Maximizing Growth in
Nursery Container Stock

Ted Bilderback
Nursery Extension Specialist
Department of Horticultural Science
North Carolina State University

Controlled environments have traditionally belonged to greenhouse production, not outdoor nurseries. In greenhouse production, growers are able to manage the environment since production is done inside structures. Structures not only restrict rainfall but greenhouses are equipped with facilities for cooling, heating, light and carbon dioxide supplement, computer operated shade cloth and ventilation systems, and DIF (day / night temperature modification). Except for shading container crops, other environmental controls in outdoor nursery production have been an indirect benefit of standard operating procedures. But in the future nursery growers will continue making subtle changes in crop production that have direct effect on modifying the environment where container crops are grown.

Pot in Pot

The best example of environmental modification of growing conditions for outdoor nursery container production is Pot in Pot. Pot in Pot (P in P or P n P) production of nursery crops emerged as a new standard method of producing large container grown nursery crops in the 1990's. One of the primary reasons for wide adoption of this practice was that plants grew faster in this system due to moderated container root zone temperatures. Summer heat loads which can exceed 130 ^{o} F in above ground containers are reduced 15 to 25 ^{o} F in P in P containers. The P in P production system also provides winter protection with no further over-wintering practices necessary. Nurseries in northern states report that approximately the top 1 inch of the container substrate surface freezes but the remaining depth of the container remains above freezing temperatures. However, there are some crops such as some viburnum and loropetalum cultivars that may not fully winter acclimate if left in P in P production in fall months. Other crops such as 'Nellie R. Stevens' holly may grow just as well in above ground containers as in P in P. Another major benefit of P in P production is that crops with big canopies do not blow over which is a frequent problem with large plants in above ground containers.

Although the P in P production system is expensive during initial installation, it provides several years of minimal maintenance, produces crops rapidly and if installed correctly is irrigation efficient and environmentally friendly. Low volume spray stake irrigation is the best way to irrigate P in P containers. Spray stakes are available in many application rates but most apply water at 5 gallons per hour to approximately 15 gallons per hour. Cycled irrigation (multiple cycles per day) is a very effective irrigation practice for P in P production. Distribution patterns and area covered are variable depending on the spray stake selected. The best irrigation practice is to install enough spray stakes to distribute water over the entire substrate surface of in the growing container. In bark substrates, little lateral movement of moisture occurs, therefore un-irrigated surface areas beget dry pockets in the substrate where roots do not grow and when plants are transplanted, the root ball tends to fall apartIf controlled release fertilizers are topdressed over the surface of the container substrate, fertilizer not wet by irrigation does not release without being moisture activated, therefore poor root distribution in the container occurs. Experience has also lead growers to beware of over irrigating P in P crops and to monitoring soluble salts (electrical conductivity) on a regular basis. Over irrigation leads to poor root vigor. Since all the irrigation applied through a spray stake theoretically enters the container, placing a spray stake in a jar provides a grower with irrigation volume applied. No more than 15% to 20% of the applied volume should leach from the bottom of the container. Reducing the irrigation operation time can be used to adjust the leachate loss. During the growing season as plants grow, irrigation time will need to be increased as plants grow and require more water. Determining the leaching fraction can also be used to determine which plants require more water and therefore provides evidence of which crops can be placed in the same irrigation zones. Monitoring EC is also important to avoid elevated soluble salts levels that damage actively growing roots. Collecting leachate from the container after irrigation and reading pH and EC levels provides a means to track fertility levels in the container. In general, pH should range between 5.2 to 6.2. Low pH readings may be due to a very acid solution held in the bottom of the container. Thoroughly leaching the container to expel this solution, then checking pH in a few days may alleviate concern related to reapplying dolomitic limestone. EC levels should range between 0.5 mS/cm (mmhos / cm x 10^{13}) to 1.5 mS/cm. If EC levels are higher, over watering the container one to two irrigation cycles to leach excess salts is recommended.

