# Forest Seedling Nursery Practices in the Southern United States: Container Nurseries

Tom E. Starkey, Scott A. Enebak, and David B. South

*Research Fellow, Southern Forest Nursery Management Cooperative, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL; Professor of Forest Pathology and Director of the Southern Forest Nursery Management Cooperative, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL; Professor Emeritus, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL*

## Abstract

The production of container-grown seedlings for reforestation in the Southern United States has increased nearly 5,000 percent since 1980. Current container seedling production in the Southern United States represents 68 percent of the entire U.S. container production. This article describes results from a comprehensive survey of container nursery practices in the Southern United States that includes nursery size, seedlings produced, container type, and growing media. In addition, production methods such as sowing, pest control, irrigation, fertilization, cultural techniques, shipping, and labor sources are also described.

## Introduction

The Southern Forest Nursery Management Cooperative (Nursery Cooperative) has worked with forest seedling nurseries in the Southern United States since 1972. The area represented by this research-based cooperative includes (east) Texas, (east) Oklahoma, Arkansas, Louisiana, Kentucky, Mississippi, Tennessee, Alabama, Georgia, North Carolina, South Carolina, Virginia, and Florida (figure 1). The goal of the Nursery Cooperative is to increase seed efficiency and seedling quality using research to develop and disseminate cultural, chemical, and biological technologies in an integrated system for the economical production of seedlings. Since 1997, the Nursery Cooperative has also conducted an annual seedling production survey of member and nonmember nurseries in the Southern Region.

Bareroot seedling culture dominates the production of forest seedlings for reforestation in the Southern United States When combining all forest tree seedling production regions together, container production accounts for 23 percent of total seedlings (bareroot and container) produced (Harper et al. 2013) within the United States. There have been several surveys of forest nursery practices since 1950 (Abbott 1956, Abbott and Eliason 1968, Abbott and Fitch 1977, Boyer and South 1984), but these surveys were limited to bareroot seedling production.

## The Nurseries

In June 2012, a 23-page survey was sent to 19 container nurseries in the Southern United States (figure 1) and returns were received from 10 nurseries. These 10 nurseries produce about 61 percent of the total Southern United States container seedling production (Enebak 2012). Because some nursery managers chose not to answer all questions, results in this article are based on the number of nursery managers responding to each question. For the purpose of this article, nursery ownership is categorized as State (nursery owned by the State), industry (nursery owned by a company that also owns land and production facilities, such as mills), or private (owned by a company with no land ownership or production facilities). Container seedlings are grown by all three categories of nursery ownership with most container production (83 percent) occurring in private nurseries (Enebak 2012). Of the nursery managers responding to the survey, 60 percent grew only container stock and 40 percent produced both container and bareroot stock, Of those responding nurseries, 60 percent grew both loblolly and longleaf pine, 30 percent grew only longleaf pine, and one nursery grews only loblolly pine. The oldest State nurseries responding to this survey were in Florida (Herren Nursery) and North Carolina (Griffith Nursery), both of which began growing container seedlings in 1972. The oldest industry and private nurseries, both in Alabama, were Westervelt Corporation and International Forest Company (originally International Forest Seed Company), that began growing container seedlings in 1981 and 1983, respectively.

## Seedling Production

Container forest tree seedling production was estimated to be 0.4 million in 1973 (Aycock 1974) and 3.5 million in 1980 (Boyer and South 1984); it now likely exceeds 181 million (Enebak 2012). Accurately quantifying container seedling production is difficult, however, because several small longleaf pine (*Pinus palustris* P. Mill.) nurseries do not participate

