A History of Container Seedling Production in the South

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Abstract

For more than two centuries, tree seedlings (e.g., citrus and shade trees) have been grown in pots (often in greenhouses) in the Southern United States. Not only has the type of container changed over time (from clay pots and wooden boxes to polystyrene or plastic trays) but so has the predominant species grown. Before 1960, researchers used containers in greenhouse trials but few conducted field trials. Promising reports from field trials in Canada, however, stimulated a flurry of outplanting trials in the South in the 1960s. Annual container seedling production in the South reached 1.0 million by 1974 and 3.5 million by 1980; it now exceeds 180 million. Some beliefs about container stock have evolved over time. This article reviews some regional history related to container seedling production of *Eucalyptus*, hardwoods, and pines. This paper was presented at a joint meeting of the Northeast Forest and Conservation Nursery Association and Southern Forest Nursery Association (Williamsburg, VA, July 21–24, 2014).

Introduction

People have used seedling containers for more than 2,000 years. Some believe the Chinese were growing trees in containers in 500 B.C. or before. The earliest known greenhouse was built out of mica around 30 A.D. for the Roman Emperor Tiberius. The containers were "beds mounted on wheels," and these were rolled out on sunny days and then moved back under protection of the "specularia" during wintery days (Paris et al. 2008). Much later, the French botanist, Jules Charles, built a more advanced greenhouse in 1599 in Leiden, Holland. In the Southern United States, 13 States have used containers to grow tree seedlings in greenhouses for more than 200 years.

Containers and Greenhouses in the 18th and 19th Centuries

Wealthy individuals in the American colonies sometimes constructed a greenhouse on their property. For example, the September 1748 edition of the *South Carolina Gazette* contains a notice of a Charleston house for sale that had 2 greenhouses. In October 1789, upon the completion of a greenhouse at Mount Vernon, Mrs. Carroll (who also had a greenhouse) sent President Washington 20 pots of lemon [*Citrus* × *limon* (L.) Burm. f. (pro sp.) (*medica* × *aurantifolia*)] and orange [*Citrus* × *sinensis* (L.) Osbeck (pro sp.) [*maxima* × *reticulata*] trees, along with 5 boxes containing various greenhouse plants. In October 1804, Thomas Jefferson hired James Oldham to build a greenhouse at Monticello. Clay pots and wooden boxes were the most common containers used at that time. By the beginning of the 19th century, there was less than 0.5 ha of greenhouse floriculture in the United States (Henderson 1888).

As the U.S. population increased, the number of greenhouses increased. The 1840 Federal Census even asked nursery managers to report how much product they sold in 1839. In 1890, the Fruitland Nursery (Augusta, GA) had 0.4 ha of greenhouses and 150,000 conifers "nearly all pot grown" (Berkmans 1893). By the end of the 19th century, the Biltmore Nursery (Asheville, NC) had several greenhouses (Alexander 2007).

Containers and Greenhouses in the 20th Century

Before 1970, researchers used several containers types in their greenhouse trials, including traditional clay pots (Kozlowski 1943, Parker 1950), drinking glasses (Chapman 1941), wax milk cartons, glass "Mason" jars (Pessin 1938), foam cups (Kaufmann 1968; figure 1), buckets (Kozlowski 1943), or tin cans (Wenger 1952). In some cases, containers were made by hand using tar paper (Smith et al. 1963, Strachan 1974). After commercial manufacturing of containers began, researchers started using newer container types (e.g., Duffy 1970, Trew 1965).

Figure 1. In the 1970s, some researchers used foam cup containers to grow seedlings. (Photo by David South, 1979)

Because greenhouses were used in Canada for the production of reforestation seedlings, many assumed that greenhouses should also be used to produce container stock in the South. Some assumed the link between greenhouses and containers was so great that “strictly controlled greenhouses” would be needed to produce “tailored” seedlings for reforestation (Mann 1975). Some believed seedling quality would be increased because of the ability to apply “more sophisticated cultural treatments” (Cloud 1972). Greenhouses initially were thought to be useful in providing environmental conditions necessary for optimum germination.

Over time, it was realized that a greenhouse was not necessary for the production of container-grown seedlings in the South. In fact, some suggested that seedling quality (as indicated by secondary needles, freeze tolerance, wax thickness, root-collar diameter, or height/diameter ratio) could be increased by growing seedlings outside (Barnett 1989, Boyer and South 1984a, Mexal et al. 1979; figure 2). In one study, growing seedlings outside resulted in shorter seedlings and survival was increased by 9 percent (Retzlaff et al. 1990). Today, more than 180 million container-grown pines are grown outside (i.e., under no roof constructed of glass or plastic) in the South.