Installation techniques for P in P production areas began with trenching or auguring holes in open fields at various spacing for placement of the in ground socket pots. For example, 4 foot x 4 foot spacing has been a common spacing for 15 gallon P in P production areas. Most growers offset spacing between adjacent rows so tree canopies overlap less between adjacent rows. Original installations were constructed without drainage underneath containers, however, experience has shown that most field soils do not drain adequately and pots tend to flood during rain events, causing anoxic root zone conditions, poor root growth and mortality of crops. Therefore, most P in P growing areas are installed with drainage systems. Attempts were made to individually drain each pot with digging holes below pots and placing gravel in the holes, equivalent to a French drain system. In recent years, solid 4 inch drain pipe with direct connection or gravel column below the socket pot has become the most common drainage methods. Drain pipe is installed with a trencher, the trench is then filled in and holes augured over the top of the drain line or in some instances a wheel trencher is used to dig a large trench and socket pots are connected or placed over the drain line before the trench if filled. Socket pots are set 3 to 4 inches above soil grade to prevent surface stormwater from washing into the containers. Irrigation distribution lines were placed on the surface of the ground in early P in P construction but temperature changes created considerable problems with shrink/swell movement of irrigation lines with spray stakes frequently being pulled out of containers. An additional problem with rabbits cutting spaghetti tubes on surface installed irrigation lines was also a common experience. Currently, construction of P in P includes placing distribution lines in a trench adjacent to each row of P in P. Placing distribution lines in the ground has eliminated the shrink/swell problem and for the most part reduce problems with rabbits. State of the art P in P production areas have truly become a hybrid of field and container production systems. Most P in P production areas are now covered with 4 mil or 6 mil plastic film and ground cloth, installed by placing the plastic and fabric over the socket pots and cutting holes over each of the socket containers. The plastic underneath the fabric is required to create a non-pervious surface, otherwise dangerous gullies frequently develop due to storm events.

Growers are able to produce large landscape sized plants, generally within one or two growing seasons. P in P crops can be installed even during summer months with very low mortality and few transplanting problems.

Growers seem to be continually experimenting with new applications for P in P. One grower innovation has been to install smaller three to five gallon containers at very close spacing for growing liners P in P. Liner potted in the Fall or even as late as in February may be ready for shift up to 15 gallon P in P containers by May or June and potentially can be sold by the next spring. Previously, growers have had difficulty finishing bareroot tree liners in one season and frequently carry plants over for part or all of an additional season.

Double pot systems

The nursery industry recognized the advantages of lower root zone temperatures associated with the P in P production system. The double pot system is an above ground adaptation using two pots to reduce container zone temperatures. In research studies conducted at N.C. State University, maximum temperatures averaged 20 to 40 ^{0}F cooler in double pots. 'Compacta' holly plants after one season of growth were 48% larger in double pot comparisons. Controlled release fertilizers had lower EC and nitrogen levels than single pots and overall maintained more optimal levels for production.

Nurseries usually have an ample supply of many sizes of containers. If smaller containers are placed inside larger containers, direct sun contact is made on the outside container but the air space between containers does not conduct the heat to the inside container root zone. One grower painted the outside container white to reflect sunlight radiation and measured temperatures that were 10 to 25^0 F lower than single containers placed in the same growing area. The same nurseryman nailed larger 3 gallon containers to the ground fabric in growing areas and placed one or two gallon containers inside the secured larger containers. An additional benefit he noted was that azaleas bloomed 10 to 14 days later in double pot containers than the same varieties he had in other traditional growing blocks and he was able to extend sales to garden centers with plants in peak bloom for that two-week period.

Micro-irrigation systems with spray stakes provide a very efficient method of irrigation for the double pot system too, although over head irrigation with sprinklers should also work. Some growers have used the double pot technique for outside containers in jammed blocks of containers. This works well for containers setting on gravel. However, this system does not work well for containers setting on black plastic or even possibly ground cloth fabric. A seal is formed on the bottom of containers causing less water to drain from single pots in comparison to double pots on same black plastic ground cover. The result is that the double pot containers dry out faster than single pots and plant quality suffers due to water stress.

