# DIFFERENCES AMONG SHORTLEAF PINE SEED SOURCES ON THE OZARK AND OUACHITA NATIONAL FORESTS AT AGE TEN

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**ABSTRACT**

Progeny test planting of shortleaf pine (*Pinus echinata* Mill.) was started on the National Forests in Arkansas in 1978, and continued through 1990. A series of progeny tests established on the Ouachita and Ozark National Forests were analyzed to determine if significant differences exist between the three seed sources in Arkansas (the East Ouachita, the West Ouachita and the Ozarks) for height, diameter and survival at age 10. Sixteen tests were from the Ouachita National Forest and fourteen from the Ozark National Forest. Significant differences among seed sources for height and diameter existed, but not for survival. Families within seed sources were highly significant for all traits, indicating that family selection will be effective.

## INTRODUCTION

Shortleaf pine has the largest native range of any pine species in the southeastern United States (Fig. 1), is considered a major component of three forest cover types, and a minor component of at least 15 other forest cover types. Adaptability to a great variety of site and soil conditions partly accounts for its wide distribution (Lawson 1990). Shortleaf pine should be at the forefront in efforts to insure genetic diversity and healthy ecosystems able to respond to climate change in the eastern United States.

In the early 1960's the U S Forest Service developed a shortleaf pine tree improvement program that included Arkansas and Oklahoma. The first step in the process was the selection of superior trees. Selection criteria included: growth and form; insect and disease resistance; flowering and cone production; specific gravity; and relative location. Fifty superior trees were chosen in each of three geographic sources—East Ouachita, West Ouachita, and Ozark. Scions were collected from the superior trees, grafted to rootstock, and planted at the Ouachita Seed Orchard. As soon as the young trees began producing cones, the cones were harvested and the seed was used for reforestation--and the breeding program was initiated. Progeny test planting on the Ouachita and Ozark National Forests was started in 1978 and continued through 1990. Data from over sixty valid full-sib progeny tests was collected and analyzed.

For approximately 20 years, from the mid 1970's through the mid 1990's, millions of genetically improved shortleaf pine seedlings were planted throughout the Ouachita and Ozark National Forests. During peak years 12 to 15 million seedlings were planted each season. After the mid 1990's the use of artificial regeneration was curtailed for political reasons, and the number of seedlings planted each year tapered off to the present level of around one million. As a result of the reduced need for seedlings, orchard management became mostly bare bones maintenance. All progeny testing was terminated (Crane, 2005). The Region 8 Regional Geneticist stated that in his opinion, the tree improvement program's objective for quality timber had become obsolete.

Here we are many years after shortleaf pine tree improvement was declared obsolete, challenged with restoring historic vegetation and maintaining or improving genetic diversity. A major epidemic of southern pine beetle damaged forests throughout the southeast in the mid to late 1990's, including thousands of acres on the Ouachita NF. In December of 1999, a significant ice storm damaged or destroyed large acreages of timber in Arkansas. Severe problems with oak decline developed in both Arkansas and Missouri. Thousands of acres were devastated, and thousands more acres of black, red, and scarlet oaks growing on dry, rocky sites are at severe risk of oak decline. These sites were historically populated by shortleaf pine, and forest plans now emphasize the restoration of historic vegetation. In addition, thousands of acres of private forest lands in need of reforestation have recently been acquired by the US Forest Service. Once again there is a need for reforestation using shortleaf pine seedlings. The value of the shortleaf pine tree improvement program has become more evident with the realization that appreciable quantities of high quality, genetically diverse, shortleaf pine seed are available from those efforts. There is also a wealth of data and genetic diversity from the Ouachita and Ozark progeny tests, which could be used to study the genetics of shortleaf pine and give guidance to restoration efforts, and perhaps provide genetic material to improve the health and resiliency of ecosystems threatened by climate change.

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Currently, breeding population 1 of shortleaf pine is divided into three seed sources: (1) East Ouachita shortleaf; (2) West Ouachita shortleaf; and (3) Ozark shortleaf. However, it should be noted that the division of this breeding population into three seed sources is based on no provenance test or other research information. The zone in which Breeding Population 1 occurs, which comprises Arkansas and southeastern Oklahoma, was based on information obtained in the Southwide Pine Seed Source Study (Wells and Wakely 1970), but the division of this population into seed sources was not based on that study, since it did not sample those three sources separately. La Farge (1991) found that the three seed sources were not significantly different for height and survival age 5. Because of the non-significant results, La Farge (1991) recommended that the three breeding populations be maintained as one population. The objective of the study is to determine if significant differences among seed sources for height and diameter existed at age 10.

## MATERIALS AND METHODS

Details of materials are in La Farge (1991). Briefly, data from 30 full-sib progeny tests distributed across both the Ouachita and Ozark National Forests was used for the analysis. The study was created for the purpose of testing the genetic worthiness of seed orchard clones and for making second-generation selection, but the purpose of this analysis was to detect differences among seed sources.

