Progeny Tests of Slash Pine (Pinus elliottii Engelm.) in Queensland, Australia

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INTRODUCTION

Slash pine (*Pinus elliottii* Engelm.) was first planted in Queensland some 40 years ago, the original seed source being northern Florida. Stocks from the first introductions grew rapidly, and younger plantations descended from the original material through mass-selected local parents remain free from serious diseases and pests and are unsurpassed by other provenances introduced at a later date. Because of its good performance, slash pine will surely play a major role as an exotic species in Queensland, probably along with *Pinus caribaea* Mor. from several sources being tested.

The progeny tests planted prior to 1948, mainly from wind-pollinations, were reported by McWilliam and Florence (1955). These and more recent tests were reviewed by Haley (1957) and Nikles (1962) and are referred to in some issues of the Annual Report of the Conservator, Department of Forestry.

The objectives of the progeny tests described here are:

1. to determine the accuracy of mass-selection as a means of identifying phenotypes with good breeding characteristics;

2. to measure the gains from both open and controlled pollination of mass-selected parents;

3. to identify the most valuable parents for propagation in clonal seed orchards and 1 for future breeding work.

The present paper summarizes assessments made in 1962 and 1963 and certain remeasurements made in 1965 of well replicated and controlled progeny tests established in the period 1952 to 1957. In addition, some older tests were examined to add to the information available on several parents being evaluated. The report given here is preliminary in nature since the data have not been exhaustively analyzed; a full study of the 1952-58 series of progeny tests is expected to be completed in approximately two years.

TEST MATERIALS AND PROCEDURES

The parent trees used in the tests were chosen from plantations 10 to 16 years old and established at a 7' x 7' or 8' x 8' spacing. Forty trees were selected from approximately' 2000 acres of plantations for superiority in a combination of bole straightness, crown form and vigor. The present appearance of two of the trees selected is illustrated in Figure 1. Open-pollinated cones were collected from all selected trees, and as many crosses as possi le and numerous selfings were made among them over a period of several years. This gave equal numbers of families per parent and for the full-sibs there was no regular mating des ign. The seeds available each year from each type of pollination were used to establish a test; hence wind-pollinated, selfed and full-sib progeny tests were separately planted eac year. In the 1952-57 plantations 59 full-sib, 42 wind-pollinated, and 20 selfed families were available in all.

Seed for the control stocks (checks) was the same as that used commercially and in th local reforestation program. For these purposes cones are collected in plantations of the Department of Forestry from the 160 most vigorous, well-formed trees per acre. Such trees are selected at approximately ten years of age, are then pruned, and will finally yield the crop of trees harvested at the end of the rotation.

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Figure 1 -- Plus trees G20 (left) and G40 (right), now 23 and 32 years old, respectively, which were selected at 10 and 12 years of age for superiority in a combination of bole straightness, vigor and crown characteristics. Progeny of these trees are shown in other figures.

Table 1. Age and composition of principal[1/] progeny tests studied.

Year when planted	Age when assessed	Type of Pollination Involved: Control-cross #parents	Control-cross #families	Control-cross #sections	Open #families	Self #families
1952	10	3	2	1[2/, 3/]	6	–[4/]
1953	10	4	3	1[2/]	21[5/]	5
1954	8	8	7	1	4	12
1955	7	11	18	3	26[2/, 3/]	4[3/]
1956	6, 9	10	21	4	6[6/]	–
1957	6, 8	9	8	2	–	–

1/ Other tests planted 1946-1949 inclusive examined also to supplement data from principal tests; involved additional 11 control-cross and 20 self-pollinated families.
2/ No checks included in these tests.
3/ Less than four replications per family in these tests.
4/ Vacant cells indicate no test that year.
5/ This test assessed at nine years.
6/ This test not reassessed at nine years.

