IS PLANTING STOCKTYPE CRITICAL TO LONG-TERM FIELD PERFORMANCE OF LONGLEAF PINE?

Shi-Jean S. Sung, Mary Anne S. Sayer, Daniel J. Leduc, and James D. Haywood

Abstract—Longleaf pine (*Pinus palustris* Mill.) seedlings of five stocktypes, namely, bareroot (BR) and 108- or 164-ml closed-walled cavities of Superblock® or Copperblock® Styroblock containers, were planted at the Palustris and Escambia Experimental Forests. The 120-ml Jiffy® Forestry Pellets (JP) seedlings were also planted at the Palustris site. Among all stocktypes at planting, the BR and JP seedlings had the greatest and smallest root collar diameter, stem length, and fascicle density, respectively. Copper treatment did not affect seedling growth variables at planting. Nine months after planting, seedling survival was the lowest for BR and the highest for seedlings of closed-walled cavities. After 8 years, the Escambia saplings did not differ in growth among all stocktypes whereas the JP saplings were shorter than the rest of the Palustris saplings. Occurrence of drought during the first two field seasons was associated with high mortality and low plot-level stem volume for the BR saplings after 8 years.

INTRODUCTION

The disappearance of about 97 percent of the 37 million ha of pre-European settlement longleaf pine (*Pinus palustris* Mill.) ecosystems in the Southeastern United States was caused by unsustainable harvest for timber and naval stores products, land-use changes that included conversion to agricultural crops or faster-growing loblolly pine (*P. taeda* L.) and slash pine (*P. elliottii* Englem.) forests, urbanization, and exclusion of natural fire regimes from the landscape (Frost 2006, Landers and others 1995). Over the last 3 decades, many public, industrial, and private land managers have planted either bareroot (BR) or container seedlings to artificially regenerate longleaf pine forests in the Southeastern United States (Landers and others 1995, Van Lear and others 2005). Compared to BR seedlings, container longleaf pine seedlings generally have a wider planting window and greater first-year field survival (South and others 2005). For the 2005–2006 planting season, 70 percent of all longleaf pine seedlings produced in the Southeastern United States were of the container stocktype (McNabb and Enebak 2008). This trend of preference for container longleaf pine seedlings continues to date. However, between the ages of 5 and 10 years, juvenile stem instability (such as leaning, toppling, and windthrow) occurs most commonly among container longleaf saplings during or after high sustained winds (Haywood and others 2012, South and others 2001, Sung and Dumroese 2014). Widespread toppling in container lodgepole pine (*P. contorta* Dougl.) plantations in British Columbia was attributed to spiraled lateral roots in the root plug (Balisky and others 1995, Burdett and others 1986).

A few modifications in container cavity designs have been attempted to improve the morphology of container seedling lateral roots. One of the improvements is to coat the interior wall of the cavities with a copper (Cu) compound (such as copper oxychloride). Cu stops seedling primary lateral roots from elongating once they reach the cavity wall (Burdett 1978, Ruehle 1985). Longleaf pine seedlings cultured in Cu-coated cavities produced more new higher order roots than those cultured in non-Cu cavities during root growth potential tests (South and others 2005; Sword Sayer and others 2009, 2011). The Cu root pruning treatment also favored root biomass allocation to the taproot and secondary lateral roots of longleaf pine seedlings (Dumroese and others 2013; Sword Sayer and others 2009, 2011). The benefit of chemical root pruning to stem vertical stability was observed by Krasowski (2003) who found that lodgepole pine grown in Cu cavities had fewer leaning seedlings than those grown in non-Cu cavities 3 years after planting. Another cavity improvement is the presence of slits or vents along the cavity wall. Once lateral roots reach these openings, they are air pruned.

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Planted Scots pine (*P. sylvestris* L.) seedlings cultured in slit cavities showed improved root system structure and stem straightness compared to seedlings grown in closed-walled cavities (Rune 2003). Longleaf pine seedlings cultured in vented cavities had fewer deformed lateral roots and a larger taproot than seedlings grown in the closed-walled cavities (Sung and Haywood 2016).

