2008 INTERIM GUIDELINES FOR GROWING LONGLEAF PINE SEEDLINGS IN CONTAINER NURSERIES

R. Kasten Dumroese, James P. Barnett, D. Paul Jackson, and Mark J. Hainds[1]

Abstract—Production of container longleaf pine (*Pinus palustris* Mill.) seedlings for reforestation and restoration exceeds that of bare-root production, but information on container production techniques has been slow to develop. Because outplanting success requires quality seedlings, interim guidelines were proposed in 2002 to assist nursery managers and tree planters in developing and using the best stock possible. The guidelines were intended to be updated as new information was generated. During the past 6 years, additional studies have confirmed most provisions of the interim guidelines, except that presence of buds (number and color) as originally described in the guidelines does not appear to be a useful metric. In addition, some new attributes have been added. This report synthesizes that new information and presents revised guidelines.

INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) forests were once a dominate ecosystem across the Southeastern United States, but intense harvesting during the past century reduced this forest type from nearly 36 million ha (90 million acres) to about 800,000 ha (2 million acres). As a result, many species found in longleaf pine-dominated forests have become threatened or endangered (Barnett 2002, Jose and others 2006, Noss and others 1995, Outcalt 2000). Restoration of this forest type has been encouraged by Federal incentive programs (Hainds 2002), especially through afforestation or reforestation using planting. Because survival and growth of container longleaf pine planting stock is often better than bare-root stock after outplanting (Barnett and McGilvray 1997, Boyer 1989, South and others 2005), use of container stock has increased dramatically. For example, in 2008 about 64 million container seedlings were produced compared to about 12 million bare root.[2]

Despite demand for container longleaf pine, very little detailed research exists concerning the production of this relatively new stock type. This information gap led to a major problem: an absence of container seedling standards and subsequent variation in stock quality (Hainds 2004). Although stock quality can be described in the nursery, what really matters is how well it performs on the outplanting site (Landis and Dumroese 2006). On one hand, plants characterized as "poor" in the nursery may perform well in the field if site factors are favorable, for example, completion of proper site preparation, planting technique, weed control, and/or ample precipitation. On the other hand, "high" quality plants may do poorly if those same treatments are done improperly, or if precipitation is below normal. Despite these existing information gaps, Barnett and others (2002a, 2002b) published interim guidelines to help growers identify container types and seedling quality attributes for growing longleaf pine seedlings in containers. These guidelines were generated based on the available completed or ongoing research, experience of growers, and the expertise of regional specialists with the intention that they would be revised as new information became available.

Since 2002, more information has been published, including Dumroese and others (2005), Hainds and Barnett (2006), Jackson (2006), and Jackson and others (2007, 2010); practical experience has also expanded over the past several years. Thus, it is timely to revisit the 2002 standards with an update.

2002 INTERIM GUIDELINES

The 2002 interim guidelines focused on needles, roots and root-collar diameter (RCD), buds, container size, and other important attributes, such as presence of "sondereggers" [*P.* x *sondereggeri* H.H. Chapm., a naturally occurring hybrid of *P. palustris* and *P. taeda* L. (Little 1979)] (Barnett and others 2002a, 2002b). For each attribute, we summarize the "2002 interim guideline" as published in Barnett and others (2002a), describe the "rationale" behind each original guideline, and provide a "2008 update" that synthesizes the new information that corroborates or refines the 2002 guidelines.

Needles

2002 Interim Guideline—If clipped, needles should be 6 to 10 inches (15 to 25 cm) long but not <4 inches (10 cm). If not clipped, needles should be 8 to 12 inches (20 to 30 cm) long. The appearance of many fascicles is preferred, and needles should have a pale-green-to-dark-green color.

Rationale: Barnett (1984) showed that repeated clipping of longleaf needles to maintain a length of 2 inches (5 cm) reduced RCD, shoot weight, and root weight during nursery production. But seedlings given single or multiple clippings to maintain a needle length of 10 inches (25 cm) were similar

[1] Research Plant Physiologist, U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station, Moscow, ID; Emeritus Scientist, U.S. Department of Agriculture Forest Service, Southern Research Station, Pineville, LA; Assistant Professor, Department of Agricultural Sciences, Louisiana Tech University, Ruston, AL; and Research Coordinator, Solon Dixon Forestry Education Center, The Longleaf Alliance, Andalusia, AL, respectively.

