selection for branch angle would be effective, and selection for this character would not affect growth rate. Tree form could also be modified by selection to improve the ratio of tree height to crown diameter.

While the potential for improving growth rate does not appear to be quite as great, results are still encouraging. Heritabilities for juvenile height and diameter are as high as or higher than those for other tree species. The close relationship between these two characters indicates that selection for one would be associated with gains in the other; if so, considerable improvement in tree volume would result, and might yield greater economic advantages than changes in the more highly heritable tree form.

Summary

Progenies from 40 sweetgum trees, selected for phenotypic variability as expressed on a range of sites in south Mississippi, were evaluated in outplantings made during 1963 at two locations in the State: the Harrison Experimental Forest near the Gulf Coast, and the Delta Experimental Forest in the west-central part. There were significant differences among families at both locations for foliation date in 1964 and 1965 and for height in 1963, 1964, and 1965. Family means also differed significantly for stem diameter in 1964 and 1965, tree form (tree height/crown diameter), and branch length, diameter, and angle (these characters were measured only at Harrison).

Of the characteristics evaluated, time of foliation was under the strongest genetic control ($h^2 = 1.11$ to 1.27 at Harrison; 0.54 to 0.98 at Delta), followed by branch angle ($h^2 = 0.90$) and tree form ($h^2 = 0.56$). Heritabilities for heights at Harrison decreased from 0.67 at the end of the first to 0.40 at the end of the third growing season, while values for the Delta plantation were constant (0.25 to 0.26) for the same period. Although the Harrison plantation maintained approximately a 2:1 height advantage over the other, mean height increase during 1965 was essentially the same in both plantations.

Correlations among families between locations were highly significant for height ($r = 0.51$ to 0.53) at the end of the three growing seasons and for foliation date in 1964 ($r = 0.82$) and 1965 ($r = 0.80$). Highly significant correlations were also obtained between height and diameter at Harrison in 1964 ($r = 0.80$) and 1965 ($r = 0.88$), between height and branch length at Harrison (0.61), and between first- and third-year height at both locations (0.71, Harrison; 0.65, Delta).

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The Inheritance of Crooked Bole in Shisham (Dalbergia sissoo Roxb.)

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Introduction

Shisham (Dalbergia sissoo ROXB.) is one of the most commercially important species growing in the plains of West Pakistan. It is almost one hundred years ago when it was introduced on a large scale in this area, with the help of canal irrigation. Since then, a number of irrigated forest plantations have been established where Shisham is grown either in pure stands or mixed with Mulberry (Morus alba), Bakain *(Melia azadarach)*, Babul (Acacia arabica), Frash (Tamarix articulata) etc. Besides the compact type of plantations, it is the chief species of canalsides, railwaysides and road avenues, extending over thousands of miles.

Shisham timber values high for furniture, building construction and other uses. Poor stem form with generally a crooked and forked bole, is the major drawback of Shisham trees. These characters are very pronounced and are visible even in one year old plants. A great variability, however, exists in the growth and stem form of Shisham. This variation indicates that it is possible to improve this species by selection and breeding.

It is only recently that work on the improvement of Shisham has been initiated. The material which was previously collected and used for getting orientation data about the heritability of height and diameter growth, was again used for investigating the heritability of crookedness of stem. The present investigations may, however, be considered preliminary as the results have been obtained with the material which was neither fully designated for breeding purposes nor it was laid out in an experimental design specific for the estimation of heritability.

The inheritance of stem form in different tree species was investigated by FISCHER (1953) for Larch, PERRY (1960) GODDARD and STRICKLAND (1964) for Loblolly pine, SHELBOURNE (1963) for Pinus Khasya, ŽUFA (1964) for European black poplar, GANSEL (1966) and NIKLES (1966) for Slash pine, SHELBOURNE (1966), SHELBOURNE and STONECYPHER (1968) for southern pines and others. In Shisham uptill now there were no such investigations except for height and diameter growth, carried out by VIDAKOVIĆ and SIDDIQUI (1968).