Eucalyptus Seedling Production

The genus *Eucalyptus* was introduced in California about 1853, and by 1908 at least 23 nurseries were selling *Eucalyptus* seedlings for $8 to $30 per thousand (Lull 1908). In the South, container-grown *Eucalyptus* seedlings were planted from Texas to South Carolina. In 1867, the French historian Jules Michelet sent seeds to his brother in New Orleans. The seedlings grew to a height of 7.9 m in less than 2 years (Mialaret 1871). However, a freeze (December 22, 1870) killed the trees. In 1873, two pot-grown *Eucalyptus globulus* Labill. ssp. *globulus* seedlings were planted near Clear Creek, TX (Anonymous 1874). The following year, Jno. A. Barksdale received seeds from Colonel Davis (Greenville, SC), sowed them in a box, and outplanted two seedlings near Lauren, SC (Barksdale 1876). In 1876, a South Carolina editor reported seeing a 2-year-old *Eucalyptus* (6 m tall) growing in Charleston (Aiken 1876). In Florida, *Eucalyptus* was planted on Merritt Island as early as 1878 (Zon and Briscoe 1911).

Containers were preferred to bareroot culture because *Eucalyptus* seeds are small and valuable. Seeds typically were sown in a wooden box and, after the young germinates emerged, they were repotted into 5-cm-diameter pots (figure 3) or transplanted into another box (Arbenz 1911, Zon and Briscoe 1911). Nurseries selling *Eucalyptus* seedlings in the 1880s included Reasoner Brothers in Oneco, FL, and American Exotic Nurseries at Seven Oaks near Clearwater, FL. In 1893, pot-grown *Eucalyptus* seedlings could be purchased from the Oneco Nursery for 20 cents each.

The demand for *Eucalyptus* nursery stock likely declined after freeze injury occurred on several species. The freeze of December 29, 1894, was so severe that Orlando, FL, recorded a low of -8 °C and West Palm Beach, FL, reached -4 °C. A second hard freeze occurred on February 9, 1895. These freeze events not only devastated the citrus industry, but also likely reduced the demand for *Eucalyptus* seedlings. Even so, in 1909, William Fremd grew more than 10,000

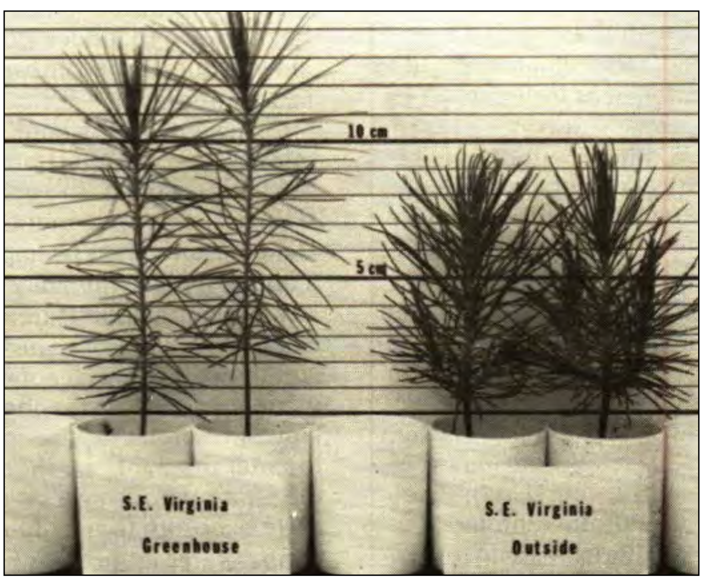

Figure 2. Loblolly pine seedlings (12 weeks from sowing) grown outside (right) had larger diameters, were shorter, and had more branches than seedlings grown inside (left) a greenhouse. (Photo from Boyer and South 1984a)

Figure 3. At the beginning of the 20th century, a person could, in 1 day, prepare soil and transplant 600 to 750 *Eucalyptus* seedlings into containers. Each wooden box contained 36 containers (5 by 5 by 20 cm). The waxed-paper containers often were not removed before planting in the field. (Photo from Toumey 1916)

Eucalyptus seedlings for use in an experimental planting for the Florida East Coast Railway. Fremd was the head gardener at the Royal Poinciana Hotel in Palm Beach, FL. The type of container used by Fremd is unknown, but Zon and Briscoe (1911: 35) indicated that "paper pots" were preferred over wooden flats. During transplanting, the paper containers were not removed, because the "moisture in the soil soon causes the paper to decay and the roots have no difficulty in piercing through it."

