.

Drainage is affected by both pore size and the shape of a container. Water occupying large pores is held less tightly because the molecules are not as close to the solids in the medium. As a result, this water is more available to the plant and also drains at a faster rate than water occupying smaller pores.

Length of the soil column also influences the rate of drainage. A taller container is more subject to the greater force of gravity on water occupying the pore space, resulting in increased drainage. Shorter columns of an equal type and volume of medium hold more water, drain more slowly and contain less air.

Compaction is another factor that affects drainage. Packing growing medium into a container can significantly reduce the number of large pores. When this occurs, it creates less available water for the plant, reduces aeration and gas exchange, increases water holding and decreases drainage. In smaller containers, the effect of compaction can be even greater.

Root distribution in container media can be influenced by particle size distribution. A medium with high water holding capacity and low aeration may result in a concentration of roots in the top portion of the container, especially if the medium in the bottom portion of the container remains saturated for extended periods. Roots growing in poorly aerated media are weaker, less succulent, and more susceptible to micronutrient deficiencies and root rot pathogens than roots growing in well aerated media.



graphic by gale allbritton

Figure 25. Comparison of the zone of saturation in identical potting media relative to the length of the soil column in different size containers.

Media Temperature

Rapid temperature fluctuations and extreme temperatures are common in container media. The high container surface area to volume ratio provides little buffering of environmental fluctuations. Root zone temperatures on a bright, sunny day often exceed the air temperature by 27^{0}F because of direct solar radiation on container sidewalls. Winter night temperatures may be lower than air temperatures because of rapid heat loss from this large surface area. These facts are particularly evident in smaller containers. The amount of water present in a container medium will influence how rapidly the temperature of the medium changes. Water buffers or reduces the rate of media temperature change, although the extent of this buffering is not clearly understood in nursery containers.

Media Volume

Container medium volume generally decreases and physical properties change over time due to compaction, shrinkage, erosion and root penetration resulting in decreased drainable pore space and readily available water. ***Compaction*** refers to the reduction in container medium volume caused by settling or compression. Compaction can occur not only as the result of poor potting procedures, but also from breakage of particles, or the impact of overhead irrigation. ***Shrinkage*** occurs as a result of media particle degradation. As certain particles decompose, they become smaller and fit closer together, thus decreasing the total volume and the volume of air-filled pores after irrigation and drainage. Compaction and shrinkage during the production period should be less than 10 percent, but slightly more may have to be tolerated for plants requiring multiple seasons for production. Soil particles can be ***eroded*** by intense rainfall and/or irrigation that can splash or wash particles from the container, and particles can be lost during removal of weeds, etc. However, ***root volume*** increases often compensate for losses in growth medium volume.

photo by gale allbritton

Figure 26. High container surface area relative to media volume leads to rapid temperature fluxuations in soil.

photo by gale allbritton

Figure 27. Shrinkage of container media during production.

Chemical Properties of Container Media

Like field soil, chemical properties commonly measured for container media and media components include pH, soluble salts, cation exchange capacity and the carbon to nitrogen ratio. These properties should be thoroughly examined during the growth medium selection and/or formulation process.

pH

The ***optimum pH*** for organic mixes tends to be 1 to 1.5 units lower than those generally considered desirable for mineral soils. Liming organic media with a pH of about 5.8 is undesirable because it will reduce the availability of phosphorus (P), manganese (Mn), boron (B), copper (Cu), and zinc (Zn). Remember, the ideal target in the previous container media pH adjustment chart was 5.7.

For containers, pH in the range of 5.5 to 6 has been the rule of thumb; however, pH as low as 4.5 is acceptable and, in some crops, desirable. In containers, most growers use ***soilless media*** (media without mineral soil) composed primarily of organic components (bark, peat, etc.). Organic container components inherently cause low container pH. Because mineral soils are not present in container media, aluminum (Al) toxicity is not a concern when pH is low. However, other minerals such as iron, manganese (Mn) and zinc (Zn) can become toxic at low pH.

Soluble Salts

Soluble salts in the range of 2,500 to 4,000 ppm are considered high for most woody crops. The moderate or suggested range after fertilization is 1,000 to 1,500 ppm, but some plants are more sensitive to salt levels than others. For example, the optimum salt level for azaleas is 500 to 700 ppm. (*Note: Multiply mmhos/cm by 640 to convert EC readings to ppm.*)

Components such as sand, small gravel and peat harvested from areas high in soluble salts may not be acceptable for use in container media or may have to be leached before used. Salts in sand and small gravel can be leached by large amounts of water while the material is in a pile or storage bin. Salt levels in peat may be more difficult to reduce by leaching because of the greater ability of this component to hold ions tightly on the surface.

If containerized plants are not provided sufficient drainage, salts from irrigation water and fertilizers can be concentrated when media drying occurs during evapotranspiration. A small amount of excess irrigation water should be provided to allow leaching from the container (usually about 15% to 20% of the water added). This leaching will ensure that salts do not accumulate and adversely affect plants. On the other hand, overirrigation will lead to unnecessary leaching of plant nutrients.

Cation Exchange Capacity

The role of ***cation exchange capacity (CEC)*** is minimal in soilless substrates as related to plant nutrient uptake and leaching. Unlike field soil, nutrients applied from a single application of soluble granular fertilizer leach rapidly from the container substrate because of increased porosity. Additionally, organic substrates have very little ***anion*** exchange capacity (negatively charged particles) and pH does not influence nutrient availability to the degree it does in a field soil. The container system requires frequent irrigations because of the limited water volume of the substrate; consequently, irrigation is a predominate factor in controlling container substrate nutrient levels. Soluble fertilizers injected frequently but in small quantities through the irrigation system or controlled-release fertilizers are used to provide a continuous supply of nutrients at optimal levels and to minimize nutrient loss due to leaching.

