Selection in Slash Pine Brings Marked Improvement in Diameter and Height Growth Plus Rust Resistance

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During the past 10 years, many thousands of dollars have been invested in tree improvement programs to provide high quality seed for artificial regeneration. Seed production areas have been established and are providing appreciable quantities of seed. Outstanding trees have been selected and grafted into clonal seed orchards; soon the orchards will be producing large quantities of seed. Undoubtedly, many of us are wondering just how much improvement the seed orchards and seed production areas will provide. Open- and control-pollinated progeny tests have been installed to determine both the genetic value of the selected parents and how much improvement will be achieved over what was planted in the past. We are all anxiously awaiting the results of these tests.

So far, the early results are very gratifying, and our data give more encouragement. Stated briefly, our results show that even mild selection provided substantial improvement relative to commercial check lots in height and diameter growth as well as in resistance to rust. Volume per acre was increased appreciably in a locality where severe rust years are common. The control-pollinated tests reaffirmed the wisdom of comparing outstanding trees with their neighbors in the stand.

EXPERIMENTAL MATERIAL

SELECTED PARENTS

The progenies grown in the three studies to be reported here originated from two groups of parent trees, both of unknown provenance. One group was selected from a slash pine plantation near Macon, Georgia, in Jones County, the other group of trees from plantations on the George Walton Experiment Forest in Dooly County, Georgia, near Cordele.

1/ U. S. Department of Agriculture, Forest Service: Southeastern Forest Experiment Station, Macon, Georgia; and Southern Forest Experiment Station, Gulfport, Mississippi, respectively.
Work was conducted with financial assistance from the Georgia Forest Research Council; plantations were growing on land provided under cooperative agreement from Georgia Kraft Co.

The trees from the Jones County plantation were chosen at an age of 18 years to exhibit a variety of phenotypes rather than being "plus" trees. Selected trees encompassed a wide range of variation in such traits as height growth, crown width, crown density, and fusiform rust infection. Heights and diameters were measured on each selected tree and on 10 neighboring trees. Several of the selected trees might be considered fair when compared with today's standards, but as a whole, the group is merely average, not outstanding.

The parent trees from Dooly County, selected primarily for outstanding growth and good form, are generally better than those from Jones County. The plantations ranged from 14 to 18 years of age. Records made during the course of other silvicultural research were screened to pick out the largest individuals. This group was examined and the ones with poor form and evidence of rust infection were eliminated. However, rust infection in this area was very light, and, therefore, the selection differential for rust resistance was low.

For a point of comparison, several "commercial" lots of seed were obtained, and check seedlings were grown in the experimental nursery along with the progenies. Seedlings from commercial nurseries provided additional reference points. These check lots can be considered representative of the quality of seedlings being planted generally throughout the range of slash pine at the time these studies were established.

TEST PLANTATIONS

The first progeny test of the Jones and Dooly County trees was an open-pollinated trial planted in 1956--the H-38 plantation. Twenty-nine seedlots were planted, using 25-tree plots at a spacing of 10X10 feet in a randomized block design with three replications. The commercial checks were replicated twice in each block. This study was severely infected with fusiform rust; of the 2,325 seedlings originally planted, only 45 percent were considered potentially merchantable at 8 years of age. A tree was considered unmerchantable if it possessed a stem canker large enough to girdle the tree completely. Only potentially merchantable trees were included in this analysis.

While routine remeasurement of the H-38 plantation was underway, the area suffered a severe ice storm on December 31, 1963. In desperation, a salvage measurement was made within a month after the ice storm. Trees remaining erect after the ice were measured satisfactorily by means of a 30-foot measuring pole. Trees severely bent or uprooted were measured by bending the pole around the bend in the tree. Heights of trees with tops broken out were determined by adding the length of the broken top to the height from the ground to the break. Diameter breast height usually presented no problem. Granted, these measurements are not as precise as would ordinarily be desired, but we believe our measurements were within 1 foot of the true height.