In most longleaf pine plantation establishment studies, the early field performance of planted longleaf pine seedlings is based on survival, groundline diameter, and seedling emergence from the grass stage. A few studies have established the relationship between planting stock quality and the early field performance of container longleaf pine seedlings. For example, in a field trial of longleaf pine seedlings cultured in three container cavity sizes with or without Cu coating, planting stock size and subsequent first-year field growth were closely related (Sword Sayer and others 2009). Seedlings from 164-ml cavities had greater root collar diameter (RCD) and biomass during nursery culture and 1 year after planting compared to seedlings from 60-ml cavities (Sword Sayer and others 2009). Although Cu root pruning did not affect longleaf pine seedling RCD at lifting, the Cu seedlings were larger in stature compared to those cultured without Cu root pruning 5 years after planting (Haywood and others 2012). Here, we compared seedling growth characteristics at planting for longleaf pine seedlings cultured in soft, meshed-walled Jiffy® Forestry Pellets (air lateral root pruning), closed-walled cavities of Superblock® containers, closed-walled cavities with Cu coating of Copperblock® (chemical lateral root pruning) containers, and nursery beds (BR). Seedling survival through 9 months after planting and sapling survival and growth 8 years after planting are also reported.

MATERIALS AND METHODS

Seedling Production

A south Alabama seed source, Seed Lot 01-2-121-1-06-01 (U.S. Department of Agriculture, Forest Service, Ashe Seed Bank, Brooklyn, MS), was used to grow all stocktypes. This seed lot was processed in 2006 and had 96-percent germination after a 14-day stratification.[1] For the BR treatment, seeds were sown in late April 2009 at the Georgia Forestry Commission's Flint River Nursery in Byromville, GA (32°17'N, 83°97'W) at a density of 86 m^{-2}. We grew all container seedlings in a facility of the Forest Service Southern Research Station in Pineville, LA (31°19'N, 92°26'W). Seeds were sown at one seed per cavity on May 19, 2009 inside a greenhouse. Seedlings were brought outdoors in late June and cultured until being planted in early December 2009. Container types included Superblock® (Beaver Plastics, Edmonton, Alta, Canada) (SB); Copperblock® (Beaver Plastics, Edmonton, Alta, Canada) (CuB) which had a coating of copper oxychloride on the interior cavity wall, except the ridges; and Jiffy® Forestry Pellets (Jiffy Products of America, Inc., Norwalk, OH) (JP) which consisted of packed peat inside a soft meshed-wall that was fully soaked in tap water prior to seed sowing. Specifications for each container type are shown in table 1.

The nursery protocol for container seedlings generally followed that of Sword Sayer and others (2009). Fertilization was accomplished by the addition of Osmocote® 19-6-12 slow-release fertilizer (Scotts Company, Marysville, OH) to the growing medium at the time of sowing and application of Peters® Professional 20-20-20 water-soluble liquid fertilizer (J.R. Peters, Inc., Allentown, PA) during seedling culture. Twice as much liquid fertilizer was given to the JP seedlings because Jiffy® Forestry Pellets do not contain slow-release Osmocote® fertilizer in their densely packed peat plugs. Seedling fascicles were not clipped during nursery culture.

Field Experiment

The study was established at two field sites on experimental forests in Louisiana and Alabama. The Palustris Experimental Forest is within the Kisatchie National Forest in Rapides Parish, LA (31°04'N, 92°37'W). The soil is a complex of Malbis fine sandy loam (fine-loamy, siliceous, subactive, thermic Plinthic

[1] Personal communication. 2019. B. Crane. Regional Geneticist, U.S. Department of Agriculture, Forest Service, Region 8, Atlanta, GA 30309.

Table 1—Container cavity specifications for both the Superblock® (SB) and Copperblock® (CuB) containers and the fully soaked, expanded Jiffy® Forestry Pellets (JP)

Container	Volume	Top diameter	Length	Density
	ml	*cm*	*cm*	*number m^{-2}*
112/105 (medium) (SB, CuB)	108	3.5	14.9	531
77/170 (large) (SB, CuB)	164	4.2	15.2	366
36100 Super (JP)	120	3.8	10.2	592

Paleudults), Ruston fine sandy loam (fine-loamy, siliceous, semiactive, thermic Typic Paleudults), and Smithdale sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults). The Escambia Experimental Forest is in Escambia County, AL (31°00'N, 87°04'W). The soil is a complex of Troup fine sand (loamy, kaolinitic, thermic Grossarenic Kandiudults) and Wagram loamy sand (loamy, kaolinitic, thermic Arenic Kandiudults).

