BUL241

# Growth Media for Container Grown Ornamental Plants[1]

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Container production of nursery stock has increased dramatically within the last 30 years. Currently, over 85 percent of the value of Florida landscape and foliage crops is from container produced material, and the trend is similar throughout the southern states. Advantages of container production compared to field production include: convenient marketing package, extension of the marketing/planting season, easier transport, and rapid crop turnover. However, container plant production requires more intense management than field production. Roots of container plants are exposed to more rapid fluctuations and greater extremes in temperatures than plants grown in the ground. The large surface area to volume ratio of these containers provides little buffering against environmental conditions.

The purpose of a container medium 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 air turbulence in the plant production area. Excess weight should be avoided since this hampers handling and increases shipping costs.

A balance between available water and aeration in the growth medium is essential for production of quality plants in containers. There must be adequate small pore space to hold water for plant uptake and enough large pores to allow exchange of air in the medium to maintain critical oxygen concentrations. Anaerobic conditions (without oxygen) do not allow the roots to obtain energy from the respiratory process and encourage disease development. Energy is required for root growth, proper hormone balance and nutrient uptake as well as maintenance of cell and organelle membranes and apparati for basic physiological processes.

Plants can be grown in many different media if proper management is provided. The optimal container medium will minimize the amount of management required for quality plant production. Plants can be grown in nutrient solutions (hydroponics) but the solution must be aerated or circulated and changed or replenished routinely. The optimal container medium will thus depend upon the

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specific plant species or cultivar to be grown, the size of 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 and the availability and cost of growth medium components.

Since the growth medium relates to every cultural practice in the production of nursery crops in containers, selection or formulation of a container medium properly suited for a given production system is extremely important. A quality, well-chosen medium is an investment that will pay great dividends in terms of plant growth and quality. Adjustment of cultural practices such as disease or insect control measures due to a poorly chosen container medium may add up to $200 in hidden or indirect cost of a 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.

This bulletin presents the principles of selecting and formulating growth media for container plant production. Measurable physical and chemical properties of growth media are discussed. The characteristics of selected growth medium components and techniques for customizing container media for specific conditions are presented, along with recommendations and pitfalls relative to media mixing, handling and storage.

## PHYSICAL PROPERTIES OF CONTAINER MEDIA

Commonly measured physical properties of container media include total pore space, waterholding capacity, air space, bulk density and particle size distribution. Total pore space is the volume of air in an oven-dry growth medium expressed as a percent of the volume. It is the non-solid portion of the volume. The waterholding capacity of a medium is the volume of water that is retained by a medium after irrigation and drainage. The amount of water held in a particular medium is dependent upon the particle size distribution and the container height. When a container medium has been saturated with water and allowed to drain freely, the medium is said to be at "container capacity." The volume of the medium occupied by air at this moisture level is termed the air space. Some researchers also refer to this air space at container capacity as the aeration porosity or drainable pore space.

Organic matter and minerals comprise the solid portion of container media. Approximately 20 to 40 percent of a growth medium will be solids. This means the total pore space averages 60 to 80 percent of the container medium volume. Particle size distribution and the porosity of individual particles determine the total pore space and the volume of water and air in a container medium at container capacity. Large particles fit together to create large pore spaces (Figure 1). These large pores are generally filled with air at container capacity. When smaller particles are mixed with the larger particles, the volume of large pore space is reduced and the volume of the medium comprised of solids and water after irrigation increases. Thus, the particle size distribution, or the relative volume of each particle size range, determines the waterholding and aeration properties of a container medium.

**Figure 1.**

The internal pore space of a particle obviously differs with the type of particle. A perlite particle essentially has no internal pore space while 40 to 45 percent of a pine bark particle volume is pore space. Much of the intraparticle pore space will be filled with water at container capacity. A portion of the water may be available for plant uptake but a substantial percentage will be unavailable. It has been determined that water in container media held at tensions greater than 100 centimeters of pressure is not readily available to plants.

The amount of water present in a growth medium decreases as tension or suction is placed on the water. By placing varying tensions on the water in a medium, a water release pattern can be developed for that medium. This pattern is usually referred to as the moisture retention curve. Moisture retention curves for various growth media and media components are presented in Figure 2. Note that most of the water in pine bark, peat and sand is held at less than 25 cm of tension. Twenty to 35 percent of the total pore space in a soilless growth medium may be filled with tightly-held water (greater than 100 cm of tension) and is considered to be of little value to container-grown plants.

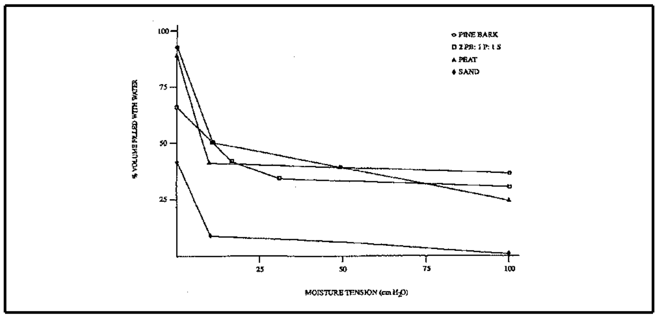


**Figure 2.**

When a containerized medium is irrigated, there is a layer of nearly saturated medium at the bottom of the container (Figure 3). The thickness of this excessively wet layer depends upon the particle size distribution, which determines the water-holding capacity of the medium. There are no capillary pores to place tension on water at the bottom of the container as one would find at the same depth in a field soil profile; therefore, water in the bottom of a container is held by very small tensions or in some cases may be essentially free water. If the container is tilted, much of this free water would drain from the lowest point of the container. Water above the near saturated medium at the bottom of the container has tension placed on it by the force of gravity. The greater the distance above the near saturated conditions, the greater the tension exerted on the water in that region of the container medium.