Although a ***high nutrient holding capacity*** is desirable, some thought must be given to soluble salt buildup that may injure plants. Media with desirable water holding and aeration characteristics will usually allow for periodic leaching necessary to prevent or reduce salt accumulation. ***Salt accumulation*** is generally not a problem unless the irrigation water is saline or the fertilizer source, rate and/or scheduling result in excess salt concentrations. Container media with 50% to 60% peat or pine bark of moderate particle size (1/8 to 3/8 inch) have proven to have adequate cation exchange capacity (CEC) for efficient production of woody plants in containers. Typical CEC values (meq/100 ml) for several container substrate components are aged pine bark (10.6), sphagnum peat moss (11.9), vermiculite (4.9), and sand (0.5).

C:N Ratio

Rapid decay of organic matter in container media can result in decreased volume and subsequently, decreased aeration. Consequently, careful attention should be paid to the ***C:N ratios*** of organic matter components in potting mixes.


photo by bob cook

Figure 28. Comparison of Canadian sphagnum peat (top) to Florida peat (bottom).

Organic Media Components

Suitable media components in potting mixes influence the growth behavior of plants during container production. Ultimately, plant quality during production influences potential success in the landscape.

Peat Moss

Peat moss is the most common growth media component for container production. However, there can be tremendous diversity among the characteristics of peat from different sources or different locations within an individual peat bog. Peat must have a high fiber content to provide internal water holding capacity (small pores) yet allow drainage of pores between particles (large pores).

Peat is a term applied to a type of soil formed from partially decomposed mosses or sedges accumulated in bogs over a period of hundreds or thousands of years. Although the term "peat moss" is widely used, it is not correct. The correct designation should be "moss peat," which indicates those peats formed from moss plants. ***Sphagnum peat*** is the preferred peat of most greenhouse operators because of its high water holding capacity, adequate air space, high cation exchange capacity and resistance to decay. Sphagnum peat is formed from sphagnum mosses in very acid bog conditions that have preserved most of the plant fiber structure. The acidity of sphagnum peat ranges from pH 3.0 to 4.0.

Hypnum peats are derived from hypnum mosses, have a higher and much broader pH range (4.0 to 7.5), and less persistent fibers than sphagnum peat. Other peats consist of fibers from sedges, reeds and grasses. These peats are particularly susceptible to decomposition, especially in the presence of fertilizer solutions. Peats that break down rapidly cause media shrinkage and compaction, a condition that hampers plant growth and makes the containerized medium difficult to manage. Many ***Florida peats*** are derived from sedges, reeds and grasses.

The peat selected as a media component should have some fiber structure and be brown in color when dry. Material that has decayed further, such as that found in muck soils, is black and has a powdery consistency when dry. ***Muck*** is a very poor component for any potting medium.

Pine Bark

Pine bark is recognized as a suitable component for container growth media and in some cases it is a good single-component growth medium. Pine bark is preferred to hardwood bark because it resists decomposition and contains less leachable organic acids than some hardwoods.

Incorporation of a liming material such as dolomitic limestone may be advisable in bark mixes. The pH of pine bark ranges between 4.0 and 5.0 and has a tendency to decrease over time when used in production systems with acidic or neutral irrigation water. Approximately 5 to 9 pounds of dolomitic limestone will normally adjust a cubic yard of bark to between pH 6.0 and 7.0 over a 60-day period. Hydrated lime may be substituted for a portion of the dolomite to raise the pH over a one-week period, while coarse limestone will extend the pH adjustment period.

The large moisture content of fresh bark makes it heavy, a characteristic that limits its shipment over long distances. However, once bark dries below 35% of its total water holding capacity, it becomes difficult to rewet. Use of a horticultural wetting agent would be helpful for rewetting bark. A moisture adjustment period of several days is required.

Sphagnum Moss

Sphagnum moss, which is the whole moss plant collected alive along with connected dead, but nondecomposed moss parts, should not be confused with sphagnum peat. Dried sphagnum moss is not generally used in potting mixes, but may be used ***shredded*** as a topdressing over seeds in germination trays. The moss is reported to have some fungicidal activity.

Sphagnum moss is also a source of the fungus *Sporothrix schenckii*, which causes sporotrichosis. Sporotrichosis in humans usually starts as a local skin disease of the hands, arms and legs, but may become generalized. Workers handling sphagnum moss are encouraged to wear gloves to prevent injury to the skin surface and prevent entry of the organism through existing skin lesions.

Figure 29. Shredded pine bark.

Figure 30. Sphagnum moss.

Figure 31. Melaleuca bark can be shredded and used in media.

Hardwood Bark

Hardwood bark from ***deciduous*** species is used extensively in many areas of the country as a container media amendment. Hardwood bark differs greatly from pine bark in its chemical and physical characteristics. The pH range of fresh hardwood bark is 5.0 to 5.5. As the bark ages in the presence of water, the pH increases to 8.0 or 9.0, a condition much too alkaline for plant production.

Hardwood bark decomposes more rapidly than pine, causing an initially high demand for nitrogen by microorganisms; this higher C:N factor will induce a nitrogen deficiency in plants growing in the fresh bark. A second potential problem in certain hardwood species relates to ***phytotoxic*** effects that have been reported on plants grown in fresh bark or plants drenched with extract from fresh bark, so it should never be used immediately for potting plants. After composting, bark induced nitrogen deficiency problems and phytotoxicity caused by bark from certain tree species are eliminated.

