THE UNIVERSITY of TENNESSEE
Extension

Conventional Container Production

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The Pot-N-Pot Production System forced us to add the word “conventional” to typical above ground container production; to differentiate from Pot-N-Pot production. A separate handout is available on Pot-N-Pot.

Container production has evolved from metal cans to plastic containers, from soil to pine bark media, and from farm grade fertilizers to controlled release fertilizers (CRF). Even with all the newer concepts, we still see a lot of problems with container media (substrate) and nutrition. Container produced plants are more susceptible to physiological stresses than field grown plants due to the limited root space, soilless substrate and dependency on irrigation. Container substrates can dry out if the irrigation system should fail for 2 days. Producers frequently cause their own problems by seeking cheaper inputs and taking shortcuts in an attempt to increase profits.

Visit a grower with an operation like the one you want. It may need to be far enough away that you would not be considered as competition, in order for them to willingly open up and share with you.

Suggested Reference Books

Request list of Horticultural books, videos and software from American Nurseryman Publishing Co. at 1-800-621-5727. In the Nursery section: "Container Nursery Design" by Dr. Bonnie Lee Appleton, $15. "Best Management Practices for Containers" by So. Nursery Assoc. Under Plant Section: "Manual of Woody Landscape Plants" by Dirr, $55.

Auburn Univ. offers "Starting a Container Nursery Business", Circular ANR-690, for $2.25. Mail request to Extension Publications, Duncan Hall, Auburn Univ, Auburn, AL 36849-5630.

The Inventory

Who will you sell to: retail or landscapers? Where is your market? What major cities are within 200 miles? Will the customer's pick-up or will you deliver? Are you located near an interstate or good major road? Will your product mix include shade trees, evergreen shrubs, flowering shrubs, flowering trees, ground covers, and perennials? Upscale markets will demand named cultivars, rather than just the species (raised from seed).

To improve product mix and cash flow, consider visiting major container producers south of here; buy small containers to bring home and bump into larger containers so plants can be grown and sold in one growing season.

Marketing

How will you position your business among the existing others: Will you grow the same inventory and compete on price, quality and service (delivery)? Will you grow (or buy and offer for sale) some of the new, different, little known species and cultivars that might be difficult to find, difficult to propagate, slow growing? Or will you grow the larger sizes in containers for the summer landscape market?

The plant inventory should be about 80% tried and true, bread and butter plants with good demand. Limit the new, different and exciting to about 20 % of the inventory.

Site Analysis

The most important requirement for container production is the availability of large quantities of good water (See Irrigation). Have an Irrigation Suitability Test run on the water before buying land. (See Water Quality).

Land with a slope less than 5% is desirable. Container pads can be crowned if land is level. Heavy clay or poorly drained soils will require extra grading with ditches or swells to move excess water out of the growing area.

Cold air will settle in low areas. Windy hilltops will challenge irrigation and pesticide application. Check zoning restrictions, future plans of surrounding land, complaining neighbors, etc. Will land be available to expand into?

Site Planning

Plan the location of irrigation ponds, collection ponds, media storage, media mixing, potting, production areas, shipping or loading areas, roads, employee and customer parking, office, security, and etc. Use topographic and aerial maps to assist in planning the operation. One third to 1/2 of the acreage is generally made up of roads, buildings, storage areas, etc. Most roads need to be 15 to 20 feet wide. Semis and other large trucks will require adequate room on all the corners.

Irrigation ponds could be located on high ground to reduce pumping costs. Collection ponds (or smaller basins) should be built to catch run-off water before it leaves the property. This water can be recycled. It can be pumped to the main reservoir and mixed with fresh water.

Container Size: gallon verses # class

Nursery containers are no longer being sized or measured by gallons. The variation in size between container brands was tremendous. Our container industry was challenged for selling container plants by a gallon volume that did not measure up to the volume of the container.

Many containers were not of actual gallons, but either more or less than the ‘gallon’ volume. The reference to gallon, a liquid volume, was not reflective in what the nursery industry was selling. Standardization was needed to base the container size on dimensions not volume.

In 1995, the container class specifications were updated in the ANSI (American National Standards Institute) 60.1, which is used to define the size of the container based on the dimensions of the container.

Each container class is defined with the minimum and maximum cubic inches or centimeters of the container. The symbol ‘#’, along with the container class number is used to reference the container size.

Container classes are #1, 2, 3, 5, 7, 10, 15, 20, 25, 45, 65, 95/100. For small plant containers, i.e. quarts or 4-inch, the designation SP appears in front of the class number. Currently, there are 5 SP classes in the ANSI 60.1 standards.

ANSI (American National Standards Institute) is a private not-for-profit association that promotes and publishes ANSI standards for industries. The adherence to the Standard is voluntary, rather than controlled by the federal government. However, due to the approved ANSI 60.1, any reference to gallons when referring to container size will be an unaccepted practice in the nursery trade.

Type the '#' symbol in front of the number and delete any reference to gallon. Ex. #1 or #5. There is no space.

Space Required for Container Production

One acre will hold about 20,000 - 22,000 #1 containers. The rest of the space is used for walk-ways and roadways.

#1 containers require a minimum of 0.8 - 1 sq. ft. each; place on 1' centers.
#2 containers require a minimum of 1.6 sq. ft. each.
#3 containers require a minimum of 2.4 - 3 sq. ft. each; place on 1.5' centers.
    ("A wide evergreen, like Nellie R. Stevens Holly needs 4 sq. ft.; place on 2' centers.")
    7,700 #3 containers per acre are reasonable.
#5 containers require a minimum of 4 sq. ft.; place on 2' centers.
#10 containers require a minimum of 9 sq. ft.; place on 3' centers.
    3,300/acre.
#15 containers can be placed on 4' to 5' centers.
#25 containers can be placed on 5' to 6' centers.

A Container Operation

A small container nursery might be less than 10 acres; a medium operation 35 to 50 acres; and a large operation about 200 acres. Labor requirements are generally one employee per acre. Start-up investment for container production is high. A return to investment may be seen in 5-6 years. Management intensity is very high and very critical. A lot can go wrong in a hurry with containers. It is not possible to operate a part time container nursery. A competent person must be present at all times.

Liners can be potted most months of the year. Container produced plants can be moved into larger containers for the next season if they do not sell. Roots in containers are more sensitive to heat and cold than the trunk and shoots. A major advantage to container production compared to field production is the ease of harvesting and handling. Container produced plants can be harvested easier and faster than field grown plants. Container grown ornamentals can be transplanted into the landscape nearly any month of the year with proper handling and irrigation at the landscape site. Preferably, avoid transplanting in the hottest and driest months.

Container Yard Floor Management

Remove the top soil. The soil under the topsoil is more stable and removal may eliminate some weed seed. The ground should be rolled and packed to discourage infiltration. Desirable floor covers are 1) 3 to 4" of gravel on top of soil, 2) ground cloth/ground cover/landscape fabric on top of the soil, 3) gravel on top of Geotextile fabric, or 4) ground cloth on top of 4 to 6 mil black poly with no gravel. Do not use poly alone due to disease potential. Most ground covers used are 20 ml woven polypropylene and UV treated with an estimated 5 to 6 year. Groundcovers are available is several widths and can be sown together. In early 2005, one estimate for bed construction was $3500 per acre for gravel and $1000 per acre for fabric.

The Natural Resources & Conservation Service recommends Geotextile fabric under gravel, especially in heavy traffic areas. This prevents gravel from sinking into soil and reduces the need for reapplication.

A slight slope to the land is desirable to aid movement of water from the growing beds and reduce disease potential. Usually, a 1 to 2% slope is adequate; but less than 5%. Crown the beds if there is no slope. One nursery built concave beds with buried drains down the center; while the roads were built high. The goal is to have no standing water around containers.

The width of the beds is often determined by the capabilities of the pesticide application equipment and the ability to apply pesticides effectively into the foliar canopy from 2 sides with an air-blast sprayer (or an overhead boom). The ability to irrigate the plants effectively must be considered, as well as how far labor must carry the plants without a conveyor.

Labor

The H2A program is administered by the Tenn. Dept of Employment Migrant Security in Nashville. Call 1-800-432-5268 ext 571. Labor is a major expense and a most constant problem. Labor is involved in potting, pruning, pulling weeds, applying herbicides, mowing, standing up blown over plants, staking, moving plants, etc. Use good management strategies, i.e.conveyors to move containers or pre-emergence herbicides to reduce time pulling weeds, to reduce labor input.

Container Media (Substrate)

Added next 5 paragraphs March, 2009

The pine bark supply is seriously limited due to the economy. Reduced housing starts have affected the timber harvest which affects the bark supply. Several of the bark suppliers are considering generating **'Whole (pine) Tree Substrate' or 'Clean Chip Residue'** to be marketed as substrate based on 5 years of successful research at southern land grant universities.

There are no serious negatives. I think the researchers have been surprised as I that it is working real well with no shrinkage or serious nutritional or moisture issues with annuals and woody ornamentals. It is used immediately, no composting.

There may be slight adjustments required in pH, nutritional and moisture management. The soluble salts have been high for the first 2 weeks until the excess leaches out and the pH is a little high. The bi-weekly monitoring of the leachate with a Myron meter would be wise while we learn to grow with it.

A nursery would be better off to have the entire crop growing in the same media or substrate to make it easier to manage, rather than two different.

The **Whole Tree Substrate** is made in the woods by grinding the entire pine tree (trunk, branches & needles). The **Clean Chip Residue** is made from the bark, branches and the needles after the wood/trunk is chipped. (The residue left from making the chips) It is approximately 40% bark.