In the absence of published volume tables for trees this small, the volume outside bark of an individual tree was calculated as that of a cone having a height equal to the height of the tree and a base equal to the basal area at breast height. This is suitable for comparative purposes at this age.

The younger 5-year-old tests included both open- and control-pollinated progenies from certain members of the two groups of parent trees. Two studies were planted; the larger, designated H-50, consisted of 25-tree plots planted in four replications of a randomized block design. In the smaller study, H-51, 5-tree plots were replicated five times in a randomized block design. Both were planted at a spacing of 10X10 feet. Rust infection in these two plantations was very light.

PROGENY PERFORMANCE

OPEN-POLLINATED PROGENIES - 8 YEARS OLD

Analyses of variance revealed that progeny differences were statistically significant for all the traits measured: height, d.b.h., tree volume, number of merchantable trees per plot, and total volume per plot (table 1). Even though these are not random progenies, heritability was calculated for individual tree volume; narrow-sense heritability within this particular plantation was 0.16 (table 2).

The relatively poor performance of the two commercial check lots is of vital interest. The commercial checks were generally the smallest of individual tree size; fourteen progenies were significantly larger at the 5 percent level than the <u>best</u> check lot (fig. 1). In terms

Table 1. Summary of F-tests of seedlots for plantation H-38.

Trait	F	Degrees of freedom	
		Seedlot	Error
Height	4.74**	28	55
D.b.h.	2.59**	28	55
Tree volume	2.05*	26	51
Number merchantable trees per plot	7.14**	28	56
Total volume per plot	8.19**	28	56

Table 2. Analysis of variance, expectations of mean squares, and calculation of narrow-sense heritability of tree volume in plantation H-38.

Source	df	MS	E(MS)	Estimate of variance components
Block	2	.791760	$\sigma_e^2 + 13.578\ \sigma_{rg}^2 + 316.229\ \sigma_r^2$	.002183
Progeny	26	.583765	$\sigma_e^2 + 12.225\ \sigma_{rg}^2 + 35.057\ \sigma_g^2$	.008407
Error	51	.284500	$\sigma_e^2 + 11.615\ {}_{rg}^2$	.007465
Within plot	870	.197792	σ_e^2	.197792
Total	949			

Computation of heritability, h^2:

$$h^2 = \frac{\sigma_A^2}{\sigma_w^2 + \sigma_{rg}^2 + \sigma_a^2} = \frac{.033628}{.172571 + .007465 + .033528} = 0.16$$

Where: σ_A^2 = total additive genetic variance
σ_{rg}^2 = plot error
σ_w^2 = within plot environmental variance
if $\sigma_g^2 = 1/4\ \sigma_A^2$
$\sigma_w^2 = \sigma_e^2 - 3/4\ \sigma_A^2$

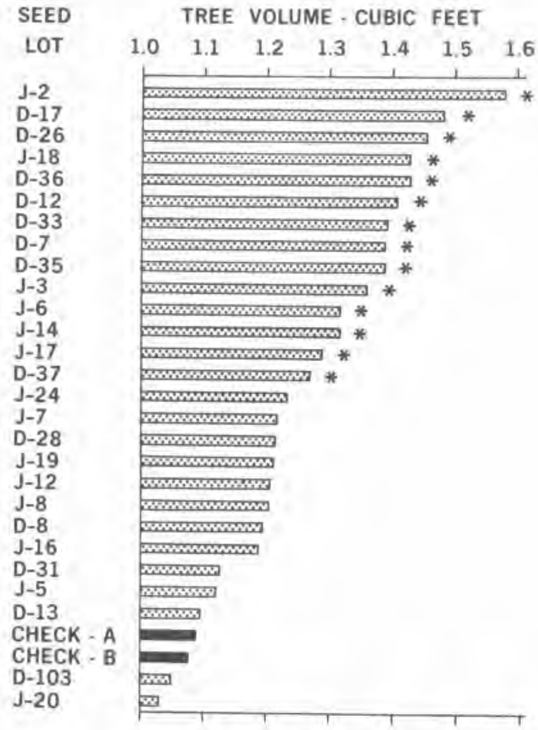

Figure 1 -- Volumes of individual trees varied widely among progenies, but the commercial checks produced consistently small trees (indicates progenies significantly larger at the 5 percent level than the best check lot).*

