Survival and Growth of Container and Bareroot Shortleaf Pine Seedlings in Missouri

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Abstract: Shortleaf pine *(Pinus echinata* Mill.) seeds collected from several half-sib families were grown as both container and bareroot stock and outplanted in two tests at the George 0 White Nursery in Licking, Missouri. After eight growing seasons, 2-year-old container seedlings had significantly better survival than 2-year-old bareroot seedlings, while survival of the 1-year stocktypes was not significantly different. Two-year-old container seedlings had 52 percent higher survival than 2-year-old bareroot stock. Two-year-old bareroot seedlings had greater stem diameter and volume growth than the 2-year-old container seedlings, but the two stocktypes were not significantly different in height. One-year-old stocktypes did not perform significantly different in all growth traits.

Keywords: shortleaf pine, *Pinus echinata,* container seedlings, bareroot seedlings, Missouri

Introduction

All shortleaf pine *(Pinus echinata* Mill.) planting stock produced in Missouri, with the small exception of seedlings produced for a recent progeny test, are grown in bareroot nurseries. Bareroot seedlings are generally inexpensive to produce, store, and transport, but may be susceptible to summer droughts. All eight open pollinated progeny tests established between 1980 and 1983 in Missouri, except one test established in 1982, had poor survival (<40 percent) due to severe summer heat and drought. It is likely that restoration and progeny testing of shortleaf pine in the dry and harsh sites in Missouri Ozarks could be improved by outplanting seedlings produced in containers. Many studies have shown that container stock survives and grows better than bareroot stock, particularly on adverse or marginal sites, for shortleaf pine (Brissette and Barnett 1992; Barnett and Brissette 2004), and other related species such as longleaf pine *(P. palustris)* (Amidon and others 1982; Boyer 1989) and loblolly pine *(P. taeda)* (South and Barnett 1986). For example, in a 5-year comparison of longleaf bareroot and container plantings in Georgia, Boyer (1989) found that container stock averaged 76 percent survival and 6 ft (1.8 m) in height compared to 51 percent survival and 4.9 ft (1.5 m) in height for bareroot stock. The improved survival and growth are generally attributed to root systems of container seedlings remaining intact during lifting while roots of bareroot seedlings can be severely damaged (Barnett and Brissette 1986). Because roots of container seedlings are less disturbed during lifting, they experience less transplant shock or adjustment than bareroot seedlings. Outplanting of container stock is now accepted as the most successful method for regenerating longleaf pine (Barnett and McGilvray 1997).

The first objective of the study was to compare survival and growth of bareroot and container-grown shortleaf pine seedlings. The second objective of the study was to provide a genetic evaluation of the parents and use this information for thinning the Ouachita National Forest clonal seed orchard at Mt. Ida, AR. The third objective was to estimate genetic parameters and to use these parameters to predict genetic gain. This study addresses the first objective. The hypotheses are: 1) container seedlings will have higher survival; 2) container seedlings will have greater growth than bareroot seedlings; and 3) 2-year-old container seedlings will have much higher survival and greater growth over the 2-year-old bareroot seedlings compared to 1-year-old container seedlings over the 1-year-old bareroot seedlings.

Materials and Methods

Planting Stock and Seedling Production

Planting stock being tested in this study were 1- and 2-year-old bareroot and container-grown seedlings of short-leaf pine. Both stocktypes were raised at George 0. White State Forest Nursery in Licking, MO. Seeds were collected from 50 half-sib families from the clonal seed orchard in Ouachita National Forest in Arkansas. This grafted seed orchard was established in 1969 to 1971 and consisted of 50 parents collected throughout the natural range of shortleaf pine in the Mark Twain National Forest in Missouri.

The 1- and 2-year-old container stocks were grown in Ray Leach Conetainers[TM] (Stuewe and Sons, Corvallis, OR) and Spencer-Lemaire RootrainersTM (Spencer-Lemaire Industries Ltd., Edmonton, AB), respectively. The Ray Leach Cone-tainersTM have a soil capacity of 10 in^3 (164 cm$^{'s}$) and a depth of 8,25 in (21 cm). The Spencer-Lemaire RootrainersTM (Hillson size) have a soil capacity of 10.5 in^3 (172 cm^3) and a depth of 5 in (12.7 cm). The Cone-tainersTM were filled with peat, vermiculite, and perlite (4:3:1) growing mix, while the RootrainersTM were filled with Grace Company Forestry mix. All seedlings received Rapid-Grow supplemental fertilizer (23N:19P_20_5:17K_20) for the first month; thereafter they received Universal fertilizer (16N:15P_20_5:16K_20) once per week. Seedlings were watered daily using a hand watering can. Seedlings were placed in cold storage for winter prior to outplanting in spring. Container seedlings were not pruned prior to outplanting.