Check and pedigreed seedlings were handled in the same way in the nursery. In the field, planting locations of average site quality were chosen, a separate progeny test experiment being planted each year in the area cleared for routine departmental planting. Square multi-row plots of both check and pedigreed progeny were planted at 10' x 10' spacing, with up to 64 trees per plot, replicated up to four times. The blocks of randomized complete-block designs were restricted to 1.5 acre in the full-sib progeny tests to minimize heterogeneity of site within blocks. Thus, no more than eight families plus checks were included in any section of the experiments established each year; in any one year, from one to four such sections, each a randomized, complete-block experiment, were planted, accommodating all the families available. The progeny test areas received standard fertilizer and tending treatments, the same as did the routine plantations. Open-pollinated families were treated similarly to the controlled crosses, except that spacing was 8' x 8' and the block size sometimes reached two acres. The self-pollinated progenies were established in separate blocks adjacent to the other material at 10' x 10' spacing in multi-row plots; a few had enough seedlings to allow replication within years and several selfs were replicated in time. Relevant details of the experimental material are summarized in Table 1.

iFigure 2 -- Portion of a nine-year-old progeny test plantation. On the right is check material in which most trees scored 6 or 7 points for straightness, only 26 per acre scoring 8 or more points out of a possible 10; average total volume per acre inside bark was 1075 cu. ft. The plot on left contains full-sib progeny of mass-selected parents; in it 135 trees per acre scored 8 points or more for straightness; volume per acre in this plot, adjacent to the check, was 1204 cu. ft. The average gain in volume of the 21 families in the nine-year experiment was 243 cu. ft. per acre.

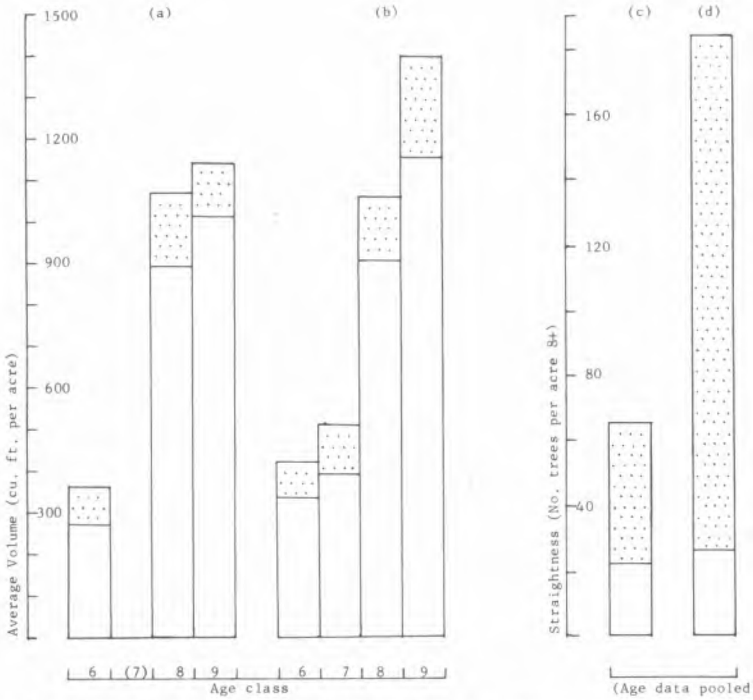

Figure 3. Histograms (a) and (b) show by type and age of progeny test the average volume per acre of checks (basal rectangles), the gains realized (stippled), and the average volume per acre of progenies of mass-selected parents (entire diagrams) after (a) open and (b) controlled pollination. Refer to Table I for details of the individual progeny tests.

In histograms (c) and (d) straightness data are pooled and averaged across age classes, within type of progeny: (c) open, (d) controlled pollination. Again, bases of rectangles represent checks, stippled areas the gains, and entire diagrams the average absolute values for the progenies.

Prior to the assessments of the progeny in 1962 and 1963 all trees were pruned to the height of approximately 8' to facilitate measurement and scoring. The following measurements and assessments were made on the interior 36 trees of each plot:

1. The diameter at breast height
2. Total tree height
3. Bole straightness.

Straightness was scored on a scale from 10 (no visible defect) to 6 (serious defect, affecting sawn recovery). The assessors (the present author and an assistant checked themselves occasionally by reassessing several trees at the beginning of and during the day. Examples of the appearance of trees with various ratings for straightness may be seen in Figure 2. Full-sib progenies average approximately 40 feet in height at 10 years of age.

Bole straightness of selfed progeny was scored in the same way but height and diameter measurements were not made, vigor being scored subjectively in relation to adjacent outcrossed progeny on a scale from 1 (equal to out crosses) to 4 (virtual failure).

RESULTS

The numbers of trees scoring 8 or better for straightness were enumerated for each plot and converted to a per acre basis; the plot mean diameter breast height and mean total height values were used to obtain the volume inside bark of the mean tree in each plot. It was then possible to calculate volume per acre for both wind-pollinated and full-sib progeny. Statistical analyses of the significance of differences between individual crosses and checks were made.

