GENETIC VARIATION IN MISSISSIPPI SWEETGUM

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Abstract.--Seed was collected from 650 sweetgum trees throughout Mississippi and southeastern Louisiana during 1962, 1963, and 1964. Progeny plantings were established in south Mississippi, central Mississippi, and southwest Tennessee. After 10 years, well defined latitudinal and longitudinal patterns of variation in height growth were evident among the half-sib progenies. Progenies from southeastern Mississippi excelled in all three plantings, but the zone of fastest growth for the northernmost planting was farther northwest than for the other plantings. Progenies from near the Mississippi-Alabama border grew faster than those from the floodplain of the Mississippi River or the loessal hills that border the floodplain to the east.

Additional keywords: Liquidambar, genecology.

INTRODUCTION

Research on geographic variability and population structure is basic to forest tree improvement programs. To be most efficient, programs should take advantage of all levels of genetic variation--geographic, stand to stand, and individual tree. Substantial tests of geographic variability with sweetgum (Liquidambar styraciflua L.) have been established by the Western Gulf Tree Improvement Cooperative (Texas Forest Service 1975), the North Carolina State Tree Improvement Cooperative (Sprague and Weir 1973), and the Southern Forest Experiment Station. These tests are expected to provide guidelines for movement of seeds from one area to another in the near future.

The provenance-progeny test reported here was begun in 1962 to characterize genetic variability throughout Mississippi, in adjacent parts of Alabama, and in the Florida Parishes of Louisiana. We sampled the population intensively enough to compare variability associated with latitude, among stands, and from tree-to-tree. Besides characterizing genetic variation, the tests can provide outstanding material to be used in improvement programs in and near Mississippi. This report gives results after 10 years in the field.

METHODS

The study area is bounded on the west by the Mississippi River drainage and on the east by the drainage of the Tombigbee and Alabama Rivers (fig. 1). Seed collection locations (sources) were planned by dividing the area into 20 latitudinal transects, 15 minutes of latitude apart, and mapping a collection point every 30 miles along the transects. Collections were made within 10 miles of these points. Fruit was collected in 1962, 1963, and 1964 from five trees in each of a total of 138 sources. Criteria for selecting parent trees were

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[1/] U.S. Forest Service, Gulfport, MS and Mississippi State University, Starkville, MS. International Paper Co. and the University of Tennessee made land available for the experiment.

undemanding. The first five fruiting trees of any age to be sighted from the road within a specified location were chosen if they were between 200 feet and 1/4th mile apart and were within 100 feet of other fruiting sweetgum.

