Growing Media

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A growing medium can be defined as a substance through which plant roots grow and extract water and nutrients. Selecting a good growing medium is fundamental to good nursery management and is the foundation of a healthy root system.

Growing media for use in container nurseries is available in two basic forms: soil based and organic based. Compared with soil based media that has field soil as a major component, organic based media (a base of organic materials that may be compost, peat, coconut coir, or other organic materials, mixed with inorganic ingredients) promotes better root development. In temperate areas, nurseries can choose from a wide range of commercial products for their growing media, including peat moss, vermiculite, and perlite, and premixed blends of these ingredients. Most nurseries in the tropics, however, do not have easy and affordable access to these materials, and even nurseries in temperate areas are seeking to replace some of these ingredients with more local and sustainable materials. In the tropics, growers often create their own media using locally available ingredients.

A favorable growing medium consists of two or more ingredients. Growers must be familiar with the positive and negative characteristics of the various ingredients and how they will affect plant growth when creating a suitable growing medium, or even when purchasing a commercial one. This chapter describes the uses, functions, and properties of growing media ingredients. From this information, you can experiment with available materials and find the best combination(s) for your nursery.

Facing Page: *Many tropical nurseries create their own growing media with a mix of local materials. Photo by Douglass F. Jacobs.*

Functions of Growing Media

A growing medium serves four functions (figure 6.1).

1. Physical Support

The growing medium must be porous yet provide physical support. Young plants are fragile and must remain upright so that they can photosynthesize and grow. With larger nursery stock in individual containers, a growing medium must be heavy enough to hold the plant upright against the wind. Bulk density is the responsible factor and will be discussed in the next section.

2. Aeration

Plant roots need a steady supply of oxygen to convert the photosynthate from the leaves into energy so that the roots can grow and take up water and mineral nutrients. The byproduct of this respiration is carbon dioxide that must be dispersed into the atmosphere to prevent the buildup of toxic concentrations within the root zone. This gas exchange occurs in the large pores (macropores) or air spaces in the growing medium. Because nursery plants grow rapidly, they need a medium with good porosity—a characteristic termed "aeration" that will be discussed in more detail in the next section.

3. Water Supply

Nursery plants use a tremendous amount of water for growth and development, and this water supply must be provided by the growing medium. Growing media are formulated so that they can hold water in the small pores (micropores) between their particles. Many growing media contain a high percentage of organic matter such as peat moss and compost because these materials have internal spaces that can hold water like a sponge. Therefore, growing media must have adequate porosity to absorb and store the large amounts of water needed by the growing plant.

4. Supply of Mineral Nutrients

Most of the essential mineral nutrients that nursery plants need for rapid growth must be obtained through the roots from the growing medium. Most mineral nutrients are electrically charged ions. Positively charged ions (cations) include ammonium nitrogen (NH_4^+), potassium (K^+), calcium (Ca^{+2}), and magnesium (Mg^{+2}). These cations are attracted to negatively charged sites on growing medium particles up to the point when the roots extract the cations. The capacity of a growing medium to adsorb these cations is referred to as cation exchange capacity (CEC), and this important characteristic is discussed in the next section. Different media components vary considerably in their CEC, but peat moss, vermiculite, and compost have a high CEC value, which explains their popularity in growing media.

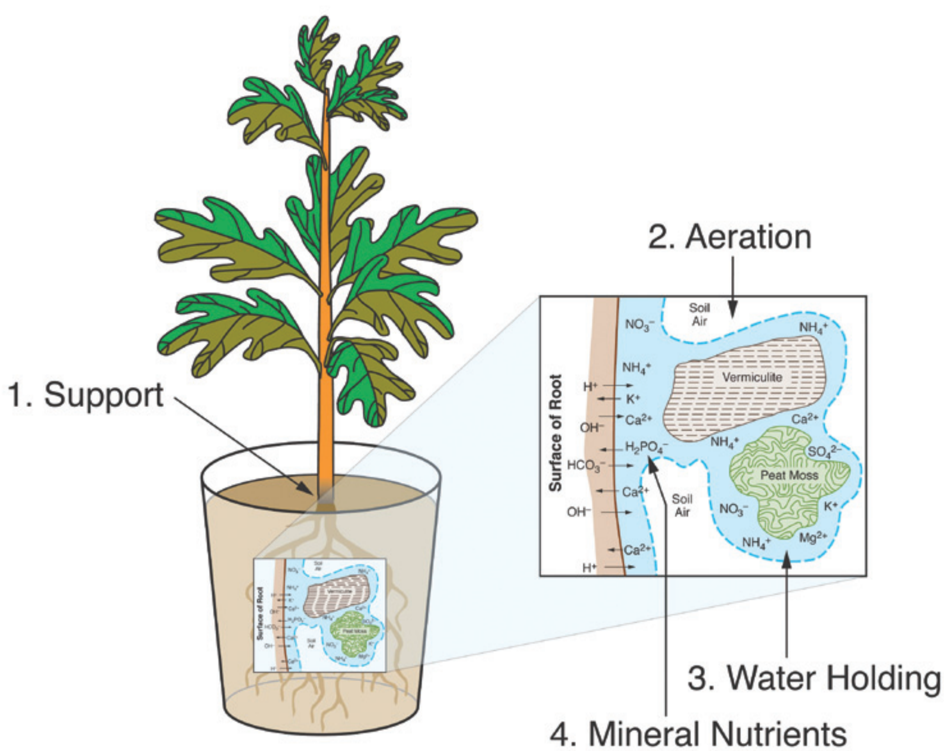

Figure 6.1—Primary functions of growing media include the capacity to hold water and nutrients for root uptake, providing adequate root aeration, and ensuring structural support to the plant. Illustration from Dumroese and others (2008).

Physical Properties of Growing Media

Water-Holding Capacity

Micropores absorb water and hold it against the pull of gravity until plants can use it (figure 6.2). The water-holding capacity of a medium is defined as the percentage of total pore space that remains filled with water after gravity drainage. A good growing medium has a high water-holding capacity but also contains enough macropores to allow excess water to drain away and prevent waterlogging. Water-holding capacity varies by the types and sizes of the growing medium ingredients. For example, a peat moss particle will hold much more water than a similarly sized piece of pumice. The degree of compaction is also extremely important. When growing medium particles are damaged during mixing or compacted when the containers are filled, the percentage of macropores is severely reduced. Overmixed or compacted media will hold too much water and roots will suffocate. Finally, the height of the container affects the water-holding capacity; a certain amount of water will always remain in the bottom of the container (figure 6.2). When filled with the same medium, short containers will have a higher percentage of waterlogging than taller ones (see Chapter 7, Containers).

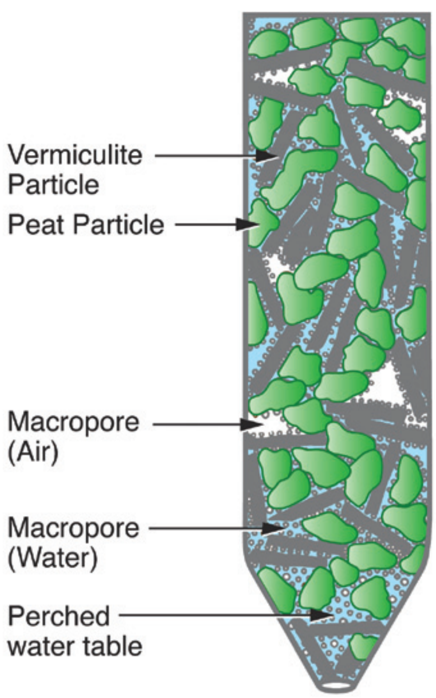

Figure 6.2—*A good growing medium contains micropores that hold water and macropores that allow for air exchange. All containers also have a perched water table in the bottom (see also Figure 7.2). Adapted from Landis and others (1989).*

Aeration

The percentage of pore space that remains filled with air after excess water has drained away is known as aeration. As we have already discussed, oxygen for good healthy roots is supplied through the larger macropores (figure 6.2), which also allow the carbon dioxide from respiration to dissipate. A good growing medium, especially for rooting cuttings, contains a high percentage of macropores.

Porosity

The total porosity of a growing medium is the sum of the space in the macropores and micropores; plants need both. A growing medium composed primarily of large particles will have more aeration and less water-holding capacity than a medium of smaller particles, which will have less aeration and more water-holding capacity (figure 6.3). Either of these media would restrict plant growth. Plants growing in a medium with all large particles would dry out too quickly, and those growing in a medium with all small particles would suffer from waterlogging. For a single-component medium, the ideal particle range to promote both water-holding capacity and aeration is about 0.03 to 0.24 in (0.8 to 6 mm). In actual practice, however, a good growing medium will contain a mixture of ingredients with different particle sizes and characteristics.

Bulk Density

Media bulk density is the weight per volume and varies with the inherent bulk density of its ingredients and how much they are compressed. An ideal growing medium is lightweight enough to facilitate handling and shipping while still having enough weight to provide physical support. For a given container type and growing medium, excessive bulk density indicates compaction. Bulk density and porosity are inversely related; when bulk density increases, porosity decreases. Even a very porous growing medium can be ruined if it is compressed when the containers are filled.