During the mid-1950s, several paper companies installed species trials in Florida (Mariani et al. 1978). In 1959, the Florida Division of Forestry produced about 50,000 *Eucalyptus* seedlings at the Herren Nursery (Punta Gorda, FL). The retail price of a container-grown *Eucalyptus* seedling was 15 cents while a bareroot pine seedling was 4 cents (Anonymous 1961). As a comparison, a bareroot *Eucalyptus* seedling from the Herren Nursery cost 10 cents. In the early 1970s, interest in *Eucalyptus* increased and an operational system was developed using Ray-Leach® tubes (Sampson 1974). To reduce costs, 12-week-old seedlings were extracted and then packed into cardboard boxes. Although not the first to ship seedlings in boxes, the Herren Nursery may have been the first to pack extracted seedlings into boxes.

By 1974, the cost for container *Eucalyptus* seedlings was 25 cents each and annual production at the Herren Nursery was about 305,000. At that time, George Meskimen (1974) said that "Eucalypts in Florida may already qualify as the largest containerized, machine-planted hardwood forestation effort in North America." That same year, 120,000 *Eucalyptus* seedlings were lost because of salt-water intrusion into the irrigation well (Horton 1974). Therefore, the Herren Nursery was relocated to Lake Placid, FL. Production increased and Balmer (1976) predicted Florida would produce "nearly 700,000 *Eucalyptus* in 1977 for summer planting, starting them under shade cloth." Species produced included *Eucalyptus camaldulensis* Dehnh., *E. robusta* Sm., *E. grandis* W. Hill ex Maid. *E. torelliana* F. Muell., and *E. amplifolia* Naudin. A few years later, about 200,000 seedlings were destroyed by *Cylindrocladium scoparium* (Barnard 1984). Several species trials were conducted from Texas to South Carolina (Geary 1977, Hicks et al. 1974, Kadambi and Richmond 1970, Mariani et al. 1978).

The annual demand for container-grown *Eucalyptus* in the South has increased to about 1.8 million (Enebak 2013). Depending on the level of genetic improvement, the price can vary from about 45 to 60 cents per plant (Rockwood and Peter 2014).

Hardwood Seedling Production

In 1785, George Washington sowed buckeye (*Aesculus* spp.) and oak (*Quercus* spp.) seeds in a wooden box at his greenhouse at Mount Vernon. More recently, the Arkansas Forestry Commission grew black walnut (*Juglans nigra* L.) seedlings in containers during the 1960s and 1970s (Balmer 1974; Forbes and Barnett 1974). By 1974, the Herren Nursery was growing about 300,000 "tropicals" in containers (Sampson 1974). Live oak (*Q. virginiana* Mill.), red maple (*Acer rubrum* L.), sweetgum (*Liquidambar styraciflua* L.), and sycamore (*Platanus occidentalis* L.) were also grown in containers (Anonymous 1975). In 1980, the Herren Nursery shipped more than 1 million container-grown seedlings (table 1). Farther north, sycamore and sweetgum seedlings were grown in containers in a greenhouse at North Carolina State University. In early May 1974, the 2-month-old seedlings were transported to the Federal Paperboard Nursery in Lumberton, NC, extracted, and then transplanted into nursery beds (Huang and South 1982). This transplanting might be the first incidence of plug+1 production at a forest nursery in the South.

Forestry commissions in Texas, Oklahoma, and Alabama also saw a need to produce hardwoods in containers. The Texas Forest Service Lubbock Nursery started producing pines in polystyrene trays about 1978. A greenhouse was constructed at the Lubbock Nursery to produce hardwoods for wildlife and windbreaks (Word and Fewin 1982). In 1989, the Hopper Nursery at Wallace State Community College (Hanceville, AL) was established using funds from the Alabama Forestry Commission to produce container-grown hardwoods. In 2008, they produced about 200,000 seedlings and sold them for about $1 each (Chandler 2008). In 2013, the Hopper Nursery produced about 75,000 seedlings. The Oklahoma State Nursery (Goldsby, OK) produces container-grown hardwood seedlings to the public for timber production, wildlife habitat, erosion control and windbreaks (at $4 each). The International Forest Seed Company began selling hardwood seedlings in the 1980s

Table 1. A partial list of container nurseries in the South in 1980.