The data were first examined for superiority of selected tree progeny over checks, which were progeny of thy best 160 trees per acre in the older plantations. These data are summarized in Figure 3. In calculating the gains for each experiment, account had to be taken of the fact that the 1955-57 experiments each comprised from two to four section$ with relatively large numbers of families per experiment. These numbers of families differed from those in the 1952-54 experiments, each of which comprized a single section. However, sections were reasonably equal in numbers of families, so it was decided to derive mean straightness and volume gains for each. The mean gains for the sections were then used to derive the mean for each experiment; from these data were computed means for each age class, which are presented in Figure 3. It must be

Table 2. General combining ability for straightness and volume of several parents tested in one or more years.

Year of test	Parent tree #	# of 1/ families	General combining ability 2/: Straightness in trees/ac. 8+	Volume per ac. cu. ft. at age 6	7	8	9
1949	16	4	215	3/			
1954	15	4	215			903	
1955	16	2	103		589		
	15	6	193		572		
	14	6	60		473		
	6	3	95		600		
	7	4	64		473		
	8	3	193		533		
	19	3	77		481		
	26	5	112		889		
1956	16	5	193	383			1367
	15	7	146	413			1423
	14	5	69	456			1479
	9	4	181	373			1299
	12	3	64	400			1419
	13	4	150	374			1428
	20	3	400	370			1247
	24	6	146	447			1505
1957	15	3	215	412		1075	
	5	3	300	400		989	

1/ Parent may have been male or female. Each parent not necessarily mated to same testers.
2/ By way of comparison, checks averaged 26 trees per acre 8+ for straightness; volume production of checks at various ages are given in Figure 3.
3/ Vacant cells indicate data not taken.

1/ The 1952 and 1953 full-sib and 1955 open-pollinated tests did not include check plots, so no estimation of gain in volume was attempted. However, gains in straightness were estimated on the basis of the over-all means of checks. II

Table 3. General combining ability[1/] and designation[2/] for straightness, and score[3/] for volume production of parents involved in three types of tests.

Tree No.	Selfed progeny: Straightness mean	Selfed progeny: Straightness designation	Selfed progeny: Volume score	Full-sib progeny: Straightness g.c.a.	Full-sib progeny: Straightness designation	Full-sib progeny: Volume score	Open pollinated progeny: Straightness g.c.a.	Open pollinated progeny: Straightness designation	Open pollinated progeny: Volume score
1	129	4/	B	206	+	B	72	+	B
2	241	+	C	180	+	C	72	+	B
3	49	-	A	86	-	B	26	-	B
5	306	+	C	206	+	C	103	+	C
6	N[5/]		N	95	-	B	26	-	B
7	21	-	C	52	-	C	21	-	C
8	215	+	C	216	+	B	77	+	B
9	35	-	C	215	+	B	47	-	B
11	228	+	B	120	-	B	73	+	B
13	168		B	172		B	60		B
14	56	-	B	73	-	B	17	-	B
15	130		B	181		B	77	+	A
16	215	+	C	172		B	90	+	B
17	34	-	C	N	N	N	47	-	B
19	73	-	B	77	-	C	17	-	B
20	380	+	C	400	+	B	170	+	B
24	N		N	146		A	142	+	A
26	N		N	129	-	A	56		A
27	86	-	C	172		B	N		N
29	52	-	C	N	N	N	69		B
33	26	-	A	180		A	50		A
TEST MEANS (15 parents)	157[6/]			176			65[6/]		

1/ Straightness for all families in each type of progeny test pooled and averaged for each parent. G. c. a. expressed as number of trees per acre scoring 8 points or better.
2/ Parents with all-family averages well above mean for type of progeny test, designated "+"; well below designated "-". Such parents would be selected for and against respectively with confidence.
3/ Parents scored subjectively as A, B, or C according to the relative performance of all their families within each type of progeny test. Parents scoring A or C would be selected for or against respectively with confidence; those scoring B are about average in breeding potential.
4/ Absence of designation for straightness indicates all-families mean is about average.
5/ N=No progeny test of this type with this parent. 6/ Both test means (157 and 65) significantly different from 176 and from each other.

realized, however, that this information came from a diversity of material in different experiments, not from the same material in one experiment over several years.