The parents came from threes sources: East Ouachita, West Ouachita and Ozark regions. The mating design of these full-sib progeny tests was a six-by-six diallel crossing scheme, such that each partial diallel crossing group consisted of six parents, two from each seed source. Crosses among all parents in a 6-by-6 diallel result in 15 crosses. In each of the diallels in these data, there were three crosses between parents from the same seed source. The other 12 crosses in each diallel were between parents from different seed sources. To maintain the integrity of the seed sources in this study, only crosses between parents of the same seed sources were used. Since all diallel groups comprised unrelated parents, this resulted in one cross per crossing group from each diallel. Hence, all crosses included in the analyses were single-pair matings and were unrelated.

## ANALYSIS OF VARIANCE

We used methods similar to those used by La Farge (1991). Seed source and family differences for survival, height and diameter were estimated at 10 years using analysis of variance with Proc GLM and Proc Mixed of SAS (Version 9.1). Plot means were used for the analysis and survival was arcsine transformed before the analyses. Because of the imbalanceness, statistical significance of fixed effects was obtained using Proc GLM. Data imbalance was present across the test sites for different reasons such as: 1) the number of blocks differed, 2) there were unequal number of families; and survival varied. To be conservative, the test random effect was fitted first followed by the fixed effects using the following model:

$$Y_{ijkm} = \mu + T_i + S_j + TS_{ij} + F_{(j)k} + TF_{i(j)k} + e_{ijkm}$$

Where:

$Y_{ijkm}$ = observation of the mth individual of the kth family from the jth seed source in the ith location

$\mu$ = overall mean

$T_i$ = random effect of the ith test

$S_j$ = fixed effect of the jth seed source

$TS_{ij}$ = random effect of the interaction between test and seed source

$F_{(j)k}$ = fixed effect of the kth family within the jth seed source

$TF_{i(j)k}$ = random effect of the interaction between test and family

$e_{ijkm}$ = random error term

Error term for testing significance of seed source was the interaction between test and seed source. Error term for testing significance of family within seed source was the interaction between test and family within seed source. The numbers of families for our analysis were: (1) 24 for the East Ouachita, (2) 27 for the West Ouachita, and (3) 29 for the Ozark seed sources.

## RESULTS

### SURVIVAL

As observed at age 5 (La Farge 1991), differences between seed sources were not significant for survival at age 10 (Table 1). At age 10, shortleaf pine seedling survival was over 72% for all three seed sources (Table 2). At age 5, survival for the three seed sources was above 91% (La Farge 1991). Thus, between ages 5 and 10 survival declined by 21%. The differences among families within seed source were highly significant for survival at age 10 (Table 1).

### GROWTH

There were significant differences among seed sources for height and diameter at age 10 (Table 3 and 5). These results differ from those at age 5, where seed sources were found not to be significantly different (La Farge 1991). The East Ouachita seed source exhibited the best growth while the Ozark seed source had the poorest growth performance (Table 4 and 6). East Ouachita seed sources had on average 8% better height growth and 10% better diameter growth compared to the Ozark seed sources. At age 5, height growth averaged 7.7ft across the seed sources (La Farge 1991) and at age 10 it averaged 19.5 ft, an increase of 153%. This shows that with good management shortleaf pine is fast growing.

As pointed out by La Farge (1991), the growth trends are expected because they parallel certain environmental

gradients. The East Ouachita seed source generally grew faster when tested at all locations than did the West Ouachita and Ozark sources because the West Ouachita and the Ozark National Forests generally have more severe summer droughts than does the East Ouachita. Also, seed source studies of forest tree species often show that seed sources from warmer climates tend to grow faster than local sources, if the difference in climate is not great (Schimdtling 2001). According to Schimdtling (2001) seedlings will survive and grow well if they come from any area having a minimum temperature within 5 $^{0}$F of planting site's minimum temperature. In loblolly pine, this is at least partly due to the warm-climate sources growing longer in the fall than the sources from colder climates (Jayawickrama et al. 1998). Thus, the two Ouachita seed sources are expected to grow faster than the Ozark seed sources and they do.
The differences between East and West Ouachita were small, and non-significant, indicating that east-west transfers are usually successful as stated by Schimdtling (2001). The differences among families within seed source were highly significant for height and diameter at age 10 (Tables 3 and 5).

## CONCLUSION

Trees from the Ouachita National Forest had superior growth than those from the Ozark National Forest, thus confirming the results from past studies which showed that southern sources grow faster than northern sources. Thus, latitudinal differences were evident. Longitudinal differences were not strong, confirming that east-west transfers are usually successful. East Ouachita seed sources had slightly better growth than the west Ouachita seed source. Maintaining a single breeding population across the National Forests in Arkansas is recommended because the large family differences indicate that there were good families from all seed sources. Therefore, tree improvement and orchard establishment programs should concentrate on identifying individuals from the best families regardless of seed source.