Chemical Properties of Growing Media

Fertility

Rapidly growing young plants use up the stored nutrients in their seeds soon after emergence. Thereafter, plants must rely on the growing medium to meet their increasing demands for mineral nutrients. As described in Chapter 12, Plant Nutrition and Fertilization, many container nursery managers prefer media with inherently low fertility (for example, peat-vermiculite) to discourage damping-off during the establishment phase and add soluble fertilizers to media throughout the remainder of the growing season. If fertilizers are difficult to obtain or cost prohibitive, organic amendments such as manure or compost can be included in the growing medium. Some plants grow better under low fertilization; in addition, beneficial microorganisms, such as mycorrhizal fungi, sometimes require low fertility to become established on plant roots. See Chapter 13, Beneficial Microorganisms, for more discussion on this topic.

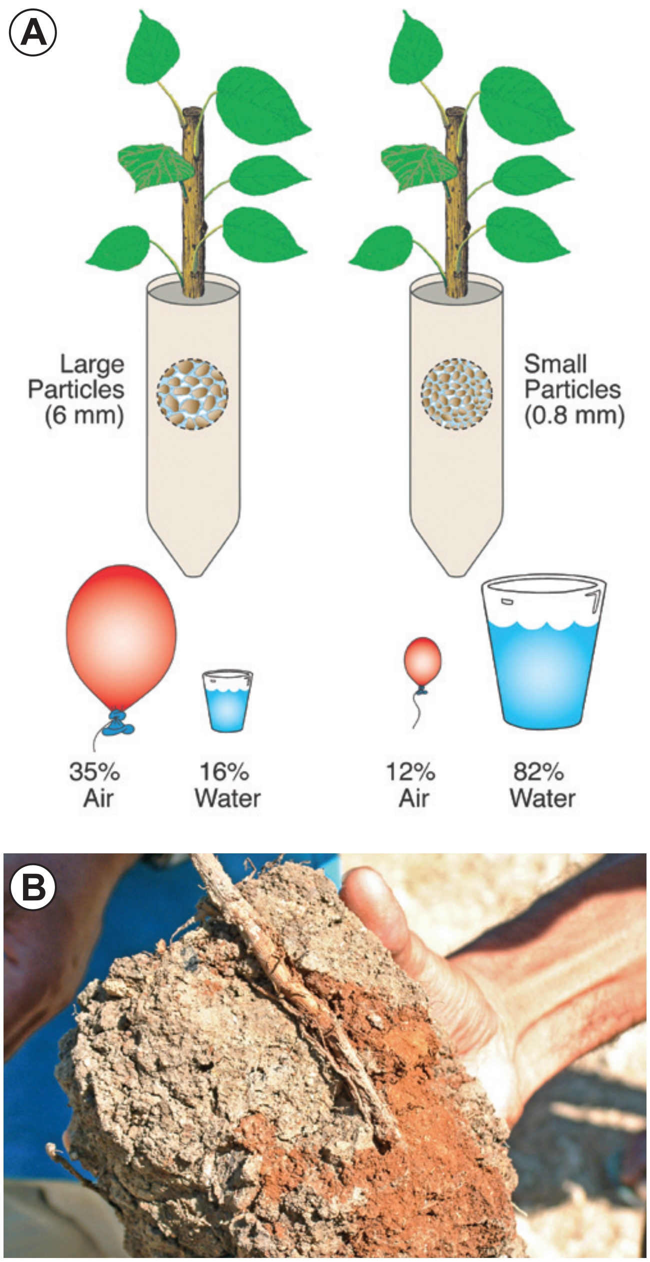

Figure 6.3*—These two containers each contain growing media with either large (left) or small (right) particle sizes (A). The corresponding balloons show the relative amounts of air being held, and the glasses show the relative amounts of water being held. When particle sizes are too small, such as this example of a high-clay growing medium, then root development is inhibited (B). Illustration A by Jim Marin, and photo B by J.B. Friday.*

pH

The pH of growing medium is a measure of its relative acidity or alkalinity. pH values range from 0 to 14; those below 7 are acidic and those above 7 are alkaline. Most native plants tend to grow best at pH levels between 5.5 and 6.5, although some species are tolerant of higher or lower pH levels. The main effect of pH on plant growth is its control on nutrient availability (figure 6.4). For example, phosphorus availability drops at extreme pH values because phosphorus binds with iron and aluminum at low pH levels and with calcium at high pH levels. The availability of micronutrients, such as iron, is even more affected by pH. Iron chlorosis, caused by high pH, is one of the most common nutrient deficiencies of nursery stock. Exceptionally

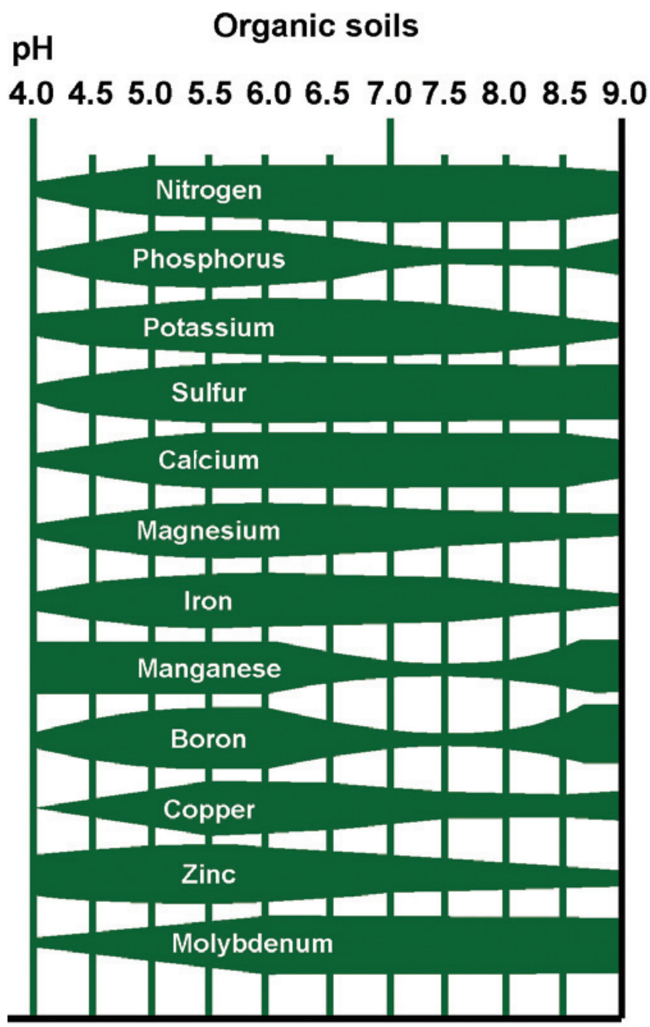

Figure 6.4*—The availability of all mineral nutrients is affected by the pH of the growing medium. In organic-based growing media, maximum availability occurs between 5.5 and 5.6. Illustration adapted from Bunt (1988) by Jim Marin.*

high or low pH levels also affect the abundance of pathogens and beneficial microorganisms. For example, low pH can predispose young plants to damping-off fungi.

Cation Exchange Capacity (CEC)

CEC refers to the ability of a growing medium to hold positively charged ions. Because most growing media are inherently infertile, CEC is a very important consideration. In the growing medium, plant roots exchange excess charged ions for charged nutrient ions (figure 6.1), and then these nutrients are transported to the foliage, where they are used for growth and development. Because the CEC of a growing medium reflects its nutrient storage capacity, it provides an indication of how often fertilization will be required. Because nutrient leaching occurs during irrigation, container nurseries prefer a growing medium with a very high CEC.

Biological Properties of Growing Media

Growing media may contain pathogenic bacteria or fungi. Growing media ingredients that may contain pathogens can be treated with sterilization or pasteurization before use, as described later in this chapter. Organic-based growing media are preferred in nurseries because they are generally pest free. Although peat moss is not technically sterile, it does not contain pathogens or weed seeds when obtained from reliable sources. Vermiculite and perlite are rendered completely sterile during manufacturing, when they are exposed to temperatures as high as 1,832 °F (1,000 °C). Well-prepared composts are generally pest free because sustained, elevated temperatures during composting kill most pathogens. Another benefit of composting is that beneficial microorganisms increase in the final stages of the process. Composted bark of some tree species, for example, contains microbes that suppress common fungal pathogens and nematodes. These suppressive effects depend on the parent material and composting time (Castillo 2004).