Melaleuca Bark

Melaleuca bark, which includes the bark and wood of *Melaleuca quinquenervia* (punk tree or paperbark tea tree), has been used successfully by several University of Florida researchers as a soilless growth medium component. The melaleuca tree was first introduced to southern Florida around 1887 from Australia as a soil stabilizer on levees, and even used in early attempts to dry up the Everglades. Melaleuca has become a major invasive plant causing a serious threat to the ecology of many areas in southern Florida.

The bark of melaleuca constitutes nearly one half the bulk of its small branches. When properly processed by special hammer mills, the bark and wood together are an excellent component for soilless mixes. Because of the many thin layers that constitute the structure of melaleuca bark, it has an open structure that provides excellent aeration. Another desirable characteristic of this bark and wood is its resistance to decay, which provides particle size stability. Processed melaleuca bark and wood is a suitable substitute for pine bark in mixes containing up to one-third pine bark (such as a blend of equal volumes of pine bark, peat and sand).

Wood Byproducts

Sawdust, wood shavings and wood chips constitute a rather broad category of wood particles generated by sawmills and other wood processing industries, often involving a wide range of particle sizes and several tree species. Wood particles are generally less desirable for potting media than bark because wood has a much greater C:N ratio; such as 1:500 for fresh wood compared to 1:120 for bark. The sawdust of hardwood species ties up nitrogen and breaks down about three to four times faster than sawdust of softwood species. Addition of approximately 25 to 30 pounds of nitrogen per ton of fresh sawdust or other relatively fine wood particles will supply sufficient nitrogen for microorganisms to prevent deficiency during plant production.

Figure 32. Shredded coconut fiber (coir).

Coir

Coconut fiber or coir is a natural fiber extracted from the husks of coconuts. The porous, granular structure of coconut fiber makes an excellent growing media component, especially in combination with sphagnum peat moss. Coconut fiber has a significant amount of pores for every particle, thus providing more pore space and a better water holding capacity in the root zone when fully hydrated. Coconut fiber has a pH close to 6.0, an excellent wetting and rewetting ability, high resistance to physical breakdown, and less shrinkage in containers over the life of the crop. Coconut husks can also be cut into specific sizes for uniform particles.

Coconut fiber or coir products will vary, depending on their origin and how they are processed. Using coir may require some adjustments in the crop management practices including, but not limited to, adjustment in watering practices and fertilizer application rates. Make sure to watch for potential high sodium levels and nutritional imbalances from higher potassium levels.

Inorganic Media Components

Inorganic media components can be natural unmodified materials, but many of them are processed and graded in such a way they become uniform sizes and sterile from treatment at high temperatures. Inorganic components include perlite, pumice, vermiculite, sand, hydrogel, etc. Some of these components hold water on their surface, others hold water within their structure, while others hold little compared to other components.

Perlite

Perlite is a light weight, white, expanded, closed pore mineral of volcanic origin widely used in the horticultural industry as a component to peat-lite mixes. The mineral is crushed and heated to approximately 1,800^{0}F causing it to expand.

Perlite is utilized extensively for its light weight, physical stability and ability to provide noncapillary pore space in a mix. Perlite has little water holding capacity since the internal pore structure is closed. It has extremely low cation exchange capacity, no nutritive value of its own, and no notable influence on pH of mixes in which it is employed.

The bulk density of perlite is approximately 6 to 8 pounds per cubic foot. The fine dust present while handling dry perlite is irritating when airborne and inhaled. Therefore, effort should also be made to minimize the physical movement of loose, dry perlite until it can be moistened or incorporated with moist peat or other amendments. Individuals involved with

photo by bob cook

Figure 33. Horticultural grade perlite.

considerable perlite handling should wear a breathing mask or respirator and goggles. A fine spray of water on perlite as it is being poured from the bag and the use of properly placed exhaust fans in an enclosed media blending area will greatly reduce the perlite dust problem.

Vermiculite

Vermiculite is a micalike mineral that, when heated above 1,400^{0}F, expands to an open, flakelike structure that provides spaces for air and water. Vermiculite particle size is determined by the particle size of the mineral prior to heating. Due to the range of pore spaces in processed vermiculite, it retains considerable moisture upon wetting. The pH of most of the vermiculite used in horticulture falls within a range of 6.0 to 8.9. Although vermiculite contains measurable amounts of potassium, calcium and magnesium available to plants, it should not be regarded as a fertilizer. Vermiculite also has good buffering action and cation exchange capacity.

One of the major shortcomings of vermiculite is its poor physical stability after wetting. Particles that have been mixed, wetted and compressed do not recover physically. Compression of moist vermiculite causes the expanded particle to collapse and frequently slip apart. This is particularly a problem when the mix is handled wet, when vermiculite containing mixes are used in large containers where the pressure is great toward the bottom of the container, and in situations where mixes are used on a second crop such as in a propagation bed or recycled mix.

There are several grades or particle sizes of vermiculite used by horticulturists, but each manufacturer of vermiculite has its own system of grades. The finer grades are generally used in mixes formulated for small pots and plug tray applications, while coarser grades are usually found in mixes designed for larger containers.

Polystyrene Foam

Polystyrene foam is a plastic product manufactured from resin beads subjected to heat and pressure. The polystyrene foam used in peat-like mixes is usually derived from scrap generated during the manufacture of polystyrene bead foam such as sheet insulation. Styrofoam® is one trademarked brand of polystyrene foam.

Polystyrene foam is utilized in potting mixes to improve drainage, reduce water holding capacity, reduce bulk density and serve as a cost effective alternative to perlite. The closed pore structure of the foam makes it one of the least water retentive components in use. The foam has no appreciable cation exchange capacity, and contains no plant nutrients.