State	Location	Name	Number of seedlings shipped
Arkansas	Hot Springs	Weyerhaeuser	200,000
Florida	Lake Placid	Herren	1,393,000
Georgia	Cedar Springs	Great Southern	210,000
Georgia	Savannah	Georgia Pacific	200,000*
Louisiana	Pollack	Stuart Project	533,000
North Carolina	Clayton	Griffith	700,000*
North Carolina	Trenton	Weyerhaeuser	11,000
Texas	Lubbock	West Texas	25,000
Texas	Silsbee	Kirby Forest	435,000

* Number estimated.

Sources: Anonymous (1981), Harris (1984)

(McRea 1999). They initially grew hardwoods at a density of 544/m² but soon realized a need to increase cell volume and reduced cell density to 244/m² (McRea 2005). The company recently switched from producing hardwood seedlings to producing native grasses.

Throughout the South, the price for container-grown hardwood seedlings varies greatly (table 2). This variation is due, in part, to different profit objectives among nursery administrators. In 2014, nurseries advertising container-grown hardwoods in the South were located in Alabama, Louisiana, Oklahoma, and Texas. The production of container-grown hardwoods (excluding *Eucalyptus*) across the South currently is likely less than 200,000 seedlings, which is about one-third of the production level in 1998 (McRea 1999). The decline in production may be partly due to adequate survival from bareroot hardwoods and a reduction in government subsidies.

Table 2. Selected examples of the retail price (2015) of nursery stock in the South.

Species	Bareroot (cents per tree)	Container (cents per tree)
Eucalyptus spp.	—	45 to 60
Hardwoods	21 to 90	25 to 400
Shortleaf pine	4	16.7
Longleaf pine	10	19.6
Loblolly pine—open pollinated	5.5	15.5
Loblolly pine—clone—miniplug+1	32	41

Pine Seedling Production

Pines have been grown in containers for more than three centuries. In England, John Evelyn (1664) provided brief instructions on growing pine seedlings in "earthen-pots." Although conifers were certainly grown in containers at horticultural nurseries in the South before 1900, most pine seedlings produced in the 20th century were produced in bareroot nurseries. Nonetheless, most of the container seedlings produced in forest nurseries in the South since 1960 have been pines (figure 4).

It was initially believed that greenhouses would produce higher quality seedlings (Cloud 1972, Mann 1975). Therefore, to reduce the cost of greenhouse-grown seedlings, early researchers often grew them in small containers (figure 5). For example, most of the tubes (and "blocks") tested in Louisiana were at densities greater than 1,000/m² (Barnett and McGilvery 1981). In Canada, a small "plantable" pine seedling could be grown in tubes in as little as 4 weeks (Saul 1968). In the South, 2- to 3-month old seedlings were initially considered old enough for planting (Barnett 1974). Some viewed growing seedlings in a greenhouse for 6 months to be a disadvantage (because it reduced the number of crops per year). Container nurseries in the South currently produce one pine crop per year. The two

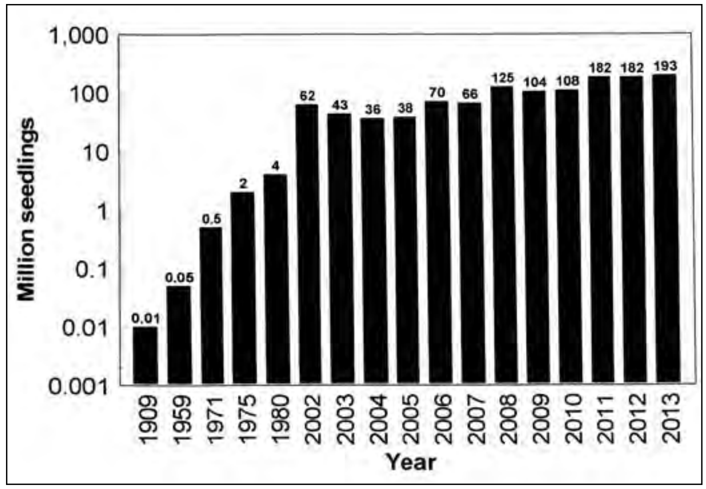

Figure 4. Estimated production of container-grown seedlings in the Southern United States. In the fall of 2013, container nursery managers produced 191 million pine (*Pinus* spp.) and more than 1.5 million *Eucalyptus* spp., 0.6 million Fraser fir (*Abies fraseri* [Pursh.] Poir.), 126,000 Atlantic white cedar (*Chamaecyparis thyoides* L. [B.S. & P.]), and more than 50,000 hardwoods. (Graph source: David South and Scott Enebak, 2014)