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Pine bark has been the media of choice with particles in the 3/8 to ½-inch size. It is not sterile, but is considered initially to be disease and weed free. It will take some thoughtful planning and good management to keep it that way. Bark should be stored on a concrete pad, thick enough to accommodate the semi-truck that delivers it. The pad should be located on high ground so that runoff water does not wash weed seed or disease pathogens onto the pad and contaminate the bark.

Because of the current demand, much of the pine bark delivered today is very fresh or referred to as being 'green'. The only concern using green bark is water management issues. The particles will be a bit larger and it will not hold as much water. The use of a wetting agent should help. It is also suggested that you test the pH of each incoming load of pine bark. We have occasionally found loads that tested below 4, indicating possible formation of acetic acid while stored in tall piles. Rainfall or irrigation may remove the acid in a few weeks if it is stored in piles less than 4 feet. Finding a pH of 4.2 or higher a few weeks later will allow use. Never use a bark that repels water.

Pine Bark sources:

McMinnville:	Morton's	931-473-2854
Clay County:	Barky Beaver	800-737-3646
Memphis:	J&B Co.	800-346-6398
Georgia:	Joe K. Smith Trucking	770-887-3125
	Pioneer Southern	800-552-8200
	Wooten Wood Products	912-375-6039
Alabama:	Sims Bark	205-381-8323
Carolina's	Seaside Mulch	800-641-0881

It is recommended to keep equipment on the bark pad clean. The tractor or skid steer with the front end loader should be pressure washed to remove mud from the tires and underneath the equipment each time it is returned to the pad. Avoid excessive driving and walking across the pad. Phytophthora root rot, other diseases and weed seed can be spread this way. Practice good weed control in the vicinity. Do not allow weeds to grow in or directly around the bark pile.

Turn the bark pile regularly if it is more than 4 or 5 feet tall. This will prevent the bark from drying out or allowing acetic acid buildup. Acetic acid can lower the bark pH to harmful levels. Irrigate the pile if necessary to prevent the bark from drying to the point of becoming hydrophobic (hard to wet). Construct some tall sprinklers to handle this. One nursery shoves a 'Drive in Well Point' into the pile every 3' to internally wet the bark. They move it over when water begins to bubble up. It is about 4' long, available at TSC for about $70.

A white fungal growth may be seen binding the particles of bark together. The media actually repels water. The pH will be less than 4.3, perhaps even 3.8. Plants are not growing, a light to yellowish green, perhaps with some dying. Once the substrate becomes hydrophobic and repels water, a 1% surfactant solution must be used to actually water the containers, a drench, not just a light spray over the media surface. Irrigate lightly afterward. Remove several root systems from their containers after 3 irrigation events (2-3 days) and look for dry spots of media around the sides of the root system. Repeat the procedure if dry spots are found. Link

Wetting agents (Aqua-Gro or any commercial surfactant or a liquid dishwashing detergent will work almost as well, but choose one that does not create excessive suds. Ajax is good; Dawn, Ivory, Joy and Palmolive are bad to suds.) Merely spray the solution over the entire media surface of the containers to reduce the surface tension. This method may work to re-wet a media pile of dry or green bark. Spray it with either a backpack or handgun. Use a 0.5 to a 1 percent solution. A 1% solution is 1 gal in 100 gallons. A larger spray tip would allow the operator to move faster. Dry or green bark can also be sprayed on the conveyor with the solution prior to blending. One pound per yard of granular Aqua-Gro can also be added in the blender when mixing to facilitate initial watering.

Occasionally, water will seek a channel through the container media in containers, and leave dry areas. The use of a wetting agent is recommended to provide more complete wetting of the entire root system. This allows reduced cohesive and adhesive tensions of the water and allows lateral movement and more uniform wetting. Drench with a 0.5% solution of the wetting agent twice a year (in March and August for example to avoid issues) to help re-wet dry spots in the media.

Avoid using sand in the media. If sand is used, do not use sand from a river or builder's sand where the particles are uniform. River sand can have contaminants such as nematodes, pathogens, seed, etc. Sand from a pit would be safer. Order coarse sand, perhaps unscreened. Sand of uniform particle size clogs pore space in the bark media which makes drainage worse and is very detrimental to plant growth and livability.

Sand increases the bulk density of the media. The bulk density determines the amount of insecticide required to meet fire ant quarantine regulations. The heavier the media the more pesticide is required to control fire ants.

One of the biggest problems of container production is water management. Media that stays too wet too long is capable of killing roots from a lack of sufficient oxygen, provide a habitat for root rot, cause an anaerobic condition to develop and ammonium levels will increase. Media that becomes too dry can stress the crop by forming acetic acid and developing hydrophobic (hard to wet) bark. Both conditions will lower the pH. Learning how to correctly water is difficult and critical. Irrigation management should not be handled by a new employee or an employee with little irrigation experience.

Learning water management is one thing. Having a media that will not drain is another. The cause might be: packed too tight, too much sand, or too many small particles. The height of the container also influences the wetness and dryness of the media. From the saturated layer at the bottom, the media becomes drier as you move up. Have you noticed how containers do not differ much in their height? This allows us to use one media recipe. Roots require oxygen to survive and grow. Poorly drained media is an invitation to reduced growth, root rot and death.

Once potted, pine bark can dry out quickly and can be difficult to re-wet. A fine textured organic amendment can be added to the pine bark to increase lateral movement of moisture in the containers and actually hold additional water and nutrients. Research has shown that 10-20 percent is helpful, but do not add more than 25 percent. Peat moss, fluff (ground household garbage), rice hulls, mushroom compost, cotton gin trash, composted yard wastes, coir, etc., are possible amendments. It is critical that the product be reasonable in price, consistently available and consistent in its characteristics (particle size, pH, texture, etc.), load after load. The additional expense must be considered. A blender (mixer) becomes much more necessary when adding an additional amendment. A fine textured amendment will be helpful in crops produced in all sizes of containers and especially when the water supply is short.

A 4:1 ratio of pine bark:organic amendment is a fairly common media blend. The units might be yards, cubic feet, scoops, wheel barrows or boxfuls; anything to measure in. A cubic yard is: 3' x 3' x 3' = 27 cubic feet.

A blender (mixer) is required to properly mix or blend the controlled release fertilizer (CRF), lime and minor elements with the bark and any other amendments. It is imperative that each container receive equal amounts of each of the amendments. Add the controlled release fertilizer last during the blending. Stop the blender when adequate blending has occurred to avoid damaging the prills.

Correct, proper blending of the ingredients is critical for uniform foliage color and growth. Also, if controlled release fertilizers are incorporated, the coating of the fertilizer prills can be weakened by the abrasive action of the blender sides if it is allowed to run too long. This might allow too much fertilizer to release too rapidly and cause burn to young, tender roots of freshly potted liners. Media (bark, fertilizer, lime, minor elements) can be mixed ahead of time, but must be stored in the dry to prevent the nutrients (salts) from releasing from the controlled release fertilizer. Moist bark or amendments can cause the fertilizer to begin releasing. Tender roots can be burned or killed almost immediately if they are potted into a media that has high soluble salts.

A new producer may think that a 1-yard blender will be large enough when just getting started; but, will be surprised how soon they wish they had purchased a larger size. Consider having your blender built slightly over size to reduce spillage, fall-out, etc., while blending. Have a 2.2-yard blender built instead of a 2. This provides sufficient space for all of the ingredients, without spillage. A 1-yard mixer was priced at $6,250; 2-yard at $7,850; and a 3-yard at $10,500 in Aug, 2007. A 16' conveyor to lift the media from the mixer outlet to a wagon or potting machine was approximately $3,800. If a mixer is not available, consider purchasing a blended media from another nursery with a blender and healthy crops.

Blenders and Potting Equipment. There are several sources in middle Tennessee that will custom build blenders, pot fillers, conveyors, tracking trailers, etc. Link to

Several nurseries use an in-line mixing system. Hoppers are placed in-line to hold and meter out lime, minor elements, and controlled release fertilizer over the bark as it passes below on a conveyor belt. A hood over the final few feet of the conveyor keeps the ingredients in place while being mixed by high speed paddles. The media then falls a few feet into a small vat, where it is picked up and carried up a conveyor to a potting machine or pot filler. The stainless steel hoppers will not corrode from the fertilizer salts.

Prices for the media mixing systems are difficult to extract from the shops because every unit is custom made to fit a specific site or need, plus steel prices fluctuate, etc. In 2001, a 6 yd hopper for the pine bark, a 4 yd hopper for the finished product, 25' of conveyor between the hoppers, and 2 fertilizer boxes (about $3,500 each) was in the neighborhood of $40,000.

The number of containers produced and labor costs may encourage the consideration of purchasing a pot filler or potting machine. Be aware of the maintenance and the number of laborers required to keep the machine running at maximum efficiency when potting. Pot fillers don't have as many moving parts. They are useful for containers larger than #3 or #5 containers. They keep the process moving and save workers' energy.

Potting Procedure

Liners should be readied for potting, especially container grown liners. Remove the container and remove the top half inch of media to remove any weed seed. Loosen the root system and remove any circling roots. If the roots are root bound and circling, consider cutting away the outer half inch of roots and media from the sides and bottom.

Research by Ed Gilman, Univ. of Fla, suggests removing the outer inch of roots and media of air pruned containers because the root deflections occur further inside the rootball. This extreme effort is to remove deflected roots and avoid future circling and potentially girdling roots which is more critical on trees.

Fill media around the root system making sure the media is firm around the roots to remove any air pockets. The end goal is for the media to settle after several irrigation events (about a ½-inch below the lip of the container) to allow space for any future topdressed materials and to trap water. Avoid using too much force to pack the media too tightly. Too tight would reduce the airspace in the media and prevent normal water movement down through the media which may ultimately cause plants to die. Container plants need to be watered very well immediately after being potted to provide moisture, leach excess salts and settle the media.