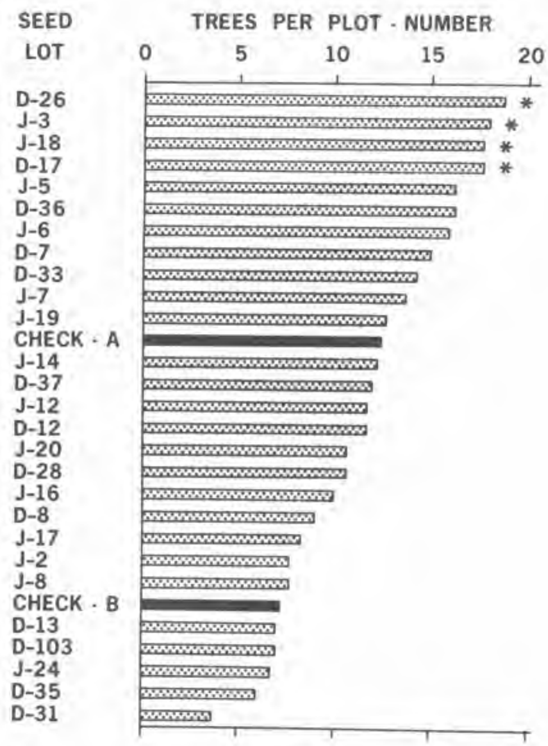

Figure 2 -- Progenies varied widely in number of potentially merchantable trees per plot, which is strongly associated with rust resistance (indicates progenies with significantly more trees, at the 5 percent level, than the best check lot).*

of number of merchantable trees per plot, which strongly reflects resistance to fusiform rust, the check lots were again well below average, but only four progenies were significantly better than the best check (fig. 2).

When tree size and number of merchantable trees per plot are combined and expressed as total volume per plot, a trend with great practical significance appears. Not only are the check lots well below average in production, but the best progeny has produced two times as much volume per unit area as the best check lot (fig. 3). Duncan's multiple range test showed that seven progenies produced significantly more volume, at the 5 percent level, than did the best check lot. These seven best progenies averaged 81 percent more volume per •unit area than the best check lot.

When the progenies from Dooly County and Jones County were considered as separate groups, both groups showed substantial improvement over average of the commercial check lots (table 3). When 7 to 10 percent improvement

Table 3. Percent improvement of progeny groups over commercial check lots (plantation H-38)

Trait	Seed source	
	Dooly County	Jones County
Height	9.7	8.0
D.b.h.	9.0	7.1
Tree volume	23.9	17.1
Number potentially merchantable trees per plot	16.2	22.2
Total volume per plot	46.6	46.0

Table 4. Summary of F-tests.

Source	df	F	
		Height	Percent free of rust
PLANTATION H-50[1]			
Seedlot	20	6.01**	5.44**
Block	3	7.78**	20.68**
Error	60		
PLANTATION H-51[2]			
Seedlot	20	4.70**	--
Block	4	6.78**	--
Error	79		

