Figure 8. — Left: Radial section, scalariform perforation plates — large bordered pits in fiber tracheids, and heterogeneous type rays with upright and procumbent cells (mag. 110×). — *Figure* 9. — Right: Tangential section, uniseriate and biseriate heterogeneous type rays — fiber tracheids with large bordered pits (mag. 110×).

in diameter on both radial and tangential surfaces (Figures 8 and 9). Gelatinous fiber tracheids were also observed in several rings. Fiber tracheid length averages 1.07 mm. near the pith and 1.34 mm. in the outer part of the stem.

Rays (*Figure 9*) are unstoried, predominately 1- and 2-seriate (3-seriate rare), heterogeneous type I (KRIBS, 1950) with both upright and procumbent cells. Uniseriate rays are 1 to 17 cells high. Biseriate rays have uniseriate tips as long or longer than the multiseriate portion of the ray; tips are 3 to 15 cells long. Ray-vessel pitting is coarse, half bordered, orbicular to oval to scalariform: coarse pitting is most abundant at crossings of the upright type cells and vessels. Gum canals when present occur in single tangential rows with angled orifices as observed from cross section; average diameter is 44 microns, range is 27 to 65 microns.

Summary

Liquidambar styraciflua L. c. v. 'Gum Ball' exhibits strong apical dominance which, combined with its short shoot habit of growth, results in a bushy, symmetrical form. Other dendrological and wood anatomy features are practically identical to those of the common growth form of the species. Except for differences in the relative size of various elements, there appear to be no anatomical differences of consequence. At 25 years of age it has not produced flower buds. Of the known specimens of 'Gum Ball', several apparently developed from seed. With their symmetrical growth habit and attractive, deep-purple fall coloration these dwarfs are of horticultural interest.

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Inherent Variation in South Mississippi Sweetgum

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Because of its broad utility and wide distribution, sweetgum (Liquidambar styraciflua L.) is one of the most important hardwoods in the Southern United States. Recent interest in planting the species has prompted research in genetic improvement. This paper reports data from a half-sib progeny planting in south Mississippi. The research indicates that much of the observed variation in growth and form of juvenile sweetgum is under strong enough genetic control to make possible considerable improvement through mass selection.

Methods

Forty sweetgum trees were selected in south Mississippi on the basis of phenotypic variability expressed on a range of sites. Seeds were collected from two to five trees in each of 12 stands and sown by family groups in the nursery of the Harrison Experimental Forest during the spring of 1962. In February 1963, the 1–0 seedlings were lifted and outplanted in a randomized block design with five replications at each of two locations about 200 miles apart: the Harrison Experimental Forest near Gulfport (30° 35' N latitude, 89° 5' W longitude), and the Delta Experimental Forest near Greenville (33° 25' N latitude, 90° 55' W longitude), Mississippi. The Harrison soil is a fine sandy loam, strongly acid, with low natural fertility. The Delta soil has a high clay content and is poorly drained, but has good productive potential.

At each location four trees per family were planted in row plots at a 12-foot (3.66 m) spacing. Rows were 10.4 feet (3.17 m) apart. Since trees were offset 6 feet (1.83 m) within adjacent rows, there was a 12-foot (3.66 m) space between all adjacent trees. Both plantations were cultivated regu-

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larly during the first growing season to control weeds. During the second growing season cultivation was continued in the Delta planting and the Harrison planting was mowed.

Foliation date was recorded in the spring of 1964 and 1965 as the date when leaves had emerged approximately 1 cm from the bud scales. Tree heights and diameters (at Harrison only) were measured following growth cessation in the fall of 1963, 1964, and 1965. Heights were taken to the terminal bud and diameters were read at 1 foot (30.5 cm) above ground. At Harrison the first three branches initiated in 1964 on three trees per plot were measured for length, diameter, and angle from vertical after 1 year's growth.

Data were subjected to analyses of variance and tests of significance were made at the 0.01 level of confidence. Correlation coefficients (r) designated by ** are significantly different from zero at the 0.01 level.

Results

Survival

Seedling survival at the end of the first growing season was significantly higher at Harrison than in the Delta plantings (*Table 1*). Differences among family means were significant in the Delta but not at Harrison.

The interaction of families × locations was also significant, an indication that families performed differently at the two locations. Two families, 1 and 2, ranked a low 38 and 39 percent in survival at both locations. Since families were grouped rather than replicated in the nursery it is possible that the low survival of these families was due to nursery environment rather than inherent weaknesses. Survival values remained essentially unchanged after the first year.

