Substrates for Plants Grown in BIG CONTAINERS?

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There are no “one size fits all” potting mix recipes for growing nursery crops in large containers. Pine bark is the key ingredient used for outdoor potting substrates over much of the Eastern US. However, “pine bark” is as variable as “soil” as a description of a potting substrate component. At least three pine species are used in container substrates including Jack pine (*Pinus banksia*na) and Red pine (*Pinus resinosa*) used in various regions of the Northern US and Canada. Loblolly pine (*Pinus taeda*) widely planted by the pulp and paper wood products industry in the Southeastern US is the predominant pine bark potting component for southern nurseries and is shipped to many other regions of the Eastern US. Bark particles of Jack pine and Red pine tend to be thinner and decompose quickly compared to loblolly bark particles which are thicker and resist decomposition during the many months of growing nursery crops in containers. Loblolly pine bark supplies are also highly variable in stability and particle size depending upon processing techniques and how old it is. Using fresh pine bark versus aged pine bark is a topic of frequent discussions among nursery professionals. Fresh pine bark may smell like turpentine although it can safely be used for growing container plants. Fresh pine bark typically has noticeable amounts of wood splinters and “rubbery” cambium. Fresh pine bark generally has very little uniformity of particle sizes, containing large particles and too few fine particles for adequate water retention. Growers usually need to add other fine particle substrate components such as sand or peat moss to fresh pine bark to increase moisture content in the substrate. Aged pine bark is an “added value” resource in container production, meaning that someone has to invest time and resources into moistening and turning the bark supply several times over several months. Growers may prefer to use aged or composted pine bark but may not be able to purchase large enough quantities required for potting their crops. Choices then become to learn how to manage fresh pine bark potting mixes that may require more frequent irrigation and possibly higher fertility rates or create a bark handling area at the nursery. A bark handling area would preferably be a concrete pad large enough to turn windrows frequently. The area should be higher in elevation than nursery growing areas or used pot storage areas to prevent runoff from entering the bark handling area. Since applying water to the inventory is generally required to keep bark supplies from drying out, a drainage system should also be developed to carry runoff away and reduce swampy conditions around the bark handling area. The next step would be to buy in fresh pine bark supplies, thoroughly wet the inventory, monitor temperature and turn between 140^{o}F to 160^{o}F repeating the process 6 to 8 times over the next 6 to 8 months. During aging, wood and cambium are decomposed, bark particles become less hydrophobic and more moisture can be observed to be adsorbed within pine bark particles. Adding nitrogen as ammonium nitrate or urea (approximately 1 pound of N/ cubic yard of inventory) can move the aging process along faster, but increases the need for monitoring temperature and turning piles before they reach $170\,^{o}$F to avoid spikes in temperature and fires due to spontaneous combustion. Electrical conductivity (EC) and pH should always be checked in pine bark supplies before potting crops. Pine bark generally has a pH between 4.0 and 4.2. Occasionally, pH may be higher. However, low pH is of concern. Anaerobic pockets develop in pine bark inventories because moisture is lost as steam in the upper portions of the pile. Dry bark layers prevent exchange of air to areas below and in the absence of oxygen, anaerobic decomposition begins. Acetic acid and alcohols are produced in the anaerobic pockets. pH reading as low as 2.3 but more commonly 3.0 to 3.3 may be measured from pine bark extracted from anaerobic pockets. EC reading may also be elevated since acetic acid and alcohol are very good solvents. EC readings may be as high as 2.5 dS/m (mmhos/cm). The bark inventory should be turned and thoroughly moistened to re-start aerobic microbial breakdown. The bark can be checked in 14 to 21 days to determine if it is ready to use. Pine bark suitable for potting should have pH above 3.8 and EC below 0.5 dS/m.

Pine bark used at nurseries have a wide range in particle size. Commercial bark producers generally hammermill and screen pine bark prior to aging. Largest particles of finished pine bark supplies are usually 5/8 or 1/2 inch with approximately 20% to 30% fine particles less than 0.5 mm. The fine particles are dust size and create micropores that hold moisture. Therefore, some nurseries use aged pine bark alone as their primary container potting substrate, even for large containers although a pine bark : sand potting mix is likely the most common for large containers . Ratio's of 6:1 or 8:1 pine bark:sand are popular. Sand in the potting mix adds weight, and provides anchorage to reduce blow over from wind gusts. The pine bark:sand mixture may also wet more thoroughly during irrigation than pine bark alone. Infiltration rate (movement downward) of water may be slowed down due to the nesting of bark and sand particles thus slower moving water wets more efficiently. The trade off is that this blend weighs twice as much as pine bark alone and much of the air space in the pot is replaced by sand particles. Beyond anchorage, the major role of container substrates is to provide a reservoir of water and nutrients for root absorption, plant survival and growth.