1/ Four replications, 25-tree plots
2/ Five replications, 5-tree plots

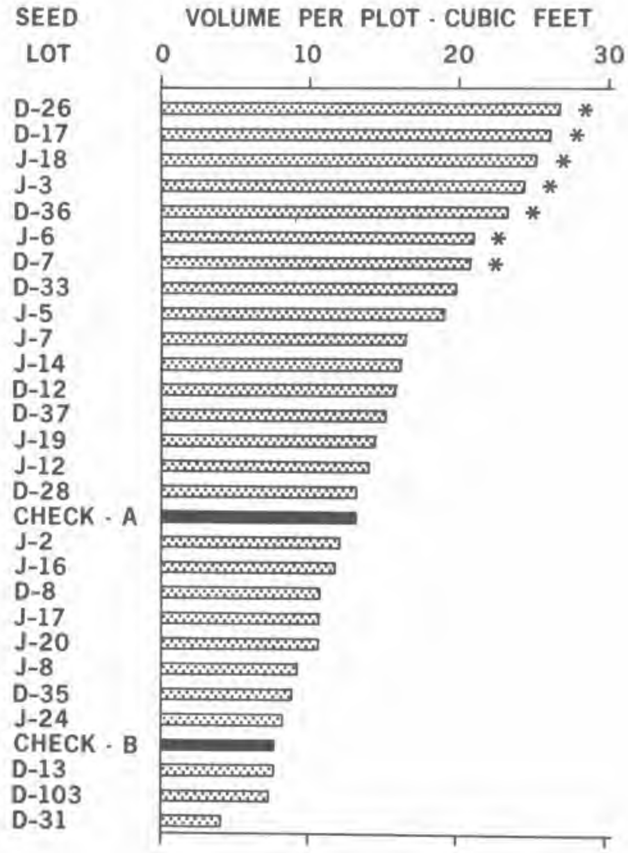

*Figure 3 — Total volume per plot, an expression of both individual tree size and rust resistance, varied among progenies, but the commercial checks produced well below average volumes (*indicates progenies producing significantly more volume per plot, at the 5 percent level, than the best check lot).*

Table 5. Comparison of rust resistance and height growth of selected progenies (both open- and control-pollinated) with performance of commercial check lots (plantation H-50)

Seed source	Seed lots	Rust resistance		Height	
		Rust free trees	Improvement over check lots	Height	Improvement over check lots
	Number	-----Percent--------		Feet	Percent
Selected progenies	18	82.1	15.1	12.71	9.4
Commercial checks	3	71.3	--	11.62	--

in height and d.b.h. were combined, an improvement of 17 to 24 percent in tree volume resulted. Selection for volume was more stringent in Dooly County than in Jones County; hence, the greater improvement in tree volume. The two groups represent a 16 to 22 percent improvement in rust resistance. This culminated in a 46 percent improvement in volume per unit area. (It must be stressed that this plantation was severely infected with fusiform rust; at 8 years of age over half of the trees were considered unmerchantable primarily because of rust infection.)

Although group selection of maternal parents strongly affected volume growth of progeny, prediction for the influence of each individual parent tree was less accurate. Graphical plotting of the data showed nonsignificant correlations between height, d.b.h., and volume of the progeny and the superiority of the female parent relative to its 10 adjacent check trees. Dorman found the same to be true for height of young open-pollinated progenies of parent trees growing at Callaway Gardens near Pine Mountain, Georgia. Maybe this should be expected for open-pollinated progenies in view of the low heritability for tree volume (h^2 = 0.16).

CONTROL- AND OPEN-POLLINATED PROGENIES - 5 YEARS OLD

The younger tests (plantations H-50 and H-51), including both open- and control-pollinated progenies, cooroborate the trends in the older, open-pollinated test. Differences among progenies were highly significant for both height growth and disease resistance (table 4). Fusiform rust infection in these plantations was very light (only 20 percent) in comparison with the older, open-pollinated test.

At 5 years of age, the progenies, as compared to commercial checks, showed improvement comparable to that in the older test. When open- and control-pollinated progenies were grouped together, they were 15.1 percent more rust-resistant and 9.4 percent taller than the average of the three check lots (table 5, fig. 4). Unfortunately, these tests do not provide a good basis for evaluating the use of open-pollinated progeny performance to predict controlled cross performance. To do this, all parents used in the crosses should be represented by open-pollinated progenies in the same test.