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Material and Working Method

In the Institute's nursery at Peshawar, one year old Shisham plants were raised from the seed of candidate plus trees which were selected in Daphar and Pirawala irrigated plantations. The plants were grown in rows so that progeny of every parent tree was represented by one or two rows of plants. In measuring the crookedness of the bole, we could not use the method proposed by SHELBOURNE and NAMKOONG (1966). Our method differs a little from the method used by ŽUFA (1964) for European black poplar. For every crookedness two points have been added whereas ŽUFA included five points for the same. Very high and rather unrealistic results were obtained when five points per crook were considered in Shisham. That is quite understandable because Shisham has in general more crookedness than European black poplar. It seems that adding a higher number of points would lead to overestimation of heritability. The details of the method adopted are as follows:

For each parent tree two photographs, at right angles to one another, were taken. Individual photographs of the 30 plants representing each progeny were also made. To get the same scale of photos, a 12' pole was used for the parent trees, a 1' long mark for the progenies, while taking the photographs *(Fig. 2 and 3)*. By getting these marks on the photos, it was possible to have the projections of mother trees on the graph paper, in the same scale. In a similar way all the plants from all the progenies were projected on the graph paper in a uniform scale. From the negative photographs, the drawing of the stem forms was made with a pencil which always followed the right edge of the stem.

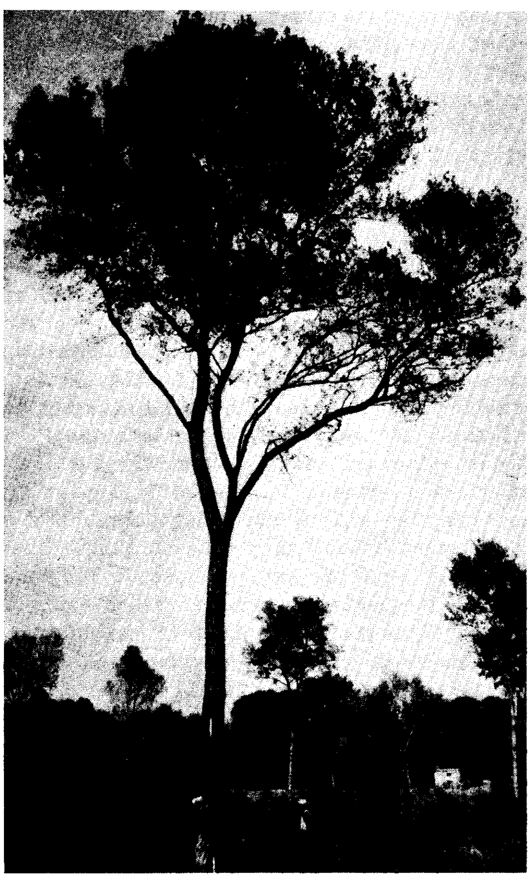

Fig. 1. — Candidate plus tree of Shisham, No. 17 in Daphar irrigated plantation.

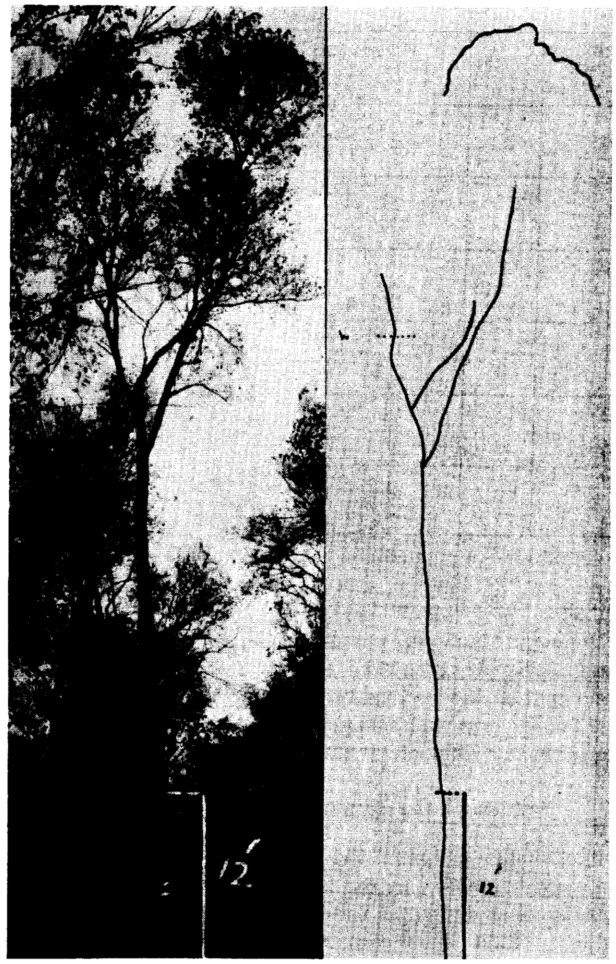

Fig. 2. — Photograph of a parent tree and graphic representation of its bole.