[2] Unpublished data, on file with The Longleaf Alliance, 12130 Dixon Center Road, Andalusia, AL 36420

to their nonclipped cohorts. In addition, survival of seedlings clipped to maintain the 2-inch length was poorer under higher levels of moisture stress than seedlings with longer needles. Barnett (1984) also reported that seedlings clipped once to 10 inches (25 cm), immediately before outplanting under severe moisture stress conditions, survived better than control seedlings and seedlings clipped too frequently. These results are similar to the conclusions of South (1998) who noted that clipping needles of bare-root seedlings improved survival, presumably because of reduced transpiration on sites where seedlings are under significant moisture stress. Clipping needles in the nursery can prevent their lodging and reduce subsequent susceptibility to disease by improving air circulation, reducing humidity levels, and allowing more uniform irrigation. Poor irrigation uniformity leads to overwatering and can increase root disease (Enebak and Carey 2002). Barnett (1989) found that seedlings grown in shade during nursery production were much smaller and suggested that clipping could allow more uniform light exposure (Barnett 1984). Seedlings with fascicles are preferred; Wakeley (1954) and Barnett (1980) reported that seedlings with fascicles perform better after outplanting. A healthy "green" color is indicative of proper nutrient status, rather than the "yellow" (chlorotic) foliage resulting from nutrient deficiencies.

2008 Update—To our knowledge, no new work has been published on clipping. However, we found that needle length of container seedlings is a function of nitrogen fertilizer rate (Jackson 2006, Jackson and others 2007). We also determined that a rate of 2 to 3 mg nitrogen per seedling per week for 20 weeks produced seedlings in Ropak® Multipot #3-96® containers [depth = 4.8 inches (12 cm); volume = 6 cubic inches (98 cm^3); density = 41 per square foot (441/m^2)] with needles within the original interim guidelines without the need for clipping. After outplanting, these seedlings survived and grew well (Jackson 2006, Jackson and others 2007). Seedlings given 4 mg nitrogen per week for 20 weeks had needles that would have required clipping under operational conditions to prevent lodging (we did not clip them, however, in the experiment). No additional benefit in terms of seedling survival or growth was seen for this stock type. It should be noted that many other fertilizer regimes appear to produce longleaf seedlings without the need for clipping (Dumroese and others 2005). It may be, however, that nutrient loading of longleaf pine seedlings in the nursery (Dumroese 2003, Hinesley and Maki 1980) in concert with clipping may improve outplanting performance, particularly because of unpublished work conducted at Auburn University. Researchers there found that clipping longleaf pine seedlings to 8 inches (20 cm) reduced water loss in a greenhouse during the first 4 days after clipping.[3] This short-term effect may be beneficial to outplanting performance.

Roots

2002 Interim Guideline—RCD, measured at the base of the needles, should be one-fourth inch (6.35 mm) or more, and no less than three-sixteenth inch (4.75 mm). Roots should be light brown in color with white root tips, free of disease symptoms, and without circling. Presence of mycorrhizae is encouraged.

Rationale: Because longleaf pine seedlings generally exit the grass stage when their RCDs are about 1 inch (25 mm) (Wahlenberg 1946), obtaining large RCDs in the nursery could shorten the grass stage after outplanting. In addition, larger RCDs are associated with better survival of bareroot stock (White 1981). The minimum value was based on observations that seedlings with < three-sixteenth inch (4.75 mm) diameter grown in Ropak® Multipot #6-45® containers [depth = 4.8 inches (12 cm); volume = 6 cubic inches (98 cm^3); density = 54 per square foot (581/m^2)] were "floppy" and had reduced survival. ["Floppy" seedlings, when held horizontally by the terminal bud, "flopped" over because of insufficient development of roots within the root plug (Hainds and Barnett 2004, 2006).] Light brown roots with white root tips indicate a healthy root system and show potential for new root development. Black roots require close scrutiny because they are likely diseased, particularly if a large portion of the root system is black. Modern, commercially available containers typically used to produce reforestation seedlings have modifications (ribs, slits, chemical coating) to prevent circling. Presence of mycorrhizae indicates a healthy root system but applying inoculant is usually unnecessary because windborne spores typically inoculate seedlings naturally (Barnett and Brissette 1986).

