COMPARING FIRST-YEAR GROWTH OF BARE-ROOT AND CONTAINER PLANTINGS OF SHORTLEAF PINE HALF-SIB FAMILIES

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Abstract.--Shortleaf pine seeds were collected from several ramets of clones identified as the female parents of seedlings that were either relatively good or relatively poor survivors in full-sib progeny tests. Seedlings from six such half-sib families were grown as both bare-root and container stock and planted on two sites in the Ouachita Mountains of Arkansas. When outplanted, the bare-root seedlings had greater mean height and root collar diameter than the container seedlings. However, the container seedlings had greater mean root volume and a more favorable shoot-to-root balance than the bare-root stock. After one growing season in the field, survival of all the families from both stock-types exceeded 94% at both locations. The container seedlings grew larger than the bare-root seedlings on both sites. Among the families, groundline diameters differed on one site, and family and stock type interacted in their effects on height on the other site.

Keywords: *Pinus echinata* Mill., family planting, stock-type comparison, Ouachita Mountains.

INTRODUCTION

On the Ouachita and Ozark National Forests in Arkansas and Oklahoma, shortleaf pine is usually planted on south- and west-facing slopes where soil moisture is often limited. One advantage cited for container versus bare-root southern pine seedlings is better performance on harsh, drought-prone, planting sites (Barnett and Brissette 1986). Superior survival and growth of container seedlings over bare-root stock on dry sites has been shown for longleaf pine (Amidon et al. 1982, Goodwin 1976, 1980), and for loblolly pine (Barnett 1980, Goodwin 1976, South and Barnett 1986).

Shortleaf pine has not been compared in as many stock-type trials as the other southern pines. Ruehle et al. (1981) compared container and bare-root shortleaf pine in an ectomycorrhizae study on two sites in the Ouachita Mountains. The container seedlings survived better and grew taller and to a larger diameter than the bare-root stock on the site with the best soil moisture characteristics. However, on the site with the drier moisture regime, the container seedlings were poorer than the bare-root seedlings in both survival and growth. The authors concluded that the container seedlings, which were considerably smaller, required more intensive site preparation to perform as well as the larger bare-root stock.

The use of half-sib family seed collections, rather than seed orchard mixes, for loblolly pine reforestation has been increasing for the past several years. One advantage of maintaining family identity is that variation in rates of seed germination and seedling growth is reduced. Thus, nursery culture can

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be tailored to individual families, or groups of families, to grow seedlings of higher quality than possible when a bulked seed collection is sown. In a previous study with a bulked seed orchard lot of shortleaf pine, our research seedlings were markedly more variable than the half-sib families of loblolly pine growing in nearby operational nursery beds. Therefore, we decided to make half-sib family collections for future shortleaf pine seedling research.

The primary objective of this study was to compare the field performance of shortleaf pine seedlings produced as bare-root and as container stock and planted on typical mountain reforestation sites in Arkansas. Additionally, we wanted to determine if family and stock-type interacted in their effects on survival and growth in the field.

METHODS

Family Selection

Seed collections were made at the USDA Forest Service Ouachita and Ozark seed orchard located near Mount Ida, Arkansas. The seed orchard is organized by geographic sources. Separate blocks in the orchard consist of selections from the Ozark National Forest and the east and west sides of the Ouachita National Forest. The geographic source of a family can be determined from the identification number; the 100's are east Ouachita, the 200's are west Ouachita, and the 300's are from the Ozark. Because no growth data were available when these selections were made, seed orchard clones were chosen on the basis of the survival of their progeny in full-sib tests planted on both forests. To be considered, a clone had to be the female parent in at least three tests. Progeny survival was compared to the average survival of each test. Thus, families that survived better than average in a test had relative survivals of greater than 100, and those that survived below average had relative survivals of less than 100. The overall average relative survival for progeny of the same female was the selection criterion.

In 1985, seeds were collected from several ramets of clones with an average relative survival greater than 100 and from others with an average less than 100. Seed processing was done at the Forest Service's Southern Forest Experiment Station laboratory in Pineville, Louisiana. Six half-sib families are in this study, two from each geographic source. Three are relatively good survivors (115, 219, and 322), and three relatively poor survivors (103, 202, and 342). The seeds were stratified for 35 days before sowing in the bare-root nursery.

Bare-root Seedling Production

The staff of the Weyerhaeuser Company Magnolia Forest Regeneration Center in southwest Arkansas grew the bare-root seedlings. The seeds were sown April 16, 1986, with a Weyerhaeuser-designed precision vacuum seeder. The machine sows eight drills with approximately 5 cm between the double row of seeds that make up each drill and about 15 cm between drills. The two outside drills on the 1.3-m wide nursery beds were planted with the seed orchard mix. The study families were assigned at random to the interior drills and re-randomized for each of seven blocks. Each family plot was 15.2 m long.