**Figure 3.**

For example, water between particles in the surface of a 15-centimeter tall container would be held at tensions greater than 15 centimeters. Water between particles held at tensions less than 15 centimeters would have drained from this depth of the container medium after irrigation. Water held in pores inside a particle may be held at greater tensions or not be in contact with water in or between adjacent particles and thus not directly affected by the gravitational pull exerted by the continuum of water from the base of the container or from the top of the saturated medium.

Therefore, the height of a container will affect the air space in the growth medium at container capacity. The concentration of water at a given height of the medium from the bottom of the container is not influenced by the container height, only the medium particle size. Therefore, increasing the height of the container increases the volume of medium with the larger pore spaces filled with air. You can demonstrate this concept to yourself or others using a sponge.

Obtain a large rectangular sponge (about 1.5 inches thick, 5 inches wide and 12 inches tall). Cut the sponge into two pieces, approximately one-third and two-thirds size portions. This sponge represents a container medium with a combination of large and small pore spaces. Just as in a container medium, a portion of pore space in the sponge will be filled with water after irrigation and drainage. Remember that the proportion of large and small pore spaces in these two sponges is the same; they were once one sponge. Saturate the sponges in water then stand them upright on a raised stand of some sort over a pan. Water will drain from the sponges. This is the force of gravity pulling water from the large pore spaces. The concentration of water at a given height in two sponges is the same, even though one sponge is taller than the other. After a few minutes, squeeze the water from the two sponges and measure the amount of water obtained from each. Try to squeeze the sponges with the same pressure. The volume of water squeezed from the two sponges will be surprisingly close. This illustrates the importance of consideration of container height when formulating a container medium. If approximately the same amount of water was obtained from each sponge, that means a greater volume of the pores in the taller sponge was filled with air after drainage.

Some have suggested the placement of gravel in the bottom of containers improves drainage. In fact, the gravel decreases the total volume of medium with favorable aeration. The pores at the interface of the container medium and gravel must be saturated before water will move down into the gravel. This means that a layer of medium with near maximum water content is positioned above the gravel rather than on the container bottom. Therefore, the effective height of this container is reduced by the depth of the gravel in the bottom.

Root distribution in container media can be influenced by the 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 such as *Pythium* and *Phytophthora* than roots growing in well-aerated media.

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 15°C (27°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 medium temperature change, although the extent of this buffering is not clearly understood in nursery containers.

The particle size distribution and thus the waterholding capacity and air space can change over time in the container. As the particle size is decreased through biological degradation, the medium volume decreases, the air space decreases and the weight of solids per unit of volume of the remaining medium increases. This degradation may or may not be accompanied with a proportionate increase in waterholding capacity. Smaller particles may wash to the bottom regions of containers over time. This has been reported especially with the use of large amounts of sand in otherwise porous media. Fine sand tends to accumulate in the bottom, thus clogging the larger pore spaces, decreasing aeration in the bottom portion of the container and water-holding capacity in the upper zones in the container medium.

Container medium volume generally decreases and general physical properties change over time due to compaction, shrinkage, erosion and root penetration. Decreases in the volume of medium in a container result 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 as the result of poor potting procedures, breakage of particles, or from the impact of overhead irrigation and/or other cultural practices. Shrinkage occurs as a result of particle degradation. As certain medium 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. Intense rainfall and/or irrigation can splash or wash particles from the container, and particles can be lost during removal of weeds, etc. Root volume increases often compensate for losses in growth medium volume.

## CHEMICAL PROPERTIES OF CONTAINER MEDIA

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

Optimum pH of a container medium differs with plant species but generally a pH between 5.0 and 6.5 is desirable. The pH has a major role in the availability of nutrient ions. In production systems where nutrients are added frequently in forms that are normally absorbed by the plant, the suitable pH range may be much wider than research with field soils would indicate. A pH above 7.5 usually results in chemical binding of micronutrients and a pH below 4.0 could result in toxic concentrations of ions such as aluminum, zinc, or copper. Field soils are limed to maintain the pH above 5.0 or 5.5 to reduce the possibility of such toxicities. However, the level of aluminum in soilless container media is generally too low to cause problems and a pH below 5.0 can be tolerated by many ornamental plants.

Generally, growers should mix the components together in the ratio that yields the desired physical properties, then determine the pH. Amendments to adjust pH such as dolomitic limestone should be added at the suggested rate to small quantities of the medium and allowed to incubate in moist, aerated conditions for a few days before the effect of the amendment is determined. Procedures for determining the pH of a growth medium are presented in Florida Extension Circular 556 : *Diagnostic and Monitoring Procedures for Nursery Crops*.

The pH of some components will change over time. Typically the pH of a pine bark based medium will decrease during the production cycle. However, irrigation with alkaline water can more than offset this tendency. The growth medium pH should be monitored regularly to allow for adjustments. Elemental sulfur, acid-producing fertilizers and dilute acids can be used to decrease pH. Liming material can be applied to increase pH but a change in pH from application of liming materials to the surface of a container medium is generally slow because the effect tends to be concentrated in the upper strata of the medium. For best results, amendments which are slowly soluble and slowest to adjust pH are best incorporated at the time of media preparation.