2008 Update—In general, the recommendation for RCDs being greater than three-sixteenth inch (4.75 mm) for typical 6 cubic inches (100 cm^3) seems acceptable. In this stock type, we note that most fertilizer regimes produce seedlings above this threshold (Jackson 2006, Jackson and others 2007). Seedlings below this threshold have reduced survival (Hainds and Barnett 2004, 2006), and it appears that seedlings with increasing RCDs have increasingly better performance in terms of reduced time in the grass stage (Jackson and others 2007, 2010). South and others (2005) report a critical threshold of 5.5 mm; seedlings with less RCD had poorer survival across a variety of sites than those with greater RCD. Recent work shows, however, that RCD cannot be increased indefinitely without a decline in survival and growth—when the ratio of RCD to the diameter of the growing container, the Root Bound Index, was >27 percent, seedling survival was compromised (fig. 1) (South and Mitchell 2006, South and others 2005). Our observation is that this critical threshold may be difficult to achieve in a 20- to 30-week growing cycle for seedlings in Ropak® Multipot #3-96® containers, but as Salonius and others (2002) point out, it could be easily achieved when seedlings are grown too long in the containers, or "held over" in the nursery in anticipation of being sold the following year. Most typical, commercially available containers used for reforestation have design features to prevent root circling. Some containers are treated with copper to prevent root spiraling, which also

[3] Personal communication. David B. South, Professor, Auburn University, School of Forestry and Wildlife Sciences, Alabama Agricultural Experiment Station, Auburn, AL.

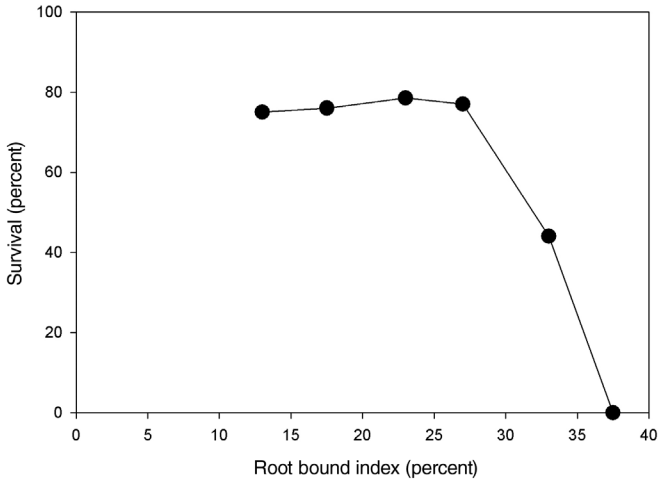

Figure 1—Effect of the root bound index (root-collar diameter/cell diameter) on second-year survival of container longleaf pine seedlings (South and others 2005).

prevents lateral roots from growing downward on the exterior of the plug and forming a "bird cage." This copper treatment is associated with changes in root system morphology, shoot and root biomass (Barnett and McGilvray 2002), and root growth potential (South and others 2005). In general, these seedlings are easier to extract from containers, especially those made of Styrofoam, and fresh copper on container walls decreases the level of potential disease inoculum (Dumroese and others 2002). Copper-coated containers yield seedlings with better, more uniform root distribution higher on the initial root plug, which is believed to improve resistance to windthrow (Burdett 1978, Burdett and others 1986). Neither South and others (2005) nor Sung and others (2010) noted any short-term benefit, in terms of survival or growth, from growing seedlings in copper-treated containers. Tinus and others (2002) determined that exposing longleaf roots to temperatures below 25 °F (–4 °C) caused significant damage. South (2006) reports damage is more severe if that temperature is achieved before seedlings have acclimated to cold temperatures (early winter) or the frost is preceded by warm temperatures that cause deacclimation of seedling tissues to cold.

Buds

2002 Interim Guideline—Buds should be present on 90 percent of the crop. Seedlings outplanted in late October or early November are more likely to have green buds, whereas seedlings outplanted in late December or January are more likely to have brown buds. Brown buds are thought to be more mature, but outplanting should not be delayed to obtain better bud development.