Growing Media Ingredients

Once the functions and characteristics of growing media ingredients are understood (table 6.1), an effective and affordable growing media can be developed. Many tropical nurseries mix growing media themselves. Some purchase premixed commercial brands. Some may mix their own media for larger containers, but purchase sterile media for germinants. A typical growing medium is a composite of

Table 6.1*—Different chemical and physical properties of some common materials used to create growing media. Soils are covered separately because they are a combination of both organic and inorganic components, and are extremely variable. Adapted from Buamscha and Altland (2005), Johnson (1968), Lovelace and Kuczmarski (1994), and Newman (2007).*

Component	Bulk density	Porosity:water	Porosity: air	pH	Cation exchange capacity
Organic ingredients					
Sphagnum peat moss	Very low	Very high	High	3 to 4	Very high
Bark	Low	Low	Very high	3 to 6	High
Coir	Low	High	High	6 to 7	Low
Sawdust	Low	High	Moderate	3 to 6	Low
Rice hulls	Low	Low	Moderate	5 to 6	Low
Compost	Variable	Variable	Variable	6 to 8	High
Inorganic ingredients					
Vermiculite	Very low	Very high	High	6 to 8	High
Perlite	Very low	High	High	6 to 8	Very low
Sand	Very high	Moderate	Very low	Variable	Low
Pumice	Low	Low	High	6 to 8	Low
Field soil					
Field soil	Variable	Variable	Variable	Variable	Variable

Why Field Soil Is a Poor Growing Medium

Although it may seem intuitive that potting up nursery plants in containers filled with local field soil would work well, it is not the case. Placing soil in a container results in growing conditions that are completely different from those of unrestricted field soil. These conditions are unfavorable to healthy root growth and plant development in the nursery. In fact, field surveys of tropical and sub-tropical areas of Africa, Asia, and Latin America showed unexpectedly poor field growth of seedlings after outplanting, and correlated this problem with poor root development because of using soil-based media in nurseries (Miller and Jones 1995). The recommended alternative is to replace soil-based media whenever possible with an organic-based, or "artificial" growing media consisting of ingredients such as compost, peat, or coconut coir (Miller and Jones 1995). If soil must be used, it should be only a small percentage of the mix, amended with other ingredients to overcome some of the problems listed in the following sections.

Restricted Volume

Unlike in field conditions, nursery plants will have access to a very limited amount of soil. This limited rooting volume provides seedlings with only small reserves of available water and nutrients and the amount of these resources can change quickly. Because plants will only have a limited area in which to grow their roots, this medium needs to be the best possible material.

Imbalance of Soil Microorganisms

Native soils contain a myriad of microorganisms: some are beneficial and some are pathogenic. These organisms exist in a natural balance in field soils, but when these soils are placed in the nursery growing environments, this delicate balance is upset and problems can develop. Frequent irrigation and fertilization in nurseries favors the development of pathogenic organisms, such as damping-off fungi. Well-processed, organic ingredients, especially composts, often discourage these harmful organisms.

Problems With Water and Air

Clay and silty soils have very small particle sizes and are therefore dense, heavy, and have few air spaces, making it difficult for water to drain freely out of the bottom of the container. Tropical soils tend to be rich in clay and low in organic material and are susceptible to compaction through routine handling and watering in the nursery. Heavy soils also accumulate at the bottom of containers, creating airless places inhospitable for root growth. In addition, some soil-based media shrink when dry and swell when wet, damaging plant roots.

Problems With Nutrition

In containers, native soils do not provide the quantities and ranges of nutrients needed for rapid plant growth and often immobilize certain nutrients (Landis 1995). Clays adsorb some nutrients so strongly that they become largely unavailable for plant uptake, while sandy soils hold nutrients poorly and lose most nutrients through leaching.

Variability and Weeds

Soils are naturally variable, so it is difficult to maintain the same quality from container to container, crop to crop, and year to year—making consistent crop production very difficult. In addition, soil also contains weed seeds, which compete for nutrients and water with the plants sharing their container and compel the grower to spend more labor on weeding.

Sustainability Concerns

Ecological sustainability must also be considered. Harvesting topsoil is actually a mining operation that uses up a limited resource that took thousands of years to develop. For example, in Mexico, millions of square meters of soil are mined each year for use in tree nurseries, leaving behind many acres of depleted areas where plants cannot grow well (Wightman 1999).

Because of these problems with field soil, growing media for tropical nurseries will ideally be based upon organic ingredients, such as composts, bark, rice hulls, or other materials, not field soil. If a medium containing soil must be used, it should contain 10 to 30 percent soil at most, amended with organic ingredients to promote aeration and drainage while maintaining water-holding abilities (Landis 1995). More detail on how to use organic materials to create growing media, and how to incorporate some soil in growing mixes if necessary, is described later in this chapter.

Figure 6.5*—Common organic ingredients of growing media include* Sphagnum *peat moss (A), compost (B), composted tree bark (C), coconut coir (D), and sawdust (E). Photos A and E by Thomas D. Landis, photo B by George Hernández, and photos C and D by Tara Luna.*

two or three ingredients selected to provide certain physical, chemical, or biological properties. Mixtures of organic and inorganic ingredients are popular because these materials have opposite, yet complementary, properties (table 6.1).

Organic Ingredients

Common organic ingredients include compost, coconut coir, peat moss, bark, rice hulls, sawdust or any other appropriate, locally available material. These materials are lightweight, have high water-holding capacity and CEC, and some contain minor amounts of mineral nutrients. Some of these organic ingredients require screening or composting of local raw materials before use. The nursery may choose to do the processing, or a local supplier may specialize in the composting or processing local materials to sell to the nursery at a reasonable cost.

Peat Moss

Sphagnum peat moss is currently the most common organic component of growing media in temperate zone nurseries (figure 6.5A). Although types of peat moss may appear similar, they can have very different physical and chemical properties. The horticultural properties of *Sphagnum* peat moss (table 6.1) and the fact that it has uniform quality make it the only peat moss choice for plant nurseries that use peat moss. Most peat moss comes from Canada, some comes from New Zealand, and the one known tropical source is Indonesia (Miller and Jones 1995). Therefore it is expensive and problematic to import peat for most tropical nurseries. In addition, extraction and transportation of peat moss on a large scale is a sustainability concern, and even temperate nurseries are considering alternatives. For tropical areas where peat moss is reasonably affordable and available, some nurseries use it in limited amounts for germinant mixes or for learning to grow unfamiliar native species. Some nurseries may use peat as a transition component, comparing peat's properties to local materials such as composts or coir to develop local alternatives for growing media while moving forward with plant production.

Compost

Because of the risks of using soils and the expense of importing peat moss, many tropical nurseries prefer organic compost as a green alternative to peat moss (figure 6.5B). For example, in Florida, a variety of native plants grown in biosolid yard waste compost were as large or larger than those grown in a peat-based growing medium (Wilson and Stoffella 2006). Composts are an excellent sustainable organic component for any growing medium and significantly enhance the medium's physical and chemical characteristics by improving water retention, aeration porosity, and fertility. Some composts have also been found to suppress seedborne and soilborne pathogens. Compost quality can vary considerably between different source materials and even from batch to batch so growers need to always test new materials before general use.

Composting is the physical and chemical decomposition of organic materials caused by the digestive activities