In fall 2009, four blocks with seven plots each were established at the Palustris site and four blocks with six plots each were established at the Escambia site. Blocks were established by topography. Treatment plots contained 14 rows of 14 trees planted at a 2- by 2-m spacing for 196 planting spots per treatment plot of 0.0784 ha. The center 10 rows of 10 trees were the measurement plot. Treatments at the Palustris site were (1) BR, (2) 108-ml Superblock® (SB-M), (3) 108-ml Copperblock® (CuB-M), (4) 164-ml Superblock® (SB-L), (5) 164-ml Copperblock® (CuB-L), (6) direct seeding (DS) of the same seed lot as the seedlings, and (7) JP. All treatments except for JP were also installed at the Escambia site. The JP seedlings were only planted at the Palustris site because low seed germination and poor seedling survival reduced the number of JP seedlings available for planting at the end of the cultural period. The DS treatment was used to produce a natural root system for comparison purposes. In early December 2009, four seeds coated with capsaicin (to deter rodents) were placed at each of the 196 planting spots in each DS plot and covered with a thin layer of soil. In early December 2009, the BR seedlings were planted within 2 days of lifting from the nursery beds. Container seedlings were watered the day before being extracted from the containers, stored in plastic bags in a cold room, and planted within 3 days of being extracted.

Laboratory and Field Assessments

Before planting, 20 seedlings of each stocktype were randomly selected for growth characteristics assessments including root collar diameter (RCD), stem length, bud diameter and length, fascicle number, and longest fascicle length. Root collar diameter was measured by digital calipers at the root collar. Stem length was measured by a ruler between the root collar and the base of a terminal bud. Terminal bud diameter was measured with digital calipers at the widest part of the bud. The bud length was measured from the base to the tip. Fascicle density (number of fascicles per cm of stem) was calculated. Seedling root-bound index (RBI) was calculated as the ratio between RCD and cavity top diameter expressed in percentage. Seedling survival was assessed 3, 6, and 9 months after planting except that 3-month survival was not assessed for the Escambia seedlings. Eight years after planting, survival, total height, and diameter at breast height (d.b.h.) were measured with a height pole and calipers, respectively. Individual sapling volume was approximated as a cone:

$$V = \frac{1}{3}\pi\left(\frac{d.b.h.}{2}\right)^2 (\textit{total height}) \qquad (1)$$

Plot-level stem volume was calculated as the sum of stem volume for all surviving saplings within a plot.

Statistical Analysis

At each site, the study was established in a randomized complete block design with each of the four blocks containing seven (the Palustris site) or six (the Escambia site) planting stocktypes. The DS treatment only produced three seedlings on the Escambia site and was dropped from the analyses. A one-way analysis of variance (ANOVA) was used to examine the effects of planting stocktypes on seedling growth characteristics at planting [RCD (mm), terminal bud diameter (mm) and length (cm), stem length (cm), number of fascicles, fascicle density (per cm of stem), length of the longest fascicle (cm), and RBI (percent)]. Field performance of stocktypes was compared at each site separately because JP seedlings were not planted at the Escambia site. A one-way ANOVA with blocks was used to examine seedling survival (percent) 3 to 9 months after planting and sapling field performance after 8 years [survival (percent), total height (cm), d.b.h. (mm), and plot-level stem volume (dm^3)] using SAS® PROC GLM (SAS 2004). If stocktypes differed, a separation of treatment means was done using Duncan's multiple range test. Data from all but JP saplings were combined by site, and a multi-location two-way ANOVA (site and stocktype) with blocks nested within sites was used to test for significant differences between sites in the growth variables. The F-tests and mean separation tests were considered significant at $\alpha < 0.05$.