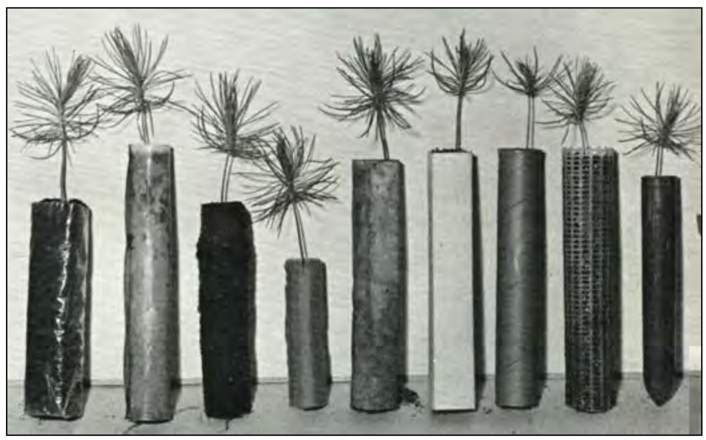

Figure 5. During the 1970s, researchers tested small containers for production of pine seedlings; some assumed seedlings would be shipped when they were just 10 weeks old. (Photo from Mann 1975)

major container species produced in the South, longleaf pine (*Pinus palustris* Mill.) and loblolly pine (*P. taeda* L.), amount to 61 and 35 percent, respectively, of the total container tree seedling production in the South (Starkey et al. 2015).

Early Field Trials With Container-Grown Pine Seedlings

Researchers were among the first to plant container-grown pines. During the early 1960s, geneticists working at the Institute of Forest Genetics (Gulfport, MS) were involved with "containerization" of longleaf pine. Traditional 1+0 bareroot seedlings were lifted (starting in December), needle-pruned to a length of 13 cm, and then transplanted into milk cartons or tar-paper pots (Smith et al. 1963). The "containerized" seedlings typically remained outside (in a concrete trough) for 1 to 4 months. This process resulted in first year survival of 95 to 97 percent (13 to 15 percent more initial survival compared with nonclipped bareroot stock), and, after two growing seasons, 94 percent of the seedlings had emerged from the grass stage.

Researchers in Florida referred to seedlings grown in "paper pots" (Hoekstra 1961) but others correctly referred to these as "fiber pots" (Vande Linde 1968). By growing seedlings in fiber pots, researchers achieved 90 percent survival of slash pine (*Pinus elliottii* Engelm. var. *elliottii*) on mine spoils east of Jacksonville (Hoekstra 1961). In 1963, West Virginia Pulp and Paper Company researchers established trials using loblolly and Virginia (*P. virginiana* Mill.) pine (Trew 1965), and later trials were established in South Carolina (Ladrach 1970a, 1970b). Seedlings in these trials were small, often less than 13 weeks from sowing. In most of these trials, the container was not removed from the seedling before outplanting.

In June 1966, LeRoy Jones (U.S. Department of Agriculture [USDA], Forest Service) established a container study at the George Walton Experimental Forest in Dooly County, GA (Balmer 1968, Jones 1967). The longleaf pine study involved testing paper and plastic tubes; in the study, tubes were planted along with the seedling.

In 1968 and 1969, researchers at Oxford, MS, established trials to compare bareroot seedlings (approximately 10 months old) with 6-week-old seedlings grown in "Walters bullet" plastic containers and outplanted (in February) with the container (McClurkin 1971). It is not surprising that the larger bareroot seedlings survived and grew better than the small container stock (Dickerson and McClurkin 1980).

In 1972, the USDA Forest Service erected two polyethylene greenhouses at Pollock, LA (Gates 1974, Slade 1972), and Dr. James Barnett subsequently tested several container types and growing systems for production of reforestation stock in the South (Barnett 1974, 1989; Barnett and McGilvray 1981). In 2009, Barnett received the Society of American Foresters' Barrington Moore Award for his substantial advances in seed and seedling research.