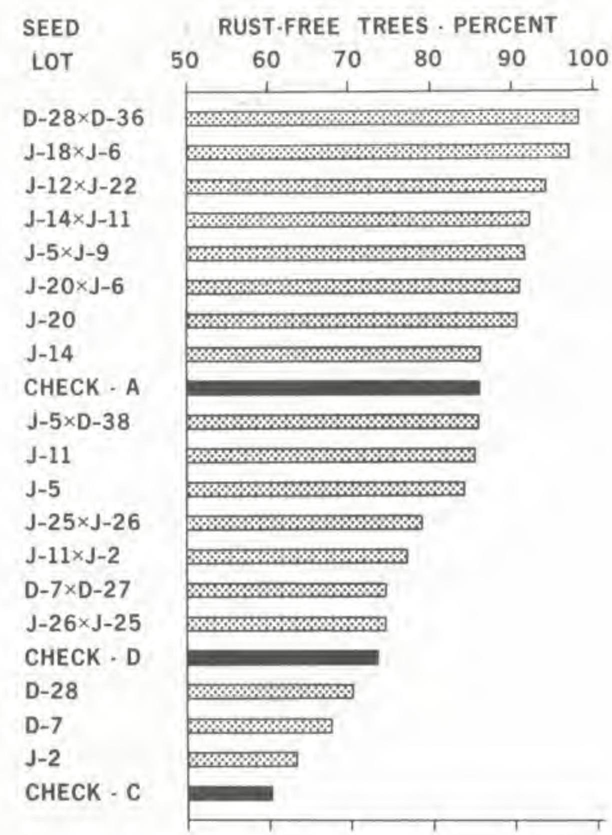

Figure 4 -- Open- and control-pollinated progenies and commercial checks varied significantly in percent of trees free of rust, but the checks contained fewer rust-free trees.

The offspring-parent regressions developed from these two plantations are of vital interest. Here the heights of single crosses among the Jones County trees were correlated with the mid-parent height superiority of their parents. The following examples illustrate the principle of "mid-parent height superiority:" two parents, one being 15 feet taller than its neighbors, the other being 5 feet taller, have a mid-parent height superiority of 10 feet. Two different parents, one being 10 feet taller, the other 2 feet taller, have a mid-parent height superiority of 6 feet. This expression of relative height is pertinent because most scoring systems compare a candidate tree with its neighbors in the stand.

These offspring-parent regressions were very strong in both plantations (figs. 5 and 6). Correlation coefficients were highly significant, and the slopes of the regression lines were very similar (b = 0.26 and 0.33). These regressions stand in strong contrast to the almost nonexistent relationship for open-pollinated progenies.

SUMMARY AND CONCLUSIONS

These data show that open-pollinated as well as control-pollinated progenies differed significantly in growth rate and resistance to fusiform rust. In terms of volume per unit area at 8 years of age, which combines individual tree size and rust resistance, progenies not only differed widely but also showed substantial improvement over commercial check lots. Only mild selection and the use of open-pollinated seed produced an improvement over commercial checks of 19 percent in individual tree volume, 19 percent more merchantable trees, and: 46 percent more volume per unit area.

Offspring-parent regressions were very strong when 5-year heights of control-pollinated progenies were related to the average height superiority of both parents over their respective check trees. However, open-pollinated progenies in this study showed essentially no