Every bend in the stem carried 2 points. To this was added the highest index of crookedness (i). Index of crookedness was calculated by dividing the height of the string 'b' with the base of string 'a' and multiplied with 100 *(Fig. 4)*. Additional two points were added for every crookedness, as shown below:

For crookedness with the string 1h
if the index is higher than 25
For crookedness with the string $\frac{1}{2}$h—1h
if the index is higher than 12
For crookedness with the string $\frac{1}{4}$h—$\frac{1}{2}$h
if the index is higher than 6
For crookedness with the string $\frac{1}{8}$h—$\frac{1}{4}$h
if the index is higher than 3
For crookedness with the string $\frac{1}{16}$h—$\frac{1}{8}$h
if the index is higher than 2

The crookedness for each mother tree and progeny plant was estimated for only $\frac{2}{3}$ of the total height of the tree (h = $\frac{2}{3}$ height of the plant). Above $\frac{2}{3}$ of the height the leader in the mother trees usually disappeared or it was not clearly visible. *Table 1* indicates the procedure for measuring the crookedness for each tree.

Calculation of heritability was carried out by using regression for one parent-progeny test. Mother trees are located in two irrigated plantations (Daphar and Pirawala) in the central part of plains in West Pakistan. Calculation of heritability was carried out separately for each plantation. The number of mother trees is 10 in Daphar and 13 in Pirawala plantation. The relationship between the par-

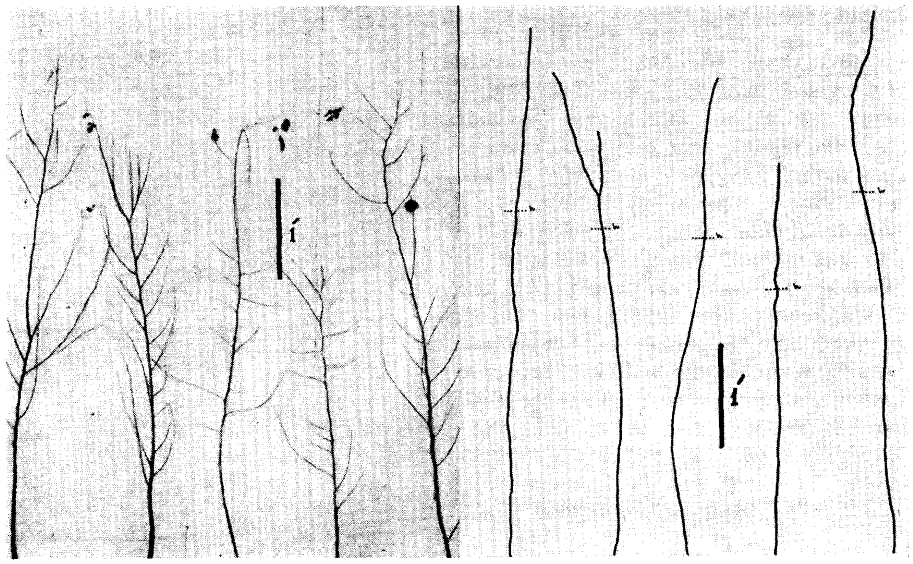

Fig. 3. — Photograph of a progeny and graphic representation of its boles.

ents and the progenies is shown in the graph. Correlation coefficient was calculated and "t" test was applied to find out whether the results obtained were significant or not. The significance of regression coefficient b_1, was tested at a probability level of 1% and 5%.

Results of the Investigations and Discussion

The results of estimated heritability for crookedness of the stem are given in the *table 2*. Heritability for Daphar plantation is 42% and for Pirawala plantation 65%. Statistically high significant results were obtained for correlation (r) and regression (b_1) coefficients for both the plantations *(Table 3)*.