The 1- and 2-year-old bareroot seedlings were produced through standard nursery culture at the George 0. White nursery. Bareroot seedlings were root-pruned to 10 in (25 cm) and top pruned to 16 in (41 cm) prior to planting.

Outplanting Site and Measurements

The outplanting site is located at the George 0. White nursery (NW°of Sec 24, T 33 N, R9 W). The planting site was previously used as a nursery bed to raise seedlings. The site was prepared for nursery planting by plowing and disking using a tractor. Shortleaf pine seedlings were outplanted on a spacing of 1 by 1 m (3.3 by 3.3 ft) in April 1986 using a soil auger.

Total height (HT, m), diameter (d.b.h., cm), form (stem straightness) and survival were measured September 1993 after eight growing seasons. Volume was estimated using volume of a cone:

$$\text{Volume (dm}^3) = \text{HT d.h.h.}^{2\ 4}\ 0.02618$$

Form was assessed using a 7-point absolute visual scale (1 = very straight to 7 = crooked).

Study Design and Statistical Analysis

Two tests (521 and 522) were outplanted in replicated experiments. Families were randomized within replications, In test 521, 2-year-old bareroot seedlings from 48 families were outplanted in replications 1 through 5; 2-year-old container seedlings from 32 families were outplanted in replications 6 through 9. In test 522, the 1-year-old bareroot seedlings from five families were outplanted in replications 1 through 5; 1-year-old container seedlings from eight families were outplanted in replications 6 through 10. Each plot was a row of four trees.

To ensure an unbiased comparison of bareroot and container stock, the families used for both stocktypes should be the same. Because of varying families across replicates, and the lack of data for replications 2 through 5, analysis was done on 24 families in only two replications in Test 521. In test 522, analysis was done on five families represented in six replications.

Plot means were used for all analyses. Data for each site was analyzed separately using a t-test to test for significant differences among treatments (container and bareroot stock) for survival, height, stem diameter, volume, and form. Survival data were transformed using the arcsine of the square root of the proportional value, but untransformed means were presented for clarity. Statistical significance was tested at $P = 0.1$.

Results and Discussion Survival

Survival of the 2-year-old container seedlings (82 percent) was significantly greater than that of 2-year-old bareroot seedlings (54 percent), a 52 percent improvement in survival using container seedlings (table 1). These results are consistent with findings from other research on effects of these two stocktypes on survival of southern pines in the United States (Boyer 1989; Barnett and Brissette 2004). Although Barnett and Brissette (2004) found that container seedlings of short-leaf pine had significantly better survival than bareroot seedlings in a study in the Ouachita Mountains of Arkansas, the improvement in survival in their study was probably not operationally meaningful because survival of the bareroot seedlings was greater than 90 percent at age 10. In longleaf pine, container seedlings had higher survival (76 percent) than bareroot seedlings (51 percent) at 5 years (Boyer 1989). The superior survival of container seedlings could be due to container seedlings experiencing less transplant shock and probably having greater root systems than bareroot seedlings. Also, the severe root pruning in the 2-year bareroot seedlings is likely to have contributed to the poor survival.

Although the 1-year-old container seedlings had better survival than the 1-year-old bareroot seedlings, the difference in survival between the two stocktypes was not statistically significant (table 1). The lack of significant differences in the 1-year-old stocktypes may reflect the small sample size.

The 2-year-old container seedlings had better survival than 2-year-old bareroot seedlings in all families (table 2). This suggests that there was no family by stocktype interaction. However, the 1-year-old container seedlings in two of

Table 1-Effects **of** stocktype on performance of shortleaf pine seedlings after eight growing seasons on two sites at the George 0. White State Forest Nursery.

Test number	Item	Container	Bareroot	Increases	P value
				percentage	
5 2 1 (2-year-old seedlings)	Survival (%)	82	54	52	<0.001
	Height (m)	6.4	6.3	2	0.669
	Stem diameter (cm)	7.6	8.6	-12	0.093
	Volume (dm3)	10.5	13.7	-23	0.087
	Form (score)	1.8	2.5	-28	0.267
5 2 2 (1-year-old seedlings)	Survival (%)	77	68	13	0.384
	Height (m)	5.4	5.6	-4	0.577
	Stem diameter (cm)	6.4	6 9	-7	0.239
	Volume (dm3)	7.4	7.9	-6	0.889
	Form (score)	1.9	1.5	27	0.252

Increase, container versus bareroot

Table 2-Effects of stocktype (C = container; BR = bareroot) on family growth performance of shortleaf pine seedlings after eight growing seasons on two sites at the George 0. White State Nursery.

