INHERITANCE OF VIGOR IN SLASH PINE

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In January, 1953, a series of controlled pollinations were initiated by Dr. Tom Perry to study the transmission of vigor from parents to off-spring in slash pine. The stated objectives of this study were: (1) to demonstrate the inheritance of vigor, (2) to demonstrate the degree of genetic superiority or inferiority of the selected trees, thus giving some measure of the economic gains to be realized through forest genetics (3) to test the validity of the genetic evaluations that were made on the basis of phenotypic comparison.

To accomplish these objectives, natural slash pine stands on the Austin Cary Forest were measured for age, total height, d.b.h., and volume. A subjective estimate of competition, form, growth potential was used in making the final estimate of the vigor of individual trees. On this basis four trees of high vigor and four trees of low vigor were selected. Diallele crosses and self pollinations of each tree were planned. Unfortunately, however, there seemed to be a strong correlation between vigor and cone production and as a consequence only one low vigor tree was used as a female parent and one low vigor tree was used as a pollen source. All four of the high vigor trees were used in the cross pollinations. In addition, several trees were self-pollinated, but the selfing resulted in poor seed set and poor survival in the seed bed. Only one selfing produced adequate seedlings for an experimental design.

In 1955, seed resulting from these controlled pollinations and seed from three check sources were planted in the nursery. Resultant seedlings were outplanted in a replicated randomized block design on Austin Cary Forest in 1956. Sufficient seedlings were available to establish seven replications of four tree plots of most of the lots.

Included in this study are: three check sources---one bulk collection from the Austin Cary Forest, one from an open grown stand near the forest and one lot of state nursery seed; open pollinated progeny from two of the high vigor selections; five different high vigor crosses; one cross of low vigor trees; and self-pollinated progeny of one of the high vigor selections.

This plantation was remeasured during the summer of 1960 after the major height growth of that season had been completed, thus, this report is based on five years growth after

outplanting. The height, d.b.h., and length and diameter of branches in the lower whorls were measured. This report is based upon analysis of variance of these data.