## Soluble Salts

Care should be taken to avoid using growth medium components with high soluble salts levels. 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 sands 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 ability of these organic materials to hold many ions. Soluble salts in the range of 2500 to 4000 ppm are considered high for most woody crops and the moderate or suggested range after fertilization is 1000 to 1500 ppm. However, some plants are more sensitive to salt levels than others. For example, the optimum salt level for azaleas is 500 to 700 ppm.

There are three common methods of measuring soluble salts of growth media, including the saturated paste extract, the 2 to 1 dilution by volume, and the pour-through or Virginia Tech extraction method. A more thorough examination of the measurement and interpretation of soluble salts is provided in Florida Extension Circular 556: *Diagnostic and Monitoring Procedures for Nursery Crops*.

## Cation Exchange Capacity

The ability of a soil or growth medium to retain nutrients against leaching by irrigation water or rainfall is estimated by measuring the cation exchange capacity (CEC). Most adsorption sites on growth medium particles are negatively charged and attract positively-charged ions. Many nutrients required by plants are positively charged and thus are attracted by these negatively-charged sites. Sands and other low-surface area materials have low cation exchange capacities while organic components have a greater ability to retain cations. Pine bark has a cation exchange capacity in the range of 10 to 13 milliequivalents per 100 cubic centimeters while a CEC of approximately 1 is common for builders' sand.

Although a high nutrient-holding capacity is desirable, some thought must be given to soluble salt buildup which 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 percent peat or pine bark of moderate particle size (1/8 to 3/8 inch; 0.3 to

0.9 cm) have proven to have adequate CEC for efficient production of woody plants in containers.

## Carbon to Nitrogen Ratio (C:N)

Rapid decay of organic matter in container media can result in decreased volume and a subsequent decreased aeration of the medium. Materials with a high cellulose (carbon) to nitrogen content will be decomposed rapidly by microorganisms in the soil. Not only will particles become smaller, but nitrogen that would normally be available for plant uptake will be utilized by microorganisms. Sawdust and shavings have a higher C:N than other organic matter such as peat and bark. Sawdust has a C:N ratio of about 1,000:1 while bark has of ratio of approximately 300:1. Decomposition of these organic particles is initially rapid and the rate of decomposition decreases with time. Therefore, older or composted materials will decompose more slowly than freshly-produced sawdust. Management of fertilization to maintain the proper nutrient concentration in the growth medium is extremely important if optimum plant growth is to be obtained when using fresh organic material with a high C:N. It is important to eliminate fresh wood contamination of the bark. Remember the C:N ratio of wood is three times greater than of bark. (For this portion of this document in another document, see *The Woody Ornamentalist*, Vol. 11, No. 1, "Properties of Container Media," published January 1989.)

## Organic Components

### Peat

The most common growth medium component for container production is peat moss. 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 waterholding capacity (small pores) yet allow drainage of pores between particles (large pores). If a peat appears oily when wet or is slick rather than fibrous when rubbed between your fingers, it may not be suitable for use in producing container-grown plants.

Peat is a term which applies to a type of soil formed from partially decomposed mosses or sedges which accumulate 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 waterholding capacity, adequate air space, high cation exchange capacity and resistance to decay. Sphagnum peat is formed from sphagnum mosses in very acid bog conditions which preserve most of the plant fiber structure. The acidity of many sphagnum peats ranges from pH 3.0 to 4.0.

Hypnum peats are derived from hypnum mosses and 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 of sedges, reeds and grasses. These peats are especially susceptible to decomposition, especially in the presence of fertilizer solutions. Peats which break down rapidly cause media shrinkage and compaction, a condition which hampers plant growth and makes the containerized medium difficult to manage. Many Florida peats are derived from sedges, reeds and grasses.

Peats with a fibrous quality are better than those reduced to a powdery consistency due to either decomposition, plant origin or harvesting and processing procedures. Very fine grades of peat are the least desirable unless mixed at the proper ratio with larger, porous particles because they have more of a predominance of small pore space than coarser grades. The peat selected should have some fiber structure and be brown in color when dry. Material which 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.

Peats derived from sedges, reeds and grasses have the ability to bind certain soil-applied, plant growth regulators, such as Cycocel, more than other types of peats. For this reason soil-applied growth regulator test reports should specify the type of peat and other media component used.

## Pine Bark

In the southeast, several pine species are important forest crops. As the wood is utilized the bark is removed mechanically. For many years this bark was regarded as a waste product that required a disposal site where the material could be stockpiled. During the late 1960's about 20 percent of Florida's sawmills and most of the pulpmills utilized pine bark for fuel. The number increased through the 1970's as oil and related fuel prices soared. It is now difficult to find operations which generate large quantities of pine bark that do not utilize it for fuel.

Pine bark has been recognized as a suitable component for container growth media since the 1960's 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. Research at the University of Georgia has shown that milled pine bark with 70 to 80 percent of the particles by volume within a range of 1/42 to 3/8-inch (0.6 to 9.5 mm) in diameter, with the remaining particles less than 1/42 inch (0.6 mm), is a good potting medium component. Although many early users of pine bark felt that aged pine was better than fresh bark, most potting media formulators today utilize fresh material and supply a small nitrogen charge, approximately 1/4 to 1 pound (113 to 454 g.) of nitrogen per cubic yard of bark, to offset the small surge in microorganism growth in fresh bark.

Since the pH of pine bark ranges between 4.0 and 5.0 and has a tendency to decrease over time in production systems with acidic or neutral irrigation water, incorporation of a liming material such as dolomitic limestone may be advisable. Approximately 5 to 9 pounds (2.3 to 4.0 kg) of dolomitic limestone will normally adjust a cubic yard of bark to pH 6.0 to 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.