Planting liners too deep into the media is a major cause of poor growth, decline and even plant death. Tall liners should not be planted deep to increase their ability to stand up. Budded plants or cut-backs should not be planted too deep in order to hide the crook. Plant so the root flare will be visible, especially with tree liners. Caution labor repeatedly and then check and re-check to ensure a proper planting depth. Do not allow labor to place the liner (bareroot or potted) in the bottom of the container before adding media. This can cause long term harmful effects to the plants. It could mean not having a crop to sell.

One way to ensure the potting crew knows where to place the root system is to draw a line at the transition zone between the root system and the trunk or major stem. This line will make it easy for management to spot check later. This is an extra step; but consider your potential loses verses the potential gains.

Container grown liners may have previously been potted too deep when they were potted the first time. Potting depths may need to be adjusted while repotting to ensure roots are located at the proper depth in the container. The old 'Rule of Thumb' of planting at the same depth they were grown could be very, very incorrect. Planting depth is also a major concern with field produced liners.

If the nutrients are not incorporated into the media, it is a good idea to add the measured amount of CRF with minors when the container is about 3/4 full. Spread them over the media and finish filling the container with media. This will prevent losing the nutrients when the containers blow over. It is great for large containers, rather than topdressing.

Re-potting, Stepping-up, Shifting-up or Bumping-up
Container grown plants must be re-potted annually before they become root-bound. This is especially important with container grown trees. Circling roots can ultimately grow, become girdling roots and cause tree decline several years prior to death. Shrubs in #1 containers are usually stepped-up into #3 containers; 3's into 7's or 10's;

7's into 15's; 10's into 25's. However, #3 container trees are often potted in #10 or #15 containers depending on growth rate.

The nutrients will also be depleted from last year. Compensate for the lack of nutrients in the old rootball. The same media and amendments used to pot new liners would be used in re-potting. Then topdress the recommended amount of controlled release fertilizer with minors (for the size of the old rootball) across the old rootball and then cover it with no more than 1 inch of unamended bark to avoid spillage from blow-over. Without this additional topdressing of nutrients, the entire plant may show nutrient deficiencies during the growing system.

Fertility

There are several controlled release fertilizers (CRF's) on the market: Osmocote by Scott's, Nutricote by Florikan, and Harrell's (Polyon) etc. Each contains nitrogen, phosphorus and potassium. Some formulations also contain the micronutrients. They are available in 3, 6, 9 or 12 month release rates (longevity) and available with several ratios of nitrogen, phosphorus, and potassium. Price of CRFs can vary by the time of the year ordered and the amount.

All CRFs will perform optimally if managed correctly. The release mechanisms of nutrients from the various CRF's function differently. **Nutricote** is released basically by temperature. Moisture is involved but is not as important as temperature. **Polyon** (by Harrell's) fertilizer is released by temperature only. It lacks an early release in spring, because of cooler weather. Therefore, Harrell's recommend either a liquid supplement in spring (150 ppm of 20-20-20 twice a week) and reduced as summer temperature progresses or a quick start fertilizer blended with the CRFs. In Tennessee, our spring rains prevent us from gaining much with liquid feeding, because of limited irrigation. If we do not need to irrigate, we do not liquid feed. **Osmocote** is released by temperature and moisture. Typically, Osmocote will release earlier in the spring than Nutricote and Harrell's.

A good management strategy is to keep all empty fertilizer bags for one growing season and tie into bundles by Lot numbers. The Lot number is stamped on each bag by the fertilizer company as a reference to the date and location of manufacture. If problems arise with a product, the bags and lot numbers can be valuable evidence.

Nutricote: www.florikan.com 800-322-8666
Polyon by Harrell's: http://www.harrells.com/products/nursery-greenhouse/
866-245-5559
Osmocote by Scott: http://www.scottsprofessional.com/en/range/19 800-492-8255
Link to Sources of Allied Supplies & Services

Agricultural grade fertilizer, such as triple 8, 10, 13 or 15, can be incorporated at a rate of 1 pound per yard of media that contains the normal rate of CRF in order to provide a quick release fertilizer. It should only be used in early spring potting i.e. March 15 to May 1. It can also be topdressed over containers that were potted earlier. (One level teaspoon / #1 container, 2 tsp/ #3; 1 Tbl / #5; 2 Tbl/ #10; 3 Tbl/ #15; 5 Tbl/ #25 container) The ag. grade fertilizers are very soluble and will only last about 3 weeks. If used too early in the spring, the nitrogen and phosphorus will be leached out of the container by the spring rainfall and not benefit the crop.

When selecting a CRF consider the longevity of the product and the time of year the ornamentals are potted. Use a 12 to 14 month CRF when potting in late winter to late April; an 8 to 9 month CRF material if potting April to June or July; and use a 3 to 4 month if potting after late July. Avoid using high nitrogen rates on *Malus* and *Pyrus,* because the vigorous growth produced is more susceptible to fire blight infection.

Fertilizer labels suggest a low, medium or high rate based on the plants fertility requirement (or salt tolerance). Select the correct rate for the crop. The high rate should only be used with crops that are considered high feeders. Plants can be successfully grown with lower rates of fertilizer if irrigated to minimize leaching. This is easily done with micro irrigation and can be achieved with overhead irrigation if cyclic applications are used. The BMP manual offers a list of plants and their nutrient requirements.

> pH is the term used for the degree of acidity or alkalinity (basic). The pH scale is 1 to 14 with 7 being neutral, 1-7 is the acid side, and 7 to 14 is the alkaline side. Lime makes the media more alkaline; sulfur makes the media more acid.

If the pH of the irrigation water routinely tests 7.0 or higher and the bicarbonate levels are reaching 200, choose a sulfur coated formulation (which is acid forming), such as Osmocote PRO. Most irrigation water in Tennessee from lakes and streams will test pH 7.0 to 7.5 (occasionally higher) and wells will vary from 4.0 to 8.0. A water pH greater than 7.0 will cause the container pH to increase over time.

Strive for a media pH between 5.0 to 6.0 during production. More nutrients are available to the plant for uptake in this pH range. If the pH range is higher or lower, some nutrients may not be available to the plant. Some plants (junipers and nandina) grow better in a container media with pH of 6.5 to 7.0; whereas, plants like rhododendrons and azaleas grow better in a media with pH around 5-5.5.

In order to keep the pH within the optimal range, we suggest beginning with 3 pounds ground Dolomitic limestone (avoid pelletized) per yard if the irrigation water pH is less than 7.0 and adjust from there in the future. If the irrigation water pH is 7.0 or higher, do not add lime to the media. [Regular agricultural lime is calcium carbonate. Dolomitic lime contains calcium (Ca) and magnesium (Mg). In past years, 6 - 10 lbs of dolomitic lime was recommended per yard, however, research by Dr. Robert Wright at Va.Tech. has shown that often no lime is needed.

Minor elements (minors or micronutrients or trace elements) must be added to container media since none of the minors occur naturally in the components of container media. In contrast, field soil does contain the minor elements, generally in the correct amounts in Tennessee and seldom are applications of minor elements recommended. A minor element package is commercially available as MicroMax, Esmigran, STEM, STEP and Fritted Trace Elements. MicroMax, used at the labeled rate of 1.5 pounds per cubic yard of media, has proven to last longer than the other products in research trials. It is essential that proper blending occurs so that each container ends up with the same amount of nutrients. Minor elements include: iron (Fe), sulfur (S), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), manganese (Mn), boron (B) and molybdenum (Mo).

Other nutrients that can be added to the media include gypsum, Epsom salts or iron sulfate. Gypsum (calcium sulfate) provides calcium and sulfur without affecting the pH. Epsom salt (magnesium sulfate, $MgSO_4$) provides magnesium which aids in chlorophyll development. Iron sulfate or 90% sulfur can be added for crops like azaleas and some oak species that need a lower pH. If any of these products are used, 1 pound per cubic yard is sufficient of each. One pound per yard of granular Aqua-Gro can be added in the blender when mixing to facilitate initial watering.

Granular Subdue can be incorporated into the media that will be used for those crops prone to root rots, such as dogwood, azalea, holly, juniper, and yew. It can offer control for 2-3 months. The best prevention for root rot is to not over water.

If a soil mixer or blender is not available, consider purchasing a blended media from another nursery with a blender or purchase a CRF that contains the minor elements, for example the Osmocote PRO products. Most of the major fertilizer companies have a similar product. These products allow growers to grow plants in 100% pine bark and supply all of the nutrients required for that growing season. There are some drawbacks to topdressing however, such as the fertilizer spilling out when the pots blow over. It is suggested to apply the correct amount of CRF when the container is three-fourths filled then finishing potting. This avoids loosing the CRF if tipped over. Research results have shown that plants grown with microirrigation grow a slightly bigger/better plant when nutrients are incorporated in the media.

Liquid feeding can be used to compliment the controlled release fertilizer during the growing season. It is not recommended to use liquid fertilization as a sole source of nutrition. As discussed above, it can be used in spring to supplement nutritional requirements until CRFs release. However, liquid feeding can also used during summer months with CRFs when high nutrient demand plants are grown or when the CRF depletes early. Typically, a water soluble fertilizer like 20-20-20 is applied at a rate of

150 ppm twice a week. Stop liquid fertilizer applications by Sept 15 to allow normal acclimation for winter dormancy. For ease and convenience of using liquid fertilizers, a plumbed-in injector is most convenient.