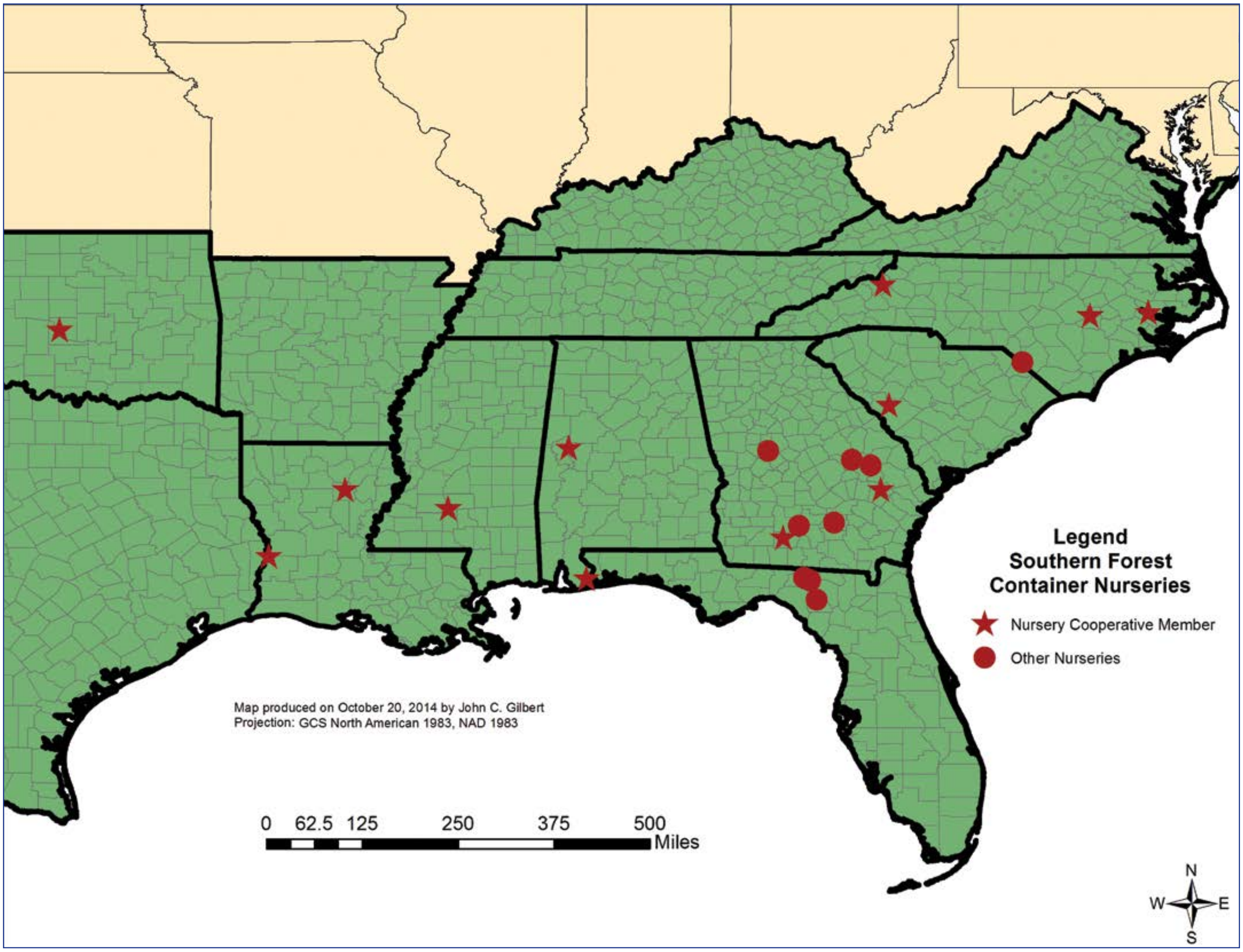


**Figure 1.** Southern States included in the container survey and location of Nursery Cooperative and nonmember container nurseries. (Map by John Gilbert 2014)

in any type of survey. Nonetheless, container production in the South accounts for more than 68 percent of the total container forest tree seedlings produced in the United States (table 1).

**Table 1.** Regional container seedling (conifer and hardwood) production in 2012 and percentage of total production by region.

| Region | Container seedlings produced | Container percent by region |
|---|---|---|
| Southern | 181,505,000 | 68.4 |
| Northeast | 1,198,566 | 0.5 |
| North Central | 6,168,565 | 2.3 |
| Great Plains | 1,109,000 | 0.4 |
| Intermountain | 4,879,630 | 1.8 |
| Pacific Northwest | 56,041,800 | 21.1 |
| Pacific Southwest | 14,323,800 | 5.4 |
| **Total** | 265,226,361 | |