Foliation

Date of foliation differed significantly between locations and among families within locations in each year. There was a 3-day difference in mean foliation date between locations in 1964 and a 10-day difference in 1965 (*Table 1*). In 1964 foliation started about 10 days earlier at Harrison than in the Delta. When dates for individual trees are compared, foliation in the Delta coincided with the last 2 weeks of the 4-week foliation period at Harrison. In 1965 initial foliation date was 3 weeks later, and the terminal date 4 days later, in the Delta than at Harrison.

The family × location interactions in the combined analyses were significant in both years. Since family means were highly correlated between locations in each year (r = 0.82 **, 1964; r = 0.80**, 1965), the interactions appeared due primarily to a compression of foliation dates in the Delta rather than to changes in family rankings between locations.

Heritabilities for this character were uniformly high except for the 1964 data in the Delta (*Table 1*). The higher values for the Harrison planting are probably due to the expression of family differences over a period of gradually warming weather. When the progenies were moved 200 miles north they tended to foliate over a shorter period as soon as the weather permitted. Additional evidences for strong genetic control of this character are the high correlation coefficients between locations and high correlations between years at each location (r = 0.93**, Harrison; r = 0.87**, Delta).

Height and Diameter

Total heights, measured to the nearest 0.1 foot, differed significantly between locations in each of the measurement years, the Harrison planting maintaining approximately a 2 : 1 advantage over the Delta (*Table 1*). The Harrison plantation showed a 3 : 1 increase in height over the Delta plantation during 1964, but in 1965 mean increases were essentially the same for the two locations.

Families differed significantly in both mean height and height increase in each year at both locations.

Table 1. — Survival, foliation dates, growth, and branch data for sweetgum progenies.

Character	Harrison Experimental Forest				Delta Experimental Forest			
	Mean	Family range	Individual range	h^2 [1]	Mean	Family range	Individual range	h^2 [1]
Survival percent, 1963	98	90—100	—	—	83	55—100	—	—
Foliation date								
1964	3/22	3/16—3/29	3/9—4/4	1.11	3/25	3/24—3/28	3/19—4/3	0.54
1965	3/24	3/19—3/29	3/11—4/4	1.27	4/3	4/2—4/5	3/28—4/8	.98
Height growth								
Height (m), 1963	0.94	0.76—1.08	0.37—1.77	.67	0.52	0.43—0.64	0.09—0.88	.26
Increase (m), 1964	1.28	.98—1.46	.43—2.19	.35	.43	.30—.55	.00—1.13	.17
Height (m), 1964	2.19	1.83—2.50	.91—3.63	.45	.94	.79—1.19	.34—1.80	.26
Increase (m), 1965	.85	.58—1.13	.06—1.80	.35	.82	.67—.98	.12—1.31	.25
Height (m), 1965	3.05	2.56—3.47	1.22—5.06	.40	1.80	1.52—2.10	.70—2.80	.25
Diameter growth								
Diameter (cm), 1964	3.5	2.7—4.0	1.0—5.7	.34	—	—	—	—
Increase (cm), 1965	1.1	.8—1.5	.0—4.0	.06	—	—	—	—
Diameter (cm), 1965	4.6	3.6—5.3	1.3—8.5	.32	—	—	—	—
Form (height/crown diameter)	2.08	1.80—2.39	1.22—3.50	.56	—	—	—	—
Branches								
Length (cm)	53.0	47.0—64.0	21.0—100.0	.20	—	—	—	—
Diameter (mm)	5.2	4.4—6.5	2.8—10.8	.38	—	—	—	—
Angle (degrees)	38.0	29.0—43.0	20.0—57.0	.90	—	—	—	—

[1]) $h^2 = \frac{4\sigma^2_F}{\sigma^2_F + \sigma^2_{RF} + \sigma^2_W}$ Where h^2 = heritability, σ^2_F = estimated family variance component, σ^2_{RF} = estimated replication × family variance component, and σ^2_W = estimated within-plot variance component (calculated on every fifth plot at each location).

Phenotypic correlations computed between locations for family height at the end of each growing season were modcrately high:

Characteristic	r value
1963 height	0.53**
1964 height increase	.31
1964 height	.51**
1965 height increase	.20
1965 height	.51**

n = 40

Correlations between locations for height increase were not significant.