There was not enough time after the **seeds** were cleaned to conduct germination tests of stratified seed. Therefore, *a* germination rate of 90% was assumed, and the seeds were sown to achieve a density of about 250 seedlings per m^2. Nursery cultural practices, such as fertilization and root pruning, were applied based on the best judgment of the nursery manager. Top pruning was not done.

The seedlings were carefully hand lifted on February 2, 1987. They were packed in kraft-polyethylene (K-P) bags and kept in cold storage (about 3 °C) in Pineville until they were transported to the sites for planting.

Container Seedling Production

The container seedlings were grown at the Forest Service laboratory in Pineville. The containers were hand seeded April 23, 1986, into Ray Leach[1] "Stubby" cells filled with a 1:1 peat-vermiculite medium. The volume of each cell is approximately 115 cm^3. One tray holds 98 of these cells at a density of about 500 per m^2. Each tray of cells was sown with a single family, with five replications of each family.

The containers were kept in a greenhouse for 2 weeks until germination was complete. They were then moved to raised benches outside in full sunlight where the seedlings were grown and hardened-off. Container southern pine seedlings grown under full sunlight have greater shoot and root dry weights than comparable seedlings grown in shaded greenhouses (Barnett 1989). Except for growing them outside, the seedlings received the culture regime recommended by Barnett and Brissette (1986).

Planting Sites

The plantings were on two typical National Forest sites in Arkansas. One site is on the Magazine Ranger District of the Ozark National Forest about 30 km southwest of Russellville. The other is on the Winona Ranger District of the Ouachita National Forest about 65 km southeast of Russellville and about 40 km west of Little Rock. Although most of the Ozark National Forest is in the Boston Mountains, the Magazine District is south of the Arkansas River and, therefore, in the Ouachita Mountains. Both sites are on gently rolling to rolling terrain with shallow, rocky soils. They were clearcut and site prepared as part of commercial operations. Both sites were ripped during site preparation.

On the Magazine site, the container seedlings were planted on December 10, 1986, and the bare-root stock on February 11, 1987. On the Winona site, the containers were planted on December 9, 1986, and the bare-root seedlings on February 11, 1987. The split planting was necessitated by the busy work schedule that winter. Consequently, stock-type is confounded with planting date in this study. For each family by stock-type combination, a 25-seedling row plot was planted.

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An electronic weather station is located at the Winona site within several meters of the study. It collects data on a 5 minute scan interval, then each hour records the means from several sensors, including several air and soil temperatures, relative humidity, soil matric potential, and wind speed and direction. Precipitation is recorded as it occurs.

Brissette and Carlson (1987) showed that the root growth potential (RGP), measured as the number of new roots greater than 1 cm long, of bare-root shortleaf pine seedlings averaged only 0.6 after 28 days at 10 °C. However, at 20 °C mean RGP for the same period was 11.7. At the Winona site, the daily mean soil temperature at a depth of 15 cm did not stay above 10 °C for more than two consecutive days until March 7. Thus, although the container seedlings were planted in December and the bare-root seedlings in February, new root elongation for both probably began at about the same time. Therefore we believe that confounding stock-type and planting date did not seriously affect the results of this study.

Measurements and Analyses

Seedling size at outplanting has a tremendous impact on first-year growth. Therefore, shoot length, root-collar diameter, and root volume were averaged for a 50-seedling sample of each family from each stock-type. We used the square of the root-collar diameter multiplied by the shoot length (D^2H) divided by root volume as an index of the shoot-to-root balance (S/R) of each seedling. After the first growing season, survival, total height, and groundline diameter of each planted tree were measured.

The experimental design for evaluating seedling morphology was completely random with each seedling an experimental unit. Stock-type, family, and the interaction between the factors were compared for each measured characteristic and for S/R with analysis of variance (ANOVA). The model had 588 degrees of freedom for error (dfe). Because of the selection method, family is considered a fixed effect in all the ANOVA models discussed.

The field data were analyzed separately for each site. The design at both locations is a split-plot in six randomized complete blocks. The experimental units are the 25-tree plots and ANOVAs for survival, total height, and groundline diameter were performed on the plot means. Stock-type is in the whole plot with 5 dfe. Family and the stock-type x family interaction are in the subplot with 50 dfe.

Survival data were transformed using the arc sine of the square root of the proportional value. This transformation ensures that the proportions are close to being normally distributed with homogeneous variance (Freese 1967). A linear contrast with the same mean square error (MSE) as the subplots was used to determine whether the field survival of families selected as relatively good survivors differed from those selected as relatively poor survivors. For F-tests of the family main effect with a $p<0.05$, family means were separated using Duncan's multiple-range test.