Source: Harper et al. 2013

The choice of stock type used for reforestation differs dramatically for the three major pine species grown in the Southern United States. Only 9 percent of loblolly pine (*Pinus taeda* L.) and 5 percent of slash pine (*P. elliottii* Engelm.) are produced as container stock seedlings whereas 96 percent of longleaf pine are produced in containers (Enebak 2012) (figure 2). The large difference between loblolly and slash pine when compared with longleaf pine is because of the better survival of container compared with bareroot longleaf pine. Other factors include more efficient use of longleaf pine seed that is frequently in short supply and a broader window for outplanting in the field (Dumroese and Barnett 2003). Longleaf, loblolly, and slash pine account for 99 percent of all conifers grown as container stock in the South (table 2), with longleaf pine accounting for 63 percent of the container total (Enebak 2012). In the South, private, industry and State nurseries produce 83, 11, and 6 percent of container seedlings, respectively (Enebak 2012).

**Table 2.** Conifer species grown in container forest seedling nurseries in the Southern United States in 2012.

| Species | Scientific name | 2012 container production | Percent of total |
|---|---|---|---|
| Longleaf pine | *Pinus palustris* Mill. | 112,905,000 | 63.3 |
| Loblolly pine | *P. taeda* L | 59,800,000 | 33.5 |
| Slash pine | *P. elliottii* Engelm. | 3,808,000 | 2.1 |
| Shortleaf pine | *P. echinata* Mill. | 1,051,000 | 0.6 |
| Sand pine | *P. clausa* (Chapm. ex Engelm.) Vasey ex Sarg. | 430,000 | 0.2 |
| Virginia pine | *P. virginiana* Mill. | 22,000 | < 0.1 |
| Other pines | | 301,000 | 0.2 |
| Fraser fir | *Abies fraseri* (Pursh) Poir. | 500,000 | 0.3 |
| Total | | 178,317,000 | |

Source: Enebak (2012)

**Figure 2.** Longleaf pine growing in a container system. (Photo by Tom Starkey 2009)

Annual seedling production in southern container nurseries ranged from 50,000 to 55 million (median annual production was about 6 million). The two largest container nurseries in the South account for 43 percent of the total in the South and nearly 30 percent for all the container production in the United States (Enebak 2012, Harper et al. 2013). Four nurseries also grow a portion of the 2.2 million native plants species used in longleaf pine ecosystem restoration. None of the responding nurseries produced container-grown hardwood seedlings (*Quercus*, *Fraxinus*, etc.) although other nurseries grew at least 2.7 million hardwoods in containers in 2012 (Enebak 2012).

A range of genotypes are sown as container seedlings. Wild sources, harvested from production areas (e.g., Blackwater State Forest, Eglin Air Force Base), represented 73 percent all the longleaf pine seedlots sold in 2012. Slash pine genotypes were equally divided between first- and second-generation families from seed orchards. The largest percentage of loblolly genotypes sold as container seedlings were advanced generation (39 percent) from controlled, mass-pollinated selections or somatic embryogenesis (table 3), which is 20 percent more than in bareroot stock (Starkey et al. 2015). CellFor Inc. produced loblolly pine clonal stock using somatic embryogenesis (Grossnickle and Pait 2008), which were used for container transplants to grow 20 percent of the 2012 container loblolly pine crop. Industry and large private nurseries with access to seed orchards tend to market the advanced genotypes. Loblolly pine rooted cuttings also accounted for a small percentage of the total loblolly production.

**Table 3.** Pine seedlot genetics sown in 2012 at 10 southern forest seedling container nurseries.

| Species | Genetics | Percent sown |
|---|---|---|
| Loblolly pine (n = 7) | 1st generation | 4 |
| | 2nd generation | 33 |
| | 3rd generation | 24 |
| | Advanced | 39 |
| Slash pine (n = 2) | 1st generation | 48 |
| | 2nd generation | 48 |
| | Advanced | 4 |
| Longleaf pine (n = 9) | Wild | 73 |
| | Improved | 27 |