A container medium of pine bark has noncapillary pore spaces between the large particles. Bark particles have a relative high cation exchange capacity, while most particles have internal water-holding capacity.

The large moisture content of fresh bark makes it heavy, a characteristic which limits its shipment over long distances. Once bark dries below 35 percent 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 peat should be not be confused with sphagnum moss which is the whole moss plant collected alive along with connected dead, but non-decomposed moss parts. Dried sphagnum moss is not generally used in potting mixes but may be used as a top dressing of shredded moss parts over seeds in germination trays. The moss is reported to have some fungicidal activity.

Historically sphagnum moss has been used extensively for packing around roots of bare root plants and for shipping plants. Another popular application of sphagnum moss has been the lining of hanging basket frames. This procedure is still used to a limited extent, but the solid plastic sidewall containers have largely replaced hanging basket frames. When frames are used, a moistened layer of sphagnum moss about 1 to 2 inches thick is placed around the inside of the wire mesh or plastic mesh frame to contain the potting medium added inside the lining.

Sphagnum moss is 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.

## Hardwood Bark

Deciduous hardwood bark is used extensively in many areas of the country as a container media amendment. In Florida, hardwood tree species are grown primarily in the northern third of the state.

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. Fresh hardwood bark should never be used immediately for potting plants.

Researchers at the University of Illinois developed an effective composting procedure for hardwood bark in the 1960's which effectively adjusts the pH and pasteurizes the bark, eliminating most soil-borne pathogens. Prior to composting, hardwood bark has two other features which render it unfit for plant production. Because hardwood bark decomposes more rapidly than pine, there is initially a high demand for nitrogen by microorganisms which will induce a nitrogen deficiency in plants growing in the fresh bark. The second potential problem relates to certain hardwood species which have been reported to have a phytotoxic effect on plants grown in fresh bark or plants drenched with extract from fresh bark.

Hardwood bark should be mechanically processed to small particles which will pass through a 1/2-inch (1.27 cm) mesh screen, with 10 percent of the particles larger than 1/8-inch diameter and 35 percent less than 1/32-inch (0.8 mm) diameter.

Composting procedures as prescribed by the University of Illinois researchers specify that for each cubic yard of a 2 parts fresh hardwood bark: 1 part sand (v:v) mix the following should be added: 6 pounds (2.7 kg) ammonium nitrate, 5 pounds (2.3 kg) superphosphate, 1 pound elemental sulfur and 1 pound iron sulfate. These materials should be blended in the medium thoroughly, preferably in a tumbling type mixer, and arranged in large deep piles, kept at approximately 60 percent moisture. Covering the pile with a plastic sheet will help stabilize the moisture content during the composting period. The high level of microbial growth in the presence of the fresh bark and fertilizer causes the temperature to approach 150°F (66°C), a temperature which eliminates most pathogens. Turning the pile of composting bark 3 to 5 times during the 60-day process is recommended to get a uniform product. After composting, bark-induced nitrogen deficiency problems and phytotoxicity caused by bark from certain tree species are eliminated.

### Melaleuca Bark

The bark or bark and wood of *Melaleuca quinquenervia*, Melaleuca or punk tree, has been used successfully by several University of Florida researchers as a soilless growth medium component. Melaleuca was introduced to southern Florida early in this century from Australia and has become a major weed in the southern third of Florida. Because it propagates so freely from seed and grows rapidly in moist exposed soil, it has become a serious threat to the ecology of many areas in southern Florida, including parts of the Everglades.

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. That which has been milled to pass through a 1/2 or 3/4-inch (1.3 to 1.9 cm) screen without excessive fines seems to be an excellent product. Because of the many thin layers that constitute the structure of melaleuca bark, it has an open structure which 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, for production of several woody ornamentals. Increasing the percentage of melaleuca bark volume to 50 percent results in less growth of juniper and *Illicium parviflorum* compared to growth in a 2 pine bark:1 peat:1 sand (v:v:v) medium.

At the present time, most melaleuca is being harvested and processed for a bark and wood landscape mulch that is too coarse for most potting media applications. As pine bark and peat become scarce, use of melaleuca will become more prevalent.

### Animal Manure

Animal manure has been used by some growers in potting mixes in the past. Although manures do contain most essential nutrients for plant growth, the concentration of elements varies considerably with the animal, mulching material used (straw, etc), the technique of manure collection and storage, and manure age. Moist manures are heavy which makes them expensive to transport long distances; therefore, they are usually limited to rather local applications. Consistency of supply has been a problem for many horticultural operations attempting to use animal manure.

Some potential dangers of manure include: soluble salt damage from high nutrient content, ammonia damage to roots and foliage from steam-pasteurized manures, and weed seeds, insects, pathogens and nematodes contained in non-pasteurized or non-fumigated manures. For this reason, popularity of animal manures in potting mixes declined sharply during the middle of this century.

If animal manure is to be included in a potting medium, only well-rotted material should be used. Other materials such as straw or shavings are combined with the manure from many sources and the degree and/or potential for degradation of these materials should be considered. Cattle manure is preferred over other animal manures because it has fewer nutrients. If animal manure is used in a potting mix, only a small amount, about 10 to 15 percent by volume, should be used and the soluble salts level in the manure and the blended potting media should be monitored closely. Use of animal manures for potting media is not recommended by the authors due to the risk factors mentioned.

### Sawdust, Wood Shavings and Wood Chips

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 great C:N ratio; about 1:1,000 for fresh wood compared to 1:300 for bark. 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 nitrogen deficiency during plant production. Sawdust of hardwood species ties up nitrogen and breaks down about three to four times faster than sawdust of softwood species.