Correlations for 1963 height with total height and height increase in 1964 and 1965 were:

Correlation	r value	
	Harrison	Delta
1963 height with 1964 height increase	0.48**	0.26
1963 height with 1964 height	.82**	.70**
1963 height with 1965 height increase	.41**	.38
1963 height with 1965 height	.71**	.65**
1964 height increase with 1965 height increase	.62**	.48**

n = 40

Heritabilities for height growth were higher at Harrison than at the Delta *(Table 1)*. Values for total height at Harrison decreased from 0.67 at the end of the first growing season to 0.45 and 0.40 at the end of the second and third growing seasons; in contrast, values were consistent for 3 years in the Delta (0.26, 0.26, and 0.25).

Heritability values for diameter at Harrison were consistently lower than those for height.

Form and Branch Characteristics

An index of tree form (recorded only at Harrison) was computed by dividing tree height by crown diameter *(Table 1)*. Analyses of these values indicated significant ($p < 0.01$) differences among family means. The heritability calculated for the form index, 0.56, was moderately high.

Progenies differed significantly in all three branching characteristics. Branch angle was the most highly heritable (0.90) of the three measurements, with diameter (0.38) and length (0.20) having considerably lower values.

Genotypic and phenotypic correlations based on family means showed essentially no relationship between branch angle and either length or diameter:

Correlation	r_G	r_P
Branch length with diameter	0.78	0.81**
Branch length with angle	±.00	—.08
Branch diameter with angle	—.13	—.10

Multiple regression analyses, used to determine contributions of branch length and agle to crown diameter, indicated that family differences in crown diameter were influenced more by branch length than angle.

Relationships Among Characters

Relationships among characters were determined from phenotypic correlations based on family totals. Height and diameter were closely associated in both 1964 (r = 0.80**) and 1965 (r = 0.88**). Height in 1964 was also associated with branch length (r = 0.61**) but not with branch angle. Correlation coefficients computed between foliation date and both tree height and diameter were low and nonsignificant in 1964 and 1965.

Discussion

Parents of the progenies included in this study represented a range of phenotypes rather than a highly select or random population. This condition probably accentuated the between-family variability and hence the strength of genetic control for those characters that affect form. For other characters, such as foliation date, the progenies can be considered a random sample of the sweetgum population in south Mississippi, though in the strictest sense the heritability values apply only to these plantations.

The very strong genetic control of foliation date in this material corresponds to results with other tree species. Broad-sense heritabilities (total genotypic variance/phenotypic variance) of 0.99 for foliation date of a random sample of cottonwood clones (Wilcox and Farmer, 1967) and of 0.56 for Norway spruce (Mergen, 1960) have been reported.

Tree height and diameter usually are less strongly controlled than phenological characteristics. Squillace and Bengtson (1961) have reported heritabilities of 0.05 to 0.10 for both height and diameter of 9-year-old slash pines. Values for height (0.08 to 0.14) and diameter (0.01 to 0.10) in 2-year-old larch (Matthews *et al.*, 1960) were also very low. In contrast, Barber (1964) calculated heritability values of 0.20 to 0.35 for height and 0.06 to 0.37 for diameter among open-pollinated slash pine progenies 5 to 8 years old. Farmer and Wilcox (1966) reported narrow-sense heritabilities (additive genetic variance/phenotypic variance) of 0.35 for height and 0.16 for diameter of first-year coppice growth of cottonwood following clearcutting to the groundline. Since the values given here for sweetgum are comparable to these height and diameter values for other species, opportunities for selection appear good.

Tree form was under stronger genetic control than either height or diameter. At the time measurements were taken the crowns were well separated and competition did not appear to influence crown diameter. Trousdell *et al.* (1963) also found crown form (expressed as the ratio of crown width to tree height) among 7-year-old progenies from good and poor loblolly pine selections to be under fairly strong genetic control ($h^2 = 0.34$).

Of the three branch characteristics measured, angle was the most highly heritable. The very high value indicates that angle is amenable to change through selection. Measurements of angle and branch diameter on Monterey pines 11 to 12 years old (Fielding, 1960) have also shown heritability of angle (0.6) to be higher than that for diameter (0.3).

The close relationship between branch length and diameter in the present material is consistent with data of Barber (1961), who reported correlations of 0.95 between these two variables in 3-year-old branches of slash pine. He also found that branch angle was negatively correlated with both branch length (—0.47 to —0.48) and diameter (—0.43 to —0.46). Fielding (1960) reported negative correlations between branch angle and diameter (—0.53 to —0.61) in Monterey pines 20 to 23 years old. In sweetgum, by contrast, branch angle showed essentially no relationship with either length or diameter.

These results indicate there is good potential for the genetic improvement of tree form in sweetgum. Juvenile 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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