# Cultural Practices

## Containers

Container size and composition is an important factor in container nurseries. In the South, 60 percent of surveyed nurseries use hard plastic containers, 10 percent use expanded polystyrene containers, and 30 percent use both container types. Of the 10 responding nursery managers, 4 indicated that they grew seedlings in more than one type of hard plastic container. Based on total seedling production, 82 percent of seedlings are grown in hard plastic containers. Only one size of expanded polystyrene container is used in the Southern United States with a seedling density of 49 seedlings/ft$^2$ (530 seedlings/m$^2$) and a cell volume of 6.6 in$^3$ (108 ml). The median seedling density for the most commonly used hard plastic containers is 52.9 seedlings/ft$^2$ (569 seedlings/m$^2$) with a cell volume of 6.7 in$^3$ (110 ml). One manager grows seedlings in a 4.0 in$^3$ (66 ml) container, which are typically planted in the fall (i.e., before December) and not sold to nonindustrial private landowners.

## Growing Media

All responding managers use growing media composed of peat moss and other soilless amendments. The average growing mix for container nurseries was 68 percent peat moss with vermiculate and perlite used as secondary ingredients by 80 percent of nursery managers. One nursery manager includes composted bark in the nursery's growing medium. One manager mixes growing medium ingredients on site rather than purchasing a custom mix from a distributor. Compressed bales of peat moss, more than 5 ft (1.5 m) in height, are used by 50 percent of managers. At sowing, the average pH of growing media was 4.7. One-half of all responding nursery managers have had to switch growing-media suppliers (2009–2012) because of price and inconsistent mixing.

## Sowing

Sowing conifer seed in Southern container nurseries typically begins in March with seedlings extracted from their containers for outplanting about 8 to 9 months later (November to December). Container nurseries begin sowing nearly a month before bareroot nurseries (Starkey et al. 2015), which allows seed germination to be complete before air temperatures exceed 90 °F (32.2 °C). Sowing of container seedlings is slower than sowing of bareroot seedlings. For example, sowing a 20-million capacity bareroot nursery can be done in less than 5 days whereas the same size container nursery may take more than 60 days to complete.

The production of native understory plants for longleaf pine ecosystem restoration is a growing segment in container production. The three most common species grown are wiregrass (*Aristida beyrichiana* Trin. & Rupr.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), and Indian grass (*Sorghastrum nutans* (L.) Nash). Because of customer requirements and length of time in the nursery, native understory plant sowing occurs March to July with the peak sowing period after conifer sowing is complete.

Vacuum-drum sowers are common in larger container nurseries (production of more than 6 million seedlings) (table 4). Vacuum-drum sowers can efficiently sow 300,000 to 400,000 cavities per day (figure 3). Smaller nurseries, especially those growing primarily longleaf pine, hand-sow their seedling crop. Hand sowing or mixing the seed as a top dress are common methods for sowing native plant species (table 4). One nursery manager commented that investment in mechanization for sowing native understory plant seed will be necessary if production increases.

After sowing, 90 percent of managers cover seed in the containers with a capping material to minimize seed desiccation. The two most common capping materials are vermiculite and sawdust. Following sowing and capping, most nurseries

**Table 4.** Sowing methods used for conifers and native plant species in container forest nurseries in the Southern United States. Some managers use more than one method.

| | Number of nurseries | |
|---|---|---|
| Method | Conifers | Native plants |
| Vacuum-drum sower | 5 | 1 |
| Needle sower | 1 | 0 |
| Vacuum-drop sower | 1 | 0 |
| Hand sow | 5 | 3 |
| Top dress or cuttings | 1 | 3 |


**Figure 3.** Vacuum-drum sowing machines (SK Design, Inc.) are used by larger container nurseries. These sowers are capable of sowing 300,000 to 400,000 cavities a day. (Photo by Tom Starkey 2009)

transport the containers outside to the field production areas. One nursery routinely palletizes the containers under cover and stores them for a short time period to allow the germination process to begin. After this pregermination process, containers are moved to outdoor growing areas. One-half of the nursery respondents germinate the seeds under shade cloth in the outdoor growing areas. Shade cloth protects the young germinants from desiccation and rain splash and deters bird predation. Following germination, the shade cloth is removed for the remainder of the growing season. Covered greenhouses are not used in the South; two nurseries, however, use their uncovered greenhouse structure to supplement their primary growing facilities.