Occasionally by mid-summer a few plants may have varying degrees of yellow foliage or chlorosis. Yellow foliage, sometimes with dark green veins, can be caused by 1) a media pH too high for the crop, causing iron to be unavailable, 2) root rot, or 3) plants planted too deep, causing root death. Chlorosis of pin oak may be more complicated than just a high pH[1].

To determine the exact cause of the yellow foliage, inspect the roots. The first major root should be within the top 3" of media. If several dead roots are found in the affected containers, send a sample of roots collected from several containers to the UT Diagnostic Lab through the local Extension office. Check the pH of the media or the container leachate. A high media pH (leachate) can be lowered by applying dry elemental 90 percent sulfur over the media surface of the container. Seek the advice of a specialist to make sure this is needed and for rates.

Sulfuric acid is often injected through a proportioner to neutralize alkalinity and reduce the pH of irrigation water if the pH always tests over 7.0. But do not go to the trouble and expense of injecting sulfuric acid to solve irrigation water problems until you eliminate lime from the media and evaluate the use of sulfur coated controlled release fertilizers on the next crop. Use a professional to help guide you through this process.

Monitoring Nutrition

The Virginia Tech Extraction Method or the Virginia Tech Pour Thur is an easy, convenient method to monitor the pH and soluble salt levels in the container media without an expensive and time consuming analysis sent to a commercial lab. It can help detect a problem before visual symptoms occur.

The leachate caught in this manner tests the same solution available to the roots. Fertilizer prills are not crushed. The collection and analysis can be done in the field with an accurate meter; results can be learned immediately. Or collected solutions can be brought to the office in sterile bottles for immediate

> The term 'electrical conductivity' or EC refers to the free charged ions available in the water. Soluble salts and EC refers to the same thing. More simply it measures the salts or fertilizer nutrients in the media solution available to the roots.

[1] In 2004, Tom Stebbins in the UT Diagnostic Lab found where Drs. Larson and VanDyk at Iowa State Univ., Hort. Dept. wrote that the "lack of available iron can be magnified by low soil temperatures; high soil moisture; large amounts of copper, manganese, or zinc; or excessive application of phosphorus" (in the soil).

testing or mailed to a commercial lab. Samples held for more than a day should be refrigerated.

No action should be taken from one reading, regardless of how high or low the numbers may be. Continue to monitor every 2 weeks and compare the results. If a problem is found, monitor more often, perhaps after irrigation or rain events totaling one inch. The results can be plotted on a graph with the dates along the bottom and the soluble salts on the left. The pH should be between 5.0 – 6.0 during production. Values above 7.0 may cause yellow foliage and poor growth.

Below are some suggested soluble salt readings for different types of crops using the Virginia Tech Extraction Method:

Salt Sensitive Plants	0.50 – 0.75 mmhos
Non-Sensitive Plants	0.75 – 1.50 mmhos
Deciduous Plants	2.00 mmhos

Irrigation water will usually supply some soluble salts, about 0.1 to 0.5 mmhos. That value should be subtracted from the container leachate readings to learn what is being supplied by the fertilizer.

Benefit of Monitoring Nutrition

Continued high soluble salt readings may indicate that the fertilizer has released too much and the containers should be leached to prevent root damage. Excess salts will kill roots. Leaching is the process of removing excess fertilizer salts by extending the irrigation time, then waiting an hour or so and irrigating again to flush excess nutrients out. Retest the leachate after irrigation or rain events totaling 1-2 inches. Leach again if necessary. Continued high readings could also be caused by insufficient irrigation to leach excess salts away.

Continued low soluble salt readings in late summer may indicate that the fertilizer has depleted. Monitor weekly. If the soluble salt readings of the containers continue to equal the irrigation water readings, then consider topdressing additional short term fertilizer or liquid feeding until Sept 15. Low readings can also indicate excessive irrigation.

Detecting continued high and low soluble salt readings or continued high or low pH readings are ways that routine nutrition monitoring can indicate potentially critical problems and allow sufficient time for management to correct the issue before growth is affected.

The Myron L Agri-Meter reads both pH and EC. It is a good durable meter to use in the field. The Myron L Agri-Meter is available from Griffin at 1-800-766-6347; possibly BWI at 1-800-489-8873; & CASSCO at 1-800-962-1922 for about $360 in 2009. A qt. of 7.0 pH buffer solution and a qt. of 3.9 standardizing solution is $20 each. A small protective carrying case is $33. The pH sensor must not dry out. Keep the pH 4.0 solution in the small tube around the pH sensor year around. Make a note to check it monthly when not in use, especially during the winter. Avoid bouncing it in a dusty vehicle. Store away from excessive heat. Do not allow to freeze.

The Virginia Tech Pour Thur procedure for small containers:

1. Select 1 or 2 containers of several different species at random. Flag and label (number) them so the same plants can be monitored throughout the growing season. Sample them about every 2 weeks, 1 hour after the irrigation event ends. If cyclic irrigation is used, sample 1 hour after the last cycle of the day finishes.

2. Make preparations during the hour after the irrigation is shut off: collect some irrigation water, calibrate the meter, test and record the irrigation water. Container sizes of #1 and smaller can be placed on a 1" thick ring of PVC pipe sitting in a shallow, square aluminum or plastic pan. It will be easier to pour from square pans. Larger containers can be placed on concrete blocks. Sufficient height is required to allow the leachate from a drainage hole to be collected into a clean bottle, pan or the meter itself.

3. After an hour, place the pots into the trays or on blocks. Tilt the containers on blocks to facilitate the leachate to drip into the pan. Twist the pot so a drainage hole will be turned to the front. A wood scrap or a rock can be used to help tilt the container to allow the leachate from one hole to drip into the pan.

4. If they do not begin to drip or are too slow, pour 1/4 cup of water slowly over the surface of the media for #1 and #3 containers. Repeat if necessary. For #10 and #15 containers, use about 1-quart of water. Use no more water than is necessary.

5. Collect the leachates (6 to 8 Tablespoons) into sterile bottles or test on site with the meter. Be sure to rinse the cup and probe of the meter 2 or 3 times with the next leachate to be tested, before testing it. Record the pH and soluble salts into a table so future readings can be compared. See the sample table below. Additional columns will be required for bi-monthly readings.

6. Be consistent with the procedure! It is critical that the moisture level be similar at each testing.

	May 2		**May 16**		**May 30**	
Container Number	**pH**	**Soluble Salts**	**pH**	**Soluble Salts**	**pH**	**Soluble Salts**
Irrigation water	7	0.25	6.9	0.1		
1- maple	5.8	1.6	6.1	1.8		
2- oak	5.7	1.5	5.6	1.1		

The Virginia Tech Pour Thur Procedure for Large Containers:
Collecting leachate is more cumbersome with large containers than small containers. One way to collect leachate is to place a container with its plant in a strong plastic bag with no holes in it. Pull the bag opening tight around the bottom of the container lip to prevent overhead irrigation water or rainfall from entering the bag. Use duct tape to secure it in place. This bag will collect and hold the leachate that moves through the container during irrigation or rainfall.

How much irrigation is needed?
No more than 20% of the irrigation applied (whether overhead or from microirrigation) should leach out of above ground containers or PNP. That means that 80% of the water stays in the container for plant use. This is referred to as a 20% leaching fraction.

The Leaching Fraction is the volume of leachate divided by the total volume of irrigation entering the container multiplied by 100. This fraction should be 10-20%.
One way to determine the Leaching Fraction is to use 2 strong trash bags with no holes. Select an empty container similar in size to the plants growing in the area and open one bag in the container and pull the bag opening over the edge of the container. This can be used for overhead or PNP by placing a micro sprinkler into the bag to collect the irrigation water and rainfall. Water (A) collected in this container tells us how much water is applied to each plant during irrigation. [Actually, the foliage (canopy) may deflect some water.]

Place a container with its plant in the second bag and pull the bag opening tight around the bottom of the container lip. Use duct tape to secure it in place. This bag will collect and hold the leachate (B) that moves through the container during irrigation and rainfall. Compare the volumes from bag A and bag B. The amount leached (B) divided by the total amount applied (A) multiplied by 100 tells us the percent leached or lost. This is referred to as the Leaching Fraction. The goal is 20% for conventional and PNP production.

Example: If 80 oz is applied per container (A) and 20 oz leaches out (B); 25% was leached, which is too much. 10 to 20% is the goal. Cut back on the amount by cutting the time or use multiple cycles. If less than 10% was caught, insure that the entire root systems are moist. Ten percent may only be possible with cyclic irrigation. This method will allow collection during one irrigation or multiple events.

Water Quality

Test the water quality of the water source before starting and investing in a container operation. Have an irrigation suitability test run before beginning production. See the last page for the parameters that should be tested and desirable ranges for specific elements in irrigation water. The BMP manual offers suggestions for high bicarbonates (high pH); sodium induced problems; and residues on foliage.

The test may cost $50, but could help avoid serious problems. Several labs are available: A&L Lab 1-800-264-4522; Scott's 800-743-4769 ext 46; MicroMacro 800-TEST-MMI. Contact them to learn the collection procedure they prefer, etc. Collect the sample on Monday or Tuesday and send it immediately. Allow a well to run for 30 minutes if new or seldom used. Obtain the sample from where the intake would be positioned in a stream, lake or pond. Rinse the container several times with the irrigation water. Fill the container absolutely full and tighten the lid. It would be good to sample twice during the first year; following wet and dry periods to obtain base line data, for future reference.

The pH of surface water collected from a pond, stream, or lake during extremely warm conditions, can be very high. Why? Because there is a constant exchange of oxygen and carbon dioxide from the surface of water, due to the photosynthesis of aquatic plants and the exchange from wind. Often the alkalinity of the water will dictate just how high the pH can go. For instance, in low alkalinity water the pH may climb over 9.0 in the afternoon, but high alkalinity water may only get to around 8.5 --- another reason to test irrigation water!

