GROWTH, CROWN FORM, AND FUSIFORM RUST RESISTANCE IN OPEN-POLLINATED SLASH PINE PROGENIES[1]

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The Ida Cason Callaway Foundation began an active program in tree improvement in 1950. Their program was devoted to selection and progeny testing among the four major species of southern pines. Field plantings were made first in 1952 with open-pollinated progenies from individual selected trees and establishment continued until 1957. During this period a large number of tests were established of both open-pollinated and control-pollinated progenies. The properties of the Foundation lie north of the natural range of slash pine, but several plantations 15 years of age or younger were available and selections from these plantations were the patents used in the slash pine tests.

The area of plantations available and their ages placed restrictions on the selection of "plus" trees. A number of good phenotypes were chosen for testing, but many of the trees had only one or two good traits. Some trees, such as C-4 and C-6 were included because of undesirable traits, such as crock and poor branching. The limited population sampled means that only a few of the Callaway selections of slash pine would be comparable to the plus trees being used in current seed orchard programs.

Periodic measurements have been made on the Callaway material through 1959. This paper deals with results of measurements taken on the 1952 plantings through 8 years in the field and the 1953 plantings through 7 years in the field. The progenies were planted in replicated randomized block designs on a Piedmont old-field site that was quite variable because of erosion and fop soil removal in the past.

The 52 study showed a range in average heights among 19 progeny groups from 194 to 250 feet at 8 years of age (Table 1). This study had three replications with plots of varying sizes. Through the fourth year significant differences were found between mean

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heights among progenies. At ages 6 and 8, differences among mean progeny heights were found to be not significant, in spite of the large differences among means.

The 1953 planting showed a range in mean heights from 16.0 to 21.6 feet at 7 years (Table 2). Signigicant differences in height were found at all ages examined, through the level of significance dropped from 1 percent to 5 percent at ages 5 and 7. This study had 4 replications of 25 tree plots.

When examined on an individual tree basis, tatal height after 2 years in the field correlated well with total height at ages 8 and 7. The correlation coefficients varied from 0.61 to 0.72, depending upon whether or not trees containing stem cankers of fusiform rust were included. Using an approximate method of analysis based on within -plot variation, the Block X Lot interaction was found to be highly significant in both studies. This inter-action was also examined in several of the younger studies and was found to be highly significant in every instance but one. This means that the various progeny groups are more sensitive to site variation than had been anticipated. In terms of progeny test design, it means that we must find more uniform sites and then sample several of these uniform sites in order to get out most sensitive trees.

Average eight-year d.b.h. values ranged from 4.4 to 5.4 inches in the 1952 study and 7-year d.b.h values from 3.2 to 4.9 inches in the 1953 study. Analyses indicated that there were no significant differences among progencies in the older study, but highly significant differences in the 7-year material. This again is probably attributable to study design and the variability in site. When examined on an individual tree basis, d.b.h. was found to be highly correlated with total height, with correlation coefficients varying from 0.83 to 0.88.

The relationship of d.h.b. to number of trees surviving per plot was examined in the 7-year-old material. The regression was found to be positive and highly significant. Thee positive regression is contrary to normal expectations. It is generally accepted that the fewer trees per unit area, the larger the diameter of the individual tree. These data were to the contrary. The explanation probably lies in the relationship of the inherent vigor of the progenies to survival, and possibly in the relationship of survival to site variation. It appeared that the progenies that survived best grew fastest and through the number of trees competing on each plot was greater, the trees grew at a faster rate so that they had larder diameters. The relationships of total height to survival was also examined and a similar positive significant regression was obtained. It is impossible from these data to determine which portion of this relationship is attributable in a major part to inherent vigor, it will seriously compli-cate adjustments that should be made in analyses to account for mortality and resulting differential competition, because mortality will be confounded with inherent vigor.

Table 1.--Mean values for various characteristics of open-pollinated progenies of slash pine, study 102 (1952)

Lot	Average height[1]	Average d.b.h.[1]	Rust free[2]	Crook[2]	Crown width[3]
	Feet	Inches	Percent	Percent	Ratio
C-4[4]	22.40	5.02	59	90	0.54
C-6	21.44	4.99	47	74	--
C-7	21.50	4.54	41	70	--
C-10	22.20	4.82	52	51	.54
C-37	22.73	4.84	70	63	.44
C-50	22.55	4.60	41	68	.38
C-51	22.12	4.76	50	62	--
C-54	24.34	5.15	88	63	.42
C-56	24.99	5.16	49	61	.44
C-59	20.89	4.23	73	74	--
C-60	22.10	4.83	48	90	--
C-61	21.65	4.81	60	39	--
C-62	22.03	4.74	37	40	--
C-63	23.96	5.35	76	66	.40
C-65	23.92	4.95	61	63	--
Sou. Miss.[5]	19.79	4.61	19	67	--
New Orleans[5]	19.43	4.44	26	72	--
Control Seedlings[6]	21.23	4.75	37	54	.52
Control Seed[7]	23.07	4.87	35	70	.53