## Irrigation

Four of the responding nursery managers (including the two largest nurseries) use center pivot irrigation, with two of these nurseries also using a stationary system (such as oscillating impact head or pop-up irrigators) or traveling boom (figure 4). Six of the responding nurseries use only a stationary head system. The largest nursery has 14 single-span center pivot systems. Wells are the source of irrigation water for seven of eight responding nursery managers. Water usage during the seedling production season is reported to government agencies by 70 percent of the nurseries.


**Figure 4.** Irrigation systems used in southern container forest nurseries include (A) a center pivot irrigation system on benches and (B) a stationary impact head on a "T"-rail bench system. (Photos by Tom Starkey 2009 and 2010)

All responding nursery managers monitor container plug moisture using a touch-and-feel system as opposed to an electronic moisture device or a container weight system. During the seed germination phase, 80 percent of nurseries irrigate every day with a goal of keeping the top 40 percent of the plug moist. After the germination phase, the goal of irrigation is to keep an average of 93 percent of the plug moist. During shipping season, all managers reduce irrigation frequency and 60 percent also reduce irrigation amount to harden seedlings for extracting, packing, and shipping.

During the summer (June to September), air temperatures in the South regularly exceed 90 °F (32.2 °C) and may exceed 100 °F (37.7 °C). Most nursery managers (80 percent) irrigate their seedlings after temperatures reach 94 °F (34.4 °C) to reduce air and container temperatures. All managers indicated they have experienced heat-related problems with seedling growth.

## Fertilization

Fertilization in container nurseries is accomplished by mixing slow-release fertilizer into the growing medium and/or by applying water-soluble fertilizers. The latter method requires a tractor-spray applicator or the ability to inject fertilizers into the irrigation system (fertigation). Tractor-sprayers are most commonly used to address specific nutrient problems during the growing season (e.g., iron chlorosis).

Most nurseries (80 percent) use slow-release fertilizer mixed in the growing medium, one-half of which use a 3- to 4-month formulation and one-half use a full-season formulation. The 3- to 4-month formulation is most common at nurseries that also use fertigation. Slow-release fertilizers with shorter release formulations enable the nursery manager to provide nutrients earlier in the season when excess precipitation can limit the ability to irrigate and to also better control seedlings growth later in the season. A previous Nursery Cooperative survey (Starkey and Enebak 2012) showed that nurseries using only full-season, slow-release fertilizers had the lowest foliar nitrogen levels at the time of shipping (October to January) compared with nurseries using fertigation.

Of container nursery managers, 80 percent use slow-release fertilizer in one of three ways: as a sole source for fertilization (10 percent), in combination with tractor/spray (40 percent), or in combination with an injector and tractor spray (30 percent) (table 5). Nurseries that use an injector apply water-soluble fertilizer with micronutrients or individual nutrients to maintain proper nutrition or correct deficiencies.

**Table 5.** Fertilization methods used in southern container forest nurseries (n = 10).

| Fertilization method | Percent of nurseries |
|---|---|
| Slow-release fertilizer only | 10 |
| Combination of slow-release plus tractor/spray | 40 |
| Combination of slow-release, plus injector, plus tractor/spray | 30 |
| Only injector-applied | 20 |

Five managers stated that they evaluate nutrient status of their seedlings twice annually, four managers evaluate their seedlings three or more times per growing season, and one manager does not monitor nutrient status at all during the growing season.

## Top Pruning

The term "shoot pruning," or "top pruning," is typically associated with pruning of central stem species, such as loblolly and slash pine, where both the needles and shoot are cut, and the term "top clipping" is usually associated with longleaf pine because only the needles are cut. To avoid confusion, top pruning will be used in this paper for both species. Top pruning in container nurseries has become a common practice in the past 15 years (figure 5). Most loblolly container nurseries (86 percent) and most longleaf nurseries (80 percent) top prune their seedlings. Of nursery managers, 40 percent top prune only one time (generally in July), whereas 60 percent top prune more than once. The most common reasons nursery managers top prune are to increase crop uniformity, to control height growth, and to produce better balanced seedlings.

**Figure 5.** Example of top pruning machine used in southern container forest nurseries. These machines are custom designed and manufactured locally to accommodate individual nursery configuration. (Photo by Tom Starkey 2009)

# Integrated Pest Management

## Mortality

The average annual seedling loss reported by nursery managers in container nurseries was 3.8 percent. The major problems are associated with pre- and post-emergent damping off and bird predation of seed and young germinants. All other factors listed caused only minor losses of less than 1 percent (table 6).