RESULTS AND DISCUSSION

Seedling Morphology

The mean morphological characteristics are shown in Table 1. The stock-type x family interaction was significant for each of the measured characteristics and for the S/R. For shoot length, root collar diameter, and root volume the interaction explains 15%, 9%, and 8% of the total variation, respectively. For the S/R, the interaction accounts for less than 2% of the total variation. However, because of the large number of dfe, the F-test was very powerful. With an MSE of 0.316, the F value was 94.76, and p-0.0. Stock-type explains 12%, 17%, 19%, and 59% of the variation in shoot length, root-collar diameter, root volume, and S/R, respectively. Family accounts for 17%, 11%, 8%, and 4%, of the variation in those characteristics. The much more favorable shoot-to-root balance of the container seedlings probably explains why they often outperform bare-root seedlings on harsh sites.

Table 1. Morphological characteristics at the time of outplanting of container (Cont) and bare-root (Bare) shortleaf pine seedlings from selected half-sib families.

	Characteristic and stock-type											
	Shoot length			Diameter			Root volume			Shoot-to-root		
Family	Cont	Bare	Mean	Cont	Bare	Mean	Cont	Bare	Mean	Cont	Bare	Mean
	- - - cm - - -			- - - mm - - -			- - - cm^3 - - -			ratio		
103	24.4	25.0	24.7	3.8	4.4	4.1	3.6	2.2	2.9	1.06	2.40	1.73
115	21.9	29.4	25.6	4.0	5.4	4.7	3.5	3.4	3.5	1.05	2.61	1.83
202	19.7	26.6	23.1	3.8	4.7	4.2	4.3	2.9	3.6	0.70	2.16	1.43
219	22.5	20.2	21.4	3.9	3.8	3.8	3.5	1.7	2.6	0.98	2.03	1.51
322	20.9	28.3	24.6	3.6	5.1	4.4	3.1	3.0	3.1	0.93	2.74	1.84
342	19.4	20.2	19.8	3.7	4.0	3.8	3.6	1.7	2.7	0.77	2.06	1.41
Mean	21.5	24.9	23.2	3.8	4.6	4.2	3.6	2.5	3.1	0.91	2.33	1.62

The size of the container seedlings in this study contrasted markedly with those planted by Ruehle et al. (1981), where container seedlings averaged only 12.3 cm tall and 2.0 mm in diameter. Their bare-root seedlings were similar to ours, averaging 23.4 cm tall and 5.1 mm in diameter.

Magazine Site

First-year survival (n the Magazine site was excellent (Table 2). Such high survival indicates that the seedlings of both stock-types were of excellent quality and that the site had enough soil moisture during establishment. The interaction between stock-type and family was not significant (MSE=0.0135, F-0.93, p=0.47), and families did not differ (F-1.20, p=0.32). The linear contrast between families selected as relatively good and poor survivors showed no difference (F=0.05, p=0.82) between the two groups. The stock-types had similar survival (MSE=0.014, F=3.13, p=0.14). The ANOVA model explains only 29%

of the variation in survival. Mortality was so low that it cannot be attributed to either treatments or environmental factors.

First-year total heights averaged from 30 to 39 cm (Table 2). With an MSE of 6.658, there was no significant stock-type x family interaction (F=1.23, p=0.31), and families did not differ (F=1.73, p=0.15). However, the container seedlings were taller (MSE=9.240, F=90.01, p=0.0002). Compared to the average initial shoot lengths, the container seedlings grew an average of 17 cm for an 81% increase in height. The bare-root seedlings grew an average of 7 cm, or increased 29%. The ANOVA model explains 76% of the variation in first-year height, with stock-type alone accounting for 61%.

Table 2. First-year survival, total height, and groundline diameter of half-sib families of shortleaf pine grown as container (Cont) and bare-root (Bare) stock and planted on the Magazine Ranger District of the Ozark National Forest.

	Characteristic and stock-type								
	Survival			Height			Diameter		
Family	Cont	Bare	Mean	Cont	Bare	Mean	Cont	Bare	Mean
	%			cm			mm		
103	97.6	95.3	96.0a1/	39	30	34a	6.0	4.7	5.4bc
115	98.7	96.7	97.7a	38	33	36a	6.1	5.2	5.7ab
202	98.7	96.7	97.7a	38	32	35a	5.7	5.0	5.3bc
219	99.3	96.0	97.6a	37	30	33a	5.7	4.7	5.2c
322	97.3	98.7	98.0a	38	33	35a	6.2	5.5	5.8a
342	99.3	98.0	98.6a	38	30	34a	6.3	4.5	5.4bc
Mean	98.3p2/	96.9p	97.6	38p	31q	35	6.0p	4.9q	5.5

1/ Family means for a given characteristic followed by the same letter are not significantly different at p=0.05.
Stock-type means for a given characteristic followed by the same letter are not significantly different at p=0.05.

