DEVELOPMENT AND POTENTIAL OF

A LONGLEAF PINE SEEDLING SEED ORCHARD

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Abstract. --A longleaf pine progeny test designed for conversion to a seedling seed orchard was established near Gainesville, Florida, in 1969, with wind-pollinated progenies of 65 ortets of superior form and vigor selected in southeast Georgia, north Florida, and south Alabama and Mississippi. A high degree of variation among progenies was noted for survival, height initiation, height, and volume. Height initiation was positively correlated with growth and survival, but survival was not significantly associated with growth. The orchard was reduced to 152 trees per acre by within-family roguing at age 4 and family roguing and subsequent thinning within selected families at age 7. A total of 53 progenies were retained, but 34 progenies constituted most of the orchard. Forty-four percent of the 34 were from south Alabama and west Florida. Suggested gains from retaining 34 progenies were 41 percent for height initiation, a large increment for survival, and 61 percent for volume, but due to the index selection practiced, the gains will be lower. The orchard has been fertilized to promote flowering, and a number of progenies have conelets.

Additional keywords: *Pinus palustris,* selection, tree improvement.

Longleaf pine (*Pinus palustris* Mill.) currently is a much less important component of Southern forests than it was in colonial times (Croker and Boyer 1975). The species has not been widely employed for artificial regeneration due to its low planting survival, susceptibility to brown spot disease, and long grass stage. However, inherent properties of longleaf such as excellent form, high specific gravity (Wahlgren and Schumann 1975), and good naval stores production plus its potential as a source of fusiform rust resistance (Dinus 1974) favor wider utilization. Recent improvements in cultural practices and results of breeding efforts (Snyder 1973; Goddard et al 1973; Goddard et al 1976) further inhance greater exploitation. One of the efforts of the Cooperative Forest Genetics Research Program at the University of Florida with longleaf pine, the development of a progeny test-seedling seed orchard, is discussed.

## METHODS

Seed were collected from 67 ortets, superior phenotypes for vigor and

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form, located from southeast Georgia, north Florida, and south Alabama and Mississippi, and established in the St. Regis Paper Company nursery at Lee, Florida,in 1968. Five tests were hand-planted in January, 1969: 65 progenies in Alachua County, Florida, and lesser numbers of progenies in Wayne County, Georgia, Nassau County, Florida, and Baldwin and Escambia Counties, Alabama. The Baldwin and Escambia plantings were failures.

The Alachua County progeny test-seed orchard was established on a typical flatwoods site that had previously supported longleaf; the soil was classified as *a* Pomona fine sand, somewhat poorly drained. Thorough site preparation and disking preceded planting. On the 2.7 acres, twelve replications were employed using progeny row plots of 5 trees. Spacing was 10 feet between rows and 3 feet within rows. Subsequent maintenance involved annual disking.

The test was measured periodically starting the first year. Percent survival and percent of trees initiating height growth were determined at ages 1 and 2. These two measurements plus total height of all living trees were taken at age 3. At age 4, survival and total height were remeasured. After the fourth year measurements, each plot was thinned to a maximum of the best two trees. Height and dbh of the residual trees were determined at age 7, and tree volumes were calculated.

Analyses of variance performed were least square analyses due to the failure of some progenies to occur in each replication. Progenies represented in six or less replications were deleted from analyses. Analyses were conducted using plot means, and in the case of height and volume, within-plot variation was also calculated. Variance components were derived for computation of heritabilities. Harmonic mean numbers of trees per plot were calculated in order to combine within and between plot analyses.

Individual heritabilities for height and volume were calculated by standard formulae employing variance components. For survival and height initiation, individual heritabilities were derived by the threshold approach (see example in Goddard and Arnold 1966). Progeny mean heritabilities were calculated for all traits. Standard errors were associated with all heritability estimates (Osborne and Paterson 1952). Predicted gains, assuming original selection of 1 in 1000 parent trees and retention of 51 percent of the families and 7 percent of the individuals in selected families were obtained (Shelbourne 1969).