The North Carolina Forest Service also constructed a research greenhouse in 1972 at the Griffith Nursery (Clayton, NC) and initiated a "Tubeling Operational Study" (Goodwin 1974). This structure perhaps was the first glass greenhouse constructed in the South for producing container-grown pine seedlings. Chris Goodwin authored one of the first manuals for producing greenhouse-grown, southern pine seedlings (Goodwin 1975) and was likely the first to set targets for stem diameter. For example, Goodwin recommended a minimum average stem diameter for loblolly pine seedlings of 1.55 mm; this average can be achieved just 8 weeks after sowing (Barnett 1989).

In 1974, Weyerhaeuser researchers compared container-grown loblolly pine seedlings grown in a greenhouse (without natural chilling) with those placed outside 13 weeks after sowing (Mexal et al. 1979) and found that seedling survival was lower when seedlings were kept in a greenhouse at temperatures of 5 °C or higher. This finding was perhaps the first in the South to question the idea that growing seedlings in a greenhouse increases seedling quality.

Following the early research described above, the number of field trials established since 1975 has increased at an exponential rate. Citations in "Google Scholar" with the exact phrase "container seedling" were not found before 1960, and only two citations occurred during the 1960s. For more recent decades, the frequency of citations observed was 56 (1970s), 106 (1980s), 231 (1990s), and 592 (2000s).

Commercial Pine Seedling Production

In 1975, at least five container manufacturing companies were in the South. Tri-State Mill Supply Company (Crossett, AR) produced polystyrene foam containers. Agritec Company, Inc. (Houston, TX) produced "test tubes" made from polyethylene, and Keyes Fibre Company (New Iberia, LA) produced a Keyes Peat Stick®. Container producers in Florida included Better Plastics (Kissimmee, FL) and Green Thumb Products (Apopka, FL). By 1980, at least nine nurseries were producing container-grown seedlings (table 1). Now more than 180 million containers are produced each year in the South (Harper et al. 2013).

The following list describes some early leaders in production of southern pine container stock.

- In 1973, the Herren Nursery in Florida was converted to a container nursery. Container-grown seedlings of south Florida slash pine (*Pinus elliottii* var. *densa*) were sold to the public for 25 cents each (Anonymous 1975). A few years later (1977), the container nursery was moved from Punta Gorda to Lake Placid.
- In Texas, Kirby Forest Industries began growing container-grown seedlings (in lath-houses) in 1973. By 1980, it was the fourth largest container facility (for reforestation) in the South (table 1). Its goal was to increase the survival of pine seedlings planted on wet, flat sites (Abbott 1982).
- Georgia Pacific constructed a shade house for the production of container seedlings near Savannah, GA. The annual production at this facility in 1975 may have been 200,000 seedlings (Balmer 1974).

- The “Plant-a-plug” company (Crossett, AR) was one of the first nurseries to contract-grow container-grown seedlings due, in part, to a local source of containers. Perhaps 560,000 pine seedlings were grown in polystyrene containers in 1975 (Balmer 1974). Seedlings were grown either outside under a shade cloth (for summer production) or inside a polyfilm greenhouse for winter production (Mason 1974). This nursery did not last very long.
- The North Carolina Forest Service turned its research greenhouse into a production nursery around 1976 (Harris 1982). By 1984, the Griffith Nursery was producing about 900,000 seedlings per year (Harris 1984). A hailstorm unfortunately damaged the greenhouse and broke many of the glass panes. Not long afterward, this facility closed.
- The Texas Forest Service began producing pines in polystyrene trays around 1978 when a greenhouse was constructed at Lubbock to produce conifers for use in windbreaks (Word and Fewin 1982). The windbreak species included ponderosa pine (*Pinus ponderosa* var. *ponderosa*) and Austrian pine (*P. nigra*). Seedlings were 18 months old at the time of distribution in March (winter crop). Both seedlings and containers were transported to outplanting sites. In 1982, the price charged to the landowner was about $1 per seedling. This facility is still in operation and currently sells container-grown pine seedlings for $2 per seedling.
- The South Carolina Forestry Commission started a container seedling program in 1983. A greenhouse was used to produce a fall crop of seedlings (sown in November) while a crop sown in April was grown outdoors in a slat house (Chilcutt 1988). Production at this facility was about 500,000 seedlings per year. This facility closed and now container-grown seedlings are produced at the Taylor Nursery in Trenton, SC.
- The International Forest Tree Seed Company (now International Forest Company) was (and continues to be) the leader in commercial production of container seedlings in the South. A container nursery was established at Odenville, AL, in 1983. The nursery manager, Wayne Bell, realized that container seedlings could be grown outdoors and that heating or cooling a greenhouse added to the cost of seedling production. At that time, it was also recognized that seedlings no longer needed to be kept small (South et al. 1994); the common container tray at Odenville had a density of 526 cells/m^2 and the annual production capacity was about 6 million. This facility closed in 2008, and a larger one is currently operational at Moultrie, GA.
  - Initially seedlings were shipped to the field in containers but returning the empty containers to the nursery was a problem. The decision was soon made to extract seedlings at the nursery and to pack seedlings in cardboard boxes. Packing seedlings not only reduced the loss of containers and eliminated the cost of shipping containers back to the nursery, but it also reduced the cost of shipping seedlings to the field. In the early 1990s, the Odenville nursery also produced rooted cuttings of loblolly pine in a glasshouse for that purpose. At that time, the total cost of producing rooted cuttings exceeded 15 cents per cutting.
  - Since the Odenville nursery opened, Bell has become “the leader” in the container business. For example, his company produced about 5 million container seedlings in 1985 and about 25 million in 2008. In 2014, the nursery at Moultrie, GA, produced more than 70 million container-grown seedlings, making it the largest container-tree nursery in the South.