1. Data recorded after 8 years in the field.
2. Data recorded after 6 years in the field.
3. Data recorded after 3 years in the field.
4. The "C" designation before a number indicates a selection of the Callaway Foundation.
5. Mixed lots obtained from Southern Forest Experiment Station, Forest Service, U. S. D. A.
6. Seedlings obtained through normal public distribution channels, source unknown.
7. Seed purchased from a commercial seed dealer, 1950.

Table 2. --Mean values for various characteristics of open-pollinated progenies of slash pine, study 103 (1953)

Lot	Average height[1]	Average d.b.h.[1]	Rust free[2]	Crook[2]	Crown width[2]
	Feet	Inches	Percent	Percent	Ratio
C-4[3]	18.46	4.12	69	79	0.49
C-6	16.82	3.92	66	74	.48
C-7	19.86	4.30	51	59	.41
C-10	19.88	4.40	58	50	.47
C-37	21.60	4.92	73	60	.39
C-50	20.82	4.30	48	72	.40
C-51	17.42	3.96	78	38	.41
C-58	20.95	4.31	56	77	.42
C-63	20.10	4.26	60	66	.41
C-65	18.99	4.04	71	54	.42
C-134	18.16	3.81	53	73	.41
Sou. Miss.[4]	16.57	3.44	38	66	.45
New Orleans[4]	17.76	3.79	48	70	.45
CA-82[5]	18.84	3.95	32	68	.42
CB-23[5]	17.53	3.53	32	55	.48
CB-74[5]	16.16	3.30	38	30	.43
A-1[6]	17.60	3.56	48	86	.46
A-2[6]	17.45	3.52	57	72	.51
Control Seedlings[7]	16.00	3.24	45	54	.47
Control Seed[8]	17.66	3.84	67	60	.45
Callaway[9]	18.27	4.02	69	89	.45

1. Data recorded after 7 years in the field.
2. Data recorded after 5 years in the field.
3. The "C" designation before a number indicates a selection of the Callaway Founds
4. Mixed lots obtained from the Southern Forest Experiment Station, Forest Service U.S.D.A.
5. Open-pollinated seed from selections made in Australia.
6. Open-pollinated seed from selections made near Auburn, Alabama.
7. Seedlings obtained through normal public distribution channels, source unknown.
8. Seed purchased from a commercial seed dealer, 1951.
9. Seed collected from dominant and co-dominant, rust-free trees at the Callaway Foundation for use in routine planting operations.

A measure of natural pruning was taken by recording the height to the lowest whorl having two or more live limbs. Striking differences were observed among progenies; some lots and individuals displayed distinct tendencies toward early natural pruning, though lateral branch competition was very low.

Crown widths were examined in the progenies at ages from 3 to 5 years. In the 1952 study, the ratios of maximum crown width at 1/3 the height of the tree to total tree height were determined and the values analyzed. The range of progeny means varied from 0.39 to 0.55 and highly significant differences were found among progenies, Similar ratios were determined for the 1953 planting at 4 years of age and highly significant differences amont progenies were obtained, with ratios varying from 0.34 to O.47. At 5 years of age, the 1953 plantings were examined and the crown-width measurements were taken at 1/2 the height of the tree and similar ratios were determined. These ratios varied from 0.39 to 0.51 and differences among progenies were highly significant.

In 1959, detailed measurements were made on certain crown characteristics in selected progenies, and 26 variables were examined in a correlation analysis. Using data collected from whorls of branches that had completed 3 growing seasons, we have found several interesting points (Table 3.). Branch length was highly correlated with branch diameter (0.95). Branch length and branch diameter were both negatively correlated with branch angle (-0.43 to -0.48). Branch length was weakly correlated with amount of stem growth above the whorl; that is, total height growth during the same period that the branches grew in length (0.18 to 0.28). Branch diameter was well correlated with d.b.h. (0.53 to 0.75), and this correlation was better than the correlation of branch diameter with the stem diameter above the whorl (0.36 to 0.55). Branch length and diameter are negatively correlated with angle. Thus, as we select trees that have more nearly horizontal branches, there will be a tendency for these branches to be shorter in length and smaller in diameters