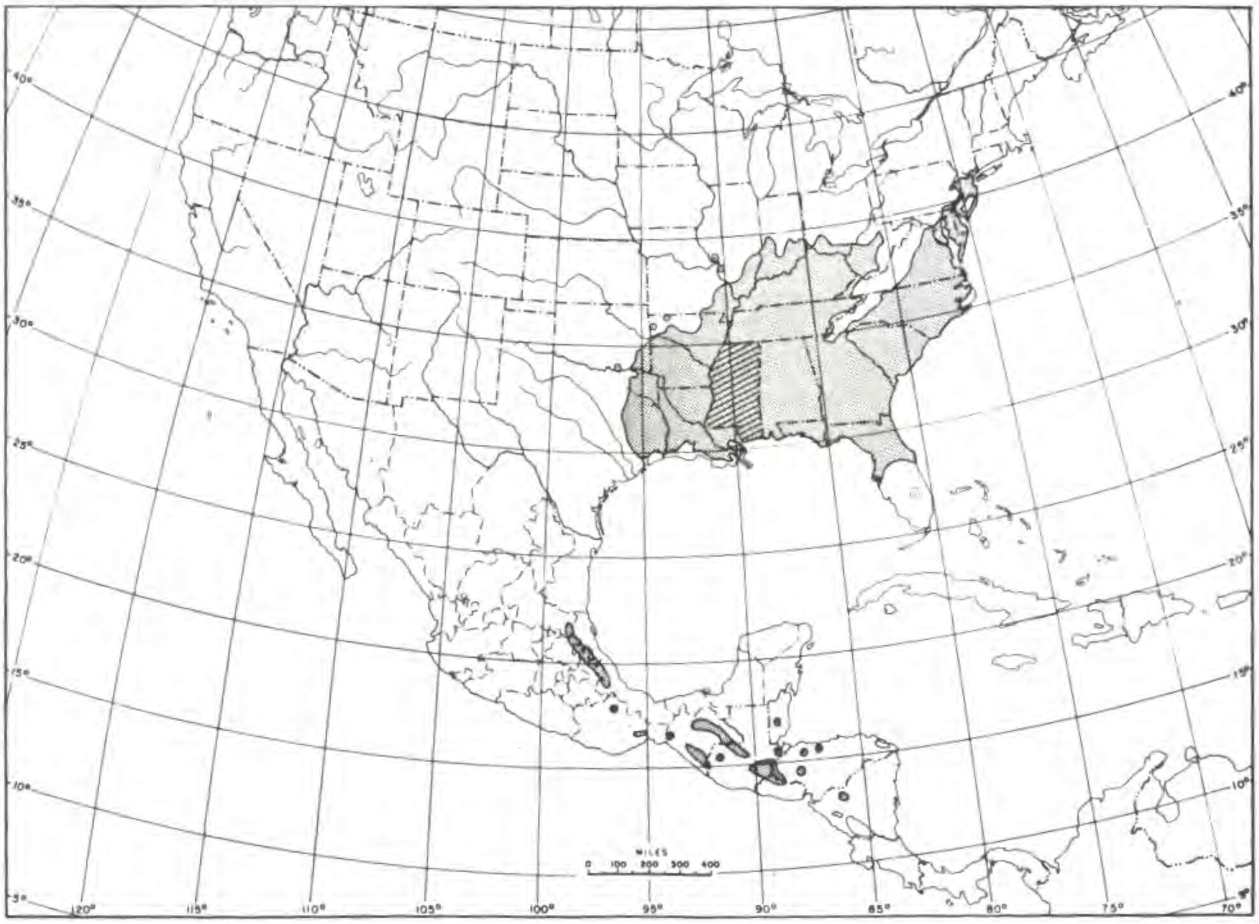

Figure 1.--The range of sweetgum and the present study area

During 1965, planting stock was grown in a three replicate design near Gulfport, Mississippi. The seedlings were planted during winter 1965-66 in three locations: near Pearlington in south Mississippi, near Mississippi State University in central Mississippi, and on the Ames Plantation, University of Tennessee in southwestern Tennessee. Stock at each location was from one nursery replication. The field design was a 10-replicate, compact family block (Panse and Sukhatme 1965) with two-tree family plots and 10-tree source plots. (As used here, family means the wind-pollinated progeny of one tree.) This design grouped the five, two-tree family plots that represented a source (the five parent trees in each collection area) rather than distributing the family plots at random over each replication. Spacing was 8 by 8 feet and each replication was about 2.0 acres. A border row was used to offset edge effects.

The central Mississippi and Tennessee planting sites were bottomland old fields that had been abandoned for many years. The alluvial soil was covered mostly with grass. The southern Mississippi planting was on recently cleared forest land (loblolly pine and mixed hardwoods, including sweetgum) on a low sandy ridge adjacent to marshland along the north coast of Lake Borgne. The topsoil was thin, and much of it was lost during site preparation.

Grasses were partially controlled in all plantings by mowing and application of herbicide around each tree. Growth was slow in the early years in all plantings (trees were less than 5 feet tall after 4 years), but generally rapid thereafter. Because of poor growth, three blocks were discarded in the northern and southern plantings and two in the central planting (Table 1). Survival averaged 83.6 percent in the remaining, usable blocks. After 10 years, trees averaged 8.2, 14.0, and 14.1 feet tall in the southern, central, and northern plantings.

Table 1.--Characteristics of the experiment after 10 years

Planting	Blocks	Sources	Sources having 5 families	Sources having 4 families	Sources having 3 families	Usable family plots	Missing family plots
	number						percent
Pearlington, MS (southern)	7	138	125	10	3	4316	12.0
Miss. State University(central)	8	136	125	7	4	4063	23.6
Ames Plantation TN (northern)	7	133	118	9	6	3891	13.7

MEASUREMENTS AND ANALYSIS

This report describes the genetic variation in the trait of greatest economic importance--height at 10 years. ANOVA was used to determine if there were differences in height among families in each of the 138 sources in each of the 3 plantings. Degrees of freedom for a typical analysis were: blocks = 6, families = 4, error = 24. The experimental unit was the mean of the 2-tree family plots. Values were calculated for missing plots; augmented means were used thereafter, and adjustments were made to the treatment sums of squares and degrees of freedom for error (Yates 1933).

Further ANOVA were used for testing for differences among sources and families over all plantings as follows:

Source of Variation	Degrees of Freedom	Mean Square
Plantings	2	60086.9*
(a) Blocks within plantings	19	10158.7
Sources	130	137.4*
Sources x plantings	260	78.7
(b) Sources x blocks within plantings	2302	68.9
Families within sources	492	23.7*
Families within sources x plantings	984	11.2
(c) Families within sources x blocks within plantings	7547	12.0

*Significant differences at the 0.05 level of significance

Statistical analyses were used primarily to detect differences among family and source means. More sophisticated calculations, particularly those based on expected mean squares, such as estimation of genetic variances and heritability, were not considered feasible because of the many missing values, the considerable environmentally induced variation within blocks, and other imbalances in the design. Although the statistical analysis is only an approximation, it still is a powerful test because of the large number of families tested. This design gave a more detailed delineation of the geographic variation pattern and a larger genetic base for future breeding work than would have been obtained from a smaller, more precise test of fewer families.

RESULTS AND CONCLUSIONS

Variation among sources--After 10 years, a well defined latitudinal and longitudinal pattern in height growth was evident (figures 2, 3, 4). Sources from southeastern Mississippi excelled in all three plantings, but in the northern planting fastest growth was centered farther to the northwest than in the other plantings. The southeastern sources generally are well adapted (at least for 10 years) to climates up to about 250 miles north of their point of origin.

The latitudinal variation pattern seems to be a straightforward selection response to climate. Populations that have developed in mild climates tend to grow faster than those from harsher climates if the comparison is made in a relatively mild climate.

The reason for the longitudinal variation pattern is more cryptic. At any given latitude, sources from the western part of the study area (near the Mississippi River) grew more slowly than those from near the Mississippi-Alabama border. The contrast is especially distinct in the southern Mississippi planting between sources from coastal Mississippi and southeastern Louisiana. The slow growth of sources from the floodplain of the Mississippi River and the loessal hills along the eastern border of the floodplain is distinct in all three plantings sites.