Rationale: Personal observations of quality seedling crops grown during a variety of research projects indicated that seedlings at the end of the growing cycle in late fall had a cessation of needle growth, hardening of tissue, and formation of notable, green, terminal buds, which then became brown during winter.

2008 Update—Early researchers noted that longleaf pine seedlings in the grass stage exhibit a progression of bud types (Pessin 1939, Wahlenberg 1946). Wakeley (1954) noted that bud status during a single growing season changed as terminal buds formed, opened, reformed, and reopened. We have observed development of the apex during several studies and have attempted some quantification. Attempting to use the bud descriptions (pincushion, round, and elongated) of Pessin (1939), Wahlenberg (1946), and Wakeley (1954) during nursery production has been problematic, as nursery stock shows a wide variation in apex characters not necessarily meeting those descriptions. Jackson (2006) found that increasing rates of fertilizer resulted in larger, more robust buds. At deficient nitrogen rates, buds were small and brownish, whereas seedlings given high doses of nitrogen had larger, green buds. In another trial, we observed that frequency of terminal buds varied by month, generally increasing from September through December and then decreasing dramatically in January (fig. 2), whereas in another study more than 90 percent of the crop still had firm terminal buds in January. Larson (2002) points out that dormant buds may be difficult to see. Therefore, additional quantification, and perhaps a new framework for describing/measuring bud development during nursery culture, would help identify if, and what, the effect of differing bud/apex condition on longleaf pine seedling quality might be. Because we have outplanted groups of longleaf pine seedlings with wide variation in the presence of terminal buds [ranging from 20 (Jackson and others 2007) to 100 percent (fig. 2)] and survival and growth have been similar, it appears that the bud criteria in the 2002 guidelines is not useful.

Container Size

2002 Interim Guideline—Container diameter should be no less than an inch (25 mm) with 1.5 inches (38 mm) or greater

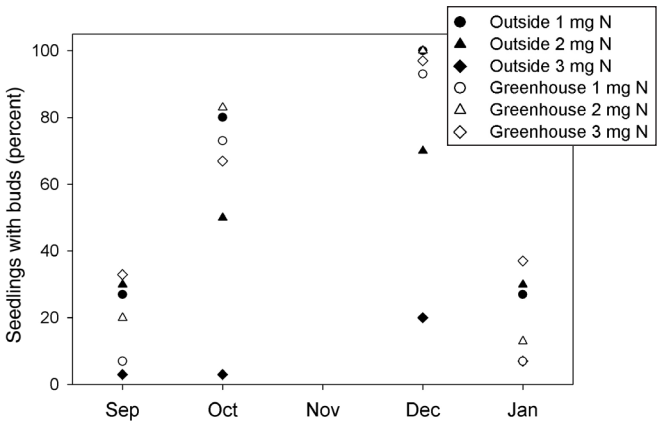

Figure 2—Bud occurrence from September through January for longleaf pine seedlings in a recent fertilizer trial completed by the authors. Although no pattern was observed between seedlings grown in a greenhouse or outside, or among three levels of nitrogen fertilizer, pooled data showed that buds formed from September, with most of the crop having discernable terminal buds in December, followed by an opening of terminal buds in January.

desired. Container depth should be no less than 3.5 inches (9 cm) with 4.5 inches (11.5 cm) or more preferred. Container volume should be no less than 5.5 cubic inches (90 cm^3) with 6 cubic inches (100 cm^3) or more recommended.

Rationale: The guidelines were based on observations from a variety of studies (Amidon and others 1982; Barnett 1974, 1984, 1988, 1991; Barnett and McGilvray 1997).