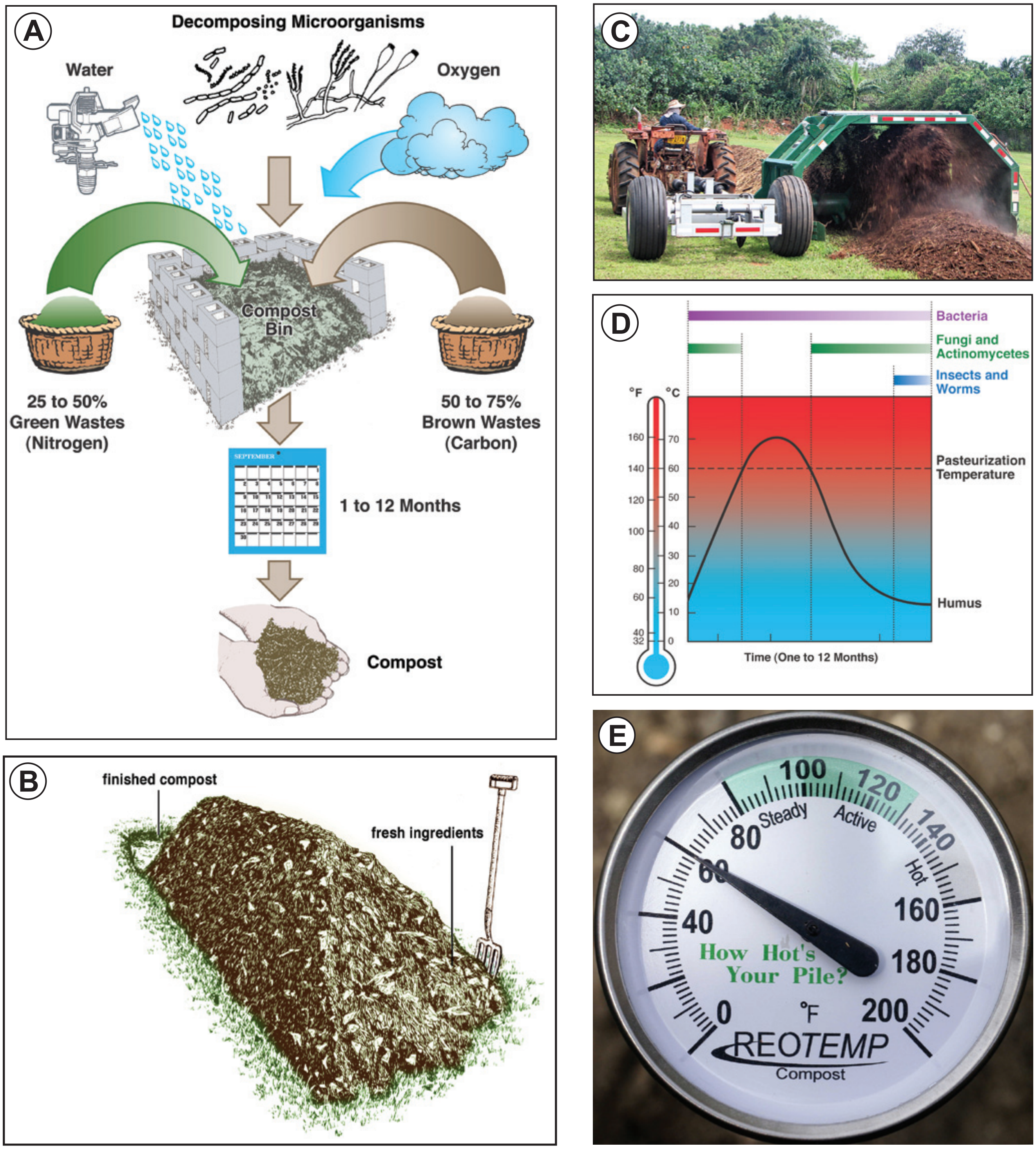

Figure 6.6 *—Creating good compost takes 1 to 12 months and requires the proper mix of organic materials and an ideal environment for the microorganisms that decompose the materials (A). Frequent mixing to foster good aeration is critical and can be done by hand (B) or using equipment (C). Compost goes through a typical temperature curve because of a succession of different microorganisms (D), so the process should be monitored with a long-stemmed thermometer (E). Illustrations A, B, and D from Dumroese and others (2008), photo C by Ronald Overton, and photo E by Thomas D. Landis.*

of insects, fungi, and bacteria (figure 6.6A). Raw materials for compost include any plant wastes such as vegetable or fruit scraps, leaves, weeds, or byproducts, such as cacao pods, coffee pulp, sugarcane bagasse, orchard prunings, and rice hulls; aquatic wastes such as aquatic weeds (such as the noxious weed water hyacinth) or fish parts from fish processing; animal wastes such as manures, feathers, and bedding; and wood wastes such as bark or sawdust. Sometimes these products are considered waste materials and are burned or disposed of at a cost to the producer—composting turns them into a valuable resource. Organic nursery wastes may also be recycled through composting, including used growing media and culled seedlings. Sustainability and renewability of the compost source is important to consider. For example, seaweeds were once considered a good compost material, until people began to understand the importance of seaweeds to fish breeding and the damage that comes from depleting wild seaweed during fish-breeding season. Some nurseries grow part of their own compost ingredients using nitrogen-fixing trees or fast-growing plants such as comfrey, which can be cut back year after year. Growers anywhere should be able to find a sustainable source of organic matter that can be composted and used as a growing media component.

Composted tree bark from a wide variety of species has been successfully used as a growing media component (figure 6.5C), especially for larger volume containers. In the Southern United States, composted pine bark has become a standard ingredient in growing media for horticultural nurseries (Landis and Morgan 2009). The size of bark particles is important, and particle size can be controlled by hammer milling and screening (Gordon 2004). Obtaining bark of consistent quality can be a problem. Composting bark with supplemental nitrogen fertilizer supplies the nitrogen that microorganisms require during decomposition and helps lower the carbon-to-nitrogen (C:N) ratio.

Creating consistent-quality compost year after year is a challenging goal (Miller and Jones 1995). A nursery may choose to make its own compost or contract this work to a local processor. Ideally, compost is made from a mixture of organic materials. All material should be chopped, shredded, or cut into small pieces (0.5 to 2 in [1 to 5 cm]) to encourage faster decomposition and a more uniform final product. The most common method of making compost is to place organic materials in piles and allow them to decompose. The piles need to be mixed periodically to maintain adequate aeration and moisture needs to be maintained at about 50 percent with the feel of a damp sponge (figures 6.6B, 6.6C). Temperatures in the piles change over time as microbial decomposition progresses (figure 6.6D). Within the first few days, temperatures rise to 100 to 120 °F (38 to 49 °C) as the smaller and easily biodegradable materials decompose. Next, temperatures rise to 130 to 150 °F (54 to 65 °C) as more materials decay. A peak temperature of about 160 °F (71 °C) needs to be maintained for several days to kill weed seeds and fungal pathogens. Finally, temperatures fall to around 105 °F (40 °C) and lower during the "curing" stage. The process can be monitored with a thermometer (figure 6.6E). Mature compost can be produced in 2 to 4 months in the humid tropics. It is important to note that the finished compost will only be about 40 percent by volume of the original fresh material. Often, growers have

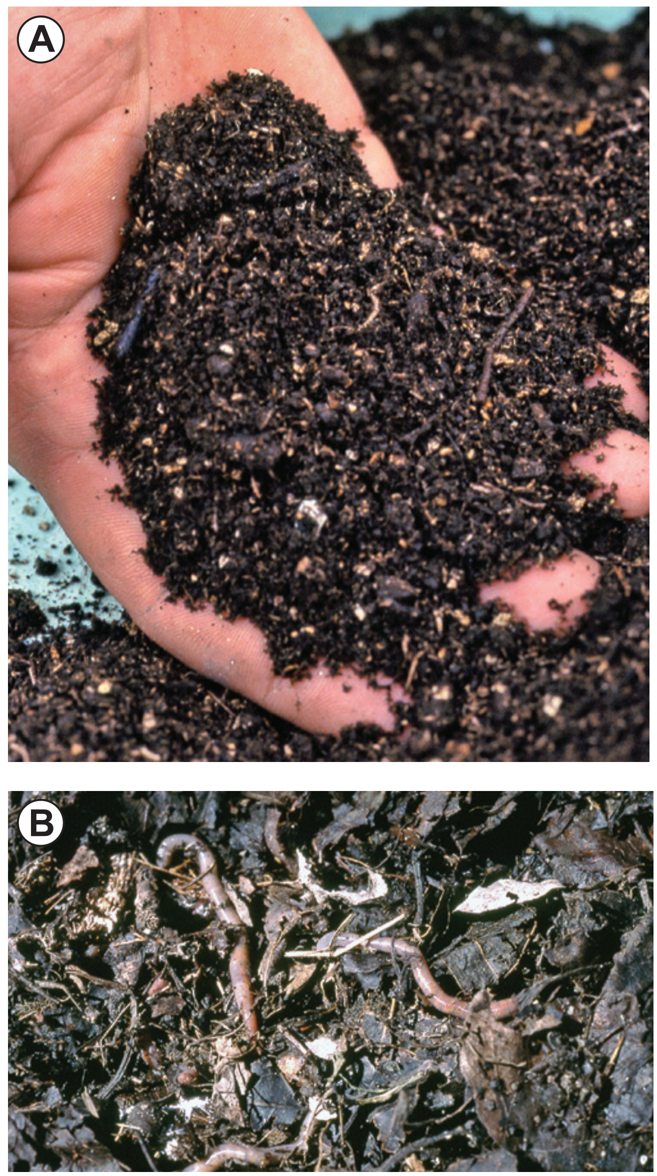

Figure 6.7*—The maturity of commercial or homemade compost needs to be checked before use in growing media; in mature compost, original components are no longer visible and the material is dark and crumbly (A). Earthworms and soil insects are often visible in mature compost (B). Photo A by Tara Luna, and photo B by Thomas D. Landis.*

two or more compost piles in varying stages of decomposition to have a continually available supply. For detailed guidelines on making compost, see Wightman (1999), Martin and Gershuny (1992), and Castillo (2004).

Mature compost should not produce an unpleasant odor or heat before incorporating into a growing medium. The compost should be dark in color and have a rich, earthy smell (figure 6.7A). The texture should be friable and crumbly; the original organic materials should not be recognizable. Earthworms and soil insects can live in mature composts and can be a sign that the compost is complete and ready to use (figure 6.7B). To determine if compost is ready, place two moist handfuls in a plastic bag, seal it, and leave in a dark, cool place. After 24 hours, open the bag: the compost is not ready if it feels hot or smells like manure or ammonia. Finished composts should be sifted through a screen similar to that used for field soil before use. Compost can be tested by sending to a soil lab, testing with a "bioassay," and testing with an EC meter as described in the section on testing growing media.

C:N is a good indicator of whether nitrogen will be limiting or excessive (Landis and Morgan 2009). The higher C:N is, the higher the risk of nitrogen being unavailable to plants. The carbon in easily decomposed compounds, such as sugars and cellulose, are quickly used as an energy source by soil microorganisms, which also need nitrogen for growth and reproduction. Because this nitrogen is stored in their cells, it is unavailable for plant uptake. As carbon sources become depleted, the high populations of soil microorganisms gradually die and nitrogen is released for plant growth. When C:N is greater than 15:1, available nitrogen is immobilized. When C:N is below 15:1, however, nitrogen becomes available for plant uptake. Some composts have C:N as low as 10:1, indicating they are such a ready source of available nitrogen that they are considered fertilizers. Wood wastes, such as sawdust, have very high C:N (400:1 to 1,300:1). These materials are often composted with manure or supplemented with fertilizer to supply the needed nitrogen. The C:N of tree bark can be considerably lower than sawdust (70:1 to 500:1), and has become a preferred material for horticultural composts.