Advantages and Disadvantages of Container-Grown Seedlings

For some tree genera (e.g. *Eucalyptus*), the advantages of container-grown seedlings are obvious, and few (if any) bareroot seedlings are produced. By contrast, for some hardwood species, the advantages of planting bareroot stock overshadow the disadvantages. The following section highlights some advantages and disadvantages of using container stock in the South.

Extending the Transplanting Season

An advantage of container seedlings is that when soil moisture is adequate, seedlings may be planted outside the traditional 3-month transplanting season for bareroot pines (December through March). During the early days, emphasis was placed on extending the season into the spring (i.e., before the longest day of the year) and summer (Aycock 1974, South and Barnett 1986). Over time, the risk of freeze injury associated with holding stock in the nursery during December and January (Grossnickle and South 2014, Hunt 1980, Tinus et al. 2002) resulted in a shift of the preferred season for planting containers to September, October, and November assuming soil moisture is adequate (Larson 2002, South et al. 1994).

Seed Efficiency

Before 1985, sowing more than one seed per cell was a common practice at container nurseries. When seed had a low value, and when greenhouse managers wanted to minimize the number of empty cells, two or more seeds were often sown in each cell. In addition, because containers often were shipped out to the field, the desire to have each cell filled was higher than when seedlings were extracted at the nursery. The British Columbia Ministry of Forests recommended sowing two or three seeds per cell when the germination percentage was 85 or 75 percent, respectively (South and Young 1995).

Today, one pine seed is typically sown per cell in the South. Emphasis has switched from calculating the optimum number of seeds per cell (Pepper and Barnett 1981) to either purchasing high-germination seed or improving germination with processing techniques. For some seed lots, treating seed before sowing can increase germination to greater than 90 percent (Barnett 2002). For organizations managing container and bareroot nurseries, a simple solution is to send the highest germ seed to the container nursery and the remaining lots to the bareroot nursery. This approach allows for single sowing and minimizes thinning and transplanting costs.

Potential for Toppling

Toppling occurs when high winds blow over young seedlings (typically less than 8 years after outplanting). Toppling is a problem with some pine species (figure 6), especially when growing on sites with high water tables or high sand content. Even with hurricanes, toppling of bareroot southern pines or slow-growing wildlings is rare (Khuder et al. 2007, Moore et al. 2008, Rosvall 1994). In a few rare cases, toppling has been reported on good sites for bareroot seedlings between the ages of 3 and 5 years (Harrington et al. 1989, Hunter and Maki 1980, Klawitter 1969) especially when the foliage was loaded with ice or snow.