Some of the parent trees included in these tests had varying amounts of crook in their stems. The 1952 plantings were examined at 6 years of age, the 1953 plantings at 5 years of age, and a record was made of stem crook. This was an occular estimate and may be biased. All of the biases, however, are probably in the some direction, and tend to be on the severe side. The percent of trees containing crook varied from 39 to 90 percent among progenies of the 1952 planting and 30 to 89 percent among progenies in the 1953 planting. These differences among means of progenies were significant at the 5 percent level in the 1952 planting and at the 1 percent level in the 1953 planting. The parents that had a greater amount of crook had progenies that were among those having the greatest percentage of crooked stems.

Table 3. -- Correlations between va rious characteristics of open-pollinated slash pine progenies at ages 7 (1953 planting) and 8 years (1952 planting).

Characteristics correlated	Planted 1952[1]	Planted 1953[2]
	Coefficient	
Branch length with branch diameter	0.95	0.95
Branch length with branch angle	- .48	- .47
Branch diameter with branch angle	- .43	- .46
Branch length with stem growth above whorl	.18	.28
Branch diameter with d.b.h.	.53	.75
Branch diameter with stem diameter above whorl	.36	.55

1. n=100

2. n-59

Tallies of the number and location of fusiform rust cankers were made in the 1952 planting at 6 years of age and the 1953 planting at 5 years of age. The percent of trees free of rust was examined for both studies and in a combined analysis. The 1952 planting varied from 19 to 88 percent of the trees free of rush and highly significant differences were obtained from progenies. In the 1953 planting the percentage of trees free of fusiform rust varied from 32 to 78 percent and the differences were also highly significant. There were 11 parents or lots which were represented in both studies The parent trees were represented by different collections of open-pollinated seed made in consecutive years. A combined analysis of variance was run to examine the relative performance of progenies of the parent trees. In the analysis, "Lots" once again showed significance at the 1 percent level and "Years" was also significant. The Lot X Year interaction was not significant. This means that the open-pollinated progenies gave similar estimates of the parent trees, though the seed were collected and planted in different years.

The relationship of fusiform rust infection to inherent rate of growth was examined by correlating the number of fusiform cankers per *tree with* the growth of the individual tree at early ages. For the *1952* planting, rust infection at *6* years of age in the field was very weakly correlated with total height at *2* years (0.16), total height at 3 years (0.12), second-year height growth (0.15), third-year height growth (0.03), and second-plus third- year growth (0.10). For the 1953 plantings rush infection at 5 years in the field was similarly weakly correlated with total height at 1 year (0.11), total height at 2 years (0.13), second-year growth (0.12), third-year growth (0.02), and second-plus third-year growth (0.08) All of these correlation values are very low, and from a practical viewpoint we can probably consider that the relationship of fusiform rust infection to inherent growth rate is negligible. It is apparent that even under severe field conditions some of the faster growing progenies remain free of fusiform rust cankers. Where fusiform rust is as heavy as in the Callaway tests, it is unlikely that this could be attributed to "escapes".

Throughout these tests, it was found that the open-pollinated progenies in the 1952 planting and the 1953 planting were in agreement for individual parents. Though the seed were collected in different years, they tend to give the same relative estimates of the parent trees. The characteristics that seemed most variable were total height and d.b.h. These characteristics, of course, are probably more sensitive to site variation than any of the others examined. These tests have established that open-pollination can be relied on to give valid relative estimates of individual parent trees

Analyses of data from these tests point up several matters that should be considered in Progeny tests design The interaction between progenies and blocks indicates the importance of using uniform sites and better samples of site conditions for testing trees.

Crown data of older progenies based on measurements in a single whorl appear to give reliable estimates of general crown characteristics. The examination of fusiform rust data collected from these studies show that if a severe rust year occurs at an early age, data following this will give a reliable estimate of the susceptibility of the individual trees among the progenies. It was also found that the presence of stem cankers of fusiform rust is detrimental to growth of the tree and that if estimates of the inherent ability of a progeny to grow are to be considered, one must eliminate all trees having stem cankers of rust. Otherwise, those progenies with heavier infections will be biased downward.

In addition to the material reported in this paper, other measurements were taken on the progenies and on a number of the parent trees. Characteristics, such as bark thickness, forking, and natural pruning were considered and analyzed. Information on these characteristics and more details on those reported in this paper will be published at a later date.