A desirable size range of polystyrene beads for potting mixes is $^{1}/_{8}$ to $^{3}/_{16}$-inch diameter particles. The extremely low bulk density of the foam beads or chips (0.75-1.0 lbs/ft^{3}) presents some handling problems related to drift and static electricity. The lightweight material should be handled in areas where there is little air turbulence to prevent particle drift. The drift

Figure 34. Professional grade vermiculite.

Figures 35. Polystyrene foam beads.

problem is compounded by the static charge of foam particles that causes them to stick to objects and surfaces in the media handling area. A small amount of water plus a wetting agent applied to the product will reduce both handling problems.

The light weight and durable nature of polystyrene foam make it an attractive alternative medium component for crops in hanging baskets and a variety of interior plants that must be packaged and shipped long distance.

Rockwool

Rockwool is manufactured from basalt (a mineral) using a heating and fiber extrusion process. Although rockwool is used primarily for insulation, it can be utilized as a rooting medium by itself or in combination with other ingredients, such as peat, bark, and perlite to make a soilless growth medium.

Rockwool formulated for horticultural use varies considerably in physical and chemical properties among manufacturers. Some product lines have been treated to make the wool more ***hydrophilic*** (attract water), while other lines are essentially ***hydrophobic*** (repel water). Blends of the two lines can be used to achieve a specific water holding capacity.

Rockwool is utilized because it can be manufactured to uniform standards and does not break down from bacterial or chemical action. When protected from excessive compaction, rockwool provides aeration but lacks any notable cation exchange capacity and nutrient supply of its own.

Figure 36. Horticultural rockwool used in potting media.

Calcined Clay

Calcined clay results from heating clay to a very high temperature (up to 1,800^{0}F) causing it to expand into a highly porous material that is physically and chemically stable. The clay is then crushed into smaller particles that are subsequently graded into specific particle size ranges.

Calcined clays provide noncapillary pore space due to the large void created between particles in the mix, thus allowing for good aeration. Water is also held internally within the porous particle structure. Most calcined clays have good cation exchange capacity, which helps in the retention of nutrients, but the particles have no nutrient value of their own.

Calcined clay is again receiving attention by a few commercial soil formulators as an amendment in some better quality peat-like mixes. Although the cost of calcined clay mixtures is still high, the greater cost can be justified in the long term management requirements of tropical plants used in the interiorscape. Potting mixes that decompose and shrink are difficult to manage and often contribute to premature plant replacements. These replacements and the additional labor required to manage interior plants growing in low quality mixes is far more costly in the long term than paying a little more for plants produced in high quality, physically stable potting mixes.

photo by bob cook

Figure 37. Calcined clay particles.

Growing Media Formulation

It is possible to formulate a growth medium for specific container size, growth environment, management intensity and plant requirements. It has been noted that container depth directly affects the percentage of growth medium filled with air at container capacity. A growth medium for plants grown in a greenhouse, where control of the moisture level is possible, can have a greater water holding capacity than a medium for container grown plants exposed to natural rainfall distribution. During Florida's rainy season, plants may receive an average of one-half inch of rainfall per day for 30 days, which dictates using container media with exceptional drainage. Unfortunately, a medium with exceptional drainage also has relatively low water holding capacity and requires frequent irrigation during drier conditions. So, a container medium must be designed to reduce stress during the most severe conditions expected for a given environment.

The first consideration in the formulation of a growth medium is the appropriate balance between ***water holding capacity*** and ***aeration***. A more porous medium is required for a shallow container, such as for propagation, than for deeper containers typical of those used in the production phase. For outdoor production of woody crops, additional drainable pore space is necessary to provide the drainage buffer required for an extended rainy period. Greenhouse crops can be grown effectively in media with less drainable pore space and a much higher water holding capacity. More intense management of the moisture relations is possible when rainfall effects are eliminated during greenhouse production.

Figure 38. Peat moss, bark, perlite potting mixture.

There may be only one growth medium formulation required for nurseries without tremendous diversity in container sizes, environmental conditions or plants. If a variety of container sizes, ranging from small to very large, and/or different environments exist within an operation, media for the different production systems should be formulated.

Media Mixing, Handling and Storage

The ideal formula for a container medium may be known, but proper mixing and handling procedures must be followed if optimum results are to be obtained. Assuming components arrive at the nursery free of weeds, weed seed, pathogenic fungi and insects, and with a uniform and acceptable particle size distribution, nursery personnel must take steps to ensure quality is maintained.

Consideration must be given to the reasons a nursery would choose to mix media on the site rather than to purchase media prepared to certain specifications by soil mixing vendors. Media obviously must be available upon demand. Therefore, advanced planning is usually more critical if preblended media are purchased, but there must also be sufficient advanced planning even if components are purchased individually. Costs of media components, labor and equipment are other considerations. It might be more economical for a small or medium size nursery to purchase media ready for use because of the high cost of mixing equipment. However, larger nurseries generally mix adequate volumes of media to justify the purchase and maintenance of appropriate equipment. The final decision should be made on an economic basis rather than holding with company tradition or doing what other local nurseries are doing.

Media components must be stored off the ground and protected from surface water. A concrete slab or bin is ideal for placement of components received in bulk. Water flow patterns around the concrete slab must be adjusted in order to eliminate the possibility that surface water (potentially carrying pathogens, weed seeds and/or insects) could come into contact with the medium. Bulk components should be covered with black plastic film or other suitable material to prevent contamination with windborne seeds, pathogens and other pests when access is not necessary.