RESULTS AND DISCUSSION

Nursery Phase

Seed germination in the greenhouse in Pineville, LA, began six days after sowing. Sixteen days after sowing, germination was 81, 79, 82, 75, and 53 percent for the SB-M, CuB-M, SB-L, CuB-L, and JP treatments, respectively. Final percentages of germination assessed 28 days after sowing were 89, 79, 85, 79, and 60 percent, respectively, for the SB-M, CuB-M, SB-L, CuB-L, and JP stocktypes. Many seeds sown to the JP plugs germinated. However, the protruding radicals <0.5 cm in length failed to penetrate the densely packed peat and eventually dried up and caused germinant mortality. An improvement in the JP design is needed to help longleaf pine germinants anchor into the peat plug. Percentages of harvestable seedlings in mid-September were 86, 75, 81, 75, and 55 percent of sown seeds for the SB-M, CuB-M, SB-L, CuB-L, and JP stocktypes, respectively.

Among all stocktypes at planting, the BR were the largest and the JP were the smallest in RCD, stem length, and fascicle number and density (table 2). Compared to container longleaf pine seedlings grown at the same facility as the current study, seedling RCD at planting in the current study was generally within the reported range of 4.2 to 7.3 mm (Jackson and others 2012, South and others 2005, Sword Sayer and others 2011). However, South and others (2005) reported a much larger RCD for BR (13.6 mm) and JP (7.0 mm) seedlings than the BR (9.0 mm) and JP (4.8 mm) seedlings in the current study. The JP seedlings also grew the shortest fascicles among all stocktypes (table 2). It is possible that the small size of the JP seedlings was, in part, due to the amount of liquid fertilizer given not meeting their needs.

At the end of the nursery culture, the Cu root pruning treatment did not affect any of the seedling growth characteristics (table 2). The effects of Cu root pruning treatment on longleaf pine seedling growth at planting or the early field performance have not been consistent among studies. Seedling RCD at planting and 1 or 2 years after planting was not affected by Cu treatment (South and others 2005, Sword Sayer and others 2011). However, Dumroese and others (2013) reported that the Cu treatment significantly affected seedling RCD at planting. Except for RBI, the SB-L seedlings were larger than the SB-M seedlings in all growth characteristics assessed (table 2). Compared to the CuB-M seedlings, the CuB-L seedlings had greater bud diameter and length but were similar in RCD, stem length, number of fascicles, fascicle density, and length of the longest fascicle (table 2). In the study of Sword Sayer and others (2011), RCD of longleaf pine seedlings grown in 164-ml cavities were greater than those in 108-ml cavities for both CuB and SB cavities.

The range of RBI for individual container seedlings in this study was between 7.9 and 26.0 with a mean of 16.2. South and others (2005) indicated that early field mortality increased greatly for seedlings with an RBI greater than 27.0. However, several studies showed that longleaf pine seedlings cultured for regular duration of 27 to 35 weeks did not have an RBI that approached the 27.0 threshold of mortality (Dumroese and others 2013, Jackson and others 2012, Sword Sayer and others 2011). In other words, seedling field mortality was not associated with inadequate rooting volume (RBI >27.0) in the current study or those studies by Dumroese and others (2013), Jackson and others (2012), or Sword Sayer and others (2011).

Seedling Field Performance

On both sites, predation completely removed seeds from all DS spots within 1 week of sowing. The DS plots were re-seeded in early January 2010, but this effort also succumbed to predation. A 2-year drought began in March 2010 (3 months after planting) on the Palustris site and in June 2010 (6 months after planting) on the Escambia site (fig. 1). The percentage of seedling survival decreased greatly from March 2010 to June 2010 for the BR and JP plots on the Palustris site (table 3). Although more BR seedlings survived on the Escambia site than on the Palustris site, we attribute early mortality among the BR seedlings at both sites and among the JP seedlings at the Palustris site to drought. The 3-month delay in drought occurrence and the sandy soils on the Escambia site may be responsible for higher survival for the Escambia BR seedlings than

Table 2—Growth characteristics of six stocktypes of longleaf pine seedlings assessed before planting (*n* = 20 seedlings per container type)

Type	RCD	RBI	Bud length	Bud diameter	Stem length	Fascicle	Fascicle density	Longest fascicle
	mm	*percent*	*cm*	*mm*	*cm*	*number*	*number cm^{-1}*	*cm*
BR	9.0 a	--	1.1 a	7.3 a	3.7 a	42 a	11.1 a	35.4 a
SB-M	5.7 d	16.3 a	0.4 cd	4.0 cd	2.0 c	12 c	6.2 c	31.1 b
CuB-M	6.2 cd	17.8 a	0.5 c	4.8 c	2.2 bc	14 bc	6.5 c	33.5 ab
SB-L	7.4 b	17.7 a	0.8 b	6.0 b	2.3 b	21 b	8.9 b	35.8 a
CuB-L	7.0 bc	16.8 a	0.8 b	5.8 b	2.4 b	18 bc	7.8 bc	35.7 a
JP	4.8 e	12.6 b	0.3 d	3.4 d	1.4 d	5 d	3.9 d	19.6 c
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

