A SEED SOURCE AND PROGENY TEST OF SELECT EAST COAST LOBLOLLY PINES IN ARKANSAS AND MISSISSIPPI

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Abstract.--This test contrasts a collection of half-sib loblolly families from orchards in the coastal plain of the Carolinas with woods-run seed from the Carolinas and Arkansas and orchard seed from Arkansas.

The three plantings are located in southern Arkansas and northern Mississippi and consist of up to 18 North Carolina families, 21 South Carolina families, a bulk collection from a southeast Arkansas orchard, and woods run checks from North Carolina, South Carolina, and Arkansas. They are planted in 64-tree plots.

After 13 years, although there was a strong location x family interaction, the Atlantic coast selections were outgrowing woods-run trees of Carolina or Arkansas origin and also were outgrowing the Arkansas orchard trees in the Arkansas planting. The advantage of the coastal sources was not as clear at the Mississippi planting after 11 years.

These results so far confirm the value of Carolina Coastal Plain loblolly for use in Arkansas.

Conclusions from the Southwide Pine Seed Source Study (SPSSS) and other provenance tests (Kraus et al. 1984, Switzer and Wells 1964, Wells and Wakely 1966, Wells and Lambeth 1983) have resulted in large-scale movement of loblolly pine seed in two opposite directions.

The first of these is the eastward movement of Livingston Parish, Louisiana, sources (Wells 1985) and more recently, Texas sources to high fusiform rust hazard sites in Florida, Georgia, Alabama and South Carolina. This has been effective in reducing rust infection in these areas.

The other large-scale movement of a provenance, which is more pertinent to the present paper, involves the westward movement of loblolly sources from the coastal plain of North and South Carolina to Arkansas and Oklahoma. In Southern Arkansas, the local seed source was the poorest growing provenance in the loblolly SPSSS and the Onslow, North Carolina, source was the best growing source (Wells 1983). A more specialized provenance test in south Arkansas

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confirmed the superiority of the coastal North Carolina sources over the local south Arkansas source (Wells and Lambeth 1983). As a result, large quantities of North Carolina loblolly have been planted in Arkansas and Oklahoma (Lambeth et al. 1984).

The present study seeks to extend the previous results by determining the growth of progeny from selected North and South Carolina coastal plain parent trees relative to woods-run Carolina coastal plain and select and woods-run Arkansas trees when planted in south Arkansas and north Mississippi.

MATERIALS AND METHODS

Orchard-pollinated seed was collected from plus-tree selections from the North Carolina State University Tree Improvement Cooperative and the Southern Region of the U. S. Forest Service (figure 1). Several check lots were also included: North Carolina coastal woods-run, South Carolina coastal woods-run, Southeast Arkansas woods-run, and South Arkansas plus-tree mix. Another check lot, Mississippi-Alabama woods-run was used in the Mississippi planting in place of the South Carolina woods-run.

The seed were stratified and sown in a nursery near Crossett, Arkansas. One-year-old seedlings were bar-planted at two locations in Arkansas in 1974, and in one location in Mississippi in 1976 (figure 1). The plots were 64 trees square with border rows around the outside perimeter only. Spacing was 8-by 8-feet.

Eighteen North Carolina families and 20 South Carolina families plus checks were planted at the Crossett location. Only 15 of the same 18 North Carolina selections and 17 of the 20 South Carolinas families were planted at the Horatio location.

The Stewart location was planted 2 years later and consisted of 14 North Carolina selections and 13 South Carolina selections plus checks. Nine of the 14 North Carolina selections and 12 of the 13 South Carolina selections had been included in the other two plantings.

All three plantings were on flat coastal plain sites. The Mississippi planting was on a well-drained soil, the Arkansas plantings were on poorly to somewhat poorly drained soils (table 1). Five replications were planted at each location.

Survival was tallied at age 1 for the Arkansas plantings and age 3 for the Mississippi planting. Heights were measured and fusiform rust infection was tallied at all three plantings at age 5.

In late summer of 1986, a southern pine beetle infestation was found in the Crossett planting. In fall of 1986, all three plantings were measured prior to the salvage operation at Crossett. Remeasurements of DBH were made on all trees, and height was measured on a 20 percent random sample from each plot. Evidence of beetle infestation was also tallied at the Crossett location.