The period of storage determines whether bagged components are stored outdoors or at least under cover. Most bags will remain intact outdoors for 6 to 8 weeks, but if an annual supply is purchased, indoor storage is needed. Covering bags stored outdoors with opaque plastic film will extend the life of the bags. Even if outdoor storage is acceptable, consider the surface water drainage pattern and the ground surface because most bags are not watertight.

Mixing procedures must yield a homogenous blend. This includes fertilizer amendments as well as growth medium components. Variability in a soil media batch or between batches can result in differences in plant growth and quality.

A rotary type mixer, such as a cement mixer commonly used on ready-mix trucks, or a drum and paddle type mixer provides a good system for mixing media components in a nursery. Some nurseries use front end loaders to mix media by turning the various components piled on a concrete slab. This system is inexpensive but simply does not provide uniform mixing, especially of fertilizer amendments. Sanitation during this type of mixing procedure can also be a problem.

Prepared media should be stored on a raised slab or in covered bin facilities. Media prepared with fertilizer amendments should generally be stored in such a way to minimize leaching. The salinity level of media stored for several weeks should be determined before it is used since there can be release of fertilizers in the medium during storage and salt levels could reach critical levels. This problem can be avoided by preparing or purchasing only the amount of media needed to satisfy the short-term demand.

Common amendments used during growth media mixing include micronutrients, dolomitic limestone for pH adjustment and pesticides. An approved insecticide for the control of fire ants must be incorporated in media of container-grown plants being shipped out of Florida. Superphosphate has been routinely added to media during mixing, but research has shown this form of phosphorus is readily leached from pine bark based media. Instead, phosphorus should be applied periodically as a part of the overall fertilization program.

photo by debra butler

Figure 39. Potting media storage facility.

photo by gale allbritton

Figure 40. Nursery soil mixing, storage and potting area.

Preblended Media

There is a strong inclination among growers to purchase preblended potting mixes from specialty firms. This trend toward use of preblended media is most developed in expensive mixes utilized in greenhouse production of small to medium size potted plants. These blends are sold in bags or in bulk.

Cheaper mixes are used primarily for landscape ornamental production beyond the liner stage and for large potted foliage plants. Use of local materials including peats, wood particles, bark and sand constitutes a considerable savings in component costs and the ultimate cost of the mix. These mixes are generally less uniform and consist of less persistent peat and other particles than those used in mixes consisting of high quality peat.

BMPS for Mixing and Handling Growing Media

- Test the media pH, electrical conductivity, and wettability before use.
- Select media components that ensure adequate water holding capacity of the mixture.
- Do not make changes to current growing media without first experimenting to see if changes may affect cultural practices.
- When mixing, thoroughly blend components, but do not overmix, especially if a medium contains vermiculite or controlled-release fertilizer.
- Do not store media that contains fertilizer, especially if the media is moist. The nutrient content may change or be lost.
- Avoid contamination of components for finished media by keeping amendments in closed bags or by covering outdoor piles.
- Do not allow mixes containing peat moss to dry out; rewetting is difficult.

Plant-Water Relationships

Water is essential for plant growth and is probably the greatest regulator of how well or how poorly a plant grows. Water is absorbed and used as a conveying vehicle for sugars, minerals and hormones within the plant, as well as in the process of transpiration to help control plant temperatures.

Water is transported throughout plants almost continuously. There is 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. The total evaporative water loss from the soil and plant surfaces to the atmosphere is called ***evapotranspiration***.

Plants that are well watered maintain their shape due to the internal water pressure of plant cells. This internal water pressure is known as ***turgor pressure***, and is necessary for plant cell expansion and consequently for plant growth. Loss of turgor pressure due to insufficient water supply can be noticed as ***wilting***.

The major economic consequence of insufficient water in plants is reduced overall growth. 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 closure 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 plant growth.

Soil-Water Relationships

The role of soil in the soil-plant-atmosphere continuum is unique. Soil properties directly affect the plant's availability of water and nutrients. Soil water indirectly influences plant growth through its effect on aeration, temperature, and nutrient transport, and its uptake and use in metabolism. Understanding these relationships is helpful in determining good irrigation design and management.

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 vertical movement of water due to gravity is negligible. The ***permanent wilting point*** is defined as the point where there is no more water held loosely enough in the soil to be available for plant use.

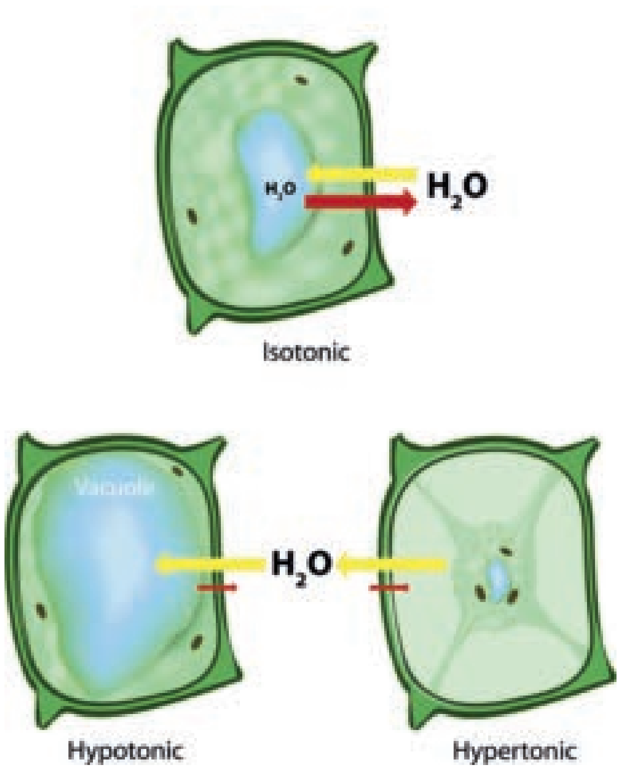


Figure 41. Water moves readily across cell membranes until pressure concentrations inside and outside the cell are equal (***isotonic***). If it is not equal, there will be net movement of water molecules into (***hypotonic***) or out (***hypertonic***) of the cell. Cells with adequate internal pressure are considered turgid.