This difference cannot be explained by climate, but it could be related to soil type. The slow-growing trees came from sites far more fertile than did the fast-growing ones, and selection for fast growth is generally greatest on optimum sites (Squillace and Kraus 1959). It is possible that sweetgum from the fertile soils of the alluvial plain of the Mississippi River does not grow to its potential on less productive sites such as those in the present study. Some evidence of edaphic ecotypes in sweetgum from different soil types in the Mississippi Delta has been found [1/], so there is support for this hypothesis.

Another plausible hypothesis is that the Mississippi and Ohio Rivers transport seed from near the northern extremity of the sweetgum range in Ohio, Illinois, and Indiana (fig. 1) and provide a constant flow of genes for slow growth into the population growing in the floodplain of the Mississippi River. Genes for slow growth might drift eastward away from the River until their effect is overcome by sweetgum from southeastern Mississippi, which has evolved in place, the tendency

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[1/] Personal communication from D. T. Cooper of the Southern Forest Experiment Station, Stoneville, Mississippi.

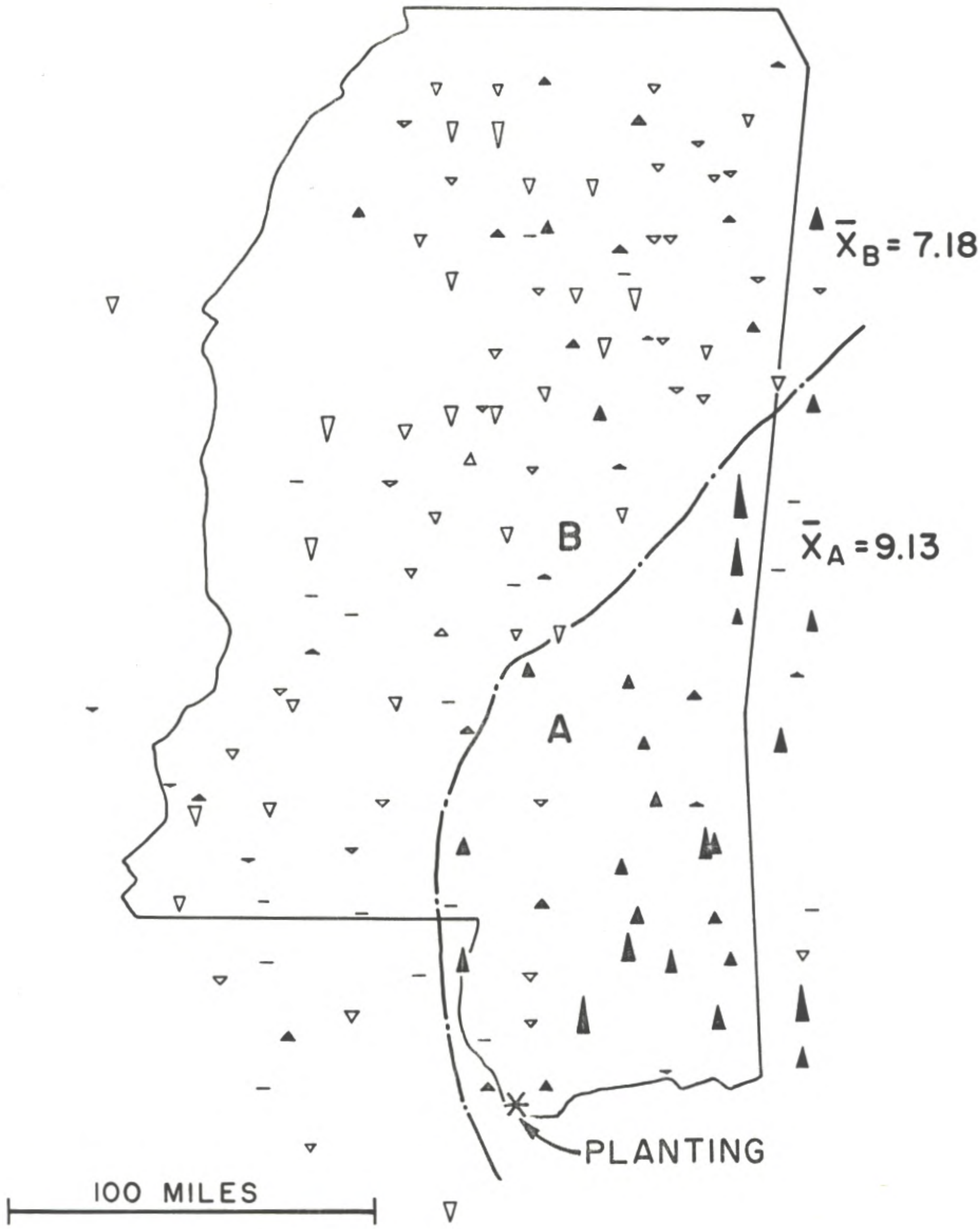

Figure 2.--Average 10-year height of the five families from each source growing in the southern planting. ▲ = source above the planting mean, ▽ = source below the planting mean. Height of the triangles are proportional to the source mean height. Average height of the sources inside (A) and outside (B) the optimum seed collection zone is shown.