## LITERATURE CITED

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**Table 1—ANOVA for survival at age 10**

| Source of variation | Degrees of freedom | Mea Square | F Value | P-Value |
|---|---|---|---|---|
| Seed source | 2 | 0.147 | 2.54 | 0.088 |
| Family (seed source) | 49 | 0.084 | 2.75 | 0.001 |
| Test | 29 | 0.439 | | |
| Seed source x test | 56 | 0.058 | | |
| Family x test (seed source) | 37 | 0.031 | | |

**Table 2—Comparison of survival at age 10 among seed sources**

| Seed Source | Mean survival (%)* |
|---|---|
| East Ouachita | 72.4a |
| West Ouachita | 74.4a |
| Ozark | 72.6a |

*Means with the same letter are not significantly different (P > 0.005)

**Table 3—ANOVA for height at age 10**

| Source of variation | Degrees of freedom | Mea Square | F Value | P-Value |
|---|---|---|---|---|
| Seed source | 2 | 26.93 | 3.55 | 0.035 |
| Family (seed source) | 49 | 10.74 | 2.65 | 0.001 |
| Test | 29 | 334.68 | | |
| Seed source x test | 56 | 7.59 | | |
| Family x test (seed source) | 37 | 4.05 | | |

**Table 4—Comparison of height at age 10 among seed sources**

| Seed Source | Mean height (ft)* |
|---|---|
| East Ouachita | 20.3a |
| West Ouachita | 19.4a |
| Ozark | 18.8b |

*Means with the same letter are not significantly different (P > 0.005)

**Table 5—ANOVA for diameter at age 10**

| Source of variation | Degrees of freedom | Mea Square | F Value | P-Value |
|---|---|---|---|---|
| Seed source | 2 | 1.139 | 3.37 | 0.042 |
| Family (seed source) | 49 | 0.601 | 2.53 | 0.003 |
| Test | 29 | 23.117 | | |
| Seed source x test | 56 | 0.338 | | |
| Family x test (seed source) | 37 | 0.238 | | |

**Table 6—Comparison of diameter at age 10 among seed sources**

| Seed Source | Mean diameter (inch.)* |
|---|---|
| East Ouachita | 4.26a |
| West Ouachita | 4.04a |
| Ozark | 3.89b |

*Means with the same letter are not significantly different (P > 0.005)

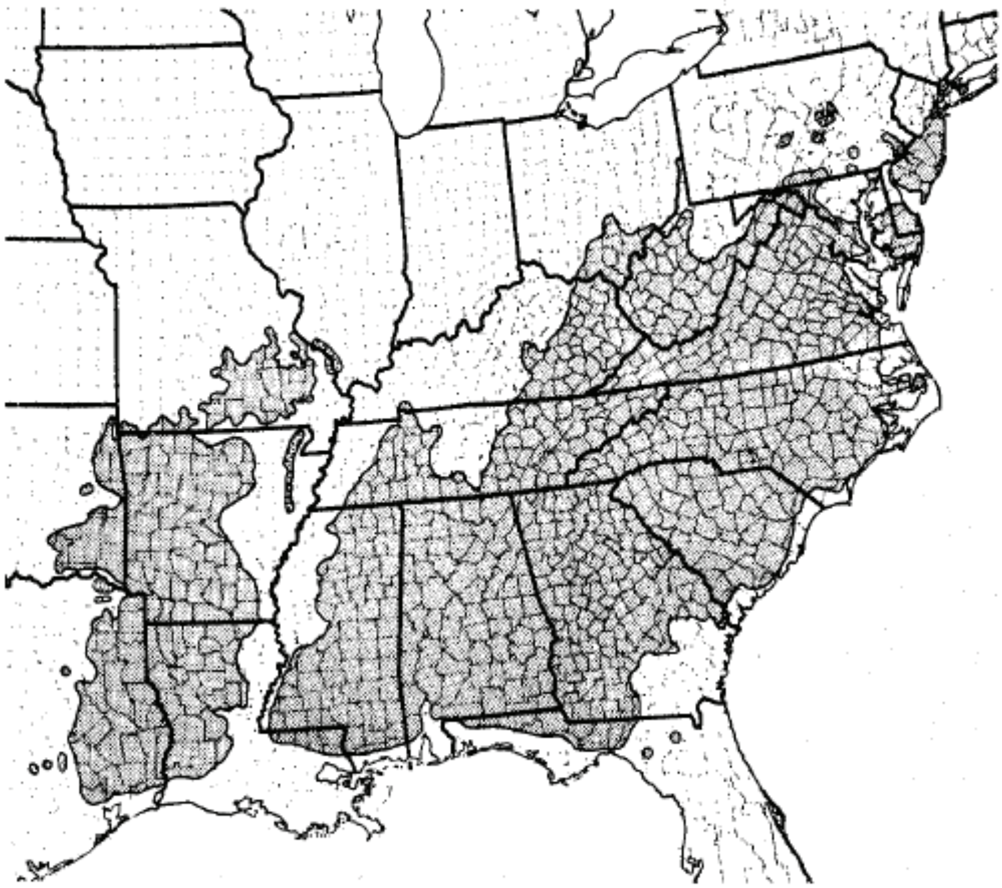

Figure 1—Natural distribution of shortleaf pine (Pinus echinata Mill.) (Lawson 1990).