The data were also examined with a view to evaluating the breeding qualities of individual parents. Problems were immediately apparent because of inequality of test intensity for each parent and incompleteness of their representation over years. However, within the more comprehensive 1954-57 full-sib test, estimates of general combining ability (g.c.a.) were possible for 14 parents. Each parent was represented by at least three families; in some cases, many more. The mean values for straightness and volume of the groups of families associated with each of the 14 parents, that is, general combining abilities, are given in Table 2.

Specific combining abilities (s. c. a.) for straightness and volume of 30 crosses in the 1955 and 1956 experiments at ages 7 and 9 years were derived as:

s.c.a. A x B= observed value A x B - g.c.a. A - g.c.a B + mean for the experiment 1/

Figure 4 -- Nine-year-old full-sib families; on left G40 x G20, much more vigorous than G16 x G20 on right. In this case both families had the same exceptionally high value for straightness.

The results can be summarized as follows:

With regard to straightness, specific combining ability was large for ten of the crosses. However, only four specific combining abilities for volume differed markedly from zero. The crosses with large, positive specific combining abilities were not outstanding in absolute terms. Moreover, none of these crosses combined a higher gain for both traits than several other families which showed no marked specific combining abilities. In other words, the most productive full-sib families with respect to straightness and volume individually, and to a combination of these traits, resulted from combinations of parents of high general combining abilities.

Analyses of the less comprehensive older experiments were attempted also to effect comparisons among an additional seven parents. The data on straightness for all full-sib, wind-pollinated, and selfed progeny tests were pooled within test types on the assumption that direct comparisons could be made across types of test and experiments. These data yielded mean straightness values for the progenies of 21 parents well represented in at least two of the three types of progeny test; families of 15 parents were so represented in all three types of test. The relative merit of all 21 parents, judged by vigor of progeny, could not be determined directly in this series of tests because of the

1/ Mean value for straightness and volume of all families involved in the particular experiment.

Figure 5 -- A nineteen-year-old plantation from controlle crossing of superior parents G2 and G3. Note the excellen straightness and fine short branches in this family. The stan was thinned commercially in 1963. Several trees have bee artifically pruned as high as 30 feet.

Figure 6 -- Eighteen-year-old progeny from selfing good phenotypes; on left a family from parent G2 showing excellent bole straightness but poor vigor; on right a family from parent G40 with poorer straightness but outstanding vigor. Performance of selfed progeny of a parent was highly indicative of its general combining ability.

haphazard distribution of families among experiments. But an attempt was made to differentiate two extreme groups on the basis of each type of test in the following way: within experiments, parents were ranked according to the mean performance of their families; across experiments, judicious comparision were made utilizing the facts that check material was common to all experiments and that some families were common to two or more tests. Parents were then scored according to their apparent potential for producing progeny of class:

A = exceptionally high volume production
B = intermediate volume production
C = very low volume production

Similarly, parents with high potential for straight offspring were designated "+" and with low potential, "-." It was considered that parents scoring +, A or -, C could be selected for and against, respectively, with confidence. Results of these further parental evaluations are presented in Table 3. Variation in performance among different families is illustrated in Figures 4 and 5 (full-sibs) and 6 (selfs). Among 20 families resulting from selfing, three showed no observable reduction of vigor compared to outcrosses, and two had straightness values as high as the best full-sib families.

DISCUSSION

1. Gains from selection and controlled breeding.

Complete control of pollination among mass-selected parents gave spectacular improvement in both volume and straightness, while open-pollinated progeny yielded useful gains (Figures 2 and 3). This confirms the results obtained by McWilliam and Florence (1955).

With regard to full-sib progeny, considerable gains in both traits occurred in all sections of the six full-sib experiments from which data were obtained to produce Figure 3. The check sources averaged only 26 trees per acre, scoring 8 or better (hereafter designated

8+) out of a possible 10 points for straightness; the very best check plot gave only 52 trees per acre, scoring 8+, while the mean gain for all 59 crosses was 158 trees per acre, rating 8+. Only in six families were there absolute gains of less than 100 per cent. For volume, there is a clear trend of increasing gain values over and above a steeply rising rate of volume production with age in the checks. It is probable that larger volume gains will yet accrue as the plantations get older. Only two families out of 50 produced less volume in absolute terms than did the checks with which they were compared. In the nine-year 1956 full-sib test which comprises 21 families involving 10 parents, the average gain was 243 cu. ft. per acre (approximately 2.7 cords), a figure significant both practically and statistically. The 21 families are nearly a 50 per cent sample of all possible family combinations which could result from random pollination in a clonal orchard composed of the same 10 parents. Therefore, the realized gain quoted is likely to be a very good estimate of that available from such an orchard. Greater improvements are possible for slash pine, since the other experiments revealed parents surpassing in general combining ability many of the 10 used in the 1956 test.