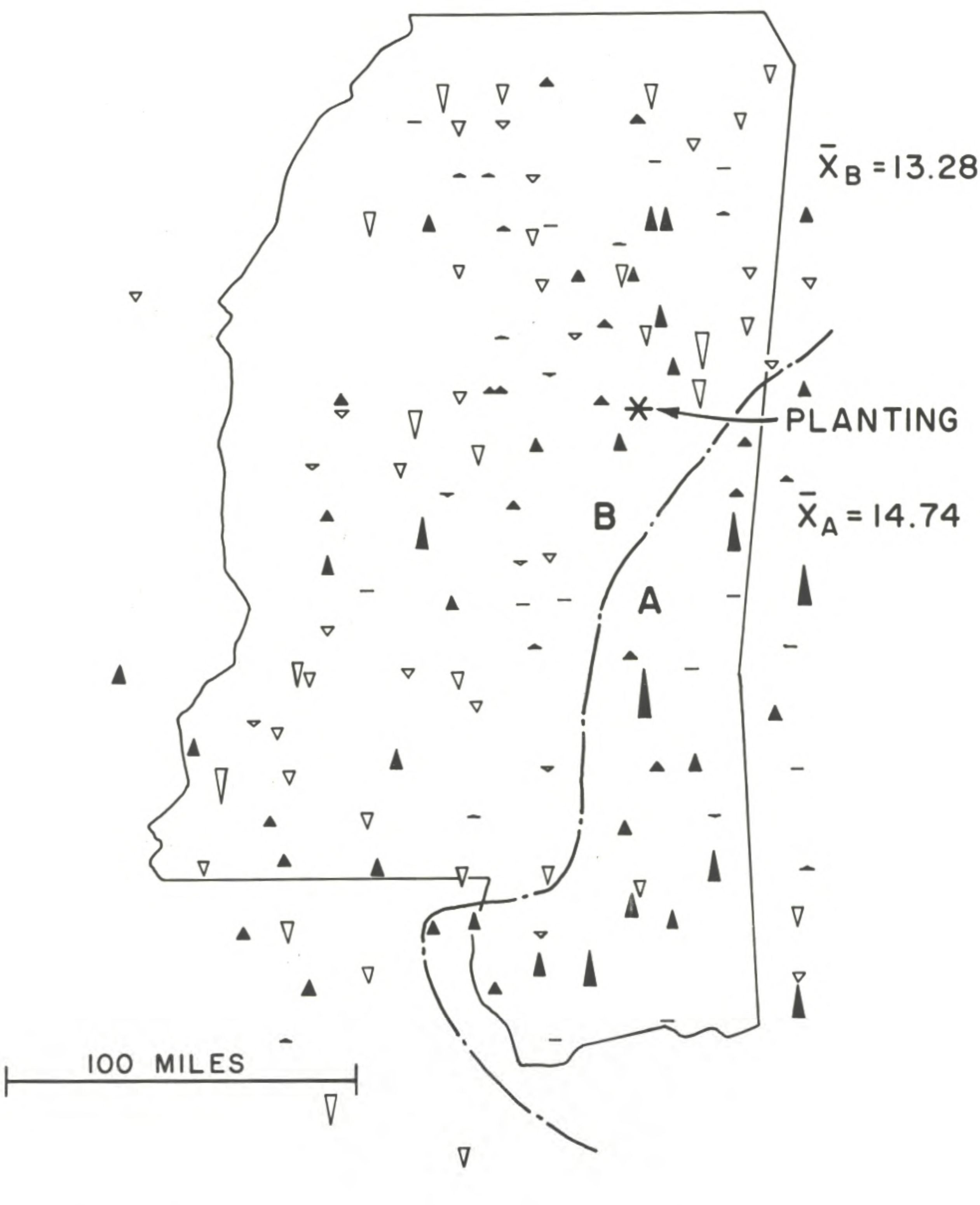

Figure 3.--Average 10-year height of the five families from each source growing in the central planting. ▲ = source above the planting mean, ▽ = source below the planting mean. Height of the triangles are proportional to the source mean height. Average height of the sources inside (A) and outside (B) the optimum seed collection zone is shown.