The water sample from surface water sources should be collected using a grab sample technique. Collect the irrigation water about 2 feet below the water surface if the pumps are not running. If the pumps are running, just collect the water from a nozzle or faucet. A simple and unique water sampler can be made using an 8-foot long piece of 2-inch diameter PVC pipe, with a string through it, and attach a tennis ball to the string. Pull the string tight and drop the tennis ball end of the pipe into the water and allow the ball to float lose at the desired depth. Pull the string and tennis ball to the PVC pipe. This will prevent water from leaking out of the pipe. Release the water into a bucket and pour it into the bottle to send to the lab.

Irrigation Water Modification

Use a professional to determine what needs to be done if the irrigation water is not suitable to use. A professional may know how to modify the water chemically or physically. Installation of a proportioner to inject chlorine or sulfuric acid or filters to eliminate particles in the water may be required. Sulfuric acid is used to lower the pH and chlorine to reduce algae and pathogens.

Irrigation

Group plants by water need to maximize plant growth and increase irrigation efficiency. This may mean moving the #3 junipers to the same irrigation zone as #1 azaleas. The Best Management Practices manual provides a list of plants by their moisture needs. Link Small containers do not require as much moisture as larger. Plan to increase the rate during the season as plants grow larger and temperatures increase.

How much irrigation is needed?

Approximately 1 pint of water is required for a #1 container per day and about 1.5 gallons of water is needed for a #15 red maple during the hottest summer temperatures. One half to two inches of water per acre per day are required with overhead irrigation. This is equivalent to approximately 12,000 to 50,000 gallons of water per day per acre.

There will be about 100-200 daily irrigations per year depending on rainfall and plant need. About 80-90% of this becomes run-off either recharging irrigation ponds or leaving the nursery production area. In any given year, about 2 to 3 million gallons of water are used per acre per year. To help determine if irrigation recycling ponds are large enough to handle runoff water and rainfall, consider that 27,000 gallons is 1 acre inch. Do you have enough water to irrigate during an extended dry period? NRCS staff can assist with calculating pond volumes.

Construct catch basins, recycling ponds and grass waterways to catch all run-off. If at all possible, do not allow runoff to leave the nursery property. Avoid using the herbicide Goal if the water is caught and recycled (check the label for herbicides that may include oxyfluorfen as an ingredient). Control weeds in the drainage ditches and the irrigation pond edges. Keep spare parts so that any repairs can be made to the irrigation system in less than 24 hours.

Place the intake as far as possible from where runoff water is returned from the production area to reduce the likelihood of introducing the pathogen Phytophthora. Phytophthora spores settle and remain with the soil near where it enters.

Three irrigation applications (events) per day: 6am, 11am, and 4pm of 30 minutes each may keep more water in pots than 2 hours of irrigation at one time; and use less water. Late afternoon irrigation should be completed in time for plant foliage to dry by dark. This will reduce foliar pathogens on plants like dogwood, laurel and photina. Early morning irrigations will not cause a similar situation since the morning dew is already present and the sun will soon dry the foliage.

Inspect the root growth and media moisture of several containers frequently. Don't be afraid to knock a few plants out of their containers and get your hands dirty. Much can be learned by doing this, i.e. media saturation, quality and amount of root growth. Perform this practice over a box or flat surface so media and fertilizer can be used to re-pot the plant. Never request assistance without knowing the condition of the roots.

Sprinkler head arrangement should be designed for 100 percent overlap. Periodically use rain gauges to measure irrigation volume and distribution. Move them around periodically. Excessive amounts of water are required when there is poor uniformity. Replace any heads when the output is not within 10% of the others. Determine what the output is per hour in inches. Check lines daily. Make it a habit to pick all blown-over plants prior to each irrigation event.

Request assistance from Extension specialists or irrigation specialists to determine sprinkler head arrangement, pipe and pump size, etc. Irrigation laterals can be placed on top of gravel or ground fabric, but many times the laterals are buried prior to spreading gravel or laying fabric on the production bed. It is a good idea to pour concrete around buried pipe junctions and turns to prevent joints from slipping apart from the sudden impact each time the water is turned on over time. Install freeze plug drains at all low points. When the water pressure drops below 2 pounds, a spring mechanism opens a ball valve and allows the pipe to drain; avoiding busted pipes.

You may wish to consult with Extension regarding how to best control algae. There may be multiple choices depending on where it is and the situation. Algae can be a major problem in irrigation systems by clogging lines, sprinklers, microsprinklers, and requiring frequent backflushing of filters. Algae formation can be reduced or eliminated in pipes by painting all white PVC above ground a dark color. This stops the light transmission that allows algae to grow inside of white PVC pipe. Reducing nutrients in irrigation water such as phosphorus or nitrogen can reduce algae.

An algae bloom can occur any month in ponds. Producers currently prefer using an aquatic dye to block light rather than using herbicides. Grass carp are also effective in controlling various types of aquatic weeds and algae. Contact Extension specialists to identify aquatic weeds and suggest solutions. An aerator helps control some types of weeds, but the size must be matched to the size of the surface.

Ideas or Methods to Reduce the ‘Blow Over’ Problem of Tall Plants:

Plants blown over lose topdressed nutrients and will miss irrigation events. Plants can die if left laying during as few as 2 irrigation events. Their foliage can be burnt by lying on hot gravels or fabric. Later, the plant may have burnt or dead foliage on one side. Make it a habit to pick all ‘blow overs’ prior to each irrigation event.

None of the methods listed below are perfect. Many are abrasive to the bark. Some are expensive and others are inconvenient for labor to work around.

1) Drive 1 to 2 pieces of **rebar diagonally** thru the 2 outside rows of containers, on all 4 sides of each block of plants. The theory is if the outer edge stands, the inner pots will usually stand. Additional pots can be staked down as necessary. The rod can be lifted out later by sliding a 3/4 or 1" box-end wrench over the rod a few inches and lifting in the opposite direction the rods were driven. This works on many sizes of pots with the correct length of rod. If a second rod is required on windy sites, drive the rods diagonally in opposing directions. Soil type will dictate the rod length to be in the soil (6 to12"). More sandy soils will require longer rods. Four rebar stakes driven through #45 pots sitting on top of the soil failed to hold plants upright for one grower, but it did keep them at 45 degrees until they were resettled. Perhaps the rods should have been driven deeper into the soil.

2) A grower in Alabama drove one metal stake vertical down beside the outside of #5 pots and two stakes on opposite sides of larger sizes. He bent the top into an 'L' or an upside down 'V' to hook over the lip. A vise or good gig made with simple bolts works well with muscle or a torch. The length of the rods must be longer in sandy soils.

3) Erect a clothesline wire down each row or occasionally between 2 rows of staggered pots, perhaps 4 to 6' high depending on tree size. Secure the trunks to the wire with a women's knee high stocking or a commercially available device. This allows some movement to build stem strength. This method can be use for all sizes but may be more convenient for containers larger than #15, or at a retail lot. (If micro irrigation is used, a lateral water line can be shared by 2 rows. Every other middle is clear for walking. The irrigation line can be tied to the wire, with the spaghetti tubes hanging down into the container below.)

4) Connect each container together with each other with a large clip made with ½" rebar bent into a 'U' or C' with a long base, turned upside down. The length of the base controls the spacing desired between containers. The length of the other 2 sides should be long enough to reach or nearly reach the container bottoms.

5) Container Sliks are molded black plastic trays with holes to support either trade, 1, 2, or #3 containers. They are 54" x 54" and cost about $15 each. Toll free 866-867-7545 www.containerslik.com.

6) A support system for the production of #3 tree liners is to drive a steel fence post at each end of each row. The post is left 3.5 to 4 feet high. A stake is placed every 10 feet or so. A single small twine (non-poly) is run down the row, on the right side of the plants and looped tightly around each stake. A second twine is brought back at the same height on the left side, looping each stake. Each twine is tight. The pots are spaced a few inches apart within each row and are on fabric. This is called the Florida Weave system. Wind may cause the outside row to lay over onto the second row, but a laborer can use an arm to bring 3-4 plants upright, which will cause several feet of the row to upright themselves.

7) A Multi-leg Wire Stabilizer can hold individual containers from #3 - #25. Many sources: www.cherokeemfg.com, 800-798-9473; Alabama Wire sells calls the Container Stabilization Basket, www.alabamawire.com, 800-749-3504.

8) Concrete reinforcement wire or livestock panels supply the holes. It must be supported above ground with blocks, gravel filled containers or 'S' hooks hung from pots being supported. This provides uniform spacing by leaving some holes empty.

9) The **Pot-N-Pot** and Pot in the Ground methods prevent blow over for sizes up to #25 containers.

10) An above ground PNP has also been used. An injected molded holder pot is secured to the soil surface with 3 pieces of ½" rebar. A 4" 'L' is bent in the top of a 24"

rebar. Three pieces are driven around the inside edge of the holder pot. The floor is fabric over gravel. This will work with container sizes from: #7 – #15.

11) An unproven idea to support above ground PNP is to weld a 3" washer on top of a length of 3/8" rebar. Drive 1-4 of these per each injected molded holder container.

12) Another unproven idea would use bridge nails and the largest washer that would stay on the nail head. Drive one through the center bottom of a container or 3 in a triangular pattern.

13) A similar idea to keep larger above ground PNP containers (#10) upright requires more rebar. Long lengths of ½" rebar are slid through the bottom (side) drainage holes from 4 sides (north-south & east-west). The pots are in a staggered formation. Walking over the rebar is difficult and hazardous.