2008 Update—Since the interim guidelines were published, most of our work has focused on seedlings grown in Ropak® Multipot #3-96® (Jackson 2006; Jackson and others 2007; Jackson and others 2010) or Ropak® Multipot #6-45® (Dumroese and others 2005) containers (described above). Seedlings grown in Ropak® Multipot #3-96® containers have been evaluated up to 3 years in the field; preliminary data shows excellent survival and growth (Jackson and others 2007; Jackson and others, in press). South and others (2005) evaluated six different containers differing in depth from 2.6 to 6 inches (6.5 to 15 cm), in volume from 4 to 6 cubic inches (60 to 120 cm^3), and in container material, outplanted on four field sites. They concluded that container type (Styrofoam, hard plastic, or mesh) may not affect survival on easy-to-regenerate sites, but mesh-type containers (such as Jiffy pellets) performed poorer on harsher sites than Styrofoam and hard plastic containers (the containers had characteristics consistent with the original guidelines). Sung and others (2010) found reduced survival, height growth, and exit from the grass stage for seedlings grown in small volume [4-cubic-inch (54-cm^3)] containers compared to larger cohorts. A study examining a wider range of container sizes [4 to 20 cubic inches (60 to 340 cm^3)] was outplanted on the U.S. Forest Service Palustris Experimental Forest (Rapides Parish, LA) in December 2008.

Other Important Attributes

2002 Interim Guideline—Root plugs should remain intact (no loss of medium) when extracted and during handling, and they should always be moist. Seedlings should lack competing weeds and insect pests. The nursery manager and the buyer should agree whether to cull sonderegger seedlings.

Rationale: Firm root plugs indicate good root development, and seedlings with firm plugs and appropriate RCD for the container diameter are not "floppy" as described in the "roots" section. Furthermore, firm plugs facilitate handling in the nursery and outplanting because they do not fall apart, and losing a portion of the root plug during the process of extraction through outplanting was associated with a decrease in survival and subsequent growth in a conifer species (Tinus 1974). Moisture held in the growing medium prevents root desiccation. A seedling sharing its container with a competing weed has less access to nutrients and water, resulting in reduced growth (Pessin and Chapman 1944). Seedlings that begin height growth during nursery production are usually sonderegger pines. These seedlings produce poorly formed trees in plantations and are less desirable than longleaf pine.

2008 Update—Many growers irrigate their seedlings just prior to extraction (Dumroese and Barnett 2004). Seedlings may be hot planted (no or very limited storage) or cooler stored for a week to a few months (Dumroese and Barnett 2004). Regardless, having moist plugs when shipped to the field is important. This may be especially true for seedlings outplanted during the April through October planting window because these seedlings likely have more exposure to greater vapor pressure deficits than seedlings hot planted, or outplanted after cooler storage, during the relatively mild "winter" season. Luoranen and others (2004) found that mortality of silver birch (*Betula pendula* Roth) increased with decreasing plug moisture content; rate of mortality with decreasing plug moisture was greatest on dry sites. More detailed observations by Hainds and Barnett (2006) suggest that seedlings with as much as 4 inches (10 cm) of height

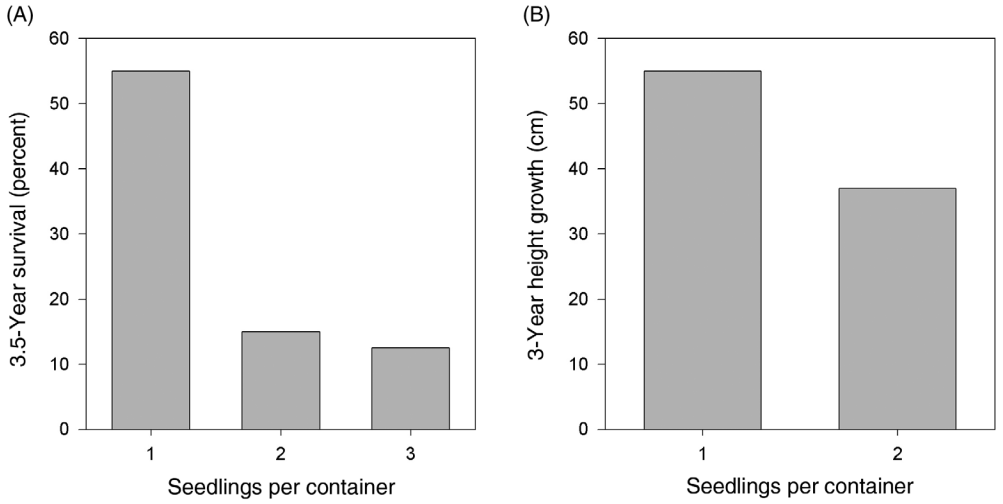

Figure 3—(A) Survival of longleaf pine seedlings decreases when multiple seedlings exist within a single container (Barnett and Brissette 1986) and (B) height growth of seedlings at the Samson site in Alabama (see Hainds and Barnett 2006 for a more details). Note: This figure was presented incorrectly in Hainds and Barnett (2006).