A regression formula was constructed for each planting to estimate heights of the non-sample trees from their DBH measurements. Plot volumes were estimated using a volume formula for young plantation loblolly (Schmitt and Bower 1970). Analysis of variance (SAS GLM procedure) was used to test differences in means.

Survival, height, basal area, volume, and rust infection were analyzed separately for each planting. An analysis was also done on the combined data for Horatio and Crossett, after deleting the six families from the Crossett data set which were not included in the Horatio planting.

RESULTS AND DISCUSSION

Survival

Most of the mortality in all three plantings occurred shortly after planting. Survival at 3 years averaged 59 percent at Horatio and 75 percent at Crossett. Survival after 1 year *was* 89 percent at Stewart. In fall of 1986, survival averaged 57 percent at Horatio, 69 percent at Crossett and 85 percent at Stewart.

The variation in survival among plantings generally follows what would be expected because of the increasing levels of moisture stress from the eastern to the western planting (figure 1). At the Horatio planting nearly 20 percent of the years would be expected to have less precipitation than evaporation according to Visher's (1954) atlas. The Mississippi planting is in a zone where yearly evaporation would never be expected to exceed rainfall. In addition, the Mississippi planting is on a well drained site, where trees should be under less stress because of better root developement than at the poorly-drained Arkansas plantings.

Survival of the local sources was no better, and sometimes worse, than the Carolina coastal plain sources. Survival of the Arkansas woods-run trees averaged only 32 percent at the Horatio site compared to 78 percent for North Carolina woods-run trees. The Arkansas sources survived better at the Crossett site (53%), but did not survive as well as the other sources (75%). The Arkansas woods-run sources survived the best at the Stewart site, although there was not much difference amoung sources.

Family differences in survival were significant in all plantings. In the combined Horatio-Crossett data, location x family interaction was significant and large. Survival of families and sources was not consistent across the three plantings.

Height growth

Results at the Horatio planting approximate those which would have been anticipated, based on the SPSSS and other provenance and progeny tests. The Arkansas woods-run source was last, both in height growth at 33.9 feet and volume (table 1). The SC and NC woods-run sources averaged 3 to 5 feet taller than the Arkansas woods run. The Arkansas plus-tree source averaged nearly 4 feet taller than the Arkansas woods-run, and was taller than the SC woods run trees. Most of the NC and SC plus tree families performed better than the NC check; all but one performed better than the SC check.

In the combined Horatio-Crossett analysis, the location x source interaction was significant for height growth. This is readily apparent in comparing the relative rankings in the two plantings in table 1. The ranking of the Arkansas woods-run at the Crossett location was similar to it's ranking at Horatio: near the bottom, at 37.9 feet in height. The Arkansas plus-tree, selections, however, were not any better than the checks at the Crossett location and actually averaged slightly shorter. At the Horatio location, the NC and SC woods-run sources exchanged places in rankings relative to the Crossett location. The NC woods-run trees are second from the bottom at Horatio, averaging 0.3 feet shorter than the Arkansas woods run.

The SC and NC select trees did perform well relative to all the checks at the Crossett location as well as at the Horatio location, but there are many examples of changes in rank when comparing Crossett with Horatio. There are also some examples of genetic stability. For instance, SC 11-10 and SC 11-25 rank second and third in height at both locations.

At the Stewart location, the relative performance of the Arkansas sources was better than in the two Arkansas plantings (table 2). The Arkansas plus-trees were above average in height, the Arkansas woods-run were just below average, along with the MS-AL local woods-run sources. The NC woods-run source was shorter by 0.3 feet than the Arkansas woods-run, but this difference is small compared to the standard error.

The relatively good performance of the non-local Arkansas sources in Mississippi is surprising, considering how poorly they did as a local source in Arkansas. These results perhaps could have been expected, however, considering the results of the SPSSS at the two locations (Wells and Wakeley 1966). In the Clark County, Arkansas SPSSS planting the local Arkansas source was fourteenth out of 15 sources in height growth; the coastal North Carolina source was first. In the Winston County, Mississippi, planting of the SPSSS, however, the Arkansas source was not significantly shorter than the North Carolina source.