Schreiner (1958) when discussing the genetic control of single characters has mentioned that stem form is of high genetic control. Perry (1960) investigated the inheritance of crooked stem form in Loblolly pine. He did not calculate the heritability, but from his experiments with crosses between crooked and straight trees, he concluded that genetics plays a major role in the development of these characters. Gansel (1966) investigated the inheritance of crookedness in the stem of Slash pine. Clone-ortet correlations were significant. The results obtained by Gansel suggest that crookedness and some other characters are inherited to a moderately strong degree. Nikles (1966) has also investigated the straightness of stem in Slash pine. He did not calculate the heritability, but from the crosses he made, it was clear that specific combining ability for straightness was large. According to him, heritability if calculated from the experiment he conducted, would be high. Shelbourne and Stonecypher (1968) found in both controlled and open pollinated families of loblolly pine with ages from two to five years and with height from three to twenty feet, that bole straightness is a heritable trait which becomes more strongly genetically controlled with the increasing size of tree. The heritability of straightness estimated from these experiments was 0.20 at the age of two years to an average of 0.38 at the age of five years. Shelbourne (personal communication) assessing 13-year old 50—60 feet high open pollinated progenies of *Pinus radiata* has noted marked family difference in bole straightness. Bannister (personal communication with Shelbourne) has calculated narrow sense heritability amounting to 0.60 for straightness, for a similar material of *P. radiata*. Remarks of Shelbourne on the heritability of straightness in *P. taeda* and *P. radiata* may also be mentioned here. He states: "Inspite of the fact that straightness seems to be acknowledged generally as a characteristic with higher heritability than many others, it is evidently much affected by site conditions. This I have noticed in both *P. taeda* and, specially *P. radiata*, Shelbourne (1963) conducting provenance test of *Pinus khasya* found considerable genetic variation in straightness. Goddard and Strickland (1964, 1966) evaluated the crookedness in controlled and open pollinated progenies of crooked and straight Loblolly pines at the age of seven years in the outplanted stock. Highly significant differences among progeny means and intraclass correlations suggested high genetic components of variance. There is a lot of new heritability study information, yet unpublished, which is being brought forth by Stonecypher and Zobel (personal communication) whose findings confirm that inheritance of

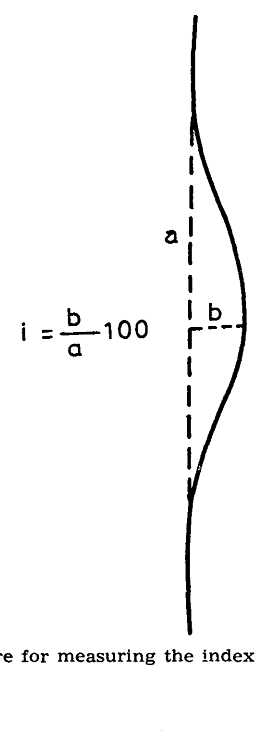

Fig. 4. — Procedure for measuring the index of crookedness (i).

Table 1

Tree No.	Height of Tree	No. of crooks	Points	Height of string b	Base of string a	a/b	Index (i) b/a × 100	Add 2 points for every crookedness if: 1h; i > 25 No.	Points	½—1h; i > 12 No.	Points	¼h—½h; i > 6 No.	Points	⅛h—¼h; i > 3 No.	Points	1/16h—⅛h; i > 2 No.	Points	Estimated crookedness (4 + 8 + 10 + 12 + 14 + 16 + 18)
1	2	3	4	5	6	7	8	9	.0	11	12	13	14	15	16	17	18	19
20PR	66	3	6	6	140	6/140	4					1	2	2	4			16
21PR	76	4	8	3	50	3/50	6							1	2	3	6	22
22PR	77	6	12	4.5	80	4.5/80	6							3	6	1	2	26
24PR	63	6	12	7	60	7/60	12							2	4	4	8	36
17DP	67	9	18	8	100	8/100	8					2	4			3	6	36
18DP	60	8	16	6	70	6/70	9							1	2	7	14	41
19DP	53	9	18	3	50	3/50	6									5	10	34
20DP	70	11	22	3	50	3/50	6									5	10	38

Table 2.

	Daphar	Pirawala
b_1	0.212639	0.328615
b_2	0.239909	0.304198
h^2	$0.425278 \approx 42\%$	$0.657230 \approx 65\%$
r	0.226	0.316
y	$0.212639x - 448$	$0.328615x + 0.245344$
x	$0.239909y + 33.170$	$0.304198y + 19.384145$

Table 3.