Test	Family	Survival		Height		Stem		Volume	
		C	BR	C	BR	C	BR	C	BR
521 2-year-old	614	100	50	5.9	7 1	7.1	9.8	8.2	1 7 9
	619	75	75	4.0	6.5	5.0	7 . 3	418	101
	621	75	75	6.7	6.2	7.7	8. 5	1014	12.9
	8126	75	25	5.8	5.2	6 . 2	5.5	6.4	4.1
	8235	75	100	6.6	7.0	6.8	9.1	10.0	15•5
	8318	100	75	6.8	6 4	7 . 5	8 . 5	101	1 2 2
	8326	100	100	6.0	6.6	7.8	9.5	9.6	1 5 1
	8329	100	25	7.1	6.1	8.4	6.0	13.7	5 7
	8330	75	50	7.0	6.1	8.5	6.8	13.4	716
	8331	100	75	6.0	4.7	6.4	5.3	7 2	6.1
	8333	100	100	5.6	6 0	6.6	8.4	8.1	12.8
	8338	100	50	6.2	6.7	6 9	9.3	8.6	14.9
	8340	75	75	6.6	5.5	8.7	6 . 8	13.6	9.1
	8343	100	50	4.9	6 7	5.0	11.5	3.8	23.3
	8344	100	50	5.9	6.3	7.4	7 . 8	8.9	9.8
	8345	75	25	6.6	3.6	8.3	5.0	12.4	2.4
	8349	75	50	6.1	6.6	7.7	7 8	101	10.3
	8350	50	50	6 1	5.8	6.3	6.8	6.3	8.1
	8353	100	50	5..3	4.9	6.8	7 . 0	7.8	9.9
	8357	100	75	6.4	6.6	7.4	8.5	101	12.6
	8362	100	100	6 2	6.6	8.3	11	11.4	22.9
	8364	100	75	5.5	4.9	6.0	7 . 5	8.1	11.1
	8355	100	50	6.2	6.5	7.6	8.5	9.9	1 2 2
	8372	75	75	6.6	5.1	8.3	7.0	1 2 6	7.9
522 1-year-old	614	92	83	5 . 2	5.3	6.1	6.3	6 5	6 1
	619	58	83	5.5	5 9	6,7	7.2	9.1	8.5
	621	83	67	5.8	6.1	7	7.7	9.6	9.8
	8126	75	17	5.6	5.2	5,9	6	5 . 7	5.1
	8281	75	92	5.2	5.1	6.2	6.6	6.7	6.3

the five families had lower survival compared to bareroot seedlings, indicating a stocktype x family interaction.

Growth and Form

Two-year-old container seedlings had significantly lower stem diameter and volume growth performance than 2-year-oldbareroot stock, but height growth between the two stocktypes was not significantly different (table 1). All growth traits between the 1-year-old stocktypes were not significantly different. The lower stem diameter and volume growth in the 2-year-old container seedlings may be due to the fact that the container seedlings were smaller in stem diameter than the bareroot seedlings at outplanting. Root pruning is likely to have reduced the difference between container and bareroot seedlings. The bareroot seedlings were severely root pruned, and the roots lost a large amount of their unsuberized, absorbtive root tissue. The lack of significant differences in height between the 2-year-old stocktypes may be due to the fact that the bareroot seedlings were top pruned prior to planting. The 2-year-old bareroot seedlings had one-third to one-half of their top pruned off. The lack of significant differences in the 1-year-old stocktypes may reflect the small sample size and top pruning of the bareroot seedlings. Container seedlings have been reported to have superior growth as compared to bareroot seedlings in shortleaf pine (Barnett and Brissette 2004), and in longleaf pine (Boyer 1989). The differences in these findings and our results may reflect differences in site conditions. Barnett and McGilvray (1993) found that when conditions are more stressful, container stock grew better than bareroot stock.

Growth was better in bareroot seedlings than in container seedlings in some families but not in others. For example, bareroot seedlings of families 614 and 8343 had greater than 50 percent greater volume growth than container seedlings, while container seedlings of families 8329 and 8345 had more than 100 percent greater volume growth than bareroot seedlings.

The stem form in 2-year-old container-grown seedlings was lower than bareroot; the stem form in 1-year container-grown seedlings was higher than bareroot. However, the differences between the stocktypes were not statistically significant (table 1).

Conclusion

The results from this study indicate that container stock had greater survival than bareroot stock, but less growth, when planting 2-year-old seedlings. Performance of container stock was similar to that of bareroot stock when planting 1-year-old seedlings. Future studies with container and bareroot shortleaf pine stock in Missouri should take the following into account: 1) better design of tests (for example, randomizing the stocktypes within blocks); 2) replicate the study over diverse sites; 3) determine the effect of seedlingspacing on survival and growth; and 4) outplant at different times to determine if container seedlings extend the planting season.

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