Bird predation of seed and young germinants had the greatest loss (1.33 percent), which was significantly higher than bird predation reported in southern bareroot nurseries (Boyer and South 1984, Starkey et al. 2015). Despite the rate of bird predation, only three of seven respondents treat their seed with compounds labeled to reduce animal and/or bird predation. One nursery manager reported two interesting observations: first, birds appear to be more of a problem in seedlots with poor or weak germination and, second, shade cloth will sometimes increase losses by not easily allowing birds that enter under the cloth to escape.

## Disease Control

Pre- and post-emergent damping off was reported by 70 percent of nursery managers as being a significant problem (table 6). Losses because of damping off most likely correlate with the amount of precipitation during germination; when precipitation is high, damping off problems would also be expected to be high.

Fusiform rust (*Cronartium querccum* f. sp. *fusiforme*) is the primary stem disease in southern pine nurseries. The fungus is commonly found within a 150 mi (241 km) band from South Carolina to Texas (Enebak and Starkey 2012). Basidiospores from the rust fungus are produced in early spring to early summer on oak trees (*Quercus* spp.) present around the nursery, coinciding with presence of susceptible seedling tissue in the nursery. Although losses because of fusiform rust were not

**Table 6.** Factors contributing to seedling mortality in southern container forest seedling nurseries in 2012 (n = 10).

| Factor | Percentage of nurseries | Percentage of loss |
|---|---|---|
| Preemergent damping off | 70 | 0.82 |
| Postemergent damping off | 70 | 1.15 |
| Fusiform rust | 0 | 0 |
| Rhizoctonia foliar blight | 20 | 0.04 |
| Rhizoctonia crown blight | 20 | 0.05 |
| Nutrient | 10 | 0.01 |
| Herbicide | 20 | 0.12 |
| Insect | 30 | 0.10 |
| Birds | 80 | 1.33 |
| Rain splash | 10 | 0.17 |

reported in 2012 (table 6), 86 percent of nurseries use Bayleton® (triadimefon) and/or Proline® (prothioconazole) to control fusiform rust. Fungicides are effective for controlling fusiform rust when used. In 2011, one nursery did not apply fungicides to control fusiform rust and reported a 20-percent infection rate on that year's crop.

The next most common pesticides reported by at least 60 percent of nurseries for controlling damping off, crown rot, and needles blights and spots were thiophanate-methyl, chlorothalonil and Banrot® (Etridiazole, 15 percent, thiophanate-methyl, 25 percent). Several phosphonate fungicides, such as Aliette® (aluminum tris), were used by five nursery managers for the control of damping-off diseases. This class of fungicides (phosphonates) was not used by any bareroot nurseries (Starkey et al. 2015). Phosphonate fungicides are most effective when applied as a root drench, which is easier to achieve in a container nursery than in a bareroot nursery. Other commonly used fungicides include Chipco 26019® (iprodione), azoxystrobin, and propiconazole. When tallying the various products reported from all nurseries, a total of 19 different fungicides were used for disease control.

### Insect Control

Annual seedling loss because of insects was reported to be less than 1 percent. Nursery managers reported that tip moth (*Rhyacionia* spp.) and plant bugs (*Lygus lineolaris* Miridae and *Taylorilygus pallidulus* [Blanchard]) cause the greatest container seedling mortality. Of the nursery managers, 60 percent reported regularly monitoring the seedling crop to determine when to apply insecticides. The most frequently used insecticides in container nurseries are chloropyrifos, permethrin, and Asana® (esfenvalerate). When tallying products reported from all nurseries, a total of nine insecticides were used to control insect pests.

### Weed Control

Black willow (*Salix nigra* Marshall) was noted as the most troublesome weed in 60 percent of the nurseries. Black willow is found along the margins of the nursery property and produces abundant small, windblown seed during the time of sowing in March and April. Thus, willow seedlings appear only in those container sets that were in the production areas at the time of seed dispersal. The second most troublesome weed was spurge (*Euphorbia* spp.). When queried as to the source of new weeds in their nursery operations, all managers indicated that windblown seed was the primary source. Of the nursery managers responding to the survey, 70 percent use nonpermanent labor for hand weeding, whereas, one nursery manager indicated that he was solely responsible for hand weeding of his entire nursery.