RCD: root collar diameter; RBI: root-bound index. BR: bareroot; SB-M: 108-ml Superblock®; CuB-M: 108-ml Copperblock®; SB-L: 164-ml Superblock®; CuB-L: 164-ml Copperblock®; JP: 120-ml Jiffy® Forestry Pellets.

Means in each column followed by the same letter were not significantly different at α <0.05 based on Duncan's multiple range test.

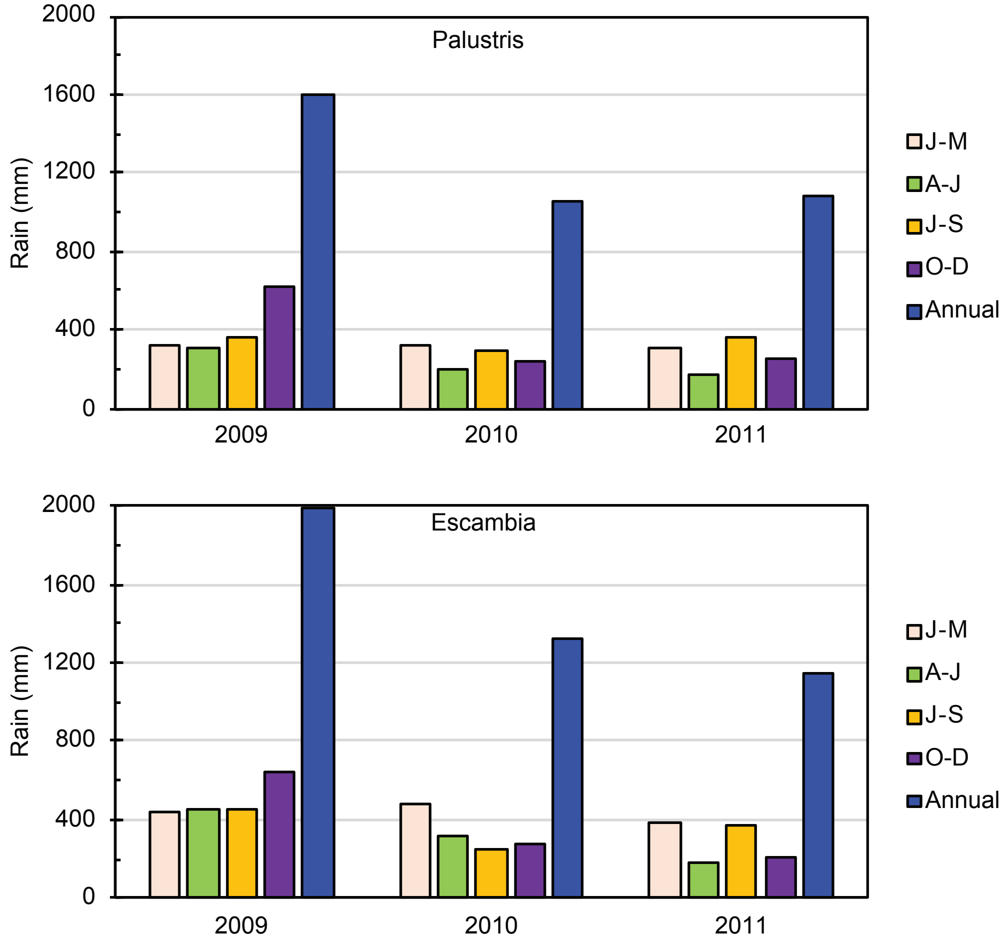

Figure 1—Quarterly and annual rainfall for the Palustris and Escambia Experimental Forests from 2009 to 2011.

for the Palustris BR seedlings. In a study by South and others (2005), BR seedlings had between 67 and 94 percent second year survival on all four planting sites with between 43 and 88 percent survival for container seedlings of various stocktypes. No drought was cited in that study. Similar to the results at the Palustris site (table 3), survival of the JP seedlings (50 to 82 percent) was the lowest among container stocktypes on each planting site in the study of South and others (2005). However, unlike the current study, seedling RCD at planting was not different between JP and the rest of container stocktypes in the study of South and others (2005), suggesting that container seedling mortality may be caused by factors in addition to seedling size.