Coconut Coir

A byproduct of processing coconut husks is known as coir dust, coco peat, or simply coir. This material has proven to be an excellent organic component for container growing media and is readily available in some tropical locales (figure 6.5D). Coconut coir has many desirable qualities: high water-holding capacity; excellent drainage; absence of weeds and pathogens; physical resiliency (withstands compression of baling better than *Sphagnum* peat); slow decomposition; easy wettability; and acceptable levels of pH, cation exchange capacity, and electrical conductivity.

Coir is very similar to peat in appearance and structure, and, like peat, physical and chemical properties of coir can vary widely from source to source (Evans and others 1996; Noguera and others 2000). Coir is low in nitrogen, calcium, and magnesium but can be relatively high in phosphorus and potassium (Noguera and others 2000).

Excess salinity and phenolic compounds in coir can be a problem in areas with inadequate quality control (Ma and Nichols 2004). In addition, some coir sources have reportedly contained chlorides at levels toxic to many plants. Thus, it is very important that salts and other compounds are thoroughly leached with fresh water before shipment and use. Compared with Asia, little coir production occurs in tropical America, and, currently, supplies of coir are limited in some areas. Nurseries must locate a quality, consistent source and then add coir to media on a trial basis first, testing effects on a species-by-species basis.

Sawdust

Raw sawdust, with its high C:N, can negatively affect nutrient availability, especially nitrogen but its properties can be improved with composting (figure 6.5E; Miller and Jones 1995). Also, because of inherent differences in chemical properties between different woods, the suitability of sawdust as an organic growing media component is extremely variable. Some species produce sawdust with phytotoxic effects. Only consider using sawdust from sawmills because other wood residues, such as from treated boards, may contain preservatives or harmful chemicals. Sawdust from coastal sawmills can contain high levels of salts, so all potential sources need to be tested before general use in the nursery.

Rice Hulls

Rice hulls are the sheaths of rice grains, a waste product of rice processing (Landis and Morgan 2009). Rice hulls or husks have been used as a component of potting medium with locally obtained peat for many years in Indonesia (Miller and Jones 1995). Several nurseries have used composted, screened, and hammer-milled rice hulls in place of composted bark (Landis and Morgan 2009).

Other Possible Organic Ingredients

Nearly any other organic material that is locally available has the potential to be an important addition to nursery growing media. Composted material takes longer to produce, but has a more reliable texture and nutrient content than raw material. For example, composted manure from livestock

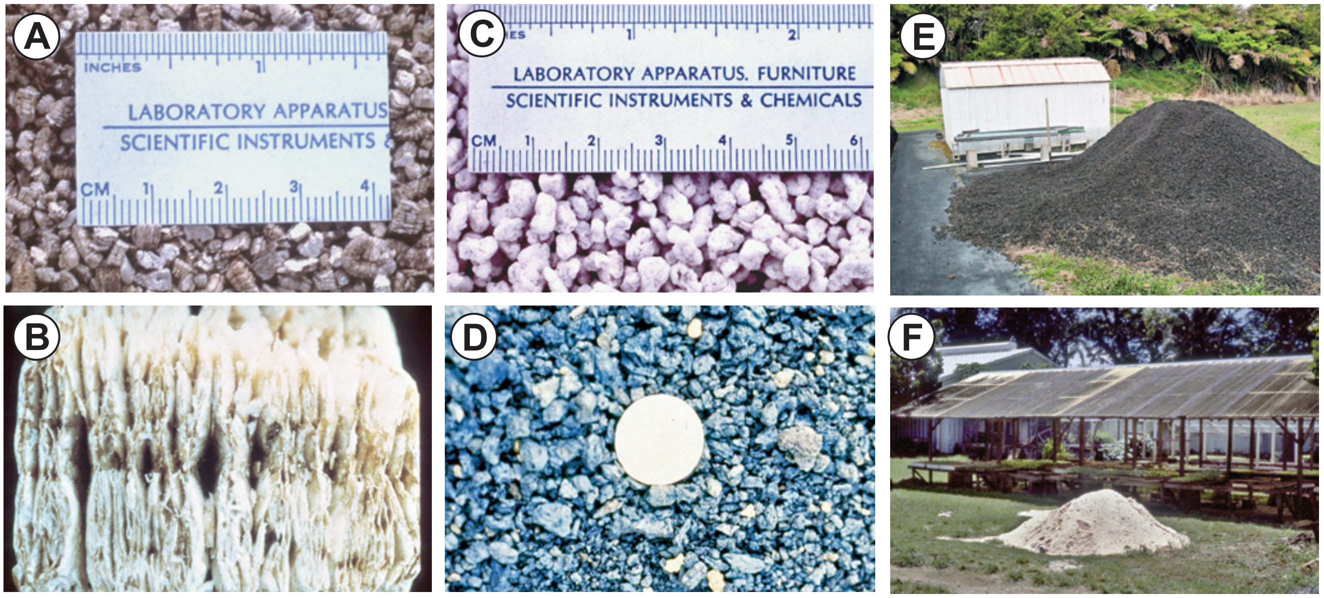

Figure 6.8*—Common inorganic ingredients of growing media. Horticultural vermiculite particles (A) look like accordions (B) because of their expanded structure of parallel plates that allow vermiculite to absorb water and dissolved mineral nutrients like a sponge. Perlite particles have a closed-cell structure that prevents water absorption and improves aeration and drainage (C). The particles of pumice (D) and cinders (E) also improve aeration. Sand is also used as an inorganic component but may affect pH (F). Photos A, B, C, and D by Thomas D. Landis, and photos E and F by Tara Luna.*

pens and other organic waste from agricultural operations are excellent candidates and are frequently available for free if you can haul them. All "homemade" materials will take effort to process and fine-tune to create a consistent product. The final product will be worth the effort because you will be developing your own specialized growing media with low-cost local ingredients that do not have to be shipped.

Inorganic Ingredients

Inorganic materials are added to growing media to produce and maintain a structural system of macropores that improves aeration and drainage (Mastalerz 1977). Many inorganic ingredients have a very low CEC and provide a chemically inert base for the growing medium. Inorganic materials with high bulk densities provide stability to large, freestanding containers. Several materials are routinely used as inorganic ingredients in growing media in native plant nurseries, including gravel, sand, vermiculite, perlite, pumice, and polystyrene beads.

Vermiculite

Vermiculite is a common component (figure 6.8A) and is a hydrated aluminum-iron-magnesium silicate material that has an accordion-like structure (figure 6.8B). Vermiculite has a very low bulk density and an extremely high water-holding capacity, approximately five times its weight. This material also has a neutral pH, a high CEC (table 6.1), and contains small amounts of potassium and magnesium. Vermiculite is produced in four grades based on particle size, which determines the relative proportion of aeration and water-holding porosity. Grades 2 and 3 are most commonly used in growing media; grade 2 is preferred when more aeration porosity is desired, whereas grade 3 produces more water-holding capacity. A 1:1 mixture of peat moss and coarse vermiculite is a common growing medium mix in many temperate nurseries.

Perlite

Perlite is a siliceous material of volcanic origin (figure 6.8C). Perlite particles have a unique closed-cell structure so that water adheres only to their surface; they do not absorb water as peat moss or vermiculite do. Therefore, growing media containing perlite are well drained and lightweight. Perlite is also rigid and does not compress easily, which promotes good porosity. Because of the high temperatures at which it is processed, perlite is completely sterile. It is essentially infertile, has a minimal CEC, and has a neutral pH (table 6.1). Perlite is typically included to increase aeration, and commercial mixes contain no more than 10 to 30 percent perlite. Perlite grades are not standardized, but grades 6, 8, or "propagation grade" are normally used in growing media. Perlite grades often contain a range of particle sizes, depending on the sieve sizes used during manufacturing. One safety concern is that perlite can contain considerable amounts of very fine dust that causes eye and lung irritation during mixing. Wetting the material while mixing and wearing dust masks and goggles can reduce this risk.

Pumice and Cinder (Scoria)

Pumice (figure 6.8D) is a type of volcanic rock consisting of mostly silicon dioxide and aluminum oxide with small amounts of iron, calcium, magnesium, and sodium. The porous nature of pumice particles improves aeration porosity but also retains water within the pores. Pumice is the most durable of the inorganic ingredients and so resists compaction. Cinder (often called scoria) is another type of volcanic rock and a common growing media component in volcanic areas such as Hawaiʻi, where growers may sift the cinder rocks to obtain the desired sizes for their containers (figure 6.8E).

Sand

Sand is one of the most readily available materials and is relatively inexpensive. The composition of sand varies widely. When considering if local sand is a suitable component, the type of sand and sand particle sizes must be considered. For example, some silty river sands with small particle size can have a serious negative effect on growing media by making them excessively heavy and not contributing to improved aeration or drainage.

Nurseries with access to siliceous (granite or schist derived) sands may be able to use local sand as an inorganic component. Sands derived from calcareous sources (such as coral or limestone) (figure 6.8F) are high in calcium carbonate ($CaCO_3$), however, and can have dangerously high pH values. Growers can test sands by adding a drop of dilute acid or even strong vinegar—a fizzing reaction indicates the presence of $CaCO_3$. It is better not to use coral-based soils or sands if at all possible but, if necessary, add lots of organic matter to help buffer the effects. Some plants grown in your nursery may be adapted to local calcareous soil conditions and may not suffer from the increased pH if the sand is used sparingly.