Water Use

The main factors influencing the amount of water used by a plant are species, size, age, stage of growth, temperature, relative humidity and wind. Some plant species require large amounts of water to grow, while others, such as cacti, possess physical features to conserve water. Plant size is an important factor of water use because a large plant has a higher water use potential. Younger plants still require more water in relation to size than older plants, probably because of active growth. Actively growing plants also require more water than dormant plants.

Temperature changes the rate of water use, both directly by affecting evaporation and transpiration, and indirectly by affecting other plant processes. Warm temperatures tend to increase water loss while cool temperatures decrease water loss.

Relative humidity directly affects the rate of transpiration and evaporation. When relative humidity is high, the amount of moisture in the air and the moisture level at the leaf surface is very similar; therefore, water loss due to transpiration is decreased. With low relative humidity, transpiration increases as does subsequent water use by the plant. Wind can also increase evaporation and transpiration. All of these factors combine to determine the water use status of the plant.

Water Stress Symptoms

A plant is stressed when water loss through transpiration exceeds the ability to absorb soil moisture. Water stress symptoms can be observed in most plants, and are used to gauge when a plant needs water. One of the first symptoms of water stress is when soft leaves and stem tissue become limp or begin to wilt. This may occur first during the hottest, driest part of the day; however, within another day or two the symptom may be present most of the day. If the plant continues without water, it may remain wilted throughout the day. In

Causes of increasing water use	***Causes of decreasing water use***
Active growth	Dormancy
Higher temperatures	Lower temperatures
Low relative humidity	High relative humidity
Windy conditions	Calm conditions
Large leaf surface area	Small leaf surface area
Broad, thin leaf surface	Leaf modifications to minimize water loss

Figure 42. Comparison of factors influencing water use.

some plants, such as grasses, the foliage color is distinctly different (a bluish-green) when the plant is in the early stages of water stress.

Plants need water when they first begin to show water stress symptoms. If a plant is not watered, wilting can be followed by yellowing and dropping of older leaves then browning of tips or margins. If water deprivation continues, the entire leaf may turn brown and die; this can lead to the eventual death of the plant. Undetected symptoms may occur when a plant is getting only marginal amounts of water. Plant growth may slow down or stop due to water stress. The decreased growth may be incorrectly blamed on fertilization or pests. Water stress symptoms vary according to the plant, so the development of well-honed observation skills is important.

Figure 43. Spathiphyllum showing signs of water stress (e.g. wilted leaves, yellowed older leaves, browning of leaf margins and tips, death of flowers).

Symptoms of Excess Water

Excess water symptoms often are similar to symptoms of inadequate water. Under conditions of excess water, the soil lacks oxygen needed for root survival. As the root system deteriorates, the plant takes up less water. Often the decline of the root system is followed by invasion of root diseases. The root system should be examined if plants with adequate moisture in the soil show what appear to be water stress symptoms.

Irrigation

A good method for determining when to water is to observe plants for water stress symptoms. Indicator plants, which show stress a day or two before others, can usually be found. Then, observe plants regularly and water whenever the indicator plants show stress symptoms. This requires careful scrutiny to be sure indicator plants are in fact representative of the needs of the majority of plants being grown. Keep in mind that either species, media or the containers in which they are growing may differ. Small containers typically need water more frequently than large containers.

Another method of determining need is to monitor the moisture level in the soil with a reliable moisture meter or by feel. Judging soil moisture by feel should be done an inch or so under the soil surface, since the surface will dry out before there is a need to water. Watering by need, rather than an arbitrary schedule, often results in healthier plants.

Additional information on irrigation practices, frequency and efficient operation of irrigation systems can be found in the *Irrigation* chapter.

Water Quality

Water quality issues play an important role in determining plant performance. Chemicals, living organisms, and particulate matter affect water quality. Chemicals may injure plants, deposit undesirable residues on plants, or clog irrigation systems. Living organisms and particulate matter may also clog irrigation systems, and water borne pathogens may spread plant diseases through irrigation water.

Irrigation water pH may adversely affect the pH of growing media and may cause problems with applications of chemicals for pest control or fertilization. If water is high in soluble salts, fertilization procedures may have to be changed. If water is high in certain dissolved minerals, it may be necessary to avoid foliar application on some plants because of undesirable deposits on leaves that spoil the appearance. Water that has been softened by a sodium ion replacement system should never be used for plant irrigation due to potential sodium accumulation that may cause plant damage.

Surface water has the potential to be contaminated with chemicals and disease-causing organisms. If it is necessary to use surface water, care must be used to avoid contamination from herbicides or other pesticides and nutrient buildup. Algae or other particulate matter, which may clog automatic controllers and drip irrigation, can be adequately removed by filtering.

Reclaimed water nutrient levels can vary by a factor of 10 or more. When applying fertilizers to a site that irrigates with reclaimed water, consider the amount of nutrients in the water and reduce fertilization appropriately. In addition to possible nutrient pollution by overirrigating, reclaimed water may contain high levels of chloride, leading to salt accumulations in the soil. Be sure to contact the reclaimed water supplier to get information on nutrient content and soluble salt levels.