Results

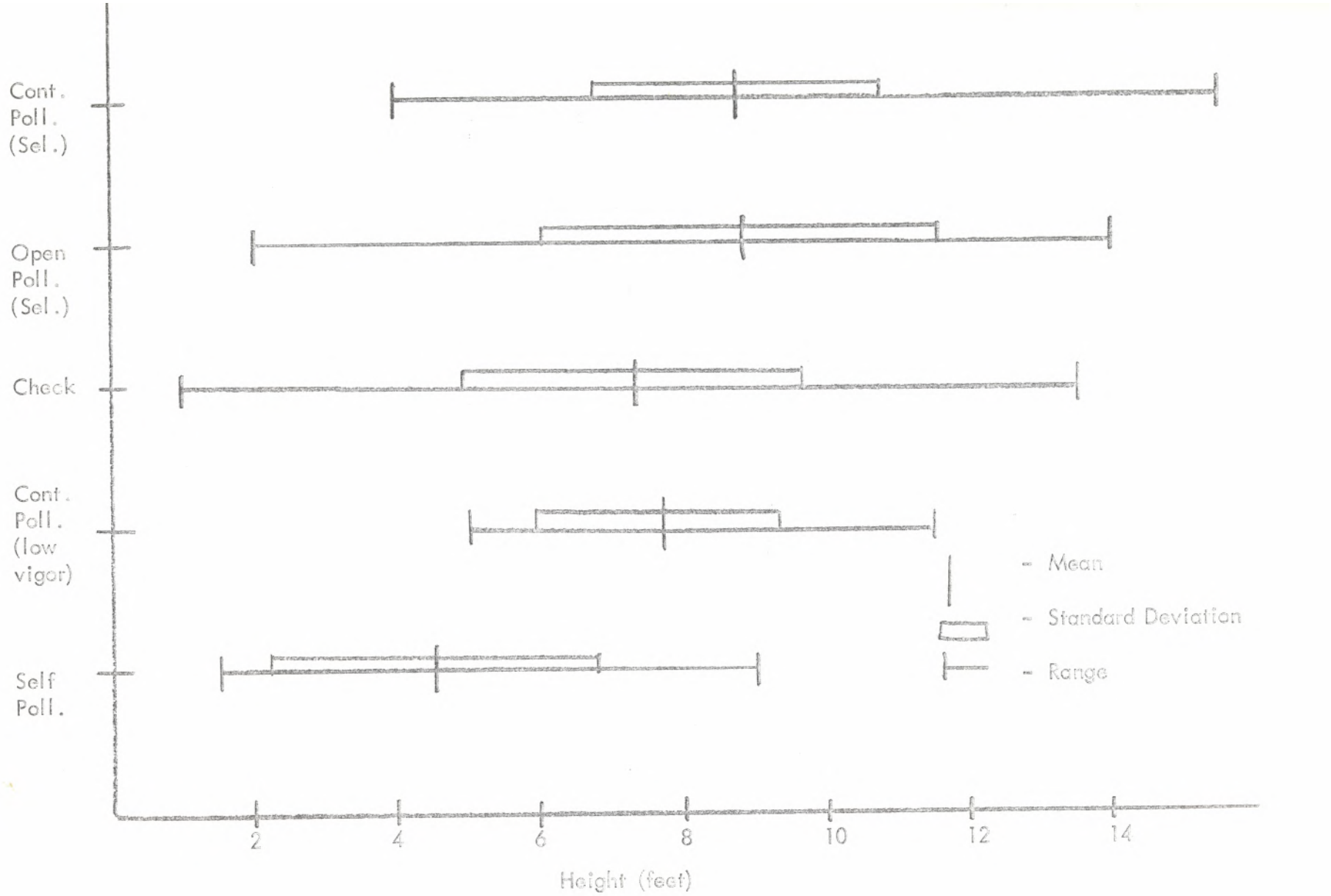
The analysis of variance showed highly significant differences among the mean heights of the various sources in the study. This does not mean so much in itself considering the variety of material included in the test ranging from self-pollinations through specific crosses to wind pollinations. However, various individual and group comparisons are quite revealing. For example, the check sources as a group made significantly less height growth than either controlled or open pollinated progeny of the select trees. It should be emphasized also that these select trees are not superior trees. In Dr. Perry's own words, "Looking back after 6 years of experience in tree selections, I now see some of the high vigor selections would not be accepted by today's standards. However, some still hold good, although the form of the selected trees is poor."

The mean and variation in height growth of several progeny groups are presented graphically in Figure 1. The average height of control-pollinated progeny of the high vigor selections was approximately 1. 5 feet higher than the average height of all check sources. The progeny of the single low vigor cross had slightly greater height, but not significantly so, than the average of the check sources. Figure 1 also indicates the highly significant depression of vigor in progeny resulting from self-pollination. The progeny of the only cross between the low vigor trees was significantly different from only the very best individual cross of high vigor trees. However, the mean height of the low vigor cross approached significance at the 5 percent level in comparison to two of the other individual high vigor crosses.

Considering these results in terms of the original objectives, one must conclude that, to some extent, vigor is a heritable trait of slash pine. Vigor, of course, might be estimated in a number of ways. In juvenile plants height growth should be one valie measure of this characteristic. The actual degree of genetic superiority of the selected parents is perhaps more open to question. In Table 1, mean heights of individual progenies and of various progeny groupings were given. Considering all of the seedlings for which tree 8-53 was one of the parents, the average height of this group was 9. 1 feet. The average height of all check seedlings combined was 7.3 feet. This superiority of the progeny of tree 8-53 could be considered an indication of the genetic superiority of this parent. The mean height of the progeny of the other parents are also indicated and their relative ranking night tentatively be suggested as a method of evaluating the relative worth of each parent

Figure 1

Mean and Variation in Progeny Height Growth



tree. On this basis height of the progeny of the low vigor cross, while lower than that of the high vigor crosses, does not indicate any genetic inferiority to the population mean suggesting that it might be more difficult to select for low rather than high vigor in mature trees.