Low Profile Containers

Searching to apply the same principles of shading sides of containers to reduce root zone temperatures, several growers have begun growing spreading junipers (J. horizontalis 'Blue Rug', J. horizontalis 'Bar Harbor' and other trailing ornamentals) in low profile (squat) pots which are shorter than standard nursery trade gallon containers. The common assumption would be that since standard containers are taller and have greater volume, they would hold more water and nutrient resources, therefore plants would grow faster in larger containers. However, this assumption does not take into account the smaller area contacted by direct sun and the effect of crops growing over the side of the pot early in the growing season. The results are that spreading plants seem to grow much faster and become fuller in shorter profile containers sooner than in standard height containers. Most customers are easily satisfied with fuller plants and quickly accept the smaller containers. Some savings may be gained by growers since more pots can be filled per cubic yard of potting substrate. An added benefit is that the shorter containers don't tip over as easily and reduce top dress fertilizer losses from containers that have tipped over. Not tipping over as easily is a plus as a best management practice in reducing fertilizer concentrations in irrigation runoff.

Finding and creating microclimates in the nursery

A new concept for production of container grown ornamentals is to look for alternative production practices which offset stressful environmental conditions. Doing so can increase profitability of crops grown due to reduced need for crop protection chemicals and high quality crops grown under less stressful environmental conditions

Most nurseries grow crops such as rhododendron, hosta, dwarf nandina, aucuba, pachysandra, some azalea and pieris cultivars and many other crops under natural shade of pine trees or underneath constructed polypropylene or lath shade structures. Synthetic polypropylene shade fabrics make using a variety of shade levels possible. Excessive light intensity exceeds the photosynthic capacity and cellular temperature tolerance of light sensitive crops causing scorching and damage to leaves. Recent trends have been to use 30 % or 47% shade rather than 60% or more shade levels since more shade than necessary can reduce photosynthesis and growth rate of crops. In the last 2 decades polypropylene shade cloth is more commonly installed at nurseries than wooden lathhouse shade. Materials cost and expected life may be the main considerations in selecting polypropylene. However, there may be subtle differences in growth of crops under the two shade structures. Light intensity under polypropylene will always be reduced evenly across the canopy of plants being grown under the shade. Lath provides intermittent shading. As the sun travels across the sky, open slits in the lath provide moments for the sun's full radiant energy to reach leaf surfaces, followed by shade as the sun strikes the lath. More recently, metallic shade materials have been shown to reduce temperatures without great reduction of light intensity. Another innovation has been use of colored films that restrict specific wave lengths of light, accelerating growth of selected crops.

Observant nursery professionals have recognized the economic advantages of reducing environmentally stressful conditions by locating or creating microclimates for specific crops with in the nursery. Crops such as "Otto Luyken" cherrylaurel are quite desirable in many urban landscapes and perform well as landscape plants. As a nursery crop, "Otto Luyken" is easily stressed, grows slowly and has significant problems with shothole fungus which leaves black necrotic edged holes in the leaves. Severe cases result in defoliation. The disease seems to be enhanced by wetting the foliage with over head irrigation and growing it in full sun. Fungicides are routinely applied during the growing season on a seven-to-ten day cycle but frequently with limited success. The crop is also difficult to place in irrigation zones with other nursery crops because best growth is achieved when irrigation frequency is reduced to two or three times per week. In order to produce a crop, some nurseries have abandoned container production and grow "Otto Luyken" as a field produced crop which tends to reduce sales to spring, fall and winter. "Otto Luyken" cherrylaurel is always in short supply and quality plants can be sold at a very profitable margin. Successful producers of quality 'Otto Luyken" plants gain new customers and truly are envied by other growers. The key for success has been to reduce heat, light and water stress. One successful nurserymen created a production area under natural pine shade. A double pot system with spray stakes placed below the canopy to avoid wetting foliage was developed, then the tops of the containers were mulched with three inches of pine straw. Under natural shade, double pots and moisture conserving mulch, containers were irrigated infrequently. Fungicide applications for the crop ranges from none to a few times per growing season.