14) A nursery in north Alabama built 20' x 230' above ground pot-n-pot in sand beds to solve: 1) winter protection for one year containerized quart liners; 2) spacing to allow development of lateral branches during the second year; 3) support to prevent 'blow-overs'. The sockets are drilled according to a pre-drilled plywood template with the sockets set on six inch centers. Each planting season the 2-year qt liners are pulled and planted in the field. New, one-year qt liners are then inserted into the socket pot. Removing pots with major root escapes forces repairs to be made. This system produces 10,000 liners per year. The owner has been well-satisfied with the results so far. There is sufficient spacing to produce heavy two-year liners, adequate winter protection, wind stabilized pots, and a cooler root zone.

15) A nursery in Texas sunk large eye bolts into the ground then staked and guyed the tree to the eye bolts. This system works well with large containers that are spaced similarly every year.

Insect & Disease Control

The frequent wetting of foliage by overhead irrigation during daylight hours will greatly increase disease pressure, especially on some species. Applying pesticides during the night or early morning hours seems to work well for the larger container nurseries trying to avoid spraying when labor is present. Irrigations or spraying prior to daylight does not extend the wet period of foliage.

Spraying pesticides when the temperature and humidity adds up to more than 140 increases the potential for foliar burn. Allow foliage to dry by dark.

UT Ext Pub. 1589, "Commercial Insect & Mite Control for Trees, Shrubs & Flowers" is available on-line. A hard copy can be ordered on-line for $8. You may refer to the on-line version or print a free copy at
http://www.utextension.utk.edu/publications/pests/default.asp#ornamental

A "Nursery Task Calendar" for container production is available from the Middle Tennessee Nursery Production Web site http://www.utextension.utk.edu/mtnpi/index.html

Information concerning how to submit plant disease samples or insects for identification or how to use the Distance Diagnosis (submitting images of the problem, not an actual sample), visit http://soilplantandpest.utk.edu/plantpestdiagnosis/index.htm It also explains the fee schedule.

Recommended Sanitation Practices

1. Store pine bark off the ground and on a high spot so rain run-off does not wash weed seed and disease pathogens into the pile. A concrete pad is considered best.
2. The mixing area should not be in a high traffic area. Wash all soil from the tires and underbelly of the loader before returning it to the mixing area if it leaves the pad. Mud from boots and tires can introduce pathogens and seed.
3. Crown beds during the construction phase, unless an existing gentle slope will allow water to never stand around the containers.
4. Never prop feet on containers. Don't use your foot to stomp the media in.
5. Don't allow mud puddles to develop in the driveways close to the containers, that would splash water onto the containers as vehicles pass.
6. Place large empty containers or barrels throughout the nursery for labor to throw trash and plant debris in. This would be a use for empty 30 gal pesticide barrels. Empty those containers routinely.
7. Pull dead plants to the aisles when found and remove frequently. If possible, burn the pile weekly. Containers can be re-used.
8. Used containers can be contaminated with various pathogens and weed seed. A handout entitled "Suggestions on Washing Used Production Containers, Regarding Weed Seed and Pathogens" is posted on the Middle Tennessee Nursery Production Web site http://www.utextension.utk.edu/mtnpi/index.html
9. Don't discard pulled weeds or plant clippings on the nursery floor.

Weed Control

A handout entitled "Container Weed Control" is posted on the Middle Tennessee Nursery Production Web site http://www.utextension.utk.edu/mtnpi/index.html

A brief Summary: If weeds are expected to be a problem (as with a gravel floor, but not fabric): Spray Princep (Simazine) annually in late winter, prior to placement of the next crop; apply granular pre-emergence herbicide over top of pots as soon as they are placed (March to May); repeat twice at 75 to 90 day intervals; existing weeds must be removed by hand prior to each application; observe proper waiting period for material selected prior to winter enclosure (refer to label or to the handout).

Potted liners bring weed seed usually, even if the weeds are pulled and removed. Research even proved that used containers after a washing still have seed stuck to their inside walls. Don't allow weeds to produce seed in the area; mow perimeters and grassed waterways frequently.

Winter Protection

Please do not short change yourself or your customers regarding providing sufficient winter protection for container plants. Do not assume it will be a mild winter or that you will sell the plants before a freeze kills them.

Roots are more sensitive to cold temperatures than stems. Roots in containers sitting on top of the ground surrounded by pine bark are not protected as well as those in the landscape or nursery field surrounded by soil. Japanese holly roots are killed when they get 23^{o} F; 19^{o} will kill burning bush roots; 22^{o} will kill dogwood roots; 27^{o} will kill boxwood roots. A list of "Root Killing Temperatures" is posted on the Middle Tennessee Nursery Production web site at http://www.utextension.utk.edu/mtnpi/index.html

Cooler night temperatures and shorter days begin the process of hardening plants off naturally. **Acclimation** is a process in which plants become less susceptible to cold temperature injury. Or we could define acclimation as the natural process in plants where they gain winter hardiness. I generally refer to plants becoming acclimated as gaining their antifreeze or putting on a sweater.

Acclimation occurs naturally during the fall. Long nights bring about the first stage of acclimation. The second stage is in response to lower temperatures. The gradual lowering of temperatures causes maximum cold hardiness. Acclimation involves changes in cell membranes to allow water to move freely out of the cells as tissues freeze.

Late fertilizations, especially nitrogen, high moisture conditions and late pruning can all interact to delay the normal acclimation process.

Premature low temperatures that come earlier than normal may injure plants before they are sufficiently acclimated. This happened Nov 4-5, 1991, when Middle Tennessee had record lows between 15-20 degrees F. Boxwoods, kousa dogwoods, nandinas and all Prunus species were damaged in varying degrees. It's impossible to protect plants in the field or landscape during such weather.

We seem to get more winter injury in the fall or spring when our plants are not fully acclimated than in the dead of winter. That's this transition zone we're in; but it does allow us to grow a wide variety of plant material.

We can assist with acclimation by irrigating less and stop liquid feeding Sept 15 to allow normal acclimation to occur. No dry fertilizers or CRF should be used that would cause plant tissue to be too tender going into the fall. Do not prune within 6 weeks of the average first frost date in the area, because pruning stimulates new tender growth that would be killed by frost.

Irrigate prior to cold spells to reduce injury because a dry media freezes much faster than a moist media, but don't overwater and create root rot. Additional precautions are listed in the order of increasing protection:

Jamming – Select a well drained site; jam or shove the containers together; surround the outside with plastic or bales of straw or a row of pots filled with bark; fill the voids with sawdust and scatter loose straw over the tops; add more after settling. Effective on plants of any height.

Cover short plants with an overwintering blanket (available in various thicknesses, widths and lengths). Overwintering blankets can be as effective as a poly covered house, but must be firmly sealed to the ground around the edges to trap the heat and prevent wind from entering. Concrete blocks or pots half full of gravel can be used. It can be left on for weeks, because it is porous and will breathe. In absence of an overwintering blanket, a sheet of poly can be laid over shade cloth but not be as good. The shade cloth protects the foliage from the poly. Plastic alone must be supported above the foliage to avoid burn. Poly must be removed when the temperature rises.

Taller plants and some plant types can be laid on their side or even stacked as if loading a truck before covering. These are not convenient for retail; too laborious to take the blankets off and on daily. Covers offer good protection, but polyhouses are the preferred method to protect container produced plant roots from freezing and are more convenient for marketing from.

A poly covered overwintering house covered with clear, white, or double poly. Maximum effort would be to lay a sheet of poly or fabric over tender plants inside of poly covered houses for greater protection during an extremely low prediction or using supplemental heat. Plan on covering houses by Thanksgiving in Tennessee generally.

While a poly covered house offers great protection from low temperatures, it will heat up during sunny days requiring ventilation to keep plants cool and dormant if the temperature rises too much. Management must make daily decisions of whether they will close the doors or leave them open over night. Doors are generally left open unless freezing temperatures are expected. It is desirable to avoid a plant getting too warm and breaking dormancy or losing acclimation. It is easier to lose acclimation than to gain it back. What is lost in one night may require weeks to regain, all dependent upon the temperatures.

Maximum temporary protection can be obtained by covering plants inside a poly house with an overwintering blanket. Maximum protection can be obtained inside of a double wall poly house with air blown between the two layers. Supplemental heat can be provided as needed, but exhaust fumes must be vented.

White poly vs. clear poly: It seems that producers that have only had experience overwintering under clear poly tend to overwater the plants when they first switch to white poly. Plants under white poly require less water during the winter. The white poly moderates the temperature extremes and will prevent premature bud swell or blooming that happens under clear poly.

Clear polyethylene has been used in covering these houses, but white poly has been found to provide the best protection from winter injury on container plants. Due to the higher light penetration of clear plastic, there is greater heat buildup and a wider range in fluctuation of temperatures under clear plastic. Higher temperatures promote greater water loss from plants and necessitate increased watering during the winter months. Houses have to be ventilated more often which also causes greater water loss, requiring increased irrigation frequency.

Research by V. P. Bonaminio and R. E. Bir showed that when outside temperatures were 46^0 F, temperatures inside white copolymer covered structures were 64^0 F and temperatures under clear plastic rose to 84^0 F. The following morning, temperatures outside had dropped to 27^0 F while temperatures under white poly and clear plastic were 28^0 F and 26^0 F, respectively. The temperature fluctuation outside was 19^0 F degrees yet in contrast, temperatures under white plastic and clear plastic 36^0 F and 58^0 F, respectively. Temperatures in the root zone of the containers during the cool part of early morning did not drop as low under white plastic, nor did they rise as high during the hotter periods of the day as they did under clear plastic.