In Florida, cypress sawdust is preferred because it is slower to decay than most other wood particles. Cypress wood products are becoming scarce due to heavy cutting of cypress stands and government protection of wetlands.

The reverse trend is occurring with melaleuca wood and bark. Plant material currently harvested in southern Florida yields up to 50 percent (by volume) bark from its medium to large size branches. The wood component of melaleuca has been shown to be long-lived in a growth medium. Since melaleuca is spreading throughout southern Florida, it can be viewed as a developing resource which is essentially renewable on a local basis.

### Composted Municipal Refuse

Municipal refuse or garbage presents a major disposal problem for most communities. Garbage consists primarily of cloth, glass, metal, paper, leaves, plastic, rubber and wood. These materials are usually sent to landfills for disposal. A few communities are studying proposals for composting operations which involve, in some cases, removing metals, paper and rags, then grinding the garbage into fine particles which can be mixed with wood chips or some other bulking agent and composted. Composting is usually done with the ground and blended material in piles which are turned several times over a period of a month or more.

The adoption of garbage composting technology by municipalities is lagging behind that of composting sewage sludge. Most of the horticultural research with composted garbage indicates that major differences exist in the quality of compost generated from different locations, many of them experimental, depending upon the type and proportion of garbage components.

If composted garbage becomes available in a given area, it should be carefully evaluated on a small scale before proceeding with large batch utilization. The material should be monitored to ensure consistency from batch to batch.

### Composted Sewage Sludge

Several large communities throughout the United States have adopted sewage sludge composting operations. Due to the variety of systems used in different communities to process sewage, it is difficult to describe a single pathway that fits all situations. Sewage used for composting in most cases is primary sewage which has had most of the water removed. Reduction of the sewage water content from the 98 to 99 percent water range to between 30 and 80 percent water is accomplished by several different procedures, depending upon the sewage plant design. Names for partially processed sludge include: drying bed sludge, heat treated sludge or dewatered sludge, depending upon the process used to remove the water.

The composting process usually involves mixing 2 to 3 parts wood chips by volume with 1 part partially dehydrated sewage sludge and piling the material to a height of 6 feet (1.8 m) or more. Height of the piles depends upon the porosity of the material, moisture content, system of aeration and other factors. Most operations in Florida employ windrows for composting sludge which must be turned every 5 to 10 days, depending upon moisture content, for a period of 1 to 3 months. Forced aeration of stationary composting sludge piles is used in some other parts of the country.

It is anticipated that composted sewage sludge will become widely available to Florida nurseries in the future. Sludge composted with wood chips has been used successfully to replace or partially replace peat and bark in media used to grow a large number of different ornamental plants. Some screening of the product may be necessary to remove large wood particles not suitable for inclusion in growth media. The amount of screening required will depend upon the uniformity of wood chip size used in the compost. Preliminary research has indicated that some composted sludges may react with manganese, rendering it unavailable for plant uptake. Therefore, manganese deficiencies may appear in sensitive plants.

### Peanut Hulls

At the present time there are several sources of peanut hulls in northern Florida and other southeastern states where hulling operations are located. Peanut hulls have been used by some flowering pot plant growers in the past as an amendment, primarily for mineral soil based potting mixes. The hulls have considerable fiber structure which will initially provide additional large pore spaces. The fibrous structure of peanut hulls is rather short lived in potting mixes due to rapid decomposition of the hulls in the presence of fertilizer and water. While they may be suitable for a crop production period of 6 to 12 weeks, peanut hulls are not recommended for long-term crops. Rice hulls have similar properties and thus are not recommended for long-term crops.

If peanut hulls are used, they should be steam pasteurized or chemically fumigated to eliminate lesion nematodes which are known to reside on the hulls for long periods. Lesion nematodes attack many ornamental plants.

### Gasifier Residue

Residues from burning organic materials such as wood and bark have relatively stable particles. Research has been conducted with such materials from a few sources and it should be noted that the physical and chemical properties of these residues will differ with source. It has been determined that a residue from the gasification of wood chips and bark can be an acceptable component for production of woody ornamentals. It should not exceed 1/3 the volume in combination with peat and pine bark. One definite disadvantage of this residue is its high pH which often exceeds 8.0 and is not appreciably lowered by leaching. Sulfur or other acidifiers must be used in conjunction with this residue. It would be essential to conduct tests with various amendments, companion components and crop species before using gasifier residues in container media. Since there are many other suitable components with desirable characteristics currently available in the nursery, industry it is doubtful if gasifier residues will be used extensively in container media for some time.

### Bagasse

Bagasse is a fibrous by-product of the sugarcane industry. Although bagasse does initially provide additional open pore space in a mix, it tends to break down rapidly with the addition of fertilizer and water. During the decomposition process the medium will shrink and much of the large pore space will be lost. If bagasse is to be considered as an amendment, it should be restricted to small containers and short term crops which would mature before its fibrous quality is lost.

Bagasse is available from a few of Florida's sugar mills, although most of the product is burned by the large mills to generate power. Bagasse has also been utilized successfully in Florida as a landscape mulch and a bulking agent for composting sewage sludge.

## Inorganic Components

### Polyphenolic Foam

One manufacturer of florist foam makes a coarse-particle, open-pore polyphenolic foam which is very light when dry and can hold a large amount of water after irrigation. Since the particles are approximately 3/8-inch in cross section and of variable length, aeration of the medium is quite good. At the present time the product is designed to be used as a single-component medium for the production of cymbidium orchids.