By the end of the eighth year, only 9 and 31 percent of BR seedlings were alive on the Palustris and Escambia sites, respectively (table 3). At planting, the BR seedlings had similar longest fascicle length to those of CuB-M, SB-L, and CuB-L seedlings, and the BR seedlings had the greatest fascicle density among all stocktypes (table 2). South (1998) suggested that the improved survival of BR longleaf pine seedlings with clipped fascicles was related to reducing transpiration stress. However, the JP seedlings had the shortest and fewest fascicles among all stocktypes (table 2) and also had low survival 9 months after planting (table 3). Therefore, numbers of fascicles and their lengths at planting alone do not explain the high mortality of JP seedlings in our study. South and others (2005 and references cited therein) concluded that low survival of BR seedlings under drought conditions is one of the main reasons container stock is the preferred stocktype for establishing longleaf pine plantations. Our results suggest that the JP seedlings are not a good alternative to other container stocktypes due to a low percentage of harvestable seedlings at lifting, smaller growth parameters at planting, and low early field survival. On the Palustris site, fewer CuB-M seedlings than SB-M seedlings were alive at 6 and 9 months after planting (table 3). Eight years after planting, neither Cu treatment nor cavity size affected sapling survival on the Palustris site. On the Escambia site, the CuB-L saplings had greater survival than the SB-L saplings after 8 years. Survival among all saplings grown in the closed-walled containers ranged between 56 and 72 percent after 8 years. A 2-year drought during the first and second field seasons in this study showed the merit of longleaf pine reforestation using container-grown seedlings instead of the BR seedlings.

Table 3—Survival (percent) between 3 months and 8 years after planting for various stocktypes of longleaf pine seedlings at the Palustris and Escambia Experimental Forests

Type	Mar 2010 (3 mo)	Jun 2010 (6 mo)	Sep 2010 (9 mo)	Dec 2017 (8 yr)
Palustris Experimental Forest				
BR	92 b	24 d	18 d	9 c
SB-M	99 a	97 a	93 a	66 a
CuB-M	97 a	88 b	83 b	62 a
SB-L	98 a	91 ab	87 ab	56 a
CuB-L	98 a	90 ab	88 ab	58 a
JP	94 b	74 c	67 c	37 b
p value	0.0002	<0.0001	<0.0001	<0.0001
Escambia Experimental Forest				
BR	-	55 b	48 b	31 c
SB-M	-	83 a	81 a	61 ab
CuB-M	-	90 a	89 a	70 ab
SB-L	-	90 a	89 a	61 b
CuB-L	-	90 a	89 a	72 a
p value	-	<0.0001	<0.0001	<0.0001

BR: bareroot; SB-M: 108-ml Superblock®; CuB-M: 108-ml Copperblock®; SB-L: 170-ml Superblock®; CuB-L: 170-ml Copperblock®; JP: 120-ml Jiffy® Forestry Pellets.

Means in each column followed by the same letter were not significantly different at α <0.05 based on Duncan's multiple range test.

The long-term impact of seedling quality at planting was evident with the JP stocktype. The JP seedlings grew the least in total height among all stocktypes after 8 years on the Palustris site (table 4). Among the Superblock® and Copperblock® stocktypes, Cu treatment and cavity size did not impact total height, d.b.h., or plot-level stem volume of longleaf pine saplings on either site 8 years after planting (table 4). In a study established with longleaf pine seedlings grown in Superblock® or Copperblock® cavities of three sizes (including the 108-ml and 164-ml cavities used in the current study), the Copperblock® saplings were greater in total height and d.b.h. than the Superblock® saplings after the fifth growing season (Haywood and others 2012). Similar to the current study, saplings from the 164-ml cavities were not different in total height or d.b.h. than saplings of the 108-ml cavities after 5 years (Haywood and others 2012). Although BR saplings on the Palustris site were similar in stature as the SB or CuB saplings, their plot-level stem volume was much lower due to low survival (table 4).