The gains from wind-pollinated progeny of the mass-selected parents were also considerable (Figure 3). On a basis of 650 trees/acre (equivalent to the standard 8' x 8' spacing) the gain in straightness was 65 trees per acre 8+; real gains in volume were obtained from some families. Since the nine-year-old 1953 test involved as many as 21 families and is well replicated and controlled, results from it are of special interest. Analyses showed eight families had volumes exceeding checks by at least two standard deviations, and none of the open-pollinated families was significantly inferior to the checks. With respect to straightness no selected parent gave progeny significantly poorer than the checks, while ten families were markedly superior, with gains of at least 40 trees per acre 8+. In the check plots only 22 trees per acre rated 8+ for straightness. These results indicate that use of wind-pollinated seed from selected parents can be beneficial, but a high intensity of selection such as was used here is necessary for really worthwhile gains.

2. Evaluation of parents.

The general combining ability values given in Table 2 are based on four or more families in 12 of the 20 crosses, while the remainder are based on three families. Although each parent was not crossed with the same group of testers, the families of many parents did have some testers in common. Thus, direct evaluation of parents using these general combining abilities must be done with caution. The following points do, however, emerge:

a. There is considerable variation among general combining abilities for straightness [3/] for some parents in different experiments, for example:

Parent	g.c.a. for straightness in different tests
16	215, 103, 193
15	215, 193, 146, 215

Possible sources of this variation are: (1) effects of specific crosses, since means for most parents represent somewhat different sets of testers; (2) genotype by environment interaction; (3) error in the subjective assessments.

b. Tentative ranking of parents in respect to breeding potential for straightness and vigor might be made on the basis of Table 2 as follows:

Year of Test	Ranking of parents [4/] as breeders		Year of Test	Ranking of parents [4/] as breeders	
	Straightness	Volume		Straightness	Volume
1955	8 15	26	1956	20	14 20 24
	6 16 26	6 8 15 16		9 16	9 12 13 15 16
	7 14 19	7 14 19		13 15 24	
				12 14	

2/ Results just received of the remeasure of the 1955 full-sib test show an average gain for the 12 families involved in two well replicated sections of 260 cu. ft. per acre over the check plots which produced 1050 cu. ft. per acre.

3/ Volume comparisons not attempted because of varying ages.

4/ Ranked in descending order of value; parents of equal value on same line.

It is of special interest to note that tree 15 shows a reversal of ranking for straightness in 1956, but the 1954 and 1957 tests (Table 2) suggest the 1956 result is atypical; and tree 14 shows a reversal for volume. Other than these two instances, most likely effects of specific crosses, parents common to both tests are similarly placed for the different years. It is evident that for precise evaluation of parents a tester system with perhaps a minimum of five testers is highly desirable. Further, the duplication of tests over years and the development of an objective assessment method for straightness appear to be necessary.

c. A further point worthy of note is that tree number 24 displays high combining ability for volume production and a very acceptable standard for straightness. This tree was selected for its outstanding vigor and good straightness within an open-pollinated family with high performance in these traits. Other examples of the efficacy of second-cycle selection within the progeny tests were noted in the 1955 open-pollinated trial. Twelve of the parents included were selected at eight years of age in two full-sib families outstanding for straightness. The open-pollinated progeny of six of the 12 selections displayed exceptionally good straightness, equivalent to the performance of open-pollinated progeny of tree number 20 (shown in Figure 1, left), which had the highest general combining ability of all trees in the whole series of progeny tests.

d. Another important point which emerged from the results in Table 2, and indeed from the whole series of tests, was that phenotypic selection of the parent trees was generally very accurate. Only rarely did mass-selected parents produce progeny without significant gains over the checks, and in no case did they give progeny significantly poorer than the checks.