Preliminary experimentation suggests other ornamental plants may also be grown in the material and it may be blended with other products such as polystyrene foam. Low bulk density, particle persistence and good water holding and aeration properties make this material potentially useful for long distance shipping of plants where weight is a major factor. There does seem to be potential application of the foam particles for production of high value foliage plants for export to distant markets where there are rigid restrictions on importation of plants grown in natural organic base media. The price of polyphenolic foam and the need to drench the foam with a solution of potassium bicarbonate to neutralize acidic materials used in the manufacture of the foam, may limit its use.

### Hydrophilic Gels

During the past 20 years, several products have been introduced to the horticultural industry which are designed to increase the waterholding capacity of growth media. These products, which are called hydrophilic gels or water absorbing polymers, are capable of holding over 150 times their dry weight when fully charged with water. The products are generally starch or acrylic polymers which are formulated as granules or flakes which can be easily incorporated in potting mixes. After the granules absorb water, they swell and assume a gel-like consistency. The swelling action of a gel tends to maintain open pore space in a mix because a mix containing a small amount of gel will increase in volume as the gel swells. A gel also increases the water-holding capacity of a mix, although a portion of the water held by the gel is held so tightly that it is not available for plant growth.

Due to cost of these gels, they have been considered for use primarily on high-value greenhouse crops. Research in some cases has not supported the cost effectiveness of utilizing hydrophilic gels on certain floricultural crops. One factor which tends to override the benefits of gels is that high quality peat-lite mixes already have excellent water-holding capacity. Gel products should be evaluated by growers on an individual crop basis. Impact of gels on crop production, crop shelf life and nursery profits should all be considered.

### Perlite

Perlite is a light weight, white, expanded, closed-pore alumino-silicate mineral of volcanic origin which has become widely used in the horticultural industry as a component to peat-lite mixes. The ore is crushed and heated to approximately 1800°F (982°C) which causes the ore to expand.

Perlite has been well received by the horticulture industry since the 1950's when it became a popular amendment for potting media comprised of mineral soils and peat. With adoption of peat-lite mixes in the 1960's, usage of perlite increased in commercial horticulture.

Perlite is now utilized extensively for its light weight, physical stability and ability to provide non-capillary pore space in a mix. Perlite has little waterholding 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 (0.1 g/m$^3$). The fine dust associated with handling dry perlite is irritating when airborne and inhaled. The percentage of such small particles in perlite should be minimized by only obtaining a horticulture grade of perlite. An effort should 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 considerable perlite handling should wear a breathing mask or respirator and goggles while performing that task. 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, an aluminum-iron-magnesium silicate, is a mica-like mineral which, when heated above 1400°F, expands to an open-flake structure that provides spaces for air and water. Vermiculite has been used increasingly as a potting mix amendment since peat-lite mixes were introduced in the 1960's.

Vermiculite particle size is determined by the particle size of the ore, prior to heating. Due to the range of pore spaces of 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 and cation exchange capacity.

One of the major shortcomings of vermiculite is its poor physical stability after wetting. Particles which 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. 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 which are subjected to heat and pressure. The polystyrene foam used in peat-like mixes is usually derived from scrap generated during the manufacturing of polystyrene bead-foam such as sheet insulation. The scrap pieces are shredded by mechanical means into small particles suitable for blending with peat, bark, vermiculite and other components. Styrofoam® is one trademarked brand of polystyrene foam. Extruded polystyrene foam is much denser than the bead-foam and is generally not used in potting medium.

Polystyrene foam is utilized in potting mixes to improve drainage, reduce waterholding 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 particle size range of polystyrene beads for potting mixes is 1/8 to 3/16-inch diameter and 1/8 to 1/2-inch (0.3 to 1.3 cm) for flakes. Due to the extremely low bulk density of the foam beads or chips (0.75-1.0 lbs/ft$^3$; 12 to 16 g/l) it presents some handling problems. It should be handled in areas where there is little air turbulence to prevent particle drift. The drift problem is compounded by the static charge of the foam particles which 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 foam 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 which must be packaged and shipped long distance.

## Rockwool

Rockwool is manufactured from a mineral called basalt through a heating and fiber extrusion process. Although rockwool is utilized 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 into blocks, cubes and slabs has been used extensively in the production of hydroponically-grown vegetables and flowers in Europe. Only a limited amount of rockwool blocks are used in the United States for ornamental production.

Within the past few years, loose rockwool and more recently granulated rockwool have been promoted as components for soilless mixes. Loose rockwool comes in rather coarse wads which resemble the formulation used for insulation while the granulated formulation is much finer with a crumb-like appearance. The granulated product was made to facilitate easier blending with other components.

Those rockwool products formulated for horticultural use vary 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 waterholding 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 notable cation exchange capacity and nutrient supply of its own.

Adoption of rockwool as a component for soilless mixes will depend upon its cost effectiveness when compared with other products which are used to provide noncapillary pore space in potting mixes. The greatest potential for this amendment is in the high quality greenhouse pot plant market. Rockwool is currently being sold in the United States under the names Grodan® and Hortwool®.

## Calcined Clays

There are now a number of companies in the United States which quarry clay and heat it in specialized kilns which cause the clay to expand under high temperature into a highly porous fused structure which is physically and chemically stable. The next steps involve crushing large chunks of calcined clay into smaller particles which are subsequently graded into specific particle size ranges. Light weight concrete products and road surfacing additives are two popular applications.

Significant applications for calcined clays in horticulture and agronomy were developed during the 1950's as it was demonstrated that the substrate for heavy traffic turf areas such as golf greens could be improved through clay products such as Turface®. When a substantial amount of calcined clay is added to mineral soils which receive heavy foot traffic, the calcined clay maintains good aeration and drainage properties needed for turf growth.