Sand is used to increase porosity, but small sand particles can lodge in existing pore spaces and reduce aeration and drainage. In general, sizes of 0.002 to 0.010 in (0.05 to 0.25 mm) are too small and will block drainage holes and reduce aeration (Wilkerson 2011). Larger (medium to course) particles are more suited to increase porosity. The general recommendation is to wash sand (flushing out salt content if present) and sterilize or pasteurize it before incorporating it in the growing medium (Miller and Jones 1995). These techniques are described later in the chapter. Perhaps the more serious drawback of using sand in growing media is its weight, which causes problems with handling and increases the cost of shipping (Gordon 2004).

Polystyrene Beads or Flakes

Polystyrene is more commonly known by its trademarked name Styrofoam™. Beads or flakes of polystyrene are a processing byproduct. Polystyrene increases aeration and drainage, decreases bulk density, and is highly resistant to decomposition (Wilkerson 2011). New polystyrene is unlikely to be a locally available material and many people are phasing out the use of polystyrene for sustainability concerns. It may be possible to recycle polystyrene and use pieces in growing media although it is not biodegradable and is often considered undesirable to outplant on project sites.

Developing a Growing Medium

It is likely that as many recipes exist for growing media as the number of nurseries; there are no global recommendations (Jaenicke 1999). Every nursery manager needs to be able to experiment and find suitable, local, affordable ingredients to create good growing media. Three general types of growing media are used in container nurseries (table 6.2):

1. **Seed Propagation Media.** For germinating seeds or establishing germinants (sprouting seeds), the medium must be sterile and have a finer texture to maintain high moisture around the germinating seeds.
2. **Rooting Cuttings Media.** Cuttings are rooted with frequent misting, so the growing medium must be very porous to prevent waterlogging and allow good aeration necessary for root formation.
3. **Transplant Media.** When smaller seedlings or rooted cuttings are transplanted into larger containers, the growing medium is typically coarser.

Because of the diverse characteristics of various growing media ingredients, a growing medium can be formulated with nearly any desired property. The physical, chemical, and biological properties of each growing medium strongly interact with nursery cultural practices, however, particularly irrigation, fertilization, and the type of container. When considering a new growing medium, first test it on a small scale with several different species and evaluate its suitability before making a major change to the whole crop. Information about testing is provided at the end of this chapter, and more details about proper ways to test are in Chapter 20, Discovering Ways to Improve Nursery Practices and Plant Quality.

Purchasing a Commercial Mix

A variety of commercial mixes are available that feature combinations of organic and inorganic ingredients described previously. To appeal to a wider market, many brands contain a wide variety of additional amendments including fertilizers, wetting agents, hydrophilic gels, and

Table 6.2—Example growing media for different nursery uses. The ideal growing medium will vary among nurseries, environments, and plant species.

Media type	Properties	Examples of media (by volume)	Reference
Seed propagation	Maintains uniform moisture around germinating seeds (not too wet or too dry); no fertilizer; free from pests and diseases.	• 3 parts perlite to 1 part coarse vermiculite (for beach plants) • 4 parts perlite to 1 part peat • 3 parts small rinsed cinders to 1 part peat and 1 part perlite	Lilleeng-Rosenberger (2005)
		• Fine, washed quartz sand [0.02 to 0.04 in (0.5 to 1 mm)] (100% sand will need frequent watering)	Jaenicke (1999)
Rooting cuttings	Porous to prevent waterlogging and to allow good aeration for root formation; provide support for cuttings; free from diseases and weed seeds.	• 3 parts perlite to 1 part vermiculite • 3 parts small rinsed cinders to 1 part peat and 1 part perlite • 100% rinsed small cinder (but needs frequent misting)	Lilleeng-Rosenberger (2005)
		• 100% washed quartz sand (2 mm)	Jaenicke (1999)
		• 1 part grit or fine gravel to 1 part washed sand to 1 part aged sawdust • 1 part grit or fine gravel to 1 part aged sawdust	Longman (1998)
Transplant	Coarser; heavy enough to keep plants upright; may contain some nutrients; free from diseases and weed seeds.	• 1 part peat and 1 part vermiculite • 2 parts cinder or perlite to 1 part well-decayed compost and 1 part peat	Lilleeng-Rosenberger (2005)
		• 1 part coarse sand, 2 parts coconut coir, 1 part topsoil/duff • 2 parts bagasse to 1 part rice hulls and 1 part alluvial soil • 1 part well-composed grasses to 1 part rice hulls or pumice • 3 parts composed bark to 1 part sand and 1 part shale	Miller and Jones (1995)
		• 2 parts well-decayed compost to 2 parts sand and 1 part clay soil	Wightman (1999)
		• 3 parts coir to one part compost • 30% composted rice hulls, 50% pine bark, and 20% sand	Lovelace (2011)

even beneficial microorganisms. Many amendments are formulated for crops other than tropical nursery plants and may do more harm than good. In particular, hydrogels can cause growing media to retain too much water and actually decrease aeration porosity when expanded. Always check the label to be sure of exactly what is in the mix.

Creating a Custom Mix

Many tropical plant growers prefer to mix their own custom growing media (figure 6.9). In addition to saving money, custom mixing is particularly useful in small nurseries where separate mixes are needed to meet propagation requirements of different species. A very porous and well-drained medium, for example, might be needed for plants from very dry habitats, but a second type is needed for coastal plants, and a third is needed for wetland species.

Standard commercial ingredients, such as peat and vermiculite, can be bought in bulk (by the pallet or container load to islands) to reduce costs. These ingredients have been used worldwide and may provide good, basic media ingredients during nursery start-up phases. Because of the steep learning curve with growing tropical plants and running a nursery, some managers may choose to import expensive but well-researched ingredients until they identify a consistent supply of local equivalents. Others may use small amounts of imported ingredients for seed propagation or cutting propagation, but use local ingredients for transplants.

Figure 6.9—Many growers prefer to mix their own species-specific media using different ingredients (A). Growing media including local sand and compost mixed with some imported ingredients is used and sold at the native tree nursery at Reserva Natural, Cañón de San Cristóbal, Barranquitas, Puerto Rico (B). Photo A by Tara Luna, and photo B by Brian F. Daley.

Use of Field Soil

The use of field soil is not recommended for growing nursery plants. Circumstances may require, however, that some nurseries include some field soil in their media while more affordable and sustainable alternatives are being developed, so soil-based media is discussed here.

When selecting soil, use dark topsoil that has a high percentage of organic matter; lighter sandy loams are better than heavy clays. After collection, sift the soil through a 0.5 in (12 mm) screen to remove debris and large objects such as rocks (figure 6.10). When using field soils, heat pasteurization (described later in this chapter) can eliminate fungal pathogens, insect pests, nematodes, and weeds.

Soil-based mixes are safest for transplant media when transplanting into larger containers, such as polybags or 1 gallon pots. The properties of soil-based mixes make them unsuitable for smaller containers, and the risk of disease makes them unsuitable in media for germinating seeds or rooting cuttings. Soil should comprise no more than 10 to 20 percent of the transplant media by volume although some nurseries use up to 30 percent. The remaining ingredients, for example, bark, sawdust, and pumice, promote drainage and aeration while maintaining a high water-holding capacity (Landis 1995).

Use of Amendments

An amendment is a supplemental material that contributes less than 10 percent of the mixture, whereas an ingredient usually constitutes a larger percentage. A variety of materials may be added to growing media during the mixing process, including fertilizers, lime, surfactants, hydrogels, and mycorrhizal inoculum. Many of these materials may not be

Figure 6.10—If field soil must be used as an ingredient, it needs to be screened for debris and other large particles before use. Photo by Brian F. Daley.

desirable, however, and, in fact, may be detrimental to plant growth because they are formulated for other crops. If the decision is made to use amendments, uniform incorporation is important because plant roots have access to only a limited volume of growing media in the relatively small containers used in tropical plant nurseries. Uneven mixing of incorporated fertilizers is one of the major factors causing uneven growth in container nursery stock (Whitcomb 2003). If you decide to use any amendments, test them first on a small scale, using the techniques described in Chapter 20, Discovering Ways To Improve Nursery Practices and Plant Quality.

Dolomitic Limestone. Called "lime" in horticulture, it has traditionally been added to growing media to raise the pH and supply calcium for plant nutrition. Better ways of supplying calcium exist, so we do not recommend limestone amendments unless the nursery is growing plants that require a neutral or alkaline pH.

Starter Fertilizers. Some commercial media contain a small "starter dose" of soluble granular fertilizer. If fertigation (irrigation water containing liquid fertilizer) is not possible, then starter fertilizer may be a good idea to ensure that young, developing plants have quick access to mineral nutrients. Because fertilizer is a salt, incorporating larger quantities of soluble fertilizer is never recommended because of the high potential for salt toxicity.

Controlled-Release Fertilizers. Commercial growing media and custom mixes often include controlled-release fertilizers. It is important to know the fertilizer formulation and release rate. See Chapter 12, Plant Nutrition and Fertilization, for more discussion about these fertilizers. Keep in mind that, when used in warm, tropical climates, controlled-release fertilizers will have much faster release rates than indicated on the label, which are targeted to temperate areas.