There are specific chemical changes that plant cells undergo to enable them to withstand colder temperatures during the winter months. However, with some species, these changes can be halted or reversed with high temperatures. Plants then become more susceptible to freeze damage. Although there is not much difference in the absolute low temperatures reached under white poly and clear poly coverings, the reduced fluctuation in temperatures afforded by the white poly is sufficient on some plants to prevent them from coming out of dormancy and being subjected to low killing temperatures.

There is no added protection derived from using 6 mil versus 4 mil plastic. There is no difference in price, for white or clear poly, when comparing the same size and mil thickness.

A 10” snow load March of 1993 gave the Middle Tennessee container producers a wake-up call. We had been building the least expensive Quonset frames available. Many Quonset bows bent or broke at the joints where holes had been drilled to connect purlings with ¼” bolts instead of cross connectors. Most houses had no center supports.

Stronger houses can be built - for a price. Closer spacing between bows, thicker wall pipe, use of cross connectors rather than drilling holes, better and more bracing, and a peaked roof would prevent snow from accumulating and would build a stronger house.

“A 3/4 inch pipe frame Quonset house will only take a load of 10 pounds per square foot (psf) or less. Freshly fallen snow adds half to 1 psf for each inch that sticks to the plastic and an inch of ice adds about 4 psf. (A row of 2x4 or 4x4 posts spaced about 12-16 feet apart under the ridge purling can provide added measure. They can be hinged with a barn door hinge, swung up, tied out of the way; and cut loose in minutes when a heavy wind or snow is predicted. One end of the hinge is welded to the purling; other end bolted to the post. Keep enough solid blocks of varies thickness to slide under the posts to allow for settling.)

A structure built with the bows 4 feet apart can only support 75 percent of what it could support if the bows were 3 feet apart. A 5 foot spacing between bows looses another 20 percent of support. Four feet between bows should be the maximum spacing.

Changing from Schedule 40, 3/4 inch galvanized water pipe to Schedule 80 pipe will increase strength by 20 percent. Changing to 1 inch, 14 gauge fence pipe will double the strength. Costs are amortized over several years and extra strength is insurance against having to make repairs. (Repairs are more expensive than doing it right the first time.)

A slight change in the shape of the bows can increase load-carrying capacity. A slight gothic peak can be added to the bows with a hydraulic jig to form a peak. This design increases the load carrying capacity by 15 percent or more and allows snow to slide off easier.

The purling should be rigid pipe or conduit rather than wire or cable. Attach purlings with a cross connector or U bolt (with the strap wrapped around the bow so the ends don't cut the plastic). Drilling holes weakens the bow at important stress points.

Use diagonal braces every 100 feet, running from near the ridge to the baseboard, across several bows to add stability. Tightening the plastic cover adds rigidity and keeps the wind from getting underneath it. Use double furring strips or a single strip and bury the edge of the plastic in the soil. End walls and doors should be closed tight to keep the wind out.

Wind speeds of 44 miles per hour (mph) can create a 5 psf load on a Quonset house. A 62 mph wind creates a 10 psf load. Even short, gusty winds can cause a house to fail. Burying the plastic edge helps.” -- Source: Dr. Dick Bir, NCSU Extension and John W. Bartok, Jr., Univ. of Connecticut. Appeared in TNA Newsletter, Dec, 1996

To avoid shadows on the crop that would reduce plant growth, build the houses to run north-south or close the ends with poly or some other opaque material to allow light through. Shipping will occur with poly on, so plan on loading semi’s from both ends and from the center of houses longer than 200 feet.

Half (Dutch) doors keep 4 legged critters out, while allowing air to circulate. Two doors will allow small trailers to be used to carry plants in or out, reducing time of walking them in; (irrigation heads would need to be mounted overhead). Houses can be purchased with vertical side walls of 2, 4, 6 or 8 feet tall, allowing greater convenience to protect taller plants. Containerized trees can sometimes be double or even triple stacked to conserve space.

Sources of overwintering house frames or greenhouses: Price quotations are generally for the frame only, with erection additional. The covering, heaters, fans, benches are usually additional.
A 16' x 96' metal Quonset house was erected 11-99 in Warren County Tennessee for $1100. The poly, shade cloth, ends, doors, gravel, and irrigation were not included.

Three experienced men covered 16 – 16' x 96' houses in 1 day with no wind and no interruptions. They spent several days making preparations. Wooden strips were cut and ready. It took another 2 days, however, to go back and finish the job, adding more strips and driving more nails. The ends did not require poly.

One thing that has been learned over the past few years is that a nursery producer cannot base plans for crop production on "normal" climatic expectations. Tennesseans have experienced major floods in certain areas of the state, three years of record breaking freezing temperatures, four years of severe drought, and -20 F degrees in December 1989. There is too much time and money invested in the production of nursery stock to risk planning for "normal or average" climatic conditions. A nursery producer must plan for extremes. Added costs of taking necessary precautions to produce quality plants should be passed on to the consumer.

Link to UT Ext Pub#1485, “Winter Protection of Nursery Stock”

Source of Quality Liners

It is imperative to find sources of high quality liners year after year, true to name, and in good quantity. Once a good source is found, work to build a good working relationship; based on trust and honesty. It could be advantageous to find more than one source for each species produced, in case of crop failures, or health of the individual, etc. A list of Liner Sources is available on the Middle Tennessee Nursery Production Web site http://www.utextension.utk.edu/mtnpi/index.html

Friendly Advice

Do not try to learn how to propagate liners and set up a new container operation at the same time. Start the container operation and get it running smoothly before trying to propagate, unless an experienced propagator is hired. Remember to buy and sell good quality liners.

After years of troubleshooting problems in container production, it is a foregone conclusion, that once you have found a good growing medium recipe that produces good quality plants, do not change it in an attempt to save a penny per container.

Troubleshooting and Diagnosing a Problem

Most of the serious problems encountered with container production concern the complex interaction between the relationships of the media, nutrition and moisture. It is not always easy to figure some of them out. Begin by looking at the roots. If the crop is young and not rooted in, work over a box or table, in order to save the media and fertilizer.

Extension agents, specialists and consultants will want to know the answers to the following questions as they seek the cause of the problem. Many may attempt to re-construct the production steps in a sequence of events.
Date or at least the month potted?
Media recipe? Is it a new recipe?
Do all containers on the nursery contain the same recipe?
How much lime per yard was added?
What brand, analysis, longevity and rate of controlled release fertilizer?
Was the fertilizer incorporated, dribbled or topdressed?
Was the media mixed and stored ahead of time?
Where the liners bare root or potted?
Determine the liner source. Is the problem limited to one species from same source?
What do the roots look like?
Could roots have dried out before being potted?
Could plants have been over watered?
Could plants have frozen?
When did plants begin looking bad?
How many plants are affected, the percent of the species potted at same time?
Are they scattered in different irrigation zones or in the same area of the nursery?
Contact the liner source and ask if they have received similar complaints
on that same plant.

Other questions may need to be pursued depending on the time of the year and the age of the plants.
How were the plants overwintered?
What is the color of the cambium wood?
How long have the symptoms been visible?

Knowledge of the previous winter and previous weather conditions will be needed. A rainy period may cause root rots. Are the roots dead or dying? A dry period may have allowed the fertilizer salts to accumulate and burn the tender roots, if irrigation was not increased to compensate for the lack of rainfall. Keep asking questions until something clicks, hopefully.

Investigators should make notes on the production details. They may keep looking at the media, nutrition and moisture interactions after pests are ruled out. If nothing can be concluded, they should begin again and ask most of the same questions again, to better understand the sequence and determine if other questions should be asked until something jumps out.

Eventually plant samples may need to be collected and sent to the UT Diagnostic Clinic. Test the pH and the soluble salts on 2 to 3 occasions, separated by 2 to 3 irrigation events. Look for a consistently high or low pH or soluble salts.

The media at potting might start out at a pH of 5.0 to 5.5. Most of our irrigation water is about 7.0. By August the media could be 7.0 or more. A primary symptom would be yellowing foliage with dark green veins. Bi-weekly monitoring of the pH can alert and allow the producer to avoid this problem.

Occasionally, bark will arrive with a pH of 4.3 and have a white fungal growth binding the particles of bark together. This can be a problem from the beginning. Refer to #23 in "Things That Can Cause Problems**".**

Things That Can Cause Problems

Many potential problems concern the complex interaction between the relationships of the media, nutrition and moisture.

1) Pine bark dust, sand, decayed bark and small particles will literally clog the drainage through the media. Partial size and partial size distribution is important. Request a porosity and a partial size distribution test of new media and of a current problem.

2) Blending media inadequately will jeopardize uniform plant growth. Containers will end up with unequal amounts of nutrients.

3) Not using minor elements.

4) Failing to check the root condition periodically for all the different crops and ages. Failing to check the media moisture periodically and balance it in your mind with the container size, the genera, time of year, recent rainfall, hours since last irrigation. A successful grower must develop a sixth sense. Successful growers must get their hands dirty and resist managing from the desk or truck.

5) Not monitoring the pH. Irrigation water may test around 7.0. The pH of the media may climb over the growing season and approach 7.0, causing some nutrients to no longer be available to the plant, even though they are present.

6) Assuming the crf has depleted and adding additional nutrients in late summer without checking the root depth, root condition, media moisture, pH and soluble salts. Insufficient moisture has caused experienced growers to assume the nutrition has run

out. This has occurred when rainfall stopped, days became hotter and plants had grown larger; but extra irrigation was not applied to compensate. Looking at the rootball by removing the container may reveal a dry media, even after an irrigation event. A dry media will test high in soluble salts and may begin to damage the roots. Adding more nutrients can be harmful and also wasteful.