Eight years after planting, total height, d.b.h., and plot-level stem volume were significantly different between the two sites (table 5). There was a significant interaction between treatment and site in regard to survival at age 8. The SB-M saplings ranked highest in the eighth

Table 4—Total height, diameter at breast height, and plot-level stem volume for various stocktypes of longleaf pine seedlings 8 years after planting on the Palustris and Escambia Experimental Forests

Type	Total height	d.b.h.	Plot-level stem volume
	cm	*mm*	*dm^3*
Palustris Experimental Forest			
BR	505 a	72.0	73.4 b
SB-M	525 a	70.2	515.1 a
CuB-M	560 a	70.7	495.0 a
SB-L	539 a	69.0	412.3 a
CuB-L	540 a	66.5	411.0 a
JP	432 b	59.8	185.2 b
p-value	0.0040	0.0506	<0.0001
Escambia Experimental Forest			
BR	598	69.0	304.4
SB-M	577	64.2	487.7
CuB-M	567	63.2	566.4
SB-L	559	61.3	440.1
CuB-L	608	66.9	629.2
p-value	0.4402	0.2798	0.0561

d.b.h.: diameter at breast height; plot-level stem volume: sum of stem volume among all surviving saplings within a plot.

BR: bareroot; SB-M: 108-ml Superoblock®; CuB-M: 108-ml Copperblock®; SB-L: 164-ml Superblock®; CuB-L: 164-ml Copperblock®; JP: 120-ml Jiffy® Forestry Pellets.

Means in each column followed by the same letter or no letters were not significantly different at α < 0.05 based on Duncan's multiple range test.

Table 5—Comparisons of field performance by five stocktypes of longleaf pine seedlings on the Palustris and Escambia Experimental Forests 8 years after planting

Site	Survival	Total height	d.b.h.	Plot-level stem volume
	percent	*cm*	*mm*	*dm^3*
Palustris	50	534	69.7	381.3
Escambia	59	582	64.9	485.6
p-value		0.0005	0.0069	0.0077

d.b.h. = diameter at breast height.

Jiffy® seedlings were not planted on the Escambia site and were not included in this comparison.

There was a significant interaction between treatment and site in survival ($p < 0.05$).

year survival on the Palustris site whereas the CuB-L saplings ranked highest in survival on the Escambia site (table 3). Saplings of the Escambia site had greater total height and smaller d.b.h. than those of the Palustris site (table 5). Therefore, the greater plot-level stem volume on the Escambia site was associated with greater survival of the Escambia plantings compared to the Palsutris site. Between the ages of 5 and 10 years, the physical stability of container longleaf pine saplings may be compromised during or after high sustained winds (Haywood and others 2012, South and others 2001, Sung and Dumroese 2014). In this and other studies, only a few saplings had stem displacement which might be the result of once-leaned or toppled saplings that later grew upward by stem overcorrection (Sung and others 2012). Unlike the improved stem stability for lodgepole pine seedlings grown in Cu containers (Krasowski 2003), the positive effects of lateral root pruning treatment (by Cu or air) on the physical stability of longleaf pine saplings are yet to be realized in this study.

CONCLUSIONS

This study extended the traditional short-term (1 to 2 years) evaluation of the field performance of planted longleaf pine seedlings to a long-term (8 years) evaluation. Seedlings grown in 164-ml Superblock® cavities were larger in all growth characteristics than those in 108-ml Superblock® cavities at planting. These cavity size-associated differences in seedling total height or diameter no longer existed 8 years after planting. The copper root pruning treatment did not affect seedling growth at planting or 8 years after planting. Jiffy® Forestry Pellets seedlings survived less and grew less compared to seedlings grown in closed-walled cavities. The surviving bareroot saplings had similar total height and d.b.h. compared to those cultured in closed-walled cavities. The 2-year drought after planting, however, caused low early field survival and low plot-level volume for the bareroot saplings compared to those from the closed-walled cavities. The timing of drought and soil texture may be associated with differences in bareroot seedling performance on the two sites. The absence of growth differences among saplings from the four types of closed-walled cavities 8 years after planting suggests that the choice of closed-walled containers for establishing longleaf pine plantations makes little difference.

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