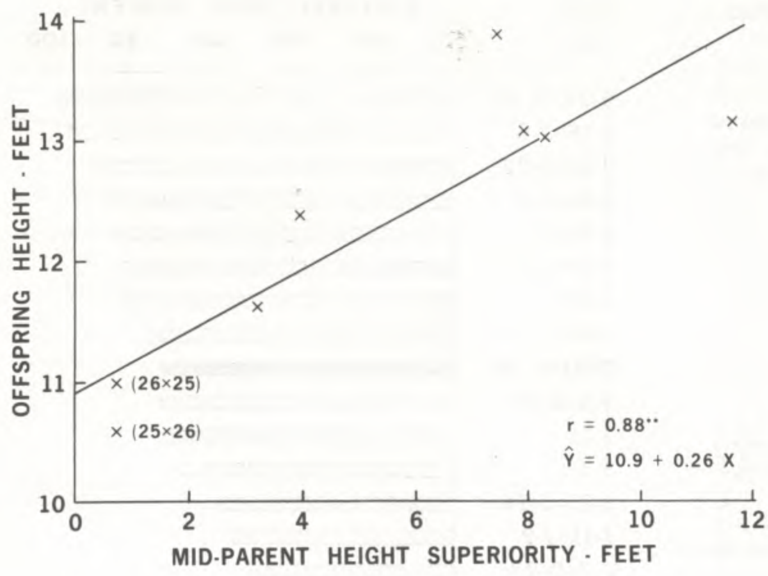

Figure 5 -- The offspring-parent regression for height in H-50 (25-tree plots, four replications). Note the reciprocal crosses among Jones 25 and Jones 26.

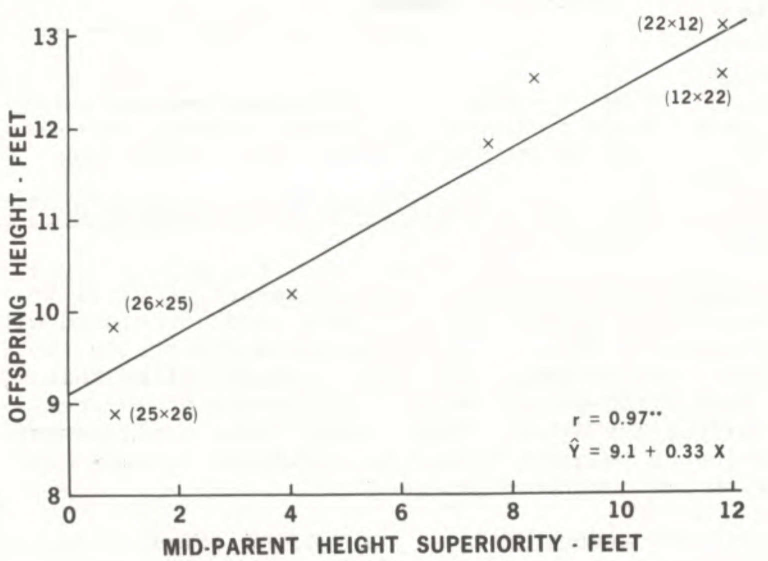

Figure 6 -- The offspring-parent regression for height in H-51 (5-tree plots, five replications). Note the reciprocal crosses involving Jones 25, Jones 26, Jones 12, and Jones 22.

relationship to the relative height" and diameter superiority of their maternal parent. Yet, form and disease resistance are reflected well in open-pollinated tests. This may mean that the relative level of acceptance or rejection should be set higher in open-pollinated tests than in trials involving controlled crosses.

These early results substantiate several assumptions made in the initial phases of southern tree improvement activity. First, seedlings of variable and often low quality come from seed collected by the general public. This method of seed acquisition provides no control over the quality of the parent trees; usually the only criteria for collection are accessibility of the trees and abundance of cones. The performance of the checks in these studies suggests that such uncontrolled seed collection is accompanied by a high risk of susceptibility to disease and of generally smaller trees producing lower volumes per acre.

Second, selection for disease resistance and for size and quality of individual trees will provide substantial improvement of future generations. The data suggest that acceptable seed is provided through closely supervised collection of cones following logging operations. Seed production areas, in which only a mild selection intensity is possible, will give substantial, quick improvement over unimproved commercial seed. Furthermore, even greater advances should accompany seed from seed orchards, because they represent much higher selection differentials.

Third, the commonsense practice of comparing outstanding trees with their neighbors is a valid procedure for initially estimating the genetic worth of a candidate tree.