The third objective of the study was to determine the validity of genetic evaluations made on the basis of phenotypes. It would appear that the pehnotypic comparisons which were the basis of the selections did furnish an estimate of the genetic value of the high vigor trees, while the low vigor selections were less successful. Using the phenotypic comparisons of height growth in the progeny and volume of the parents we made an estimate of heritability of high vigor. Lush has suggested that the ratio of progeny superiority to parent superiority constitutes an estimate of heritability. The four high vigor selected trees had an average of 135% volume superiority over the stands from which they were selected. The progeny of these trees had an average height superiority of 20% over the check sources. If volume superiority in the parental generation and height superiority in the progeny can be accepted as indications of relative vigor in the two populations, our heritability estimate is:

$$H = \frac{20.3}{135.5} = .15.$$

In other words, 15% of the extra vigor of the selected trees was passed on to their offspring. This is admittedly a tenuous heritability estimate but it does give some indication of the possibility of improvement of growth rate and vigor of slash pine through selection. This should be particularly encouraging to those who have given considerable weight to volume superiority in their selection schemes. As a word of caution, it should be pointed out that the 20% height superiority of these five year old progeny cannot be interpreted as indicating a proportional volume superiority at harvest. It is impossible to say at this time whether the differential will increase or decrease.

Another point of interest in these data is the highly significant difference between the mean heights of some of the crosses of high vigor trees. Of particular note, crosses H and J both have tree 5-52 as a female parent but different pollen parents. J has the poorest average height of the high vigor crosses while H has the greatest. It seems that trees 5-52 and 8-53 complement each other. To borrow a term from the corn breeders, tree 5-52 has good specific combining ability with tree 8-53 but much poorer specific combining ability with tree 3-53. Other similar contrasts are apparent in Table 1. One might capitalize upon good specific combining ability by establishing a seed orchard having only

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[1] Lush, J. L. 1945. Animal Breeding Plans. Iowa State College Press, Ames, 3rd Ed. 443 pp.