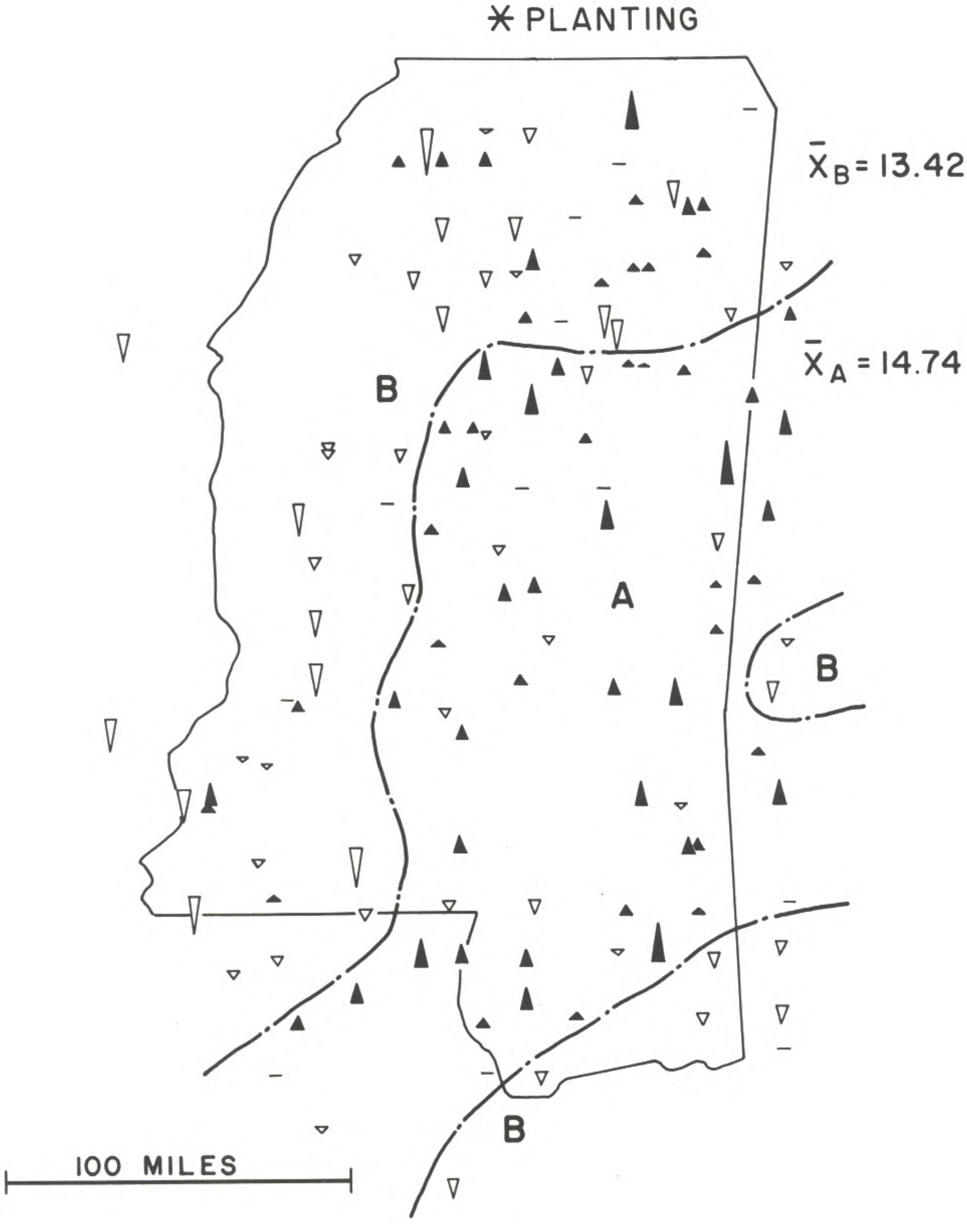

Figure 4.--Average 10-year height of the five families from each source growing in the northern planting. ▲ = source above the planting mean, ▽ = source below the planting mean. Height of the triangles are proportional to the source mean height. Average height of the sources inside (A) and outside (B) the optimum seed collection zone is shown.

for faster growth. Unlike the Mississippi and Ohio Rivers, the lesser drainages in the study area (Tombigbee, Pearl, Pascagoula Rivers) have their headwaters at least 500 miles south of the sweetgum populations in Ohio, Illinois, and Indiana, and would not have such slow-growing germ plasm to transport downstream.

Within source variation--On the average, there was a demonstrable amount of genetic variation among the families within a source and as indicated by the lack of significance for family within source x location interaction, the amount of this variation does not change significantly from planting to planting. The F value of 1.97 for family within source is small and statistical significance seems to be the result of a small biological effect and many degrees of freedom (492 over 7547). Another test of the within-source effect is the ANOVA of each source where the five families were tested in seven or eight blocks at each planting location. On this basis, significant differences in height among families occur in about 9.8% of the sources at any one planting location, as the following tabulation shows:

Planting	Sources (number)	Sources with significant differences among the families within (number)	(percent)
Southern	138	10	7.2
Central	136	19	14.0
Northern	144	12	8.3
Total	418	41	$\bar{x}$ = 9.8

Family differences were sizeable in the cases where significance was attained. The average difference between the best family in a source and the mean of the families in that source was 2.7 feet, an advantage of 24% over the source mean (Table 2).

The sampling and planting design of this experiment was nested, so G x E interaction for families refers only to the amount of variation within each source and indicates nothing about whether the family means change rank from planting to planting. We looked at rank changes by inspection of the family means in those sources where genetic differences existed (Table 3). In about half of the 38 sources where there were differences in height, the family or families primarily responsible for the within source difference performed about the same in at least one other planting.

Thus, demonstrable differences in growth rate occur in about 10% of the sources tested and the fast-growing families exhibit fairly strong G x E stability. This is solid evidence that a breeding program for enhanced vigor in sweetgum would be biologically feasible.

APPLICATION

The best trees growing in the test plantation of the study will be used for a breeding program. The objective of this program is to produce improved strains for Mississippi, adjacent parts of Alabama and Tennessee, and the Florida Parishes of Louisiana, that is, the area covered by the present study. These improved strains are likely to be adapted to other parts of the southeastern U.S. as well. Results from several other sweetgum provenance tests underway in the South should soon be available for developing guidelines for sweetgum seed movement.

These results should also serve as a general guide to sweetgum improvement programs outside of the present study area. It is likely that the latitudinal

Table 2. -- *Family and source means for sources having significant between-family differences (feet).*

Southern Planting

Source	Family	$\bar{x}_f$	$\bar{x}_s$
047	1	10.5	
	4	9.3	
	5	6.7	7.6
	3	5.9	
	2	5.6	
145	4	8.3	
	3	7.6	
	1	7.5	6.8
	5	5.4	
	2	5.2	
243	1	9.1	
	2	7.0	
	4	5.8	6.4
	5	5.6	
	3	4.5	
321	1	11.6	
	2	11.1	
	3	9.7	9.4
	5	7.5	
	4	7.2	
331	1	10.3	
	2	9.0	
	4	8.1	7.9
	3	6.8	
	5	5.5	
346	3	9.8	
	4	9.0	
	2	8.4	7.3
	1	5.2	
	5	4.0	
414	3	10.6	
	5	9.7	
	4	8.3	8.4
	2	7.2	
	1	6.1	
415	4	11.2	
	3	10.6	
	5	10.2	8.9
	2	7.5	
	1	5.1	
424	3	8.0	
	1	6.4	
	4	6.0	6.0
	5	5.5	
	2	4.3	
427	5	9.3	
	4	7.6	
	1	7.1	7.1
	3	6.2	
	2	5.4	