Progeny roguing was conducted in April, 1976, by an index system that weighted survival, height initiation, and volume equally. Surviyal and height initiation assessments were taken from as many of the three surviving tests as possible; volume data were obtained only from the orchard test. Progenies were classified by the number of traits for which each exceeded the average. Ten progenies below average for all traits were eliminated. Nineteen progenies better than average for any one trait were subjected to within-family roguing of 50 percent, 23 progenies exceeding the average for two traits to 33 percent, and 11 progenies above average for all traits to 25 percent.

## RESULTS AND DISCUSSION

Survival, although only 45 percent after the first year, decreased little through age 4 (Table 1), and relationships among progeny means for survival during the four years were extremely strong (Table 2). The percentage of trees out of the grass stage was 27 after one year and averaged '7 after three years. Progeny performance for height initiation at age 3 was not correlated with the first year's, but the age 2 evaluations were. Average tree heights after three years were low but were well correlated with heights at ages 4 and 7. Fourth year height was associated equally well with seventh year height and volume, an indication that the removal of the poor phenotypes at age 4 did not bias subsequent progeny evaluations for growth.

Progeny assessment for survival, height initiation, and growth rate can apparently be made by age 3, at least on average or better sites when control of competing vegetation is practiced. Survival evaluations could be made as early as the first year and height initiation by second year, but three years are suggested for an appraisal including growth. Similar recommendations have been made for longleaf pine in South Carolina (Schoenike and Williams 1975).

Relationships among the traits indicate that progenies having high survival, early height initiation, and fast growth can be obtained. Third year height initiation was highly correlated with third year survival and height. Survival, however, was positively but not significantly associated with height at either age 3, 4, or 7 (Table 2); a similar conclusion has been reported from another study (Schoenike and Williams 1975). Consequently, progenies with above average height or volume coupled with good survival and a short grass stage can be obtained only by screening a large number of families. In this orchard, the 20 "best" progenies were 16, 24, and 19 percent better, respectively, for height initiation, survival, and height, but not all progenies exceeded the average for each trait (Table 3).

Brown spot was not a problem in the orchard, and no observations on incidence were taken. Consequently, the better progenies cannot be directly characterized from brown spot resistance. With their strong tendency to initiate height growth early and for fast growth, the progeny are likely to possess some resistance since the two traits have been associated with resistance (Snyder and Derr 1972; Schoenike and Williams 1975).

Thirty-four progenies constituted the bulk of the orchard at age 7. Of these, 44 percent were from the "optimum" seed collection area for longleaf (Wells and Wakeley 1970). Twenty-five percent of the progenies heavily or completely rogued from the orchard were from the "optimum" area. Thus, the reported superiority of the western Gulf sources is somewhat in evidence.

Performance of the eastern selections, which represent geographic sources not included in the Southwide Pine Seed Source Study, indicate that southeast Georgia and north Florida longleaf should be included in

Table 1.--Performance of longleaf pine progenies by trait and age.

| Trait | | Age 1 | 2 | 3 | 4 | 7 |
|---|---|---|---|---|---|---|
| Survival (%) | Mean | 45 | 44 | 42 | 41 | |
| | Range | 18-82 | 18-78 | 17-78 | 12-80 | |
| Ht. Initiation (%) | Mean | 27 | 41 | 67 | | |
| | Range | 0-74 | 6-75 | 25-100 | | |
| Total Ht. (ft) | Mean | | | 1.1 | 3.7 | 17.2 |
| | Range | | | .5-2.1 | 1.1-5.5 | 14.9-20.0 |
| Volume/Tree ($ft^3$) | Mean | | | | | .352 |
| | Range | | | | | .246-.513 |

Table 2.--Correlations among longleaf progeny means for survival, height initiation, height and volume at various ages.

| Trait | Age: | Survival 2 | Survival 3 | Survival 4 | Height Initiation 2 | Height Initiation 3 | Height 4 | Height 7 |
|---|---|---|---|---|---|---|---|---|
| Survival | 1 | .99** | .97** | .96** | | | | |
| | 2 | | .99** | .97** | | | | |
| | 3 | | | .98** | | .53** | | |
| | 4 | | | | | .41** | .20 | .17 |
| Height Initiation | 1 | | | | .60** | .25 | | |
| | 2 | | | | | .53** | | |
| | 3 | | | | | | .54** | .50** |
| Height | 3 | | | .24 | | .66** | .93** | .74** |
| | 4 | | | | | | | .79** |
| | 7 | | | | | | | |
| Volume | 7 | | | .06 | | .39* | .74** | .92** |

* and ** - significant at the 5 and 1 percent levels, respectively.