The information in Table 3 represents an attempt to utilize the data collected throughout all the experiments for evaluation of a maximum number of parents. This further illustrates variation of breeding value among parents and points up a general coincidence of parental ranking in all three types of progeny test. Thus, with respect to breeding value for straightness, of the 15 parents common to all three types of test essentially the same groups of parents would be chosen by positive selection in each of the three types of progeny; in only two cases (parents 9 and 11) are there conflicting indications. In addition, the same parents (trees 3, 7, 14, 19) are selected against on the basis of each test method. With respect to vigor there appears to be very substantial agreement among the three methods in indicating the best and the poorest parents. Exceptions to the rule that parental evaluation can be made on the basis of either type of progeny test might be explained on the basis of the particular sample of pollen parents involved in the full-sib or wind-pollinated families. Thus for example, all the full-sib families available of tree 33 (the selfed progeny of which is crooked - Table 3) involved pollen parents known to have high general combining ability for straightness; this would bias the result of full-sib tests.

It appears, therefore, that provided the full-sib and wind-pollinated progeny tests represent several families of the parent in question (perhaps a minimum of five) then all three progeny test methods will give very similar evaluations of the breeding quality of the parents. However, more precise experimentation is necessary to determine the real relationship of the three types of test, and particularly if selfed progeny alone can be relied upon to indicate the breeding potential of a parent. As is discussed more fully below, this phenomenon involves the relative amount of additive gene action for the trait concerned. From personal correspondence with several other conifer breeders, four researchers have reported evidence of a fair relationship between self- and cross-pollinated progeny performance. This was also reported by Diechert (1964) for spruce and larch and has been found also in corn (Koble, 1964; Lonquist and Lindsay, 1964).

There are indications in Table 3 of negative phenotypic correlations between straightness and vigor. For example, trees 2, 5 and 20 gave straight progeny of average vigor, while trees .3 and 33 gave vigorous but relatively crooked progeny. However, progeny of tree 7 showed a positive correlation. Clearly, more studies are needed to determine this point and to investigate the genetic correlation between the two traits.

3. Possible gene action; choice of breeding methods.

Although the experiments discussed in this paper were not designed to yield information on gene action *per* se, some evidence on it can be obtained and is discussed here because of its importance in determining the most efficient breeding method.

It is generally recognized that complex traits such as yield (for example, volume production) are not controlled by simple Mendelian inheritance but are quantitative in character. Quantitative inheritance is best considered in terms of the relative magnitude of the three major kinds of associated genetic variance - additive, dominance and epistatic. Explanations of the nature and sources of these variances are beyond the scope of this paper; for a general treatment of this subject, reference may be made to a standard text such as Falconer (1964). An attempt will be made here to indicate evidence on the relative magnitude of these variances in the breeding population of slash pine which was studied.

Considerable additive variance for both straightness and volume is manifested by the large gains realized (Figure 3) from the simple selection schemes used. Estimates of realized narrow sense heritabilities are obtainable from these experiments but were not calculated for the present paper. However, such values will surely prove to be relatively high since phenotypic selection was very accurate and the mass-selected parents gave progeny much superior to the base population.

Further evidence of the importance of additive variance in straightness in this population is provided by the facts that the selfed and the full-sib progeny tests yielded similar values and essentially the same ranking of parents for this character (Table 3). Finally, the occurrence of specific combining ability effects for both straightness and volume, though evidence of dominant gene action, was such that the level of dominance and the amount of dominance variance appeared to be low. This conclusion was arrived at as follows:

Apparently real specific combining ability effects, though not statistically tested, were present for straightness in 10 out of 30 crosses (p. 5), but none of the families involved had outstanding straightness while all the families with outstanding straightness had parents of very high general combining ability. Hence the level of dominance in the alleles controlling straightness appears to be low. As regards vigor, there were only four out of 30 crosses with apparently real specific combining ability effects (p. 5). Further, inbreeding depression of growth (and effects on straightness) were very variable in expression (Table 3). Although mean straightness of 15 selfed families was significantly depressed compared to the controlled crosses, it was not markedly reduced (Table 3). These points suggest that dominance variance for vigor and straightness in this population may be low. A large proportion of additive variance for yield, though it is a complex character, is not without precedence in other crops (Gardner, 1963). However, in other samples of slash pine or even in later selection cycles of this population, non-additive genetic variance may increase in importance. Clearly, a breeding procedure enabling utilization of both general and specific combining ability would be optimum.