How much water is typically available in a large pot? A hypothetical example might consider a red maple with a large canopy in mid summer in a 15 gallon container. Analysis of physical characteristics of a 6 aged pine bark: 1 sand (v/v) potting mix indicated that approximately 30% of the volume of the substrate was available water content. Therefore, on a hot day in July for a crop of red maples, 5 gallons of water may be required per container to avoid water stress. Deciduous crops tend to have the highest water requirements during the growing season, followed by broad leaved evergreens and then conifers, however there are many exceptions and each crop may require it's own irrigation strategy based on the moisture retention characteristics of the potting substrate and environmental conditions. (For further details on water requirements of various nursery crops refer to Yeager et al. 1997. Best Management Practices Guide for Producing Container-Grown Plants pg 16-17).

For large containers, growers are usually interested in increasing moisture retention and weight compared to potting substrates used for smaller containers. Adding greater amounts of a fine particle component can be one potential method of increasing moisture retention and weight. The height of large containers allows more of the container profile to drain due to gravitational forces. However, choosing the right fine particle components is important since some components tend to separate from other components and collect at the bottom, creating extremely waterlogged conditions in the lower profile of the container.

Adding 10% to 20% of sphagnum peat moss or shredded coconut husks (coir), to the bark, replacing builders sand, increases water retention, but since peat moss and coir significantly increase the moisture retention of the substrate, containers may become water logged under frequent heavy rainfall or too frequent irrigation. Peat moss or coir containing substrates may require irrigation only every other day during hot weather and even less frequently during other seasons. An additional side note is that ingredients and specifically peatmoss and pine bark should always be pre-moistened before blending. Mixing dry components results in very different air and water retention characteristics than mixing components when they are moist. Dry peat moss and dry pine bark blended together tend to "set up" like concrete. Water may be observed pooling on top of the container substrate. Mixing moist components allows water to swell the peat moss fibers and wet the pine bark particles resulting in a fluffy resilient blend.. (See Table 1 for examples of typical physical properties of various potting substrates).

Most organic alternative components require composting. Un-composted /unstable organic components decompose rapidly, leaving a full container, 3/4 full in a few weeks. Some organic materials such as hardwood bark, may cause phytotoxic damage or stunting of nursery crops unless they are composted before use. Additionally, composted materials often lack the large coarse particles necessary for adequate aeration and therefore should not be used in volumes greater than 50% for addition to pine bark container substrates. Usually, the greatest consideration for using alternative materials is that they are available locally and have the potential to reduce the cost of the potting substrate. Some alternative components that are being used by nurseries include composted yard wastes and animal wastes, composted cotton gin wastes, composted hardwood bark, mushroom compost, municipal compost, rice hulls, peanut hulls, and pecan shells. The stability and chemical and physical characteristics may limit the volume of alternative materials that can be used in a potting substrate. Animal wastes characteristically have high electrical conductivity (soluble salts) and nutrient levels, therefore are usually limited to 10 to 30% volume in potting substrates. Pine bark potting mixes containing compost components will generally have higher pH levels ranging from 6.0 to 6.5 in contrast to pine bark or sphagnum peat moss substrates which even with dolomitic limestone addition frequently range 5.0 to 6.2. The higher pH is generally not a problem for growing most nursery crops but, since composts have a "liming effect" dolomitic limestone should usually not be added to compost containing potting mixes. Some crops may exhibit iron deficiency symptoms under conditions of high pH. Adding a pound of elemental sulfur or iron sulfate may help to reduce the pH. Another alternative is application of an iron chelate, however, the chelating ability of most chelates decreases sharply above pH 7.0. Setting up trials with a variety of crops is highly recommended before making large scale changes in the potting substrate. Remember, the potting substrate only has everything to do with how the crops grow.

Some growers are experimenting with addition of 5% to 10% soil (by volume) to pine bark for growing large container plants. Soil may not increase weight as much as sand. Growers are usually intent on increasing available water content and nutrient retention. The key to adding soil would be to increase moisture retention without limiting aeration and using irrigation practices that coincide with the substrate. Traditionally, if soil is used in potting substrates, it should be sterilized to reduce disease, nematode and weed infestation problems. A possible alternative may be to mine soil well below topsoil layer. Sub-soil from the B-horizon, harvested 6 feet to 10 feet below top soil might be less likely to be infested. Unfortunately, there is great variability in the chemical and physical characteristics of B-horizon sub-soil and their contributions to potting substrates will vary from location to location.