Central Planting

Source	Family	$\bar{x}_f$	$\bar{x}_s$
031	2	15.7	
	3	14.4	
	1	12.9	13.0
	4	12.4	
	5	9.5	
041	5	14.5	
	3	14.5	
	1	13.2	11.9
	4	8.9	
	2	8.4	
125	2	13.6	
	1	13.0	
	4	11.9	12.1
	3	11.9	
	5	10.3	
126	3	16.6	
	2	15.9	
	1	14.4	14.5
	5	13.5	
	4	12.1	
142	5	23.2	
	4	21.7	
	1	17.3	18.8
	2	16.1	
	3	15.8	
214	1	15.9	
	5	15.3	
	3	14.1	14.1
	2	13.1	
	4	11.9	
224	2	16.1	
	4	14.0	
	5	13.5	13.8
	3	13.0	
	1	12.2	
225	3	17.2	
	5	16.1	
	4	15.8	15.2
	2	14.9	
	1	11.8	
234	1	16.7	
	2	14.7	
	3	14.1	13.5
	5	11.2	
	4	10.7	
244	4	16.6	
	1	15.5	
	2	13.7	14.3
	5	13.0	
	3	12.6	
312	2	18.1	
	1	16.3	
	3	15.1	15.3
	4	13.9	
	5	13.0	
345	1	17.4	
	2	15.4	
	3	13.9	14.8
	5	13.8	
	4	13.7	
431	2	13.9	
	1	12.7	
	5	12.1	12.1
	3	10.9	
	4	10.7	
348	3	14.4	
	5	13.6	
	4	13.5	12.4
	2	10.3	
	1	10.1	
418	2	14.5	
	1	13.6	
	3	9.7	11.1
	4	9.2	
	5	8.6	
427	5	17.2	
	3	14.7	
	4	14.0	14.0
	2	12.5	
	1	11.5	
236	4	16.7	
	1	16.4	
	2	16.1	15.7
	5	15.4	
	3	13.9	
436	5	15.7	
	1	13.8	
	4	13.4	13.6
	3	12.9	
	2	12.2	
315	3	15.3	
	4	13.4	
	5	12.8	12.3
	2	10.8	
	1	9.2	

Northern Planting

Source	Family	$\bar{x}_f$	$\bar{x}_s$
033	1	21.7	
	2	19.5	
	3	15.4	16.2
	5	12.9	
	4	11.5	
022	3	15.7	
	2	15.3	
	1	13.6	13.1
	5	10.9	
	4	10.0	
035	2	21.9	
	3	18.1	
	1	17.1	16.5
	4	13.8	
	5	11.5	
212	1	19.7	
	2	18.9	
	4	16.8	17.1
	3	16.7	
	5	13.4	
412	1	17.8	
	3	16.6	
	2	16.6	15.0
	4	12.5	
	5	11.3	
414	3	18.4	
	2	16.0	
	5	14.6	14.9
	1	14.3	
	4	11.4	
423	2	17.8	
	3	17.7	
	4	14.5	15.1
	5	13.2	
	1	12.1	
235	5	16.1	
	2	14.7	
	4	11.9	12.3
	1	10.4	
	3	8.6	
245	5	18.8	
	3	15.9	
	4	14.8	15.1
	1	13.7	
	2	12.3	
424	2	16.4	
	5	16.0	
	4	14.6	14.5
	3	14.4	
	1	10.9	
425	5	15.2	
	3	12.2	
	4	12.2	11.7
	2	10.4	
	1	8.5	
436	3	21.1	
	2	16.0	
	1	15.6	15.3
	4	13.5	
	5	10.2	
444	5	15.9	
	1	15.6	
	4	14.3	13.9
	2	12.7	
	3	11.2	
435	3	18.4	
	4	17.2	
	2	15.1	
	1	14.0	
	5	13.8	

Table 3. — *Family within source x planting site interaction for sources that had significant differences among the families within them at one planting or another. Instances of stable performance are underlined.*