Toppling of container-grown and bareroot stock has occurred in several countries (Van Eerden and Kinghorn 1978). In the South, toppling of container-grown longleaf pine was first reported following Hurricane Opal in 1991. Toppling also occurred during Hurricane Floyd in 1999 (South et al. 2001), Hurricane Lili in 2002, Hurricane Ivan in 2004, Hurricane Rita in 2005, and Hurricane Gustav in 2008 (Haywood et al. 2012). In young stands that have not yet experienced high winds, toppling of container-grown longleaf pine may be less than 2 percent (South 2011). Longleaf seedlings with no taproot (or no sinker roots), asymmetrical lateral roots, or spiraled lateral roots (at time of planting) are likely to topple in high winds (Sung et al. 2013).

Figure 6. Some pine species have an increased risk of toppling when grown in containers. (Photo by David South, 2010)

Miniplug Containers and Somatic Embryogenesis

In the Pacific Northwest, containers have been used in the production of plug+1 seedlings in bareroot seedbeds for more than three decades (Hahn 1984). The idea of using "miniplug" containers as plug+1 transplants in the West was pioneered by Weyerhaeuser (Hee et al. 1988). In the South, miniplug+1 bareroot stock became operational in 2002 when miniplugs (figure 7) were mechanically transplanted into nursery beds (Pait and Weir 2007). CellFor (Vancouver, Canada) pioneered the use of somatic embryogenesis to produce clones for nursery production (Sorensson 2006, Sutton et al. 2004).

In 2011, CellFor technology produced more than 12 million tissue-cultured miniplugs. This number included more than 7 million miniplug+1C plants (i.e., miniplugs transplanted into larger containers) and more than 4 million miniplug+1BR bareroot plants (Grossnickle 2014). Although CellFor went bankrupt in 2011, Arborgen is continuing the production of both miniplug+1BR stock and miniplug+1C stock in its Southern U.S. nurseries. For loblolly pine, miniplug+1BR and miniplug+1C stock sell for 32 and 41 cents, respectively (table 2).

Figure 7. Polystyrene tray containing 400 loblolly pine miniplugs produced from somatic embryogenesis. (Photo by David South, 2006)

Hand Planting Costs

Before operational container nurseries were established, many thought that container seedlings would cost less to plant than bareroot stock (e.g., Mann 1977). This view likely developed from an assumption that small container seedlings could be planted more quickly than bareroot seedlings. Because the size of container seedlings has increased over time, the total number of seedlings a planter can carry has decreased. Today, bulky container-grown seedlings cost more to transplant and plant than bareroot seedlings. In one survey, hand planting a container seedling cost 14 cents while the cost for planting a bareroot seedling was 11 cents (Dooly and Barlow 2013). Cost for shipping container-grown loblolly pine is about double that for bareroot stock. It may take two boxes to pack 670 container plugs, but it takes only one box for the same number of bareroot loblolly pine seedlings.

Selected Perceptions

In reviewing the history of container seedling production, I came across several statements regarding container stock. Some declarations are still valid today, but others are now questionable. The following statements (with associated publication dates) were found in the literature, but the full citation has been withheld. See if you can tell which statements have stood the test of time.

- "Since there is little likelihood of reducing reforestation cost with container-grown seedlings, there is little incentive to plant them during the dormant winter period." (1974)
- "The days of a man riding behind a tractor and hand-placing seedling in a slit will soon be gone." (1975)
- "Total time, from germination to shipping, will not be more than eight to ten weeks." (1975)
- "Because a long period is needed for roots to completely enmesh the growing medium, plugs do not appear ideal for southern conditions. Moreover, they must be handled carefully to prevent loss of soil from the roots, so they don't seem adaptable to mechanized planting." (1975)
- "To prevent cold damage, loblolly and shortleaf pines should be preconditioned or hardened off before planting in the fall. Slash and longleaf pines are relatively hardy and can withstand normal winter temperature within their geographic ranges." (1977)
- "Recent economic analyses indicate that for the same or better survivability and growth, container seedlings may be as inexpensive as bare-root seedlings." (1984)
- "When tissue culture is used, the greenhouse container nursery is certain to be intermediate between the flask and the field." (1984)
- "Loblolly pine and slash pine can be grown to plantable size in 12 to 14 weeks." (1986)
- "Most of the variations in performance are more of a reflection of cavities per unit area, or seedling density, than container per se." (1986)
- "The development of adverse root forms increases rapidly with the length of time seedlings are grown in containers. With 12- to 15-week growing cycles and removal of the seedlings from the container, there should be no problem if you are using properly designed containers." (1986)
- "If 5 to 15% of cavities contain ungerminated seeds, germinants from cavities with multiple seedlings or from germination flats should be transplanted to the empty cells." (1991)

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