The variation in soils among the three locations may also be a factor in the difference in relative performance among locations. The Arkansas plantings are on poorly drained, or somewhat poorly drained, soils which is more similar to the soils on the Carolina coastal plain than the well-drained soils of the Mississippi planting.

Volume

Plot volume was not closely related to height growth, since at this age volume is heavily dependent on initial survival. The poor survival of the Arkansas sources in Arkansas is reflected by their low plot volumes, however. At Horatio, the Arkansas woods-run ranks last in volume as well as height (table 1). The Arkansas plus-tree source is slightly below average in volume as well as height. At the Crossett location the Arkansas woods-run and plus-tree selections rank fortieth and forty-second, respectively, out of 42 sources in volume.

At the Stewart location, the Arkansas plus-tree and woods-run sources are at or slightly above average in volume, in line with their height growth ranking.

Volume measurements will be more definitive in a few years, when the plots reach culmination. There is already evidence for some compensation in diameter growth for low stocking levels, as average diameter and survival are negatively correlated on a plot mean basis ($r = -0.59^{**}$, Crossett planting). There is also some evidence for self thinning in the plots with the best survival. Losses subsequent to the 3 year measurements have been negligible on plots with poor initial survival, but amount to up to 15 percent on plots with good survival.

Southern Pine Beetle

The measurements of these plantings were scheduled in fall of 1986 mainly because of a southern pine beetle infestation in the Crossett planting. The outbreak was primarily in a 1-acre area at the head of a draw, and appeared to have originated outside the planting. The plot with the most damage was a North Carolina Selection, 8-131, where most of the trees were dead. The infestation was related to location rather than genetics, however. All heavily infested plots were adjacent to each other, and out of eight plots which had beetle-killed trees, two were local sources: an Arkansas woods-run

plot and an Arkansas plus-tree plot. This would seem to be evidence that the Carolina sources are not any more susceptible (at age 13) than local sources, since only 2 out of 42 sources are local.

Rust Infection

Fusiform rust infection at the two Arkansas plantings was negligible, and could not be analyzed. Rust infection at the Stewart location averaged about 13 percent, and there were significant differences amoung sources (table 2). As expected, the Arkansas sources were only lightly infected, 3.2 percent for the Arkansas checks and 6.6 percent for the Arkansas plus-trees. There was wide variation in rust infection among the coastal plain families, ranging from 2 percent for family SC 11-16 to 37 percent for family SC 7-58.

CONCLUSIONS

The poor growth rate of the Arkansas sources in Arkansas is difficult to explain. In the loblolly SPSSS, the western sources survived better (Wells and Wakeley 1966) and it was concluded that the western sources, though slower growing, had a survival advantage under the stressful conditions in the western part of the loblolly range. Lambeth et al. (1984), did not find that the Arkansas sources were clearly superior in early survival to coastal Carolina sources in Arkansas and Oklahoma. This was also not true in this test in Arkansas. In both Arkansas plantings survival of the Arkansas woods-run and the Arkansas plus-tree sources was below average. In the Horatio planting, the Arkansas woods-run ranked last in survival, as well as height and volume. The natural regeneration situation is quite different from that of bar-planting 1-0 stock on intensively site prepared land however, and under natural conditions the Arkansas sources may have a clear survival advantage.

There is some evidence for mortality in coastal sources planted in Arkansas due to moisture stress late in the rotation (Lambeth et al. 1984). This has not been the case in the Loblolly SPSSS planting in south Arkansas after 30 years. [1]/

There is undoubtedly some risk associated with planting coastal Carolina sources in Arkansas, but the record drought of summer 1980 and the record cold of December 1984 did not appear to affect these plantings adversely. Planting improved Carolina Coastal Plain loblolly in southern Arkansas seems to be justified based on these results. Planting these same sources in North Mississippi seems to be less advantageous.