Table 1—2008 interim guidelines for nursery production of longleaf pine seedlings

Needles	Needles should be 6 to 12 inches (15 to 30 cm) long and not less than 4 inches (10 cm). Needles should have a "medium-to-dark" green color. Avoid yellow or brown seedlings.
Roots	Root-collar diameter (RCD), measured at the base of the needles, should be no less than 3/16 inch (4.75 mm). Larger RCDs are encouraged as long as the ratio of seedling RCD to container diameter is <27 percent to avoid root binding. Roots should be light brown in color with white root tips, free of disease symptoms, and without circling. Cambium at or near the root collar should be whitish or greenish, never orange or brown. Plugs should be firm and moist and stay intact during extraction and outplanting. Avoid "floppy" seedlings—these seedlings, when held horizontally by the terminal bud, bend or flop, unable to maintain a straight horizontal alignment. Seedlings with a very large callus at the tip of the air-pruned taproot might not form a strong taproot.
Buds	May or may not be present.
Container size	Diameter ≥1 inch (25 mm) with 1.5 inches (38 mm) or greater desired. Depth ≥3.5 inches (9 cm) with 4.5 inches (11.5) or more preferred. Volume ≥5.5 cubic inches (90 cm^3) with 6 cubic inches (100 cm^3) or more recommended.
Other important attributes	Seedlings should be free of weeds and insects. Avoid multiple seedlings within a single container. Sonderegger pines retained or removed pending decision by grower and buyer in agreement.

growth in the nursery may not necessarily be sonderegger pines. This may complicate identification of hybrid seedlings in the nursery; as always, the best solution is for the grower and the buyer to communicate about this beforehand.

Not discussed in the original guidelines were "double seedlings," two seedlings growing in a single container. During nursery production, a "single" seedling can have twice the dry weight of a "double" seedling (Barnett and Brissette 1986), which affects outplanting performance. After outplanting, Barnett and Brissette (1986) showed that survival was greatly reduced when two or three seedlings occupied the same container (fig. 3A), and Hainds and Barnett (2006) report that height growth was also diminished (fig. 3B).

SUMMARY

Results from recent studies confirm that most of the recommendations made when the 2002 interim guidelines were developed are still sound (table 1). The main exception is related to the presence of terminal buds and its effect on outplanting performance. Additional information regarding "floppy" seedlings, double seedlings, and classification of sonderegger pines has also been included.

ACKNOWLEDGMENTS

We appreciate the comments and suggestions provided by Dr. David South on earlier drafts.

LITERATURE CITED

Amidon, T.E.; Barnett, J.P.; Gallagher, H.P.; McGilvray, J.M. 1982. A field test of containerized seedlings under drought conditions. In: Guldin, R.W.; Barnett, J.P., eds. Proceedings of the southern containerized forest tree seedling conference. Gen. Tech. Rep. SO-37. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 139–144.

Barnett, J.P. 1974. Tube lengths, site treatments, and seedling ages affect survival and growth of containerized southern pine seedlings. Res. Note SO-174. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 3 p.

Barnett, J.P. 1980. Density and age affect performance of containerized loblolly pine seedlings. Res. Note SO-256. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 5 p.

Barnett, J.P. 1984. Top pruning and needle clipping of container-grown southern pine seedlings. In: Lantz, C., comp. Proceedings: southern nursery conferences. Atlanta: U.S. Department of Agriculture Forest Service, State and Private Forestry, Southern Region: 39–45.

Barnett, J.P. 1989. Site preparation, containers, and soil types affect field performance of loblolly and longleaf pine seedlings. In: Proceedings, 5th biennial southern silvicultural research conference. Gen. Tech. Rep. SO-74. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 155–158.

Barnett, J.P. 1989. Shading reduces growth of longleaf and loblolly pine seedlings in containers. Tree Planters' Notes. 40(1): 23–26.

Barnett, J.P. 1991. Effects of morphological grade on field performance of container-grown southern pine seedings.