Groundline diameters averaged from 4.5 to 6.3 mm after the first growing season (Table 2). The stock-type x family interaction was not significant (MSE=0.2486, F=1.90, p=0.11). Families differed (F=3.01, p=0.0188); Family 322 was the largest and Family 219 the smallest (Table 2). However, compared to average root-collar diameter at outplanting, both families increased an average of 34%. The container seedlings had a larger average diameter than the bare-root stock (MSE=0.558, F=20.91, p=0.0017). The mean diameter of the container seedlings increased 58% compared to the mean root-collar diameter at outplanting, while the bare-root seedlings increased 11%. Stock-type explains 47%, and family 8% of the total variation in first-year groundline diameter.

Winona Site

Survival was also excellent at the Winona site (Table 3). There was no stock-type x family interaction (MSE=0.018, F=0.17, p=0.97), or difference due to family (F=0.28, p=0.92). There was also no difference between the relatively good and relatively poor surviving families (F=0.00, p=0.95). The container seedlings survived better than the bare-root stock (MSE=0.010, F-21.90, p=0.0054). Although the difference is statistically significant, it is of little practical importance. The ANOVA model explains 31% of the variation.

There was a significant stock-type x family interaction in total height (MSE=8.162, F-2.42, p-0.0483). Although each family was taller from containers, the ranking of the families differed. The biggest differences were in Families 219 and 322. Family 219 was tallest from containers, but from bare-root it was the second shortest. Family 322 was shortest from containers, but the second tallest bare-root family. The interaction explains only 3% of the total variation in total height. Although such an interaction is not important to silviculturists, it may be of interest to geneticists, especially if early evaluations of families are planned. Stock-type accounts for 66% and family 4% of the variation in total height. First-year mean total heights represent growth of 35% to 91% compared to average shoot lengths at outplanting.

Table 3. First-year survival, total height, and groundline diameter of half-sib families of shortleaf pine grown as container (Cont) and bare-root (Bare) stock and planted on the Winona Ranger District of the Ouachita National Forest.

	Characteristic and stock-type								
	Survival			Height			Diameter		
Family	Cont	Bare	Mean	Cont	Bare	Mean	Cont	Bare	Mean
	%			cm			mm		
103	98.0	95.3	96.6a[1]	41	30	36	6.6	5.1	5.9a
115	99.3	96.0	97.6a	40	34	37	6.8	5.6	6.2a
202	100.0	95.3	97.6a	41	30	35	6.9	5.6	6.3a
219	98.7	96.0	96.4a	42	29	35	6.7	4.8	5.8a
322	98.7	94.0	96.4a	38	30	34	7.1	5.3	6.2a
342	99.3	96.0	97.6a	39	27	33	7.1	5.5	6.3a
Mean	99.1p[2]	95.4q	97.3	40	30	35	6.9p	5.3q	6.1

1/ Family means for a given characteristic followed by the same letter are not significantly different at p=0.05; no letter indicates a stock-type x family interaction at p=0.05.

2/ Stock-type means for a given characteristic followed by the same letter are not significantly different at p=0.05; no letter indicates a stock-type x family interaction at p=0.05.

Mean groundline diameters ranged between 4.8 mm and 7.1 mm (Table 3). They were not affected by the stock-type x family interaction (MSE=0.383, F=0.57, p=0.72), or by family (F=1.51, p=0.20). The container seedlings had a larger mean diameter than the bare-root seedlings (MSE=0.746, F=57.56, p=0.0006). First-year diameter growth of the container stock represented an average 82% increase compared to the mean root-collar diameters at outplanting. The bare-root seedlings grew an average of 20%. The model explains 79% of the total variation in first-year diameter with stock-type accounting for 48%.

CONCLUSIONS

If quality seedlings are planted, either bare-root or container, shortleaf pine will survive well on prepared sites in the Ouachita Mountains. However, in this study container seedlings grew better than bare-root stock during their first growing season. The superior field performance of container stock is probably due to larger root systems and better balanced seedlings.

Differences in morphology suggest that half-sib families of shortleaf pine are different enough that maintaining family integrity during seedling production will improve the overall quality of the planting stock. Stock-type and family may interact to affect growth after outplanting on some sites. Although container shortleaf pine can be expected to outperform bare-root stock, the difference will be greater for some families than for others.

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