Plant-Light Relationships

Light influences many aspects of plant growth and development; it is required for photosynthesis, the sole process for sustaining life. ***Light level (intensity)*** is a primary consideration when deciding what plants to use for a specific location. Some plants require full sun to grow satisfactorily and will not grow well in partial sun or shade. Plants adapted to shady environments need less light than plants adapted to full sun. Plants requiring partial shade can be used in sunny areas, if shade is provided during the higher intensity of the afternoon sun. Plants that do not receive enough light often grow weakly and become stretched or "leggy." Plants adapted to shade and lower light usually show signs of sunburn or scald when planted in too much sun. It is also important to reduce both irrigation and fertilization levels for plants in the shade to avoid fungal growth and stress.

In order for plants to survive successfully indoors, they must be able to adapt to low light levels. Field grown foliage plants in Florida are placed under shade cloth to be better adapted (***acclimatized***) to the low light of interiors. Plants that can withstand low light levels must be acclimatized if they are moved from an area with higher light. Conversely, sunscald occurs in plants exposed to bright sunlight after being in an area with lower light levels. This happens when a plant is moved from a protected area or when a plant is pruned and lower leaves are exposed to full sun.

In addition to light intensity, ***light duration*** also influences certain aspects of plant growth and development. Daylength controls flowering in many species. The relationship of the length between day and night is known as ***photoperiod***. Daylight and darkness influence the rate of change in a light sensitive pigment (phytochrome) responsible for triggering flowering at the appropriate time.

Flowering is initiated in some plants when the nights get longer. Examples of these ***short-day*** plants include chrysanthemum and poinsettia. Placing these plants under a light disrupts their perceived day length, and they will not bloom properly. Other plants bloom

Figure 44. Sun scald on spathiphyllum leaves.

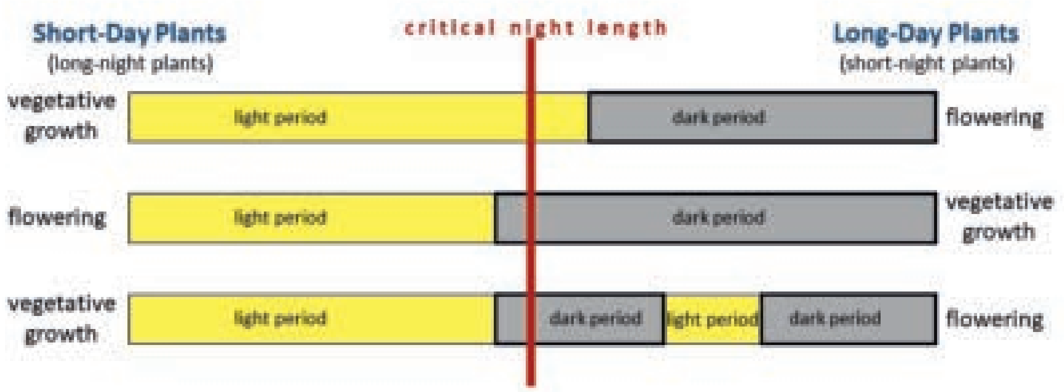


Figure 45. Influence of photoperiod on flowering of short-day and long-day plants.

in the spring with flower initiation triggered by nights getting shorter (***long-day*** plants such as sunflower, salvia, and petunia), while another large group of plants are not affected by the relationship of day/night hours (***day neutral*** plants such as geranium, impatiens, and begonia). Phytochrome pigments also influence the germination of seeds. For example, some seeds such as lettuce do not germinate in darkness.

Plant-Temperature Relationships

Temperatures play an important role in determining the performance of a plant at a given location. When temperatures are too low, many plants, especially tropicals, perform poorly. Alternatively, high temperatures limit the growth of many plants. The high summer temperatures in Florida are what limit many annual species to the cool season.

Every plant has an ***ideal temperature range***, although certain plants can survive at much lower and somewhat higher extremes. Changes in temperature influence processes such as photosynthesis and respiration. When temperatures go above or below the optimal range, growth slows and can eventually stop. Temperatures far from the optimal range can result in death of the plant. These are not absolute temperatures; rather, they involve relationships between temperature and time. A plant might withstand freezing temperatures for a few hours, but when exposed to these temperatures for 24 hours, it can die.

Optimum temperature ranges vary greatly among species. The situation becomes very complex as one considers the ideal temperatures for a particular species vary not only with cultivar but also with the stage of development, the tissue involved, the length of exposure, and environmental factors such as radiation received from the sun and water stress. With many plants, the daytime optimum temperature is higher than the optimum temperature at night. This is one reason many desert plants may perform poorly in a humid environment. They may be adapted to 110^{0}F during the day, but they are adapted to much lower nighttime temperatures than experienced in Florida. These warmer nights speed up a plant's metabolism so much it cannot produce enough food through photosynthesis to maintain itself.

Some plants slow down or stop growing all together in the summer simply because temperatures have exceeded their optimal temperature range. This phenomenon is called ***heat stall***. As temperatures decrease, the plants will resume growth.

Minimal winter temperatures determine the northern and southern limits of plants, the former in terms of ***cold hardiness*** (winter survival) and the latter in terms of ***chilling hour requirements*** needed to break dormancy so growth and reproduction can resume properly in the spring. The length of high summer temperature periods also influences plant species adaptation to a region. Both factors influence the natural distribution of plants.

photo by united states department of agriculture

Figure 46. Map representing USDA Hardiness Zones (http://planthardiness.ars.usda.gov).

There are a number of plants that cannot be grown successfully in Florida because summer temperatures are too high. For this reason, annuals such as pansies, petunias and snapdragons grown in the North during the spring and summer are grown as winter annuals in Florida.