In: Coleman, S.S.; Neary, D.G., eds. In: Proceedings, 5th biennial southern silvicultural research conference. Gen. Tech. Rep. SO-74. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 94–99.

Barnett, J.P. 2002. Longleaf pine: why plant it? Why use containers? In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 5–7.

Barnett, J.P.; Brissette, J.C. 1986. Producing southern pine seedlings in containers. Gen. Tech. Rep. SO-59. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 71 p.

Barnett, J.P.; Hainds, M.J.; Hernandez, G.A. 2002a. Interim guidelines for growing longleaf seedlings in containers. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 27–29.

Barnett, J.P.; Hainds, M.J.; Hernandez, G.A. 2002b. Interim guidelines for growing longleaf seedlings in containers [Leaflet]. Gen. Tech. Rep. SRS-60. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 3 p.

Barnett, J.P.; McGilvray, J.M. 1997. Practical guidelines for producing longleaf pine seedlings in containers. Gen. Tech. Rep. SRS-14. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 28 p.

Barnett, J.P.; McGilvray, J.M. 2002. Copper-treated containers influence root development of longleaf pine seedlings. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 24–26.

Boyer, W.D. 1989. Response of planted longleaf pine bare-root and container stock to site preparation and release: fifth year results. In: Proceedings, fifth biennial southern silvicultural research conference. Gen. Tech. Rep. SO-74. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 165–168.

Burdett, A.N. 1978. Control of root morphogenesis for improved mechanical stability in container-grown lodgepole pine. Canadian Journal of Forest Research. 8: 483–486.

Burdett, A.N.; Coates, H.; Eremko, R.; Martin P.A.F. 1986. Toppling in British Columbia's lodgepole pine plantations: significance, cause and prevention. Forestry Chronicle. 62: 433–439.

Dumroese, R.K. 2003. Hardening fertilization and nutrient loading of conifer seedlings. In: Riley, L.E.; Dumroese, R.K.; Landis, T.D., tech. coords. National proceedings, forest and conservation nursery associations—2002. Proceedings RMRS-P-28. Ogden, UT: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station: 31–36.

Dumroese, R.K.; Barnett, J.P. 2004. 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. Proceedings RMRS-P-33. Ogden, UT: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station: 22–25.

Dumroese, R.K.; James, R.L.; Wenny, D.L. 2002. Hot water and copper coatings in reused containers decrease inoculum of *Fusarium* and *Cylindrocarpon* and increase Douglas-fir seedling growth. HortScience. 37: 943–947.

Dumroese, R.K.; Parkhurst, J.; Barnett, J.P. 2005. Controlled release fertilizer improves quality of container longleaf pine seedlings. In: Dumroese, R.K.; Riley, L.E.; Landis, T.D., tech. coords. National proceedings, forest and conservation nursery associations—2004. Proceedings RMRS-P-35. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station: 3–8.

Enebak, S.; Carey, B. 2002. Pest control for container-grown longleaf pine. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 43–46.

Hainds, M.J. 2002. Longleaf seedling trends. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 3–4.

Hainds, M.J. 2004. Establishing longleaf pine seedlings on agricultural fields and pastures. In: Connor, K.F., ed. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 309–313.

Hainds, M.J.; Barnett, J.P. 2004. Container grown longleaf pine seedling quality. In: Connor, K.F., ed. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 319–320.

Hainds, M.J.; Barnett, J.P. 2006. Container grown longleaf pine seedling quality. In: Connor, K.F., ed. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-92. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 102–104.

Hinesley, L.E.; Maki, T.E. 1980. Fall fertilization helps longleaf pine nursery stock. Southern Journal of Applied Forestry. 4: 132–135.

Jackson, D.P. 2006. Relating morphology, nutrition, and bud development to liquid fertilizer application of containerized longleaf pine. Ruston, LA: Louisiana Tech University, College of Applied and Natural Resources. 62 p. M.S. thesis.

Jackson, D.P.; Dumroese, R.K.; Barnett, J.P.; Patterson, W.B. 2007. Container longleaf pine seedling morphology in response to varying rates of nitrogen fertilization in the nursery and subsequent growth after outplanting. In: Riley, L.E.; Dumroese, R.K.; Landis, T.D., tech. coords. National proceedings, forest and conservation nursery associations—2006. Proceedings RMRS-P-50. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station: 114–119.