7) Watering on a schedule without allowing for rainfall or the absence of rain and therefore watering too much or too little.

8) Plants planted too deep within the container.
9) Plants blown over lose their topdressed nutrients and will miss irrigation events. They can die if they are left laying and miss 2 irrigation events. Their foliage can be burnt by laying on hot gravels or fabric. (Later, the plant may have burnt or dead foliage on one side.)
10) Producers frequently cause their own problems by seeking cheaper inputs and taking shortcuts to increase profits. Cutting too many corners can lead to disaster.
11) Herbicides can be applied too strong and result in growth reduction. Some granular preemergence herbicides will burn if applied during a flush of tender growth or to wet foliage. Plants can be damaged or killed with glyphosate (Roundup) drift.
12) Cold injury/ winter freeze damage: Can occur in fall or spring by an early or late freeze. Can occur during mid-winter by extremely low temps. May be observed near doors and around the inside walls of poly houses. Made worse by dehydration, so irrigate prior to cold spells.
13) Over fertilized or under fertilized.
14) Replacing sprinkler heads with whatever is available. Not checking the distribution pattern. Allowing some containers to be over watered while some may be under watered. Not segregating plants by genera and container size---by water needs.
15) Not having an irrigation suitability test done.
16) Not monitoring nutrition.
17) Not scouting for problems; pests.
18) Allowing weeds to take over.
19) Not following the simplest of sanitation practices.
20) Insufficient spacing, blank or dead foliage due to crowding.
21) Beginning with poor quality liners.
22) Lack of market planning.
23) Media is discovered to be dry after normal irrigation. Wilting may be observed. Dry spots are discovered within the root ball. A white fungal growth can be seen binding the particles of bark together. The media actually repels water. The pH will be less than 4.3, perhaps even 3.8. Plants are not growing, a light to yellowish green, perhaps with some dying.

The bark or media became hydrophobic (hard to wet) because it dried out excessively somewhere. It may have occurred in storage at the bark source, in storage at this nursery, after being potted or even while sitting forgotten about in overwintering houses. Normal irrigation will not solve the problem. Once the substrate becomes hydrophobic and repels water, a 1% surfactant solution must be used to actually water the containers, a drench, not just a light spray over the media surface. Irrigate lightly afterward. Remove several root systems from their containers after 3 irrigation events (2-3 days) and look for dry spots of media around the sides of the root system. Repeat the procedure if dry spots are found.

Wetting agents (Aqua-Gro or any commercial surfactant or a liquid dishwashing detergent will work almost as well, but choose one that does not create excessive suds. Ajax is good; Dawn, Ivory, Joy and Palmolive are bad to suds.) A 1% solution is 1 gal in 100 gallons.

Bark becomes hydrophobic when it is stored in tall piles for several months. Regardless of average rainfall or sprinklers used, the interior of the pile will dry severely. Proper bark pile management is required: Turn the bark pile regularly if it is more than 4 or 5 feet tall or keep it less than 4-5' tall. This will prevent the bark from drying out or allowing acetic acid buildup. Irrigate the pile if necessary to prevent the bark from drying to the point of becoming hydrophobic (hard to wet). Construct some tall sprinklers to handle this. Wetting agents can be used if necessary. Acetic acid can lower the bark pH to harmful levels.

Definitions

Anaerobic - Refers to without oxygen, as in anaerobic decomposition. Occurs with bark media if bark piles are too tall and not turned often.

Bulk density - The weight of dry substrate per unit volume of substrate (g/cc).

Air space - The percentage of container volume occupied by air-filled large pores from which water drains following irrigation.

CRF or crf – A controlled release fertilizer. A controlled release homogenous fertilizer refers to each pellet of fertilizer containing NPK and minors; rather than each component offered in individual separate particles (a blended fertilizer).

Dirt - What is swept from the floor or is on your pants.

Fluff - Ground household garbage.

Fungicide - A chemical that kills fungi.

Greenhouse - Any structure built for any phase of plant production that is heated &/or cooled. Could be a poly covered Quonset house or glass**.**

Herbicide - A chemical that kills plants, not necessarily just weeds.

Hydrophobic (hard to wet) Turn piles of pine bark or wood mulch regularly if it is more than 4 or 5 feet tall. This will prevent it from drying out or allowing acetic acid buildup. Irrigate the pile if necessary to prevent it from drying to the point of becoming hydrophobic (hard to wet). Construct some tall sprinklers to handle this. Wetting agents can be used if necessary. Acetic acid can lower the bark pH to harmful levels.

Insecticide - A chemical that kills insects.

Irrigation - The redistribution of previous precipitation.

Leaching Fraction - The volume of leachate divided by the total volume of irrigation entering the container multiplied by 100. This fraction should be 10-20%.

Liner - A young plant ready to be planted in the field or container. Could have started as a rooted cutting, seedling, bud or graft. Can be 6 inches or 6 feet tall.

Media - What plants in containers grow in. Normally pine bark based. Substrate is the new term for media.

Miticide - A chemical that kills mites.

Nematicide - A chemical that kills nematodes.

Overwintering house - A Quonset or framed structure covered with clear or white poly to protect containerized plants from cold temperatures.

Pesticide - The catch-all term for all of the chemicals that kill plants, insects, mites, fungi, bacteria, nematodes, etc, etc.

Pesticide Signal Words -- Caution, Warning, or Danger – tell you how likely the pesticide is to make you sick. It appears in large bold print on every pesticide label.
Caution - The least poisonous. Considered safe when used according to directions.
Warning - More poisonous or irritating.
Danger - Very poisonous. Considered dangerous even when used according to the directions. These products also have ‘a skull and crossbones’ in addition to the word ‘Danger’.

pH is the term used for the degree of acidity or alkalinity (basic). Lime makes the media more alkaline; sulfur makes the media more acid. The pH scale is 1 to 14 with 7 being neutral. 1-7 is the acid side. 7 to 14 is the alkaline side.

Phytotoxicity or Phyto - “Anything that alters the appearance or growth (rate) of a plant.” -- Dr. Chuck Powell in McMinnville May 2, 2002

Planting depth – Plant so the root flare or collar is level with the soil or media surface. Too deep is worse than too high. Roots too deep will die without sufficient oxygen.

Postemergence herbicide - A chemical that kills a plant after (post) it has emerged out of the ground, such as Roundup.

Preemergence herbicide - A chemical that kills a germinating seedling before (pre) it emerges out of the ground, such as Surflan.

Propagate - To use seed, cuttings, tissue culture or bud and graft to increase plant numbers.

Propagation house - A Quonset or framed house covered with clear poly used for rooting cuttings.

Quonset house - A frame of bowed pipe, covered with shade cloth or poly. An inexpensive design to build and maintain.

Shade house - A Quonset or framed structure covered with shade cloth to protect some species of containerized plants.

Soil - What plants in a field grow in.

Substrate - New term for media.

Weed - A plant in the wrong place. An unwanted plant, wherever it is. Could be a dogwood tree in a block of maple; a walnut tree in a corn field.

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References:

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BMP Manual, "Best Management Practices, Guide for Producing Container-Grown Plants", Southern Nurserymen's Assoc., July, 1997. Phone 770-953-3311; e-mail: mail@mail.sna.org
"Starting a Container Nursery Business", Jan, 1993; Circular ANR-690, for $2.25. Mail request to Extension Publications, Duncan Hall, Auburn Univ, Auburn, AL 36849-5630

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Table 1: Number of pots* filled with a cubic yard of media:
(Assuming a bareroot liner, because a potted liner will require less media.)

# 1	187-369
# 2	104-140
# 3	68-70
# 5	49-57
# 7	26-35
# 10	20-22
# 15	15
# 20	10
# 25	7
# 45	4
# 65	3

* Nursery Supplies catalog
http://www.nurserysupplies.com/pdf/2008%20BROCHURE.pdf

(Precise container dimensions vary with manufacturer; media physical properties vary with moisture content; machine vs. hand filling and degree of packing are reasons why it is difficult to predict number of pots filled by a yard of media.)

Link to ANLA stds

Table 3: The left column contains parameters that should be tested. The right column contains desirable ranges for specific elements in irrigation water.

Phosphorus (P)	0.005 - 5.000 mg/l
Potassium (K)	0.500 -10.000 mg/l
*Calcium (Ca)	40.000 - 120.000 mg/l
*Sulfate (So_4)	24.000 - 240.000 mg/l
Magnesium (Mg)	6.000 - 24.000 mg/l
Manganese (Mn)	0.500 - 2.000 mg/l
Iron (Fe)	2.000 - 5.000 mg/l
*Boron (B)	0.200 - 0.800 mg/l
*Copper (Cu)	0.000 - 0.200 mg/l
SAR	0.000 - 4.000 mg/l
*Soluble Salts	0.000 - 1.500 mmhos/cm
Zinc (Zn)	1.000 - 5.000 mg/l
*Sodium (Na)	0.000 - 50.000 mg/l
Aluminum (Al)	0.000 - 5.000 mg/l
*pH	5.000 - 6.500 mg/l
Molybdenum (Mo)	0.000 - 0.020 mg/l
Chloride (Cl)	0.000 - 140.000 mg/l
Fluoride (F)	0.000 - mg/l
Nitrate ($N0_3$)	0.000 - 5.000 mg/l
Ammonia (NH_4)	undetermined
*Alkalinity (Bicarbonate)	**0.000 - 100.000 mg/l $CaCO_3$

*Key parameters to be considered.
**BMP says <61 is no concern; 61- 214 is a concern; >214 is severe. 180 is high for bedding plants

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