During the 1950's and early 1960's, Turface was also marketed to the nursery industry as a potting medium component with limited success. Rather high bulk density and cost of the product were major factors limiting its acceptance during a period when modified field soils were used extensively for potting media.

After a long period of rejection by nurserymen, calcined clay is receiving some attention again by a few commercial soil formulators as an amendment in some of the highest quality peat-like mixes. Although the cost of calcined clays is still high, many growers of long-lived pot plants recognize that the quality of the potting mix is frequently the factor most limiting the successful management of their product once in the hands of the consumer.

Many calcined clays have properties which make them desirable as potting media components. Those clays which are receiving the most attention are more porous and therefore considerably lighter in weight than Turface. Calcined clays are essentially indestructible particles, which provide non-capillary pore space to a mix due to the large spaces created between particles, and hold water internally within their open-pore particle structure. Most calcined clays have good cation exchange capacity which helps in the retention of nutrients but have no nutrient value of their own.

It is suspected that justification for more extensive use of calcined clay will come as the long term management of tropical plants is better understood by interiorscapers. Potting mixes which decompose and shrink once installed in commercial interiorscapes are difficult to manage and often contribute to premature plant replacements. The cost of plant 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. Some large interior plants can be kept in place for a period of 5 to 10 years with proper care and use of a good potting medium.

In Florida, a calcined clay product for potting mixes is available from Florida Solite Company in Green Cove Springs. The firm has the ability to obtain a specified particle size range through crushing and screening, and sells a product called Solite® which is suitable as a container medium component. Calcined clays are also available from other states, Europe and South America. (For this portion of this document in another document, see *The Woody Ornamentalist*, Vol. 11, No. 2, "Characteristics of Container Media Components," published February 1989.)

## FORMULATING A GROWTH MEDIUM FOR EACH PRODUCTION SYSTEM

It is possible to formulate a growth medium for a specific container size, growth environment, management intensity and the plant's requirements. It has been noted that container depth directly affects the percent of the growth medium that is 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 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 capacities which requires frequent irrigation during drier conditions. This means that a container medium must be designed to reduce stress during the most severe conditions expected for a given environment. This directly influences the required management intensity.

The first consideration in the formulation of a growth medium is the appropriate balance between waterholding 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, a drainable pore space equal to 20 to 30 percent of the volume provides the drainage buffer required for an extended rainy period. The corresponding waterholding capacity ranges from 30 to 50 percent. Greenhouse crops can be grown effectively in media with 10 to 15 percent drainable pore space and a much higher waterholding capacity. More intense management of the moisture relations is possible when rainfall effects are eliminated.

Once the desired characteristics have been determined and the available components selected, a medium can be formulated to meet those characteristics. At the present time the only method for determining the correct formulation is by trial and error, although researchers are in the process of developing computer assisted models to predict the medium characteristics based on measured characteristics of individual components.

A grower experienced with particular components knows the approximate component ratio required. For example, a woody plant grower in north Florida has available pine bark, peat and sand. Generally for outdoor production, a medium consisting of 15 to 25 percent by volume of a coarse sand or fine gravel is required to have the weight necessary to keep the containers upright when placed on open production beds. The percentage of pine bark and peat required to formulate a container medium with 25 percent air space depends most upon the particle size distribution of the bark. If the bark is composed primarily of particles in the range of 1/4 to 1/8-inch (0.63 to 0.32 mm) diameter with few fine particles, a medium of 60 percent pine bark, 25 percent peat and 15 percent sand would be an appropriate medium to start testing. If significant small particles are present in the bark source, less peat may be required. Once a sample of the test medium has been prepared, waterholding capacity and air space after irrigation and drainage must be determined in the container size for which the medium is being formulated. Step-by-step procedures for these determinations have been presented in Florida Extension Circular 556 : *Diagnostic and Monitoring Procedures for Nursery Crops*.

If waterholding and air space characteristics of a given medium are within the desired ranges, record this formulation in an appropriate record book and make plans to prepare the volume required for current needs. In most cases, the characteristics of the first trial medium will be outside the desired range. If the air space is too low, then more larger particles must be added to the formulation. In the above example, more pine bark and possibly less peat would be mixed in the next trial medium. Keeping good, permanent records of these procedures will reduce the need for future trials and ensure the medium will be formulated consistently with the desired characteristics. If trial medium air space is too high, then more small particles should be added to the next mixture. Peat or sand can be added to reduce the size and possibly the number of the larger pore spaces.

Such trial and error procedures should be repeated until the desired characteristics of media for various container sizes are achieved. The number of different media prepared for a particular nursery should be minimized. Only one growth medium formulation may be 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 a single operation, media for the different production systems must be formulated.

Make sure the medium prepared in one batch has the same water-holding and pore space characteristics as the next batch mixed from a different load of components. The particle size distribution of each load of components should be tested. If the particle size distribution is the same as the load from which the medium was formulated, then the grower can confidently prepare the next batch using the same formula. However, if the particle size distribution is different on subsequent loads, the formula should be tested and adjustments made as required.

## 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, the nursery operator must take steps to ensure the quality is maintained.

### Component Storage

Components must be stored off the ground and protected from surface water. A concrete slab or bin is ideal for components received in bulk. The surface water patterns around the concrete slab must be adjusted to eliminate the possibility that surface water, carrying pathogens, weed seeds and/or insects, could come into contact with the medium component. Bulk components should be covered with black plastic film or other suitable covering to prevent contamination with wind-borne seeds, pathogens and other pests when access is not necessary.