Success stories lead to new experiments with cultural practices at many nurseries. Some crops such as variegated conifers like *Chamaecyparis pisifera 'Filifera Aurea'* and many variegated junipers and variegated broadleaf ornamentals grow well in full sun during most of the year, but the very hot and bright days in mid-summer cause browning and discoloration because heat and light energy exceed their photosynthetic and respiratory capacities. Placing such crops in microclimates located in the nursery where they receive full sun during morning hours but are shaded by a back drop of natural shade in the afternoon has provided good production conditions to maintain high quality for these crops.

Retractable roof growing structures have been constructed at a number of nurseries throughout the US. Although retractable roof structures are expensive to install, they represent a state of the art method to manipulate environmental conditions. A retractable roof is opened during morning hours to allow full sun conditions but shade cloth may be automatically drawn over growing blocks during afternoon hours of excessive light exposure. Polypropylene films can also be programmed to automatically close the facility to maintain desired temperatures in the structures. Therefore, these structures also become winter production facilities during cold months of the year, or can be used just for frost protection.

<u>Above Ground Large Container Production</u>

The largest expansion in the nursery industry since 2000 has been construction of large container production areas. Common container sizes installed include 15, 25, 45,65,75, 85, 100, 200, 300, 400, and 700 gallon production areas. Shade trees and large broad leaf and conifer screening plants are most frequently grown in the large container production facilities. Multiple spray stakes per container are almost unanimously installed for irrigation in these large containers. A multitude of container types and materials can be seen at nurseries. Production containers include standard large plastic containers, wooden boxes, several woven fabric or polypropylene bags, and a variety of polypropylene cloth rings and structural support methods. Most nurseries use controlled release fertilizers either as a topdress, incorporated or some method of application of the CRF in the back fill adjacent to the rootball of the transplanted plant. Some nurseries also fertigate during shoot flushes to push growth.

The biggest problem encountered in large above ground production areas is tipping and blow over of plants. Many staking, anchorage, guying and attachment systems have been developed by nurseries as well as many additional products that are marketed to nurseries to keep plants upright. Some anchorage systems attach to containers, however most systems attach to the plants in the containers. Rebar used in several applications, cables and wooden box frames have been secured to containers to keep them from tipping. Hanger systems (like outdoor clothes lines) using wires or cables are used most frequently to keep shade trees from turning over. Trees have often been directly attached to hanger wires, however, experience with hurricanes has caused many nurseries to develop methods to attach wires to stakes in containers, followed by attaching trees to stakes with no direct contact to hanger wires. There are also several commercial attachments that can be used to attach hanger wires to trees. Additionally, there are many systems developed for stakes that are driven into the ground adjacent to containers with commercial attachments from the stake to the tree. Guying systems using auger anchors (mobile home anchors) and polypropylene straps (like seat belt straps) attached to anchors and to plants are most frequently used for the largest sized containers. Straps are used for shade trees and as attachments for large evergreen container plants.

Summary of Maximizing Growth

P n P, double pots, low profile squat pots and creating micro-climates are examples that can be attributed to the 1990's, as growing practices that were adopted to minimize environmental stress and maximize growth in outdoor nursery facilities. These new best management practices continue to have lasting influence on how nursery crops are grown, but they also peaked imagination and have encouraged nursery professionals to explore additional opportunities to maximize growth.

Looking for Alternatives to Stress

Many of the techniques for maximizing growth of nursery stock are not new technologies. Night lighting in heated propagation and liner production houses is practiced by few nurseries but provides opportunity for accelerating growth in many nursery crops. Dark period interruption can be accomplished by continuous lighting or intermittent periods of light during the nights, for example, lighting between hours of 11:00 p.m. to 2 a.m. Relative low light intensity, only 50 foot candles, are needed to trigger the chemical changes that cause plants to begin growth. Strings of 100 watt incandescent light bulbs at 5 foot lengths and 5 feet above leaf surfaces can be strung over growing beds and provide enough light for extending photoperiod. Florescent cool white tubes will also serve this purpose. Interrupting dark periods with light can produce a flush after cuttings are rooted in propagation houses and is most frequently used on crops such as hybrid rhododendrons, but many other nursery crops begin flushing when light periods are extended.