Source	Planting 1/ Southern Family	Ht.	Central Family	Ht.	Northern Family	Ht.
047	1	10.5	5	19.6	5	19.0
	4	9.3	4	17.5	2	14.8
	5	6.7	3	17.4	4	14.6
	3	5.9	1	16.3	1	13.8
	2	5.6	2	15.2	3	12.8
145	4	8.3	2	14.9	2	14.3
	3	7.6	3	14.4	1	14.0
	1	7.5	4	13.1	4	13.3
	5	5.4	1	12.3	3	12.5
	2	5.2			5	11.7
243	1	9.1	5	19.3	4	16.0
	2	7.0	3	18.0	1	15.8
	4	5.8	1	14.6	2	13.7
	5	5.6			5	13.6
	3	4.5				
321	1	11.6	5	21.5	1	16.2
	2	11.1	1	16.5	3	15.6
	3	9.7	3	16.3	2	14.9
	5	7.5	2	15.4	5	14.8
	4	7.2	4	14.5	4	13.9
331	1	10.3	1	17.8	1	13.1
	2	9.0	2	14.7	3	12.5
	4	8.1	3	14.3	2	12.0
	3	6.8	5	14.0	5	11.2
	5	5.5	4	13.2	4	9.7
346	3	9.8	2	18.4	4	13.1
	4	9.0	1	16.0	5	13.1
	2	8.4	4	15.2	3	12.3
	1	5.2	3	14.7	2	12.2
	5	4.0	5	12.1	1	11.9
414	3	10.6	4	15.0	3	18.4
	5	9.7	5	14.5	2	16.0
	4	8.3	2	14.4	5	14.6
	2	7.2	3	12.8	1	14.3
	1	6.1	1	12.2	4	11.4
415	4	11.2	4	15.8	2	18.0
	3	10.6	1	14.6	1	17.4
	5	10.2	3	13.5	5	16.3
	2	7.5	2	13.2	4	15.7
	1	5.1	5	11.9	3	14.2
424	3	8.0	2	12.7	2	16.4
	1	6.4	4	12.5	5	16.0
	4	6.0	3	12.1	4	14.5
	5	5.5	1	11.8	3	14.4
	2	4.3	5	10.6	1	10.9
427	5	9.3	5	17.2	3	13.0
	4	7.6	3	14.7	2	12.9
	1	7.1	4	14.1	5	11.9
	3	6.2	2	12.5	4	11.2
	2	5.4	1	11.5	1	10.6

Source	Plantings 2/ Northern Family	Ht.	Southern Family	Ht.	Central Family	Ht.
033	1	21.7	3	9.2	1	14.9
	2	19.5	1	7.6	5	14.0
	3	15.4	5	7.2	4	13.6
	5	12.9	4	6.9	2	13.2
	4	11.5	2	6.8	3	12.7
022	3	15.7	1	10.4	2	14.8
	2	15.3	2	9.3	5	14.6
	1	13.6	5	8.2	4	14.6
	5	10.9	3	8.1	3	13.6
	4	10.0	4	7.4	1	11.6
035	2	21.9	5	8.2	1	17.6
	3	18.1	2	8.0	5	17.6
	1	17.1	1	8.0	4	17.1
	4	13.8	4	6.3	3	15.0
	5	11.5	3	6.1	2	13.8
412	1	17.8	1	11.4	2	15.9
	3	16.6	5	8.8	1	15.2
	2	16.6	3	7.6	3	14.8
	4	12.5	2	7.0	5	12.6
	5	11.3	4	6.6	4	11.1
414	3	18.4	3	10.6	4	15.0
	2	16.0	5	9.7	5	14.5
	5	14.6	4	8.3	2	14.4
	1	14.3	2	7.2	3	12.8
	4	11.4	1	6.1	1	12.2
423	2	17.8	3	8.2	1	15.0
	3	17.7	2	7.4	3	14.1
	4	14.5	4	7.2	4	13.8
	5	13.2	1	6.5	2	13.8
	1	12.1	5	5.6	5	11.7
235	5	16.1	4	8.3	3	18.1
	2	14.7	2	7.6	5	17.6
	4	11.9	3	6.8	2	17.4
	1	10.4	5	6.7	1	17.3
	3	8.6	1	5.3	4	15.5
245	5	18.8	3	10.2	5	14.2
	3	15.9	5	6.1	3	14.0
	4	14.8	4	6.0	4	13.6
	1	13.7	1	5.9	1	13.2
	2	12.3	2	5.5	2	12.8
425	5	15.2	4	7.9	4	15.8
	3	12.2	2	6.6	2	13.5
	4	12.2	3	6.4	3	12.9
	2	10.4	5	6.3	5	12.3
	1	8.5	1	4.2	1	11.3
435	3	18.4	5	7.4	4	13.9
	4	17.2	3	5.6	5	12.4
	2	15.1	4	5.5	3	11.7
	1	14.0	1	4.9	1	11.6
	5	13.8	2	4.7	2	11.5
436	3	21.1	3	8.7	5	15.7
	2	16.0	2	7.5	1	13.8
	1	15.6	5	7.4	4	13.4
	4	13.5	1	6.8	3	12.9
	5	10.2	4	6.7	2	12.2
444	5	15.9	1	7.0	5	14.0
	1	15.6	2	6.8	2	12.2
	4	14.3	5	6.4	4	11.3
	2	12.7	3	6.3	3	11.2
	3	11.2	4	6.1	1	10.6
212	1	19.7	1	9.8	1	14.7
	2	18.9	4	9.8	4	14.6
	4	16.8	2	8.8	2	14.2
	3	16.7	5	8.6	3	13.9
	5	13.4	3	6.2	5	10.4
424	2	16.4	3	8.0	2	12.7
	5	16.0	1	6.4	4	12.5
	4	14.6	4	6.0	3	12.1
	3	14.4	5	5.5	1	11.8
	1	10.9	2	4.3	5	10.6