Surfactants. These chemical amendments, also known as "wetting agents," break down the surface tension of water and increase the wettability of hydrophobic organic materials such as peat moss and pine bark. Some surfactants have been shown to adversely affect plant growth. Before using surfactants, be certain that a problem really exists and can potentially be solved by using the product. Ask other nurseries about their experiences with surfactants and perform small tests before using them operationally.

Hydrophilic Gels ("hydrogels") are cross-linked polymers that absorb many times their own weight in water. They have been proposed as additives to increase the water-holding capacity of growing media. Several brands of growing media contain hydrogels, but no empirical evidence shows they improve plant growth. Because nursery crops are regularly irrigated, the use of hydrogels is rarely justified.

Mycorrhizal Inoculum. One method of inoculating native plants with beneficial mycorrhizal fungi is to incorporate inoculum into the growing medium at the time of mixing. As with all amendments, this practice needs to be tested first before adopting it on a large scale. See Chapter 13, Beneficial Microorganisms, for more discussion on this topic.

Rock Phosphate. Rock phosphate may be added to increase phosphorous availability. Excessive phosphorus, however, may hinder development of mycorrhizae and also interfere with the absorption of other mineral nutrients (Wilkerson 2011).

Other Amendments. Some growers add small amounts of other amendments to their mixes, such as worm castings, bone meal, kelp, guano, humic acid, compost tea, and others. Consider any amendment carefully as to what it will accomplish, if it is necessary, and if it may do more harm than good.

Treatment of Growing Media Ingredients

Some growing media ingredients may need to be treated before mixing to reduce potential damage to plants. These treatments may include removing salts, killing unwanted organisms, and sifting.

Flushing Out Salts

Flushing out salts may be necessary for materials such as coir, sand, sawdust from mills near the ocean, and composts with excessive soluble salt levels. Leaching with fresh water can effectively lower soluble salts below damaging levels (Carrion and others 2006, Landis and Morgan 2009). Because of its low salinity, rainwater is ideal for this process but any fresh water source will work if enough is applied. Check the electrical conductivity (EC) of the leachate from the ingredients or composts to verify that the salts have been removed (as described in the following section on testing growing media).

Pasteurizing Ingredients

Sterilization refers to the complete elimination of all living organisms whereas pasteurization targets pathogenic fungi and bacteria. For growing plants, completely sterile growing media is not desirable because many beneficial microorganisms normally found in growing media can actually be antagonistic to pathogens. Some commercial growing media are pasteurized to prevent the introduction of pests, weeds, and diseases into the nursery. If concerned, contact the supplier to find out if their media has been treated. If you mix your own media, common inorganic ingredients, such as vermiculite and perlite, are inherently sterile; organic ingredients are suspect. The heat from the

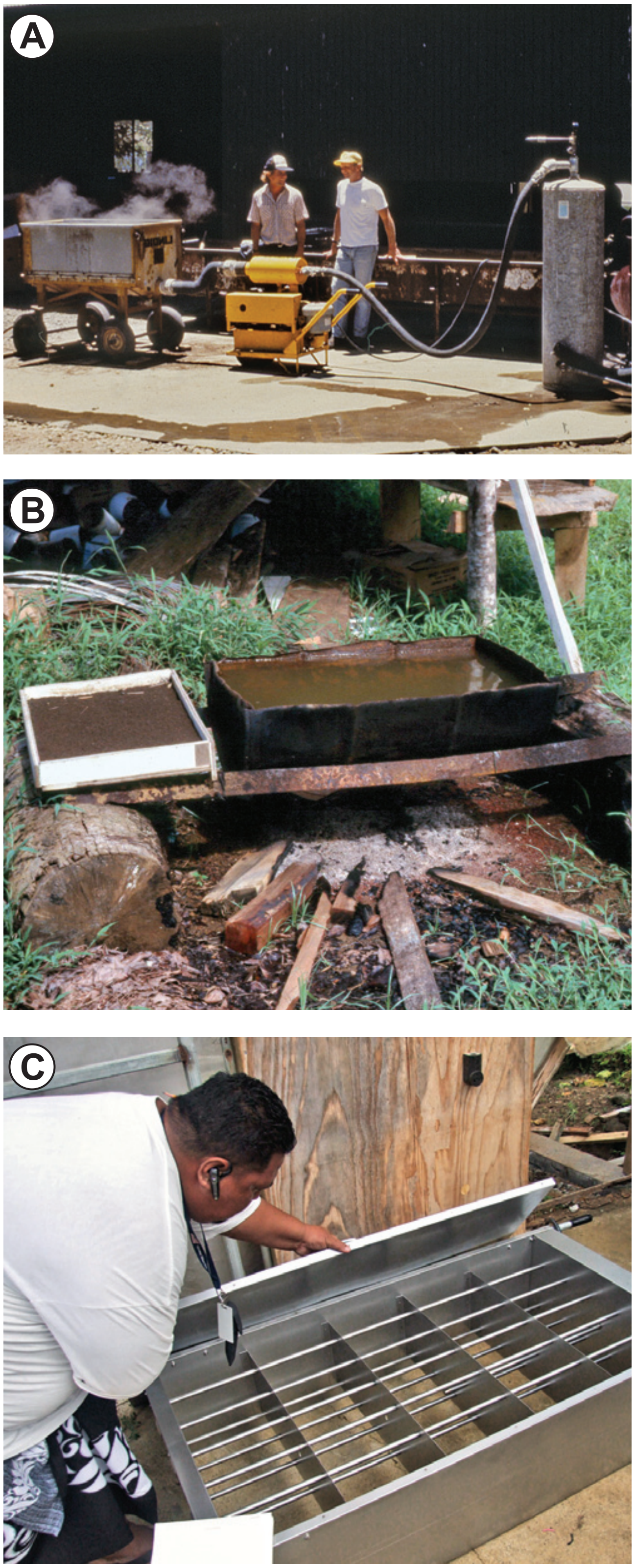

Figure 6.11—For nurseries making their own media, pasteurization with steam (A) or wood heat (B) is simple, effective, and can be accomplished with portable equipment. Electric soil sterilizers can heat the soil long enough to eliminate most weed seeds and pathogens (C). Photos A and B by Thomas D. Landis, and photo C by J.B. Friday.

composting process will kill pathogens and other pests in composts, but when using field soil, growers need to seriously consider pasteurization.

Heat pasteurization is the most common way of treating growing media. Several heat sources can be used for pasteurizing growing media: moist heat from steam, aerated steam, or boiling water; dry heat from flame, electric pasteurizers, or microwave ovens; and solar heat. Ingredients and media are pasteurized commercially with large, expensive equipment, but smaller pasteurizing equipment is available for nurseries (figures 6.11A, 6.11C) and some nurseries have developed their own pasteurization process using fire or solar heat (figure 6.11B). A practical technique would be to enclose small batches of media spread thin (no more than 6 in [15 cm] deep) under black plastic tarps on an inclined table or on top of a tarp to expose it to maximum sunlight. Long-stemmed thermometers can be used to penetrate the tarp in several locations to ensure that temperatures stay in the recommended range of 140 to 177 °F (60 to 80 °C) for 30 minutes. After treatment, the material can be dumped off the table or tarp into a clean wheelbarrow or mixing area, cooled, and used in the growing medium.

Regardless of the heating method, it is important to maintain the entire mass of growing medium at a uniform temperature that exceeds the thermal mortality threshold of the various nursery pests. Pests may vary in their inability to tolerate high temperatures (figure 6.12), but most can

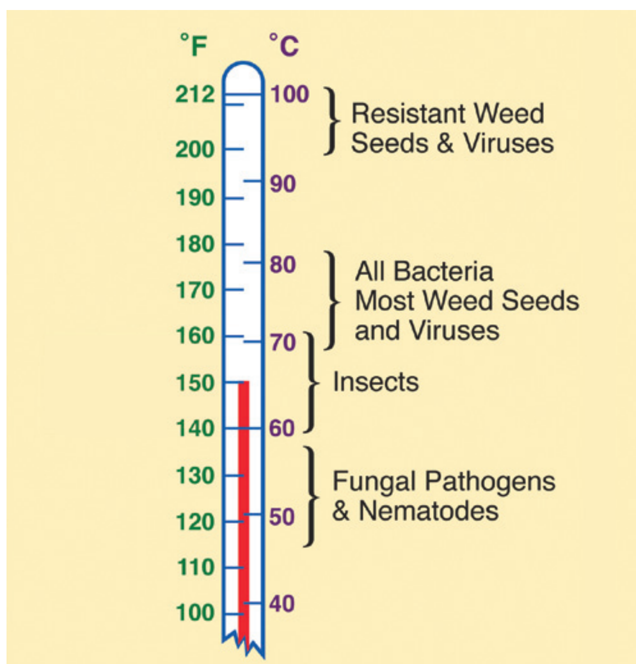

Figure 6.12—Necessary temperatures for heat pasteurization vary depending on the target pest. Temperatures need to be held for 30 minutes in the target range to be effective on that pest. Illustration adapted from Baker (1957) by Jim Marin.