The most commonly used herbicides for broadleaf weeds were Goal® (oxyfluorfen), GoalTender® (oxyfluorfen), and Cobra® (lactofen). Sethoxydim was the most common herbicide used for grasses. Tank mixing of broadleaf and grass herbicides is used at seven nurseries.

## Lift, Pack, and Ship

One distinct advantage of container planting stock is that the planting window is longer than for bareroot seedlings (Brissette et al. 1991). Nearly 80 percent of nurseries ship their seedlings between September and January 1 (table 7). In bareroot nurseries, shipping normally does not begin until December.

At the time of shipping, 40 percent of nursery managers bring their seedlings to a packing shed, 30 percent pack only in the field, and the remaining 30 percent pack in both the field and shed. All container seedlings in the South are packed and shipped in wax-coated, cardboard boxes. Depending on tree species and root plug size, these boxes commonly hold 250 to 300 seedlings. The average number of seedlings extracted from the container and packed in shipping boxes is 175,000 per day, with a range of 15,000 to 350,000 per day. Of the container nurseries responding to the survey, 70 percent have a cooler in which to store seedlings and 30 percent store their seedlings in a shed or pole barn before customer pickup or shipping.

In the Southern United States, soil and air temperature conditions are such that pine seedlings continue to grow during the winter months. Therefore, seedlings increase in both root-collar diameter (RCD) and root biomass from December to February with the average reported target RCD for loblolly pine shipped in late November of 4.0 mm (0.16 in) while a loblolly pine shipped in January has a target RCD of 4.5 mm (0.18 in).

Container nursery managers were queried if they believed that container seedlings out-perform bareroot seedlings. Not unex-

**Table 7.** Percentage of container seedlings shipped by month in 2012 for southern container forest seedling nurseries (n = 10).

| Month | Percent seedlings shipped |
|---|---|
| Before September | 3 |
| September | 17 |
| October | 4 |
| November | 27 |
| December | 29 |
| January | 20 |
| February | 9 |

pectedly, they all answered this question with a “yes” or “sometimes.” The reasons for their response included (1) intact root system at shipping, (2) broader planting window, (3) higher initial survival, and (4) early planting to provide more root growth.

## Labor

In 2012, southern container tree nursery managers reported that their labor sources included permanent employees, part-time local labor such as U.S. nationals and legal foreign nationals, and migrant labor, which includes H1A and H2B workers (table 8). Local labor is more commonly used throughout the season than any other labor source. Local and migrant labor is used at a higher percentage of total labor during the sowing and shipping seasons. Shipping season (November to February) uses more nonpermanent labor than any other operation. Nursery managers indicated that 30 and 62 percent of their total temporary labor budget is used during sowing and shipping season, respectively. For 50 percent of the nurseries, the use of temporary labor sources from 2008 to 2011 increased from 6 to 10 percent.

Nursery managers’ top concerns with temporary labor were cost and lack of attention to details. One interesting comment was that companies or independent contractors that specialize in providing agricultural labor were more reliable than local staffing agencies that supplied temporary, nonspecialized labor.

**Table 8.** Source of labor used in southern container forest seedling nurseries in 2012 (n = 10). More than one labor source was listed by most nurseries.

| Labor | Percentage of nurseries | | |
|---|---|---|---|
| | Sowing | Summer | Shipping |
| Permanent | 50 | 60 | 40 |
| Local | 80 | 70 | 70 |
| Migrant | 60 | 40 | 80 |

Permanent = Full-time employees.
Local = Includes U.S. nationals and legal foreign nationals.
Migrant = Includes H1A and H2B labor, etc.

## Summary

Container seedling production in the Southern United States has increased dramatically since 1974 and currently represents 20 percent of the total regional seedling production. In the future, bareroot will be the primary stock type for the production of loblolly and slash pine and container will continue to be the preferred stock type for the longleaf production. Container seedlings may increase their market share of loblolly and slash pine as companies reserve advanced genetics of these species for container stock.