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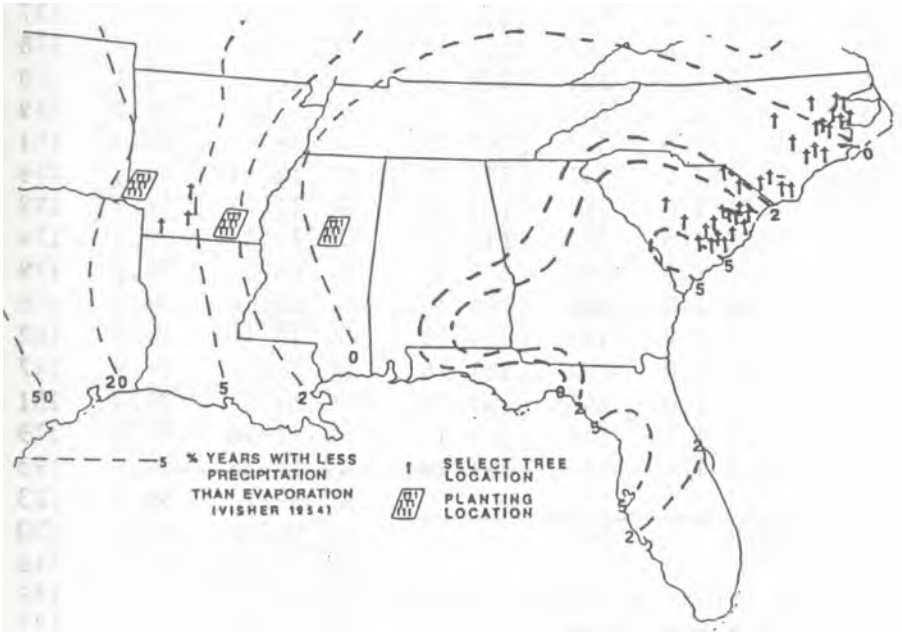

Figure 1. Map of Southeastern U. S. showing location of plantings and seed sources. Dashed lines are adapted from Visher 1954 and show the percentage of years in which precipitation is less than evaporation; used here as an indication of droughtiness.

Table 1.--Family means for Plot volume and height growth of select Carolina coastal families and checks planted in south Arkansas. They are ranked by average height.

Horatio AR Planting						Crossett AR Planting			
Family	Ht ft	SE [1]	Plot Vol Cu Ft	Rank	SE[1]	Family	Ht ft	Plot Vol Cu Ft	Rank
NC 6-26	41.0	1.2	230	(2)	18	SC 7-34	42.5	194	(9)
SC 11-10	40.7	1.2	210	(5)	18	SC 11-10	42.4	164	(28)
SC 11-25	40.9	1.2	195	(9)	18	SC 11-25	42.4	185	(13)
NC 7-29	40.4	1.2	185	(13)	18	SC 11-9	42.1	181	(17)
SC 18-117	40.0	1.0	239	(1)	16	SC 7-56	41.6	170	(27)
NC 9-6	40.0	1.2	147	(23)	18	SC F-67	41.4	228	(1)
NC 8-74	40.0	1.0	168	(18)	16	SC F-39	41.2	198	(6)
SC 7-4	39.9	1.2	194	(10)	18	SC 7-2	41.1	185	(15)
SC 11-36	39.8	1.2	224	(3)	18	NC 7-29	41.1	173	(26)
NC 7-88	39.8	1.2	150	(22)	18	SC 11-22	41.1	187	(12)
SC 11-21	39.7	1.2	213	(4)	18	NC 8-103	41.1	161	(29)
NC 7-60	39.7	1.2	177	(15)	18	SC 11-16	41.0	152	(32)
SC 7-2	39.7	1.0	142	(27)	16	NC 7-60	40.9	193	(10)
NC 8-131	39.6	1.2	201	(6)	18	SC F-209	40.9	199	(5)
SC 7-34	39.6	1.0	168	(16)	16	NC 7-62	40.9	177	(23)
SC F-209	39.2	1.0	168	(17)	16	NC 8-74	40.8	204	(3)
NC 8-103	39.1	1.0	134	(30)	16	SC 11-21	40.7	203	(4)
SC F-39	39.1	1.2	192	(12)	18	NC 9-3	40.7	195	(8)
SC 11-26	39.0	1.0	156	(21)	16	NC 9-6	40.7	158	(30)
NC Check	38.9	1.2	199	(8)	18	NC 8-131	40.5	178	(22)
NC 7-59	38.8	1.2	144	(24)	18	SC 7-4	40.5	185	(14)
SC 7-56	38.5	1.2	116	(33)	18	NC 8-136	40.4	137	(38)
SC 7-58	38.4	1.2	167	(19)	18	NC 8-30	40.2	178	(21)
SC 11-9	38.2	1.0	162	(20)	16	SC 18-34	40.1	179	(20)
SC 18-102	38.2	1.2	200	(7)	18	NC 7-88	39.7	149	(35)
NC 7-90	38.0	1.5	137	(28)	22	NC 7-59	39.5	151	(33)
AR + Tree	37.8	1.2	137	(29)	18	SC 18-117	39.5	219	(2)
SC 18-34	37.8	1.0	194	(11)	16	SC 11-41	39.4	192	(11)
NC 8-30	37.6	1.5	180	(14)	22	SC 7-58	39.4	174	(25)
NC 8-35	37.6	1.0	144	(26)	16	NC 6-26	39.2	179	(18)
NC 7-62	37.6	1.0	106	(34)	16	SC Check	39.1	156	(31)
NC 8-136	37.5	1.2	132	(31)	18	SC 18-102	39.0	182	(16)
SC 11-16	37.4	1.0	102	(35)	16	NC 7-90	38.9	147	(36)
SC Check	37.2	1.0	144	(25)	16	NC 8-35	38.8	151	(34)
NC 8-27	37.2	1.2	126	(32)	18	SC 11-26	38.6	179	(19)
AR Check	33.9	1.2	88	(36)	18	SC 11-36	38.2	195	(7)
						NC 8-27	38.1	123	(41)
Mean	38.9		166			AR Check	37.9	130	(40)
						AR + Tree	37.7	112	(42)
						NC 9-4	37.7	136	(39)
						NC Check	37.6	177	(24)
						NC 8-46	36.8	138	(37)
						Mean	40.0	173	
						St. error	0.8	10	