Some ornamental crops such as roses are day neutral and growth are not affected by day length, however many ornamental crops particularly trees such as conifers including blue spruce and white pine or hardwoods including red maple and white birch do respond to photoperiodic manipulation. If a grower's primary objective is to accelerate growth and keep seedlings or vegetatively propagated liners, continuously growing rather than going into dormancy, then 12 to 16 hours of light intensity sufficient for photosynthesis is required. Most propagation houses are supplemented with heat so lighting is not an excessive additional cost. Crops receiving supplemental lighting are generally given a light period of 16-18 hours including the time when lamps are on as well as when it is bright enough to turn lamps off. Liners can be grown in a fraction of the time normally required to grow the same crops under conventional production practices. Supplemental lighting should begin in September after the fall equinox and continued in winter months if days are cloudy and low in light intensity. Generally supplementing light to achieve at least 300 to 600 foot candles (fc) for 12 hours provides best results. Cool white florescent tubes equipped with reflectors, combinations of incandescent and florescent or high pressure sodium lamps have been used for supplemental lighting. The preference in lighting in greenhouse production for finishing crops has been 400 Watt high pressure sodium (HPS) lamps which provide a light intensity of about 400 fc. These lamps cost in the range of $2.25 per square foot of illuminated space and have a life expectancy of approximately 24,000 hours. Although, initial installation costs for high pressure sodium lamps are expensive, the idea of getting several years growth of liners in one year might prove to be very economical when other costs are considered.

Greenhouse growers have distinct advantages in manipulating environmental growing conditions for greenhouse container crops over outdoor nursery container crop production. Programming temperature differences between day and night in greenhouse facilities (called DIF) seems to be a major distinction between these two types of ornamental container crop growing. DIF refers to the differential obtained when subtracting the night temperature from day temperature. The DIF values +10 and -10 correspond to 70^{o} F day and 60 ^{o}F night or 60 ^{o}F day and 70^{o} F nights. In greenhouse crops plant height can be controlled by DIF. A shift from a positive DIF toward a zero DIF results in a large reduction in height. A long list of greenhouse crops are commercially grown using DIF, including Easter lily, fuschia, geranium, gerbera, impatiens, chrysanthemum, dianthus, roses, poinsettia, french marigold, tulip, salvia, sweet corn, tomato and watermelon. A shift in growth can be seen within one or two days. Flowering and maturation are also affected by DIF but it is the 24-hour average and not just day or night temperatures that control the rate of development. In greenhouses, during hot weather DIF effects can still be produced by lowering the day temperature for the first two hours of the day immediately after sunrise. This is based on the fact that the greatest rate of internode elongation occurs during the night with a maximum peak at sunrise. For Easter lily, applying a negative DIF only during the two hours after sunrise provides more height suppression than maintaining negative DIF for seven hours during the day.

Generally, nurseries are trying to maximize growth, and not suppress growth for balance of plants to containers, however the physiological effects of DIF need to be studied and adaptations may lead to new techniques for maximizing growth of nursery crops. For example, many nurseries irrigate early in the morning for varied reasons; possibly to complete irrigation in all zones before crews begin work in growing blocks in the nursery. Early morning irrigation would seem to be physiologically the correct practice, since the greatest amount of internode expansion and growth occurs within 1 to 2 hours of day break and growth might be reduced if available was water limiting. Conversely, if container plants in the nursery are irrigated in the early a.m. is it only water that affects subsequent growth? Are there any DIF affects by early morning irrigation? When nurseries irrigate using several cycles during the day, is there an effect on temperature that influences terminal or lateral shoot growth? I do know if these questions merit scientific inquiry, nevertheless, temperature manipulation has changed the way the greenhouse industry grows crops, even if just for two hours at dawn. Maybe nurseries can do something about the weather!