The USDA Plant Hardiness Zone Map consists of regions defined by the average minimum temperatures over a 30-year period, not the lowest temperature that has ever occurred in the past or might occur in the future. The regions are divided into 10^0F ***hardiness zones***. Each zone is further divided into 5^0F ***a*** and ***b*** half-zones. The USDA reminds map users that the zones are just guides. Growing plants at the outermost edge of the coldest adaptation zone provides the potential that a rare, extreme cold snap lasting just a day or two could occur; ultimately, plants that have thrived in that zone for several years could be lost. It is important to keep that in mind and also understand that past weather records cannot be a guarantee for future weather variations.

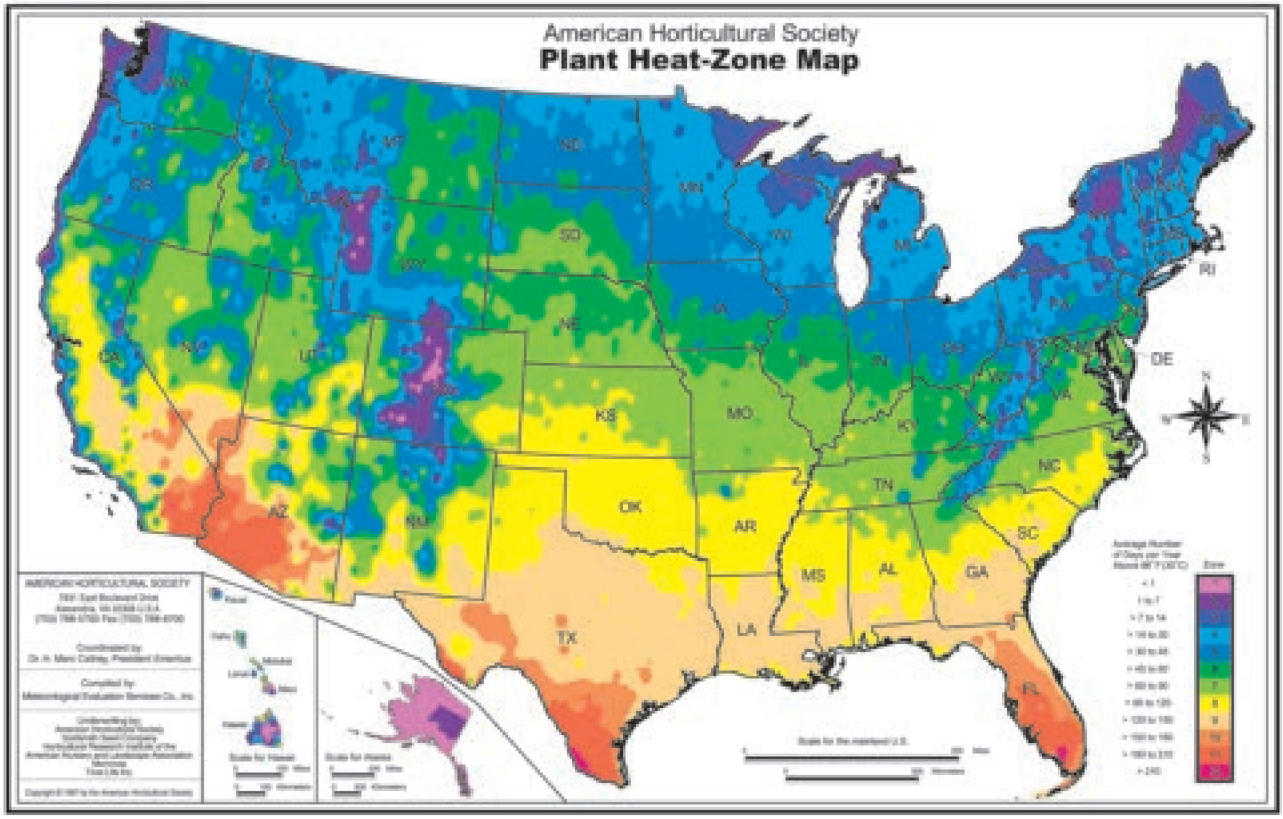


photo by american horticultural society

Figure 47. Map representing AHS Heat Zones. Reproduced with permission of the American Horticultural Society (www.ahs.org).

The American Horticultural Society Heat Zone Map defines 12 zones that indicate the average number of days each year a given region experiences ***heat days*** or temperatures over 86^0F. This is considered the point plants begin suffering physiological damage from heat. The designated zones range from less than one heat day to more than 210 heat days. The AHS Plant Heat Zone ratings assume that adequate water is supplied to plant roots at all times. The accuracy of the zone coding can be substantially distorted by a lack of water, even for a brief period in the life of the plant.

Both maps provide aid in the selection of plants appropriate to a given geographic region. More information on temperature influences related to plant selection is found in the *Plant Identification* chapter.

Summary

Plant growth depends on important interrelationships with soil and water. Soil provides support plus functions as a storehouse for plant nutrients, as habitat for soil organisms and plant roots, and as a reservoir for water. Water forms a dynamic continuum in soils, plants, and the atmosphere. Soil water is periodically renewed by infiltration from rain or irrigation and, for the most part, is continually depleted by evapotranspiration.

Water is essential for plant life processes. The amount of water a soil can hold for plant use is determined by physical properties that affect the movement, retention and use of water, and chemical properties that affect nutrient availability. Management of essential plant growth resources requires understanding of relationships between soil, water, and plants. It is especially important to horticulturists using best management practices for irrigation and nutrient scheduling, both to promote optimum yields and to protect the environment.

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