Table 3.--Performance of the 20 "best" longleaf progenies for height initiation, survival, height, and volume.

| Progeny | Parent Location | 3rd Yr. Ht. Init. | 4th Yr. Survival | 4th Yr. Height | 7th Yr. Vol./Tree |
|---|---|---|---|---|---|
| | (County) | (%) | (%) | (ft) | ($ft^3$) |
| 102-61 | Alachua, FL | 74 | 57 | 4.1 | .354 |
| 111-61 | Alachua, FL | 82 | 37 | 4.5 | .451 |
| 59-63 | Wayne, GA | 75 | 45 | 4.0 | .341 |
| 122-63 | Camden, GA | 68 | 38 | 4.5 | .439 |
| 135-63 | Santa Rosa, FL | 77 | 66 | 3.7 | .353 |
| 7-65 | Escambia, FL | 78 | 36 | 4.6 | .358 |
| 12-65 | Escambia, AL | 66 | 54 | 4.3 | .301 |
| 13-65 | Escambia, AL | 88 | 64 | 4.9 | .326 |
| 15-65 | Santa Rosa, FL | 66 | 63 | 3.7 | .391 |
| 24-65 | Santa Rosa, FL | 72 | 68 | 4.6 | .375 |
| 50-65 | Bacon, GA | 100 | 43 | 4.1 | .326 |
| 55-65 | Bacon, GA | 70 | 56 | 3.6 | .379 |
| 58-65 | Bacon, GA | 81 | 55 | 5.2 | .462 |
| 8-66 | Hamilton, FL | 90 | 47 | 5.5 | .478 |
| 9-66 | Hamilton, FL | 77 | 52 | 5.4 | .513 |
| 10-66 | Hamilton, FL | 83 | 49 | 5.2 | .433 |
| 13-66 | Hamilton, FL | 84 | 47 | 4.0 | .392 |
| 37-66 | Glynn, GA | 72 | 38 | 4.2 | .491 |
| 61-67 | Mobile, AL | 65 | 47 | 3.4 | .341 |
| 79-67 | Alachua, FL | 82 | 58 | 4.1 | .447 |
| Average | | 78 | 51 | 4.4 | .398 |
| Test Average | | 67 | 41 | 3.7 | .352 |

a breeding program. The basis for our progeny evaluations, plantings in Wayne County, Georgia, and Alachua and Nassau Counties, Florida, may of course favor the eastern selections. Testing of these sources further west is needed for height, volume, height initiation, and brown spot resistance; survival relative to western sources will be lower (Goddard et al 1971).

Variation among progenies in the orchard was noted for each trait (Table 4). A high degree of variation among replications was attributed to one tier of replications being adjacent to a deep drainage ditch. Instability of progeny performance across replications was evident for fourth year height but not seventh year volume.

The variation in height initiation at age 3 was the least heritable of four traits, but a meaningful reduction in the length of the grass stage is predicted (Table 5). Heritability of survival was high, and a large gain was derived.

Table 4.--Analyses of variance for height initiation at age 3, survival and height at age 4, and volume at age 7.

| Source | Height Initiation d.f. | Height Initiation MS | Height Initiation F | Survival d.f. | Survival MS | Survival F |
|---|---|---|---|---|---|---|
| Reps | 11 | 6,322 | 4.85** | 11 | 6,477 | 10.59** |
| Progenies | 56 | 2,300 | 1.77** | 56 | 2,737 | 4.47** |
| Error | 530 | 1.303 | | 582 | 612 | |

| Source | Height d.f. | Height MS | Height F | Volume d.f. | Volume MS | Volume F |
|---|---|---|---|---|---|---|
| Reps | 11 | 18.36 | 8.30** | 11 | .1455 | 11.05** |
| Progenies | 49 | 6.05 | 2.73** | 43 | .0450 | 3.42** |
| Error | 413 | 2.21 | 1.52** | 351 | .0132 | 1.24 |
| Within Plots | 730 | 1.46 | | 182 | .0107 | |