[1]SE=Standard errors of family means (based on error term from analysis of variance). These vary by family in the Horatio planting because of missing plots.

Table 2. Family means for plot volume, height and rust infection of select Carolina coastal families and checks planted near Stewart, Mississippi. They are ranked by height.

Family	Ht ft	Plot Volume Cu Ft	Rank	Rust Infection %	Rank
NC 8-61	35.0	124	(1)	10.9	(16)
NC 9-6	34.3	99	(9)	15.6	(19)
NC 8-131	34.1	109	(2)	11.7	(18)
SC 11-25	34.1	96	(12)	20.8	(24)
NC 8-136	34.1	76	(29)	13.2	(17)
NC 8-103	33.6	100	(7)	8.7	(10)
NC 8-73	32.9	104	(3)	10.0	(14)
SC 7-4	32.9	95	(14)	9.0	(12)
SC 11-16	32.7	94	(15)	2.0	(01)
SC 7-34	32.6	100	(5)	15.4	(19)
SC 7-58	32.4	86	(23)	37.0	(28)
NC 7-59	32.3	84	(25)	8.8	(09)
SC 11-10	32.2	84	(24)	6.8	(05)
SC F-39	32.1	87	(22)	15.8	(21)
AR + Tree	32.0	90	(19)	6.6	(04)
NC 8-27	32.0	88	(21)	16.0	(22)
SC 7-56	31.8	73	(30)	8.8	(11)
SC F-8	31.5	100	(6)	9.3	(13)
SC 18-34	31.1	104	(4)	11.7	(08)
NC 8-66	31.1	82	(27)	17.0	(20)
AR Check	31.0	99	(8)	3.2	(03)
MS-AL Ck	31.0	95	(13)	7.7	(07)
NC 7-88	31.0	92	(16)	19.0	(23)
NC 8-35	30.9	96	(11)	17.9	(20)
NC 9-4	30.8	91	(17)	8.5	(08)
SC F-67	30.7	98	(10)	7.2	(06)
NC Check	30.7	91	(18)	10.1	(15)
NC 8-46	30.4	89	(20)	24.2	(27)
NC 7-90	30.2	82	(26)	2.6	(02)
SC 11-21	28.9	77	(28)	23.2	(25)
SC 11-26	27.6	71	(31)	23.6	(26)
Mean	31.8	92		13.1	
Standard Error	1.1	8		2.8	