Daphar	Correlation	$K = 297$ $t = 3.999^{**}$
	Regression	$\sigma b = 0.05477$ $b_1 > 2.58; \sigma b = 0.1413066^{**}$
Pirawala	Correlation	$K = 378$ $t = 6.476^{**}$
	Regression	$\sigma b = 0.050497$ $b_1 > 2.58; \sigma b = 0.130282^{**}$

straightness is strong and has a large additive component. Žufa (1964) in his substantial investigations of variability and inheritance of straightness in the stem of European black poplar (*Populus nigra* L.) found that the heritability of this character is of very high genetic control. He estimated the heritability from regression for parent-progeny half sib and full sib families. For parent-progeny tests the heritability was from 0.88—0.96; and from sib analysis it came to be 0.40—0.98.

From the above mentioned investigations it seems that in forest tree species, straightness of the stem is of high genetic control. Our investigations in Shisham confirm it. As already pointed out a good deal of variation in the stem form and other phenotypic characters exists in Shisham. Given pictures (*Fig. 5 and 6*) represent the extreme degree of variation in this species. Knowing that crookedness of the stem is of high genetic control and that a great variation exists in the stem form, we can predict a great improvement of this character by selection and breeding. In the previous paper written by Vidaković and Siddiqui (1968) the problem of environmental influences in selecting plus trees of Shisham in the irrigated plantations has been discussed. The growth of trees is greatly affected by the amount of irrigation water and management practices. That fact was one of the main factors which influenced our results on estimation of heritability of height and diameter growth. The heritability of height growth varied from 0.068 to 0.110 and diameter growth from 0.003 to 0.012. It is evident from the results obtained that environments affect the growth of Shisham much more than the straightness of the stem. It is quite conceivable that selection of Shisham plus trees in the irrigated plantations with respect to the straightness of the stem would be much more fruitful in comparison to height and diameter growth. It can be well presumed that straightness of the stem can be improved more than the height and diameter growth.

Summary

The heritability of crookedness of the bole in Shisham (*Dalbergia sissoo* Roxb.) has been estimated by using one parent-progeny regression. The mother trees were selected

Fig. 5. — Phenotypic variation in Shisham; plus tree No. M-3 in the middle.

in two irrigated plantations — 10 trees from Daphar and 13 trees from Pirawala. The progenies aged only one year. The heritability was 42% for Pirawala and 65% for Daphar plantation. Correlation (r) and regression (b_1) coefficients are highly significant for both the plantations.

From these results and from the previous investigations on heritability of height and diamater growth in Shisham, it seems that the environments, particularly the irrigation water affect the growth much more than the straightness of the stem. Therefore, selection of Shisham plus trees in the irrigated plantations with respect to the straightness of the stem will be much more effective in comparison to height and diameter growth. It can be well presumed that

Fig. 6. — Phenotypic variation in Shisham; plus tree No. M-2 in the middle.

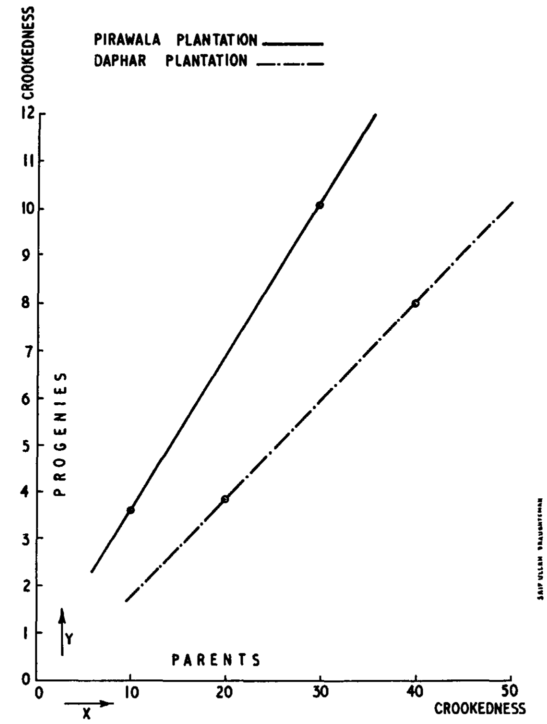

Fig. 7. — Regression line for crookedness.

the straightness of the stem can be improved more than the height and diameter growth.

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