Figure 6.13—Screening growing medium ingredients may be necessary to achieve the desired particle size. Photo by Thomas D. Landis.

be eliminated by heating the growing medium to 140 to 177 °F (60 to 80 °C) for at least 30 minutes. Excessively high temperatures can eliminate beneficial soil organisms and produce toxic chemical compounds.

Sifting or Screening Ingredients

Some ingredients, such as soil, sand, and cinder, may require screening or sifting to achieve the desired particle size (figure 6.13). Excessively small or fine particles can clog container drainage holes and reduce aeration whereas excessively large particles can interfere with container filling, root development, and plant extraction. It may be necessary to sift twice, once with a small mesh to eliminate material larger than desired, and a second time with a larger mesh to remove material smaller than desired.

Mixing Growing Media

Whitcomb (2003) emphasized that improper media mixing is one of the major causes of variation in container plant quality. Mixing should be performed by diligent, experienced workers who will faithfully monitor the growing media quality. Creating a uniformly mixed growing medium that has not been compacted, contaminated, or compromised is the challenge and the goal.

Small batches of growing media ingredients can be mixed by hand. Measure out the ingredients by volume and mix together in a wheelbarrow or bucket (figure 6.14A). Workers can mix larger batches on any clean, hard surface using hand shovels. Pile the ingredients on top of one another and broadcast any amendments over the pile. Then work around the edge of the pile with a large scoop shovel, taking one shovel full of material at a time and turning it over onto the top of the pile (figure 6.14B). Make sure that all parts of the pile are mixed by gradually moving the location of the pile

Figure 6.14—Nurseries that mix their own media can do so by hand (A) or by using the moving pile technique (B). To reduce labor, a cement mixer (C) can also be used but care must be taken to avoid overmixing and resultant damage to particle size and structure. Photo A by Diane L. Haase, and photos B and C by Thomas D. Landis.

to one side. Some organic ingredients repel water when dry, so frequently misting the pile with water at regular intervals during mixing improves water absorption. Continue this procedure until samples from the pile appear to be well mixed. Do not compress or compact the mixture.

Managers of nurseries that regularly require larger quantities of custom growing media should consider purchasing a mixer. A cement mixer (figure 6.14C) works well as long as care is taken to avoid excessive mixing, which breaks down the size and texture of ingredients. Fragile materials, such as vermiculite and peat moss, are particularly vulnerable to overmixing, which can easily happen when mixers are run too long, are overfilled, or if the ingredients are too wet. Over-mixed media compacts easily during container filling, which leads to reduced aeration and waterlogging.

Safety Considerations

Workers need to follow certain precautions when handling growing media or its ingredients, including the time spent filling containers. Dust is the most common concern, so work areas need to be well ventilated and workers need to wear protective dust masks and safety glasses (figure 6.15). Misting the growing media and work areas with water reduces dust.

Perlite dust is of particular concern because of potential for silicosis, an inflammation that occurs over time when dust that contains silica is inhaled into the lungs. Based on medical studies, however, no relationship exists between handling perlite and the development of silicosis (Schundler Company 2002). The use of commercial vermiculite horticulture products presents no significant asbestos exposure risk to commercial greenhouse or home horticulture users (Chatfield 2001). Nonetheless, dust is irritating and common sense dictates that proper safety precautions be taken.

Workers with cuts or abrasions on their hands need to be especially careful handling *Sphagnum* peat moss because of sporotrichosis, which is a condition caused by a fungal pathogen sometimes found in peat moss and other organic materials. The spores of this fungus can invade cuts on the hands or arms of workers or can even be inhaled (Padhye 1995). Preventative measures include the following—

- Store peat moss and peat-based growing media under dry conditions.
- Ventilate work areas well.
- Wear gloves, dust masks, and long-sleeved shirts to protect hands and arms.

Figure 6.15*—When mixing growing media or filling containers, nursery workers need to wear dust masks and safety glasses. Photo by J. Chris Hoag.*

- Thoroughly wash arms and other exposed parts of the body with soap and water to reduce the risk of infection.
- Treat any injury that breaks the skin with a disinfectant, such as tincture of iodine.
- Regularly sweep and wash work areas.

Testing Growing Media

As each nursery develops its own growing media based on local ingredients, issues can arise because of variability in materials. Homemade materials, particularly composts, may vary in their quality despite best efforts to achieve a consistent product year after year. Purchased materials can also be variable on occasion depending on source and quality control procedures.

To preclude surprises, test compost and mixed growing media well in advance of use. It is also recommended to test and record the results of growing media batches that worked well, to compare them to new or experimental batches (Grubinger 2007), and to develop and refine suitable alternative mixes with similar favorable properties.

Plant Bioassay Test

One easy and effective test is known as a plant bioassay (Grubinger 2007). Simply put a sample of the growing medium in the containers that will be used in the nursery, sow an abundantly available, fast-growing species into the medium, and observe how the planting performs over a few weeks. Some growers like to use more sensitive, slower growing crops to test their mixes. It is also a good idea to test a few seeds of other plant species intended for the mix in addition to the bioassay seeds. Do the seeds germinate as expected? As they grow, is damping-off observed? Are pest problems, such as gnats or maggots, emerging? Is the medium stable, not becoming compacted or waterlogged over time? If the results are not good, growers will be glad they tested the mix with readily available seeds instead of with rare native plant seeds. If the mix works, it is ready to try in the nursery.

Figure 6.16*—Growing media salinity can be measured using an EC meter. Photo by J.B. Friday.*

Testing With an Electrical Conductivity (EC) Meter

The salinity (salt level) of the growing medium is a key parameter affecting the development and health of plant roots. Salts may come from growing media ingredients, irrigation water, and from added fertilizers. Measuring EC is a way to measure the amount of nutrients and salts present to ensure they are in the appropriate ranges for the species grown. Excessively high salt levels can damage or even kill succulent young plants.

The best growers routinely measure the EC of their growing media ingredients, their growing media before and during a crop cycle, their fertilizer applications to ensure correct dosages, and their water quality. Some types of EC meters can only be used with aqueous solutions and so are ideal for measuring irrigation water and fertilizer solutions but are not ideal for growing media (for more details on proper technique with these meters, see Landis and Dumroese 2006). Direct sensor models are small handheld devices and have probes small enough to be inserted directly into growing media (figure 6.16). The advantage of the direct sensor procedure is that readings can be taken quickly and nondestructively. To ensure the probe has good contact with the growing medium, always test at the same media moisture content. The recommendation is to monitor about 1 hour after irrigation or fertigation. Direct sensor testing works best with small containers; readings in larger containers can vary significantly so a couple of readings should be taken and averaged. Always take readings at a standard depth. If the probe is inserted into a medium containing controlled-release fertilizers and the tip of the probe gets close to or punctures a prill, the EC reading might be extremely high, requiring a second insertion of the probe into a different area. Regardless of the type of EC meter used, it needs to be calibrated frequently to ensure correct readings.

Three things make using EC data challenging. First, EC can be measured in a variety of units, so pick a unit and stick with it. Conversions for the most common EC units are available in Landis and Dumroese (2006). Second, native plants vary considerably in their tolerance to salinity; a plant growing on the beach may have a much greater tolerance for high salt levels than a plant growing far inland or at higher elevations. Third, little information is available on the EC tolerances of many native plants. These challenges make providing an acceptable range for EC difficult, but start with general guidelines (table 6.3).

Regularly record EC values throughout each crop production cycle, especially during the Establishment Phase, and compare those with the quality of the final plants (see Chapter 4, Crop Planning: Propagation Protocols, Schedules, and Records). Often, it can be the change in EC values that is more important. For example, if during the course of 1 month, the crop growth is declining at the same time the EC values are dropping, this pattern indicates insufficient nutrients are available and fertilization needs to be increased. Conversely, if growth is declining and EC values are increasing dramatically, this pattern could indicate salt toxicity that can be remedied by reducing the fertilizer rates and leaching the medium with clear water. Collecting EC data for a couple of years will help any nursery manager hone in on the proper levels for their particular nursery and crops. More information about EC meters and water quality is in table 11.1 of Chapter 11, Water Quality and Irrigation.

Table 6.3—Electrical Conductivity (EC) guidelines for artificial growing media. Adapted from Timmer and Parton (1982).

EC range (µS/cm)	Salinity rating
0 to 1,200	Low
1,200 to 2,500	Normal
2,500 to 3,000	High
3,000 to 4,000	Excessive
Greater than 4,000	Lethal

µS/cm= microSiemens per centimeter

Sending Growing Media to a Soil-Testing Laboratory

For more formal testing, growing media samples can be sent to a soil-testing laboratory (private, local extension office, or land-grant university) for testing. A measurement of pH, soluble salts (electrical conductivity), and nutrients should be requested (Grubinger 2007). Results can vary among laboratories depending on their procedures, so it is best to stick with one lab for testing from year to year, provided that the data appears accurate and consistent.

Obtaining test results from laboratories may take a few days to several weeks, and bioassay results always take several weeks. Laboratory staff can help with interpretation of results. Results may indicate that the growing medium requires modification and further testing before it can be used. Therefore, start the testing well in advance of when the medium is needed. Changing to a new growing medium will also require adjusting irrigation, fertilization, and other cultural procedures, so other trials and experiments might be valuable (see Chapter 20, Discovering Ways to Improve Nursery Practices and Plant Quality).

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