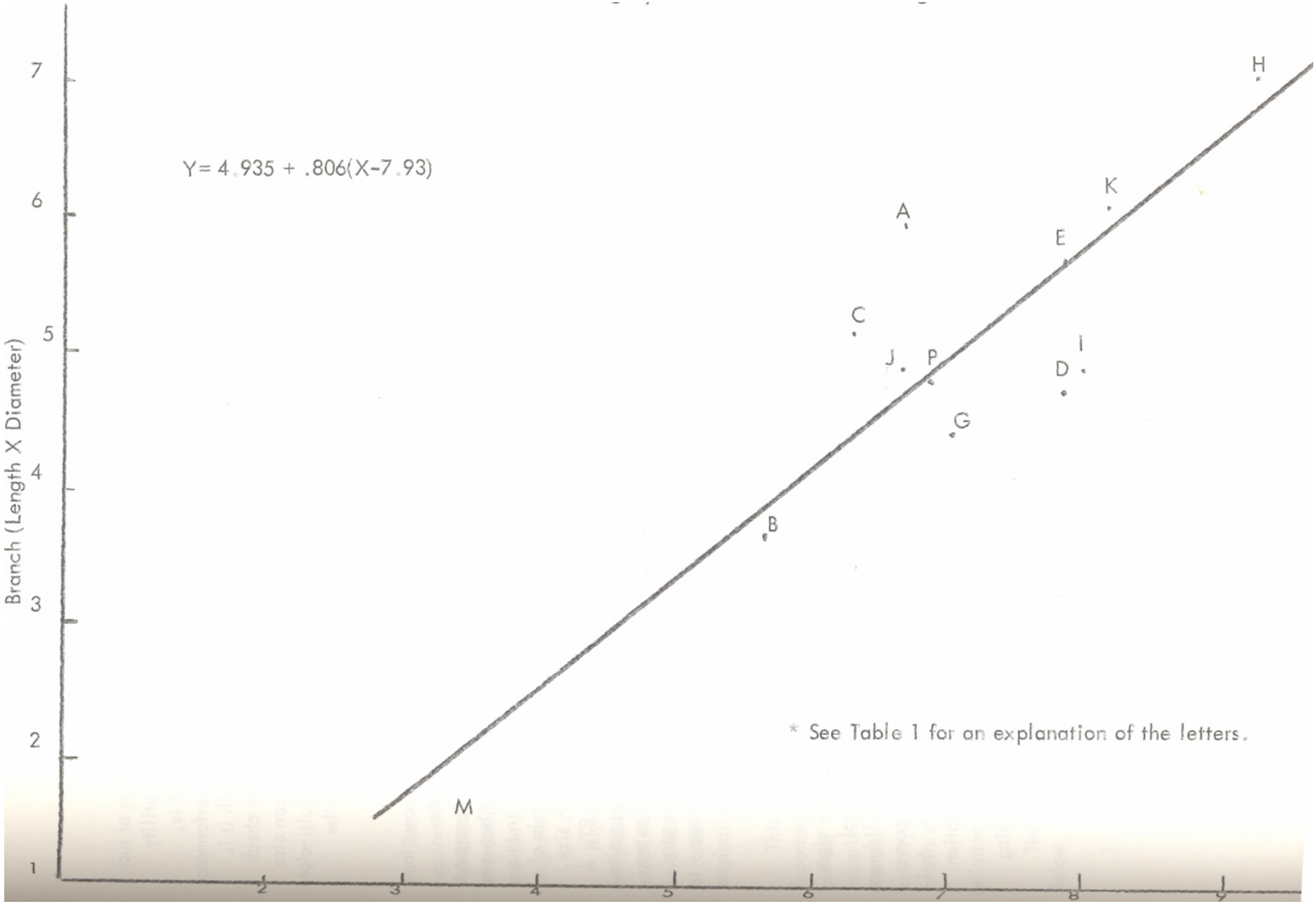
Table 1

Mean Heights of Progeny Groupings

Source	Description	Average Height (feet)
A	Austin Cary Forest check	7.68
B	Waldo Road check	6.64
C	State Nursery check	7.43
	Combined check mean	7.29
D	2-53 x wind	8.82
E	5-52 x wind	8.84
	Open pollinated select mean	8.83
G	2-53 x 8-53	8.00
H	5-52 x 8-53	10.23
I	2-53 x 3-53	8.95
J	5-52 x 3-53	7.63
K	8-53 x 3-53	9.16
	Control-pollinated select mean	8.77
	8-53 as one parent	9.10
	5-52 as one parent	8.85
	2-53 as one parent	8.59
	3-53 as one parent	8.59
P	1-53 x 6-53 (low vigor cross)	7.70
M	2-53 x 2-53 (self-pollination)	4.54
	General mean	7.96

Figure 2

Correlation of Progeny Branch Size with Tree Height*



two clones which so complement each other. However the risks and disadvantages of such an arrangement probably far outweigh the possible benefits. Of greater general utility would be clones which combined well with a number of other pollen parents, that is, clones which have good general combining ability. While there is variation in performance of the individual crosses, tree 8-53 performs rather well in all the crosses in which it is involved. The two open pollinated progenies also have heights above the general check sources. These results might indicate satisfactory general combining ability. It can also be expected that there will be examples of good specific combining ability in a multi-clone orchard and that the progeny of such crosses will upgrade average performance of the general seed orchard progeny.

Thus far, the discussion has been concerned exclusively with tree height. Crown form is another indication of vigor and has, of course, important bearing on general tree quality. In this respect, there was also considerable variation among the various progeny groups. As should be expected in trees of this age, there was a close relationship between tree height and crown size. This relationship is shown quite clearly in Figure 2. In this figure, crown size is indicated by the product of the length and diameter of the limbs of the lower major whorls. This product merely gives an indication of relative branch size. Tree height and branch size has very highly significant correlation coefficient of .87. A noteworthy point in this figure is the location of G, I, and D in relation to the regression line. All of these are offspring of tree 2-53. All of the progeny of this tree tend to produce small branches in relation to their total height when compared to all other progeny in the planting. In contrast, seedlings from one of the check sources had rather large branches in relation to total tree height.

SUMMARY

Both open and controlled pollinated progeny of trees selected for high and low vigor and progeny from three check sources were established in a replicated design. Total tree height and limb size were measured five growing seasons after plantation establishment. Check sources did not differ significantly among themselves but were significantly poorer than both open and controlled pollinated high vigor selected trees in height growth. Self pollinated progeny were significantly poorer in height growth than any cross pollination. Heritability of vigor in the study was very roughly estimated as 15%. Among the controlled pollinated progenies there were definite indications of variations in specific combining ability. There was a close positive correlation between tree height and limb size.