Source	Plantings 3/ Central Family	Ht.	Southern Family	Ht.	Northern Family	Ht.
031	2	15.7	2	12.4	5	15.3
	3	14.4	3	11.3	1	13.0
	1	12.9	1	11.3	2	11.4
	4	12.4			3	11.3
	5	9.5			4	10.7
041	5	14.5	3	8.6	5	15.4
	3	14.5	5	7.6	3	13.5
	1	13.2	2	7.3	2	12.5
	4	8.9	1	7.3	4	12.2
	2	8.4	4	4.9	1	11.2
125	2	13.6	1	8.9	1	12.7
	1	13.0	3	7.7	3	12.0
	4	11.9	4	7.2	5	11.2
	3	11.9	5	7.0	2	9.0
	5	10.3	2	6.7	4	4.8
126	3	16.6	1	8.5	1	14.6
	2	15.9	2	8.5	5	14.6
	1	14.4	3	8.2	3	13.7
	5	13.5	4	7.3	2	12.9
	4	12.1	5	5.5	4	11.8
142	5	23.2	4	10.5	5	18.6
	4	21.7	5	9.6	4	17.9
	1	17.3	3	8.8	1	16.1
	2	16.1	2	8.7	2	13.2
	3	15.8	1	6.7	3	12.3
214	1	15.9	1	10.8	1	17.9
	5	15.3	2	9.8	2	16.9
	3	14.1	3	9.7	3	14.2
	2	13.1	4	7.9	5	13.5
	4	11.9	5	7.4	4	13.4
224	2	16.1	5	7.6	2	18.3
	4	14.0	4	7.4	5	17.5
	5	13.5	2	7.2	4	17.4
	3	13.0	3	6.6	3	17.0
	1	12.2	1	4.9	1	13.4
225	3	17.2	2	8.8	5	16.6
	5	16.1	3	8.7	4	16.0
	4	15.8	1	8.3	3	16.0
	2	14.9	5	8.3	2	15.5
	1	11.8	4	7.2	1	9.6
234	1	16.7	4	9.2	4	18.1
	2	14.7	5	7.8	3	17.4
	3	14.1	1	7.5	1	16.1
	5	11.2	2	7.4	2	14.5
	4	10.7	3	5.5	5	14.1
244	4	16.6	5	8.8	3	16.4
	1	15.5	3	6.6	4	14.3
	2	13.7	1	5.6	5	14.2
	5	13.0	2	5.4	2	11.1
	3	12.6	4	5.4	1	10.9
312	2	18.1	5	9.7	1	16.0
	1	16.3	1	7.9	2	15.8
	3	15.1	3	7.8	5	15.4
	4	13.9	2	7.7	4	13.1
	5	13.0	4	7.1	3	12.3
345	1	17.4	4	7.6	1	17.2
	2	15.4	3	7.3	4	14.4
	3	13.9	2	7.0	2	13.3
	5	13.8	1	6.6	3	13.2
	4	13.7	5	4.1	5	12.7

Source	Plantings 3/ Central Family	Ht.	Southern Family	Ht.	Northern Family	Ht.
418	2	14.5	2	8.5	5	14.1
	1	13.6	3	6.6	1	14.0
	3	9.7	1	6.0	4	12.7
	4	9.2	5	6.0	2	10.9
	5	8.6	4	5.6	3	10.7
236	4	16.7	3	8.8	1	12.2
	1	16.4	4	8.5	4	12.2
	2	16.1	1	7.9	5	11.8
	5	15.4	5	7.2	2	11.4
	3	13.9	2	6.8	3	9.6
315	3	15.3	3	10.2	4	16.1
	4	13.4	4	6.9	2	15.2
	5	12.8	5	6.6	5	14.4
	2	10.8	1	6.6	1	14.1
	1	9.2	2	6.6	3	13.3
348	3	14.4	4	7.1	5	14.6
	5	13.6	3	6.0	4	11.6
	4	13.5	1	5.9	1	11.2
	2	10.3	2	5.9	3	11.0
	1	10.1	5	5.3	2	9.8
427	5	17.2	5	9.3	3	13.0
	3	14.7	4	7.6	2	12.9
	4	14.0	1	7.2	5	11.9
	2	12.5	3	6.2	4	11.2
	1	11.5	2	5.4	1	10.6
436	5	15.7	3	8.7	3	21.1
	1	13.8	2	7.5	2	16.0
	4	13.4	5	7.4	1	15.6
	3	12.9	1	6.8	4	13.5
	2	12.2	4	6.7	5	10.2
431	2	13.9	1	7.6	4	14.8
	1	12.7	4	7.1	1	13.6
	5	12.1	2	6.9	3	13.1
	3	10.9	5	6.0	5	13.0
	4	10.7	3	5.3	2	12.2

1/ Differences among families within sources significant at the 0.05 level in the southern planting.

2/ Differences among families within sources significant at the 0.05 level in the northern planting.

3/ Differences among families within sources significant at the 0.05 level in the central planting.

variation pattern found in Mississippi sweetgum occurs in other Gulf Coast states as well because the correlation of height growth with latitude is well-known in many other species. The east-west variation found in the present experiment is not predictable elsewhere, however, and may or may not occur in other sweetgum populations.

There is sufficient genetic variation within the present study area to make selection for increased growth rate in the Mississippi sweetgum population feasible. The variation occurs within sources, among sources, and among larger geographic areas; improvement strategy needs to take this into account. First of all, the optimum geographic area, or zone in which selection is to be based should be chosen (figs. 2-4). Gains in height growth of 1.8 feet in 10 years can be obtained by selecting sources in the Mississippi area. For plantings of improved stock in the southern or central part of Mississippi, the decision is straightforward--selection should be made in the A zone of Figs. 2 and 3. For plantings farther north, the seed collection zone should be shifted to the northwest.

Once the optimum zone is chosen, the next step is to make selections within it. The present results show source to source variation within the optimum zone, but no obvious pattern to it. Source performance commonly varies from well above the mean of the optimum zone to well below it