Experiments at N.C. State in 2002 compared plant growth, nutrient leaching and water use of an 8 pine bark:1sand substrate to four commercial soil products (Oil Dri Corp. Chicago, Il) incorporated at 8% (by volume). The Oil Dri treatments were pine bark amended with course particles (mesh sizes 5/20) or fine particles (mesh sizes 24/48) and one of two soil pre-treatments; either calcined (700^{o} F) or hot air dried (250^{o} F). A fresh pine bark source was used in the study. *Cotoneaster dammeri* ‘Skogholm’ was selected as the test crop and grown in trade 5 gallon (14.0 liter) containers. Plants were grown in a plant production area subdivided into 15 separate plots that allowed for collection of all leachate leaving each plot. Ten plants were placed in each plot. Irrigation was applied using spray stakes placed in each pot. Harrell’s/Polyon 17-5-12 (5 to 6 month) controlled release fertilizer applied at 60 grams (10 g N) per pot was used in the study. There were no differences in plant growth, however the fine particle clay treatments reduced daily water application by 1/4 the volume required for a 0.2 leaching fraction compared to the 8PB:1Sand substrate. The savings in water represents 100,000 to 200,000 gallons of water / acre depending on container spacing during the 112 day study. In the grips of one of the worst droughts on record, this was a week of water supplies that many nurseries in the Southeast were desperately seeking during the August 2002. An added benefit was that approximately 2/3 less phosphate was leached from the clay amended substrates.

Commercial soil products such as the Oil Dri clays provide known particle size and chemical characteristics. The commercial products are 2:1 crystallin structured clays that high buffering capacities compared to 1:1 layer clay such as kaolinite. In a separate study, results from Oil Dri clay: pine bark substrates were compared to other B-Horizon soil:pine bark combinations. The only benefit of using a red B-horizon sub-soil was adding weight compared to pine bark alone. However, the 8PB:1Sand substrate had a greater bulk density than any of the soil additions. There was no benefit in plant growth and no observed reduction in nutrient loss or water use. A kaolinite clay used in the study continually separated from the pine bark and washed out drain holes of containers. Additions of 20% and 30% (by volume) of the B-horizon red clay appeared to create anaerobic conditions in the container, as indicated by a putrid smell.

The pool of nutrients available for adsorption and subsequent growth of container crops must be soluble and contained in the liquid solution held by the container substrate. For a grower to understand the nutrient status, this liquid solution must be extracted and analyzed. Obtaining liquid solution or leachate from large containers is a greater challenge than using the Pour Thru Extraction Technique used for smaller nursry containers, since it is difficult to lift the container and collect leachate from drainage holes. However, equipment is available for extraction of solution from large containers. Soil water samplers, called suction cup lysimeters, are available for extracting nutrients from large containers (5 gallon and above). The samplers are installed to the bottom of the container and left in place for periodic sampling of the solution in the container. The sampler consists of a porous ceramic cup attached to the bottom of a sampling tube. One to two hours following irrigation, a vacuum pump is used to create a vacuum in the sampler, which draws water from the container through the ceramic cup and into the sampler. Adequate water collects in the sampler in 10 to 30 minutes which can be withdrawn with a syringe for subsequent EC, pH or a complete nutrient analysis. Three or four water samplers should be installed for plants of similar size and nutrition. Preferably, pH should range between 5.2 to 6.2 and EC in the range of 0.5 –1.0 dS/m is a safe range and should provide adequate growth if the soluble salts truly are plant nutrients. The only way to know for sure is to send a sample to a lab for analysis. Monthly nutrient analysis might be considered for some crops, however at least once a season could provide insight related to subsequent crop nutrient programs. Additional information, cost and ordering information for suction cup lysimeters can be found at the following webpage: http://www.soilmoisture.com/horticulture.htm

Ultimately, the right potting mix for large containers at any nursery is one the grower learns how to manage. Irrigation and fertilizer practices are the liquid components of the potting substrate. Desirable plant growth happens when the balance of well timed irrigation and appropriate rates of fertilizer application correspond to the available water and nutrients retention characteristics of the potting substrate.

Table 1. Physical properties of selected substrates.[z]

Substrate[y]	Total Porosity	Air Space	Container Capacity	Available Water	Unavailable Water	Bulk Density (lbs/ft³) (Dry wt.)
			(% Volume)			
Fresh Pine Bark	86	42	44	13	31	11.9
Aged Pine Bark	82	31	51	21	30	11.9
8 Fresh Pine Bark: 1 Sand	81	31	50	19	31	21.2
8 Aged Pine Bark: 1 Sand	82	27	55	24	31	22.5
9 Aged Pine Bark: 1 Peat moss	79	15	63	39	34	11.9
9 Fresh Pine Bark: 1 Red Soil	80	30	50	16	33	20.0
Normal Ranges	50.0-85.0	10.0-30.0	45.0-65.0 (% volume)	25.0-35.0	25.0-35.0	0.11.9-0.32.5.0 (lbs/ft³)

[z]All analyses performed using standard soil sampling cylinders (7.6 cm ID, 7.6 cm h)
Air Space and Container Capacity affected by height of container.
[y]Substrates are as follows (by volumn): Fresh and Screened Pine Bark - (no aging); Aged and Screened Pine Bark; 8 Fresh Pine Bark:1 Coarse Builders Sand; 8 Aged Pine Bark : 1 Coarse Builders Sand; 9 Aged Pine Bark : 10 Sphagnum Peat moss and 9 Fresh Pine Bark: 1 Red Sub-soil.