Jackson, D.P.; Dumroese, R.K.; Barnett, J.P.; Patterson, W.B. 2010. Effects of liquid fertilizer application on the morphological and outplanting success of container longleaf pine seedlings. In: Stanturf, John A., ed. In: Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 229–234.

Jose, S.; Jokela, E.J.; Miller, D.L., eds. 2006. The longleaf pine ecosystem-ecology, silviculture, and restoration. New York: Springer. 438 p.

Landis, T.D.; Dumroese, R.K. 2006. Applying the target plant concept to nursery stock quality. In: MacLennan, L.; Fennessy, J., eds. Plant quality: a key to success in forest establishment. Proceedings of the COFORD conference. Dublin, Ireland: National Council for Forest Research and Development: 1–10.

Larson, D.R. 2002. Field planting containerized longleaf pine seedlings. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 62–63.

Little, E.L., Jr. 1979. Checklist of United States trees (native and naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture. 375 p.

Luoranen, J.; Rikala, R.; Smolander, H. 2004. Summer planting of hot-lifted silver birch container seedlings. In: Ciccarese, L.; Lucci, S.; Mattsson, A., eds. Nursery production and stand establishment of broadleaves to promote sustainable forest management. Rome, Italy: APAT (Italy's Agency for the Protection of the Environment and for Technical Services): 207–218. http://www.iufro.org/publications/proceedings/. [Date accessed: January 23, 2009].

Noss, R.F.; LaRoe, T.E., III; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biol. Rep. 128. Washington, DC: U.S. Department of the Interior, National Biological Service. 58 p.

Outcalt, K.W. 2000. The longleaf pine ecosystem of the South. Native Plants Journal. 1: 42–44, 47–53.

Pessin, L.J. 1939. Density of stocking and character of ground cover as factors in longleaf pine reproduction. Journal of Forestry. 37: 255–258.

Pessin, L.J.; Chapman, R.A. 1944. The effect of living grass on the growth of longleaf pine seedlings in pots. Ecology. 25: 85–90.

Salonius, P.; Hallett, R.; Beaton, K.; French, C. 2002. Extended nursery rearing compromises field performance of container-reared conifer seedlings. Inf. Rep. M-X-214E. Fredericton, NB: Canadian Forest Service. 20 p.

South, D.B. 1998. Needle-clipping longleaf pine and top-pruning loblolly pine in bareroot nurseries. Southern Journal of Applied Forestry. 22: 235–240.

South, D.B. 2006. Freeze injury to southern pine seedlings. In: Connor, K.F., ed. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-92. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 441–447.

South, D.B.; Harris, S.W.; Barnett, J.P. [and others]. 2005. Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama, U.S.A. Forest Ecology and Management. 204: 385–398.

South, D.B.; Mitchell, R.G. 2006. A root-bound index for evaluating planting stock quality of container-grown pines. Southern African Forestry Journal. 207: 47–54.

Sung, S.S-J.; Haywood, J.D.; Sword-Sayer, M.A. [and others]. 2010. Effects of container cavity size and copper coating on field performance of container-grown longleaf pine seedlings. In: Stanturf, J.A., ed. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 241–245.

Tinus, R.W. 1974. Characteristics of seedlings with high survival potential. In: Proceedings of the North American containerized forest tree seedling symposium. Publ. 68. [Place of publication unknown]: Great Plains Agricultural Council: 276–282.

Tinus, R.W.; Sword, M.A.; Barnett, J.P. 2002. Prevention of cold damage to container-grown longleaf pine roots. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 35–42.

Wahlenberg, W.G. 1946. Longleaf pine: its use, ecology, regeneration, protection, growth and management. Washington, DC: Charles Lathrop Pack Foundation. 429 p. In cooperation with: U.S. Department of Agriculture Forest Service.

Wakeley, P.C. 1954. Planting the southern pines. Agric. Monogr. 18. Washington, DC: U.S. Department of Agriculture. 233 p.

White, J.B. 1981. The influence of seedling size and length of storage on longleaf pine survival. Tree Planters' Notes. 32(4): 3–4.