**significant at the 1 percent level.

Table 5. Individual and

gains for height at age 3, survival and height at age 4, and volume at age 7.

| Trait | $h^2_I$ | $h^2_x$ | Gain Unit | Gain Percent |
|---|---|---|---|---|
| Height Initiation | .17 | .41 ± .12 | 28% | 41 |
| Survival | .33 | .73 ± .17 | 54% | 131 |
| Height | .32 ± .09 | .58 ± .09 | 2.6 ft | 70 |
| Volume | .51 ± .14 | .62 ± .09 | .216 $ft^3$ | 61 |

The progeny mean heritability of fourth year height was comparable to other reported estimates for height (Snyder 1973; Snyder and **Derr** 1972) and similar to the heritability of seventh year volume. The magnitudes of gains expected for both growth traits were also **alike. A considerable** improvement in volume per unit area is anticipated, however, due to the composite selection for survival and growth, as was observed for longleaf in Mississippi (Snyder 1973).

Two reasons for expecting less gain from the orchard than the above cited predictions are the index selection used for progeny roguing and the statistical analysis of data from only the orchard test. The selection of progenies was based on their evaluation equally for survival, height initiation, and growth; only a few of the 34 progenies assumed to be retained for the production orchard excel in all three traits, Consequently, actual gains from these progenies will be less.

The progeny evaluations for survival and height initiation were also based on progeny evaluations over as many as three tests. An analysis of composite test data, incorporating genotype by environment effects, would give more applicable gain estimates for the two traits. Even considering that the expected gains given will be lower, the potential for improving each trait seems good.

Fertilization of the orchard during the eighth growing season following roguing to 152 trees per acre promoted conelet production; 95 of 406 trees had conelets at age 9. Nitrogen and nitrogen plus phosphorous applications increased the proportion of progenies and trees flowering in addition to the number of conelets per tree. Phosphorous alone produced little response (Table 6).

Table 6.--Conelet production in the longleaf orchard following fertilization.

| Variation Among Progenies | | Influence of Fertilizer | | | |
|---|---|---|---|---|---|
| | | | Percent Flowering | | Conelets Per |
| Conelets Per Tree | Number of Progenies | Fertilizer | Progenies | Trees | Flowering Tree |
| 0 | 21 | Check | 20 | 11 | 2.6 |
| 1-5 | 30 | N | 54 | 31 | 10.3 |
| 6-10 | 1 | P | 23 | 15 | 2.4 |
| 11-15 | 1 | NP | 46 | 32 | 7.3 |
| | 53 | | | | |

Variation among progenies was evident. Some 60 percent of the progenies had conelets, but only two progenies had sizeable numbers of conelets per tree. One progeny had 88% of its trees flowering, one of which had 32 conelets. Correlations of flowering with other traits were nonsignificant although a slight inverse relationship with seventh year growth existed.

These flowering patterns indicate that longleaf seedling seed orchards can be a relatively quick source of seed. Flowering has been noted by age 9, and certain fertilizers seem to promote flowering.

Alternatively, the number of progenies and trees not yet flowering and the scarcity of conelets per tree suggest another emphasis in longleaf pine selection. The parents of these orchard progenies were outstanding phenotypes for vigor and form; they were not selected for cone productivity. Evidence suggests that parental selection is not highly productive and that progeny evaluation is needed for best identification of good surviving, fast growing trees (Snyder 1973; Goddard et al 1973). Parental consideration for cone productivity should be emphasized however in order to offset longleaf pine's notoriously bad cone production and an apparently slight tendency for fast growing trees to have lower flowering rates.

## CONCLUSIONS

A seedling seed orchard appears to be a feasible method of producing longleaf pine planting stock suitable for artificial regeneration. Seed production can be achieved by age 10 with resulting improvement in survival, height initiation, and growth rate. Parental selection criteria should include cone productivity,and sufficient parents should be employed to derive progenies with good overall performance. Appropriate maintenance and fertilization of the orchard are required.

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