To sum up the discussion on gene action and breeding methods it appears that additive variance is of greatest importance for both volume growth and bole straightness but that larger non-additive effects may become apparent in other populations of slash pine or in later selection cycles of the material studied or with greater tree age. It is evident that for precise estimation of the relative magnitude of the different components of genetic variance use of improved mating and field designs will be necessary. In the meantime, selection with major emphasis upon general combining ability combined with restriction of interbreeding to the trees selected appears to be by far the best approach. For example, a seed orchard might be developed, composed of clones of the best individual tree in each family of a best fraction of all families available as indicated by Squillace and Dorman (1961) and Johnsson (1964). Since the full pedigree of each family is known, it would be possible to ensure that all clones to be retained permanently were unrelated, thus minimizing inbreeding. Gains can be expected to accrue for several cycles of selection, and they may in fact improve, since heritability should increase when selections are made within rather uniform progeny test areas and when the more accurate combination of family and mass selection is applied. If a particular cross were found to out-yield all others to a large enough extent to warrant its mass production, then the specific combining ability demonstrated might be so utilized.

SUMMARY

Progeny tests of slash pine (*Pinus elliottii*) established in Queensland between 1952 and 1957 were studied when six to ten years of age to determine the gain in volume and bole straightness over commercial stock, resulting from mass-selection of parents combined with controlled and open pollination. Progeny resulting from the selfing of many parents were also available and, together with the cross-pollinated material, were examined to. evaluate the breeding qualities of the parent trees. The results also provided a basis for some speculation on the

5/ The raw data from the assessments were not available to the writer at the time of preparation of the paper; it is planned, however, to make a fuller analysis later.

relative importance of types of genetic variance present in the population and hence on the optimum breeding procedure.

The replicated and controlled full-sib experiments involved 59 families from 25 parents. Subjective assessments of bole straightness revealed on the average seven times the number of trees of a defined high standard (8+) in these progeny as compared to the checks of commercial stock, which averaged 26 per acre 8+. The gain in volume per acre increased with age, reaching 243 cu. ft. per acre (approximately 2.7 cords solid wood per acre) at nine years and appeared to be still rising. Gains realized in the wind-pollinated progeny tests were smaller but considerable. Twice as many trees scored 8+ for straightness compared to checks which averaged 22 per acre 8+, and in one large experiment the gain in volume was 123 cu. ft. per acre at nine years of age.

Evaluation of the breeding qualities of parent trees was attempted by comparison of theirs general combining abilities for straightness and volume. Estimates for 14 parents involved in the more comprehensive full-sib tests showed great variation in their capacities to produce superior offspring, indicating progeny test selection to be potentially of great benefit.

When all the data within each of the three types of progeny test (full-sib, wind-pollinated, and selfed progeny) were pooled, 15 parents were found to be represented in all types of test. A significant difference between the means for straightness of the full-sib and self-pollinated progeny was found; the respective means were 176 and 157 trees per acre 8+. The wind-pollinated progeny mean was 65. The three types of progeny test differentiated the same trees, with few exceptions, into groups of parents characterized by: excellent and very poor straightness; very high and about average vigor.

Specific combining abilities for straightness and volume were calculated for 30 crosses, resulting in high values in 10 and 3 cases, respectively. However, the most outstanding single crosses encountered did not show high specific combining ability, and those with high specific combining ability were relatively poor in absolute terms.

The test results provided indirect evidence on the relative magnitude of components of genetic variance for straightness and volume; additive variance appeared to predominate in the breeding populations studied. Consequently, the breeding procedure recommended was one with major emphasis on general combining ability but which also allowed utilization of any worthwhile specific combining ability effects.

ACKNOWLEDGMENT

Tree breeding work in Queensland, in which the progeny testing described here is a major element, was initiated by Mr. V. Grenning, then Director of Forests, and has continued under the direction of Mr. A. R. Trist, formerly Deputy-Director and now Conservator of Forests. The demonstrated success of the work is a tribute to the foresight of these foresters. Several research officers have been involved in the work over the years, in particular Messrs. C. Haley, J. J. Smart, J. R. McWilliam, R. G. Florence, and M. U. Slee. Mr. T. R. Chard has been an invaluable technical aid throughout the program. Photographs used in the paper are due to Mr. G. Trinder. Permission to use the data accumulated by myself and these workers was kindly given by the Conservator, Department of Forestry, Brisbane. Finally, I wish to thank Dr. B. J. Zobel for encouragement to prepare this paper and for his criticisms of an earlier draft.

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