Container stock can also increase market share by reducing costs and increasing seedling quality. Areas in which costs may possibly be reduced include (1) changing growing media composition by eliminating or reducing high-cost items such as vermiculite and perlite; (2) increasing seeding efficiency of longleaf pine and native plant species; (3) finding more effective herbicides for weed control, especially black willow; and (4) developing mechanization for seedling extraction and packing. Container seedling quality can be improved by (1) use of more efficient seed treatments; (2) greater fill of root mass in the container, especially at shipping; (3) better seedling height management; (4) better seedling nutrition at the time of shipping; and (5) shipping container seedlings as early in the fall or early winter as possible.

### Address correspondence to—

Tom E. Starkey, Southern Forest Nursery Management Cooperative, Auburn University, School of Forestry and Wildlife Sciences, 602 Duncan Drive, Auburn, AL 36849; e-mail: tom.starkey@auburn.edu; phone: 334–844–8069.

### Acknowledgments

The U.S. Department of Agriculture, Forest Service, Southern Region Cooperative Forestry, Atlanta, GA, provided funds for this survey. The authors thank Stan Bartkowiak, Jeff Chieppa, Joe Clark, Rachel Conley, and Ferhat Kara for their assistance in summarizing the survey data.

## REFERENCES

Abbott, H.G. 1956. Forestry tree nursery practices. American Nurseryman. 103(6): 17–18, 130–134.

Abbott, L.G.; Eliason, E.J. 1968. Forest tree nursery practices in the United States. Journal of Forestry. 66: 704–711.

Abbott, L.G.; Fitch, S.D. 1977. Forest tree nursery practices in the United States. Journal of Forestry. 75: 141–145.

Aycock, O. 1974. Field performance of containerized seedlings in the Southern Region, USDA Forest Service. In Tinus, R.W.; Stein, I.; Balmer, W.E., eds. Proceedings, North American containerized forest tree seedling symposium. Denver, CO. Great Plains Agriculture Council Publication 68: 321-328.

Boyer, J.N.; South, D.B. 1984. Forest nursery practices in the South. Southern Journal of Applied Forestry. 8: 67–75.

Brissette, J.C.; Barnett, J.P.; Landis, T.D. 1991. Container seedlings. In Duryea, M.L.; Dougherty, P.M., eds. Forest regeneration manual. Dordrecht, The Netherlands; Boston; London: Kluwer Academic Publishers: 117–141. Chapter 7.

Dumroese, R.K.; Barnett, J.P. 2003. Container seedling handling and storage in the Southeastern States. In Riley, L.E.; Dumroese, R.K.; Landis, T.D., tech coords. National proceedings, forest and conservation nursery associations—2003. Proc. RMRS-P-33. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 22–25.

Enebak, S.A. 2012. Forest tree seedling production in the South for the 2011–2012 planting season. Tech. Note 2012-01. Auburn, AL: Auburn University, Southern Forest Nursery Management Cooperative. 10 p.

Enebak, S.A.; Starkey, T. 2012. Fusiform rust. In Cram, M.M.; Frank, M.S.; Mallams, K.M., tech. coords. Forest nursery pests, Agriculture Handbook 680. Washington, DC: U.S. Department of Agriculture, Forest Service: 41–44.

Grossnickle, S.C.; Pait, J. 2008. Somatic embryogenesis tissue culture for applying varietal forestry to conifer species. In Dumroese, R.K.; Riley, L.E., tech. coords. National proceedings, forest and conservation nursery associations—2007. Proc. RMRS-P-57. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 135–139.

Harper, R.A.; Hernández, G.; Arseneault, J.; Bryntesen, M.; Enebak, S.; Overton, R.P. 2013. Forest nursery seedling production in the United States—fiscal year 2012. Tree Planters' Notes. 56(2): 72–75.

Starkey, T.E.; Enebak, S.A. 2012. Foliar nutrient survey of loblolly and longleaf pine seedlings. Res. Rep. 2012-02. Auburn, AL: Auburn University, Southern Forest Nursery Management Cooperative. 11 p.

Starkey, T.E.; Enebak, S.A.; South, D.B. 2015. Forest seedling nursery practices in the Southern United States: bareroot nurseries. Tree Planters' Notes. 58(1): 4–17.