The length of storage period 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

When various components are mixed together, a homogenous mixture must be obtained. This includes fertilizer amendments as well as growth medium components. Variability in a growth medium batch or between batches can result in differences in plant growth and quality, because the waterholding and aeration characteristics and fertilizer concentrations would differ from container to container. Obtaining uniform mixtures without altering the particle size distribution of the medium is not easy, but its importance can not be overemphasized.

Consideration must be given to the reasons a nursery operator would choose to mix media on the site rather than purchasing media prepared to certain specifications. Media must be available upon demand. Advanced planning is usually more critical if pre-blended media are purchased, but there must be sufficient advanced planning even if components are purchased individually. Cost is another consideration. It might be more economical for a small to medium size nursery to purchase media ready for use because of the high cost of effective mixing equipment. However, larger nurseries generally mix adequate volumes of media to justify the purchase and maintenance of appropriate equipment.

A good system for mixing medium components in a nursery utilizes a rotary-type mixer, such as a cement mixer commonly used on ready-mix trucks, or a drum and paddle type mixer. There appears to be less breakage of the component particles when rotary-type mixers are used, but difficulties include loading the mixer and retrieving the mixture. Adjust rotating drum speed so materials are carried well up the drum wall before tumbling. Drum and paddle-type mixers can be used effectively if the mixing duration is carefully monitored. Stationary horizontal drum mixers should not be filled above two-thirds the auger diameter or the top-added components can float and not mix into the lower materials. With prolonged mixing, the particle size of some components can be reduced significantly resulting in a medium with unknown and possibly undesirable water-holding and aeration characteristics.

The proper mixing system can also vary with the medium components. Perlite can be easily crushed during mixing, reducing the particle size. Vermiculite is an expanded material and if crushed, it will not expand again. When the particle size of such materials is reduced, they do not serve the purpose for which they were chosen. Resin-coated fertilizers and other pelletized fertilizers may be crushed by prolonged mixing in some mixing equipment.

Systems are now available that allow the components be placed in large bins from which they drop onto conveyer belts in layers or directly into the mixer at the proper ratio. Fertilizers and other chemical amendments can also be applied in this manner. Other systems require loading the components into the mixer with a front-end loader at the proper ratio.

Some nursery operators utilize 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. It is impossible to uniformly distribute 1 to 3 pounds (0.45 to 1.4 kg) amendment per cubic yard of medium by sprinkling it on the surface of a pile of growth medium components to be turned by a front-end loader. The problem with adequate distribution of amendments during mixing with a front-end loader can be solved by purchasing one of the components, for example pine bark, with the amendments already uniformly distributed in the component at a rate that will result in the proper rate for the final medium. If 10 pounds of a fertilizer is desired per cubic yard of medium and the bark comprises 50% of medium volume, then the fertilizer should be added to the bark at the rate of 20 pounds per cubic yard. Sanitation during this type of mixing procedure can also be a problem.

Shredder-mixers are also used to prepare media. Such a system can greatly reduce particle size and is unsatisfactory for blending fertilizers, especially controlled-release fertilizers, into the container medium.

Growth medium components should have a relatively low to moderate moisture content for mixing. This is especially true if dry fertilizers are to be added during mixing. It is difficult to achieve an uniform distribution of the dry fertilizer particles in a moist medium. If the fertilizer amendments have already been added to one of the components, a moderate moisture level during mixing might be satisfactory. Another consideration is to add moisture after the medium has been mixed. It is often difficult to rewet pine bark, peat and other components when they have a moisture content below 30 percent. Chemical wetting agents can be used effectively to reduce this problem.

### Media Storage

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

### Amendments

Common amendments to growth media during mixing include micronutrients, dolomitic limestone for pH adjustment and pesticides. An approved insecticide for the control of fire ants must be incorporated in the growth medium of container-grown plants to be shipped out of Florida. Superphosphate has been routinely added to media during mixing, but research has shown that the phosphorus in superphosphate is readily leached from pine bark based media. Adequate phosphorus for a growing season can not be added during media preparation by adding superphosphate. Therefore, phosphorus should be applied periodically as a part of the overall fertilization program. (For this portion of this document in another document, see *The Woody Ornamentalist*, Vol. 11, No. 3, "Engineering a Container Growth Medium," published March 1989.)

## INDUSTRY TRENDS TOWARD PREBLENDED MEDIA

Fifteen years ago most nurseries obtained container media components and blended them according to their specifications. During the past ten years, there has been a strong trend among nurserymen to purchase preblended potting mixes from specialty firms. This trend continues today and the specialty firms can be divided into two rough categories — those blenders which use primarily native peats, barks, sand, and those which employ primarily imported peats, perlite, vermiculite, calcined clay and other relatively expensive components. The trend toward utilization of preblended media is most developed in the expensive preblends which are utilized extensively by greenhouse pot plant growers producing plants in small to medium size pots. These blends are sold in bags or in bulk.

The 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 the cost of components and ultimate cost of the mix. These mixes are generally less uniform and consist of less persistent peat and other particles than used in mixes consisting of high quality peat.

The important decision nursery operators must make is to evaluate the benefits of using nursery-made mixes versus commercially preblended products. Consideration should be given to costs of media components, labor (ordering products, mixing components and quality control), and equipment for blending (equipment purchase and maintenance). Loss in crop value from restricted growth, dead plants or increased production time should also be considered in determining actual costs. The final decision should be made on an economic basis rather than holding with company tradition or doing what many of the other local nurseries are doing.

Some companies have gone one step beyond preblending potting media and are prefilling pots with specified preblended materials and delivering them directly to the nursery. This is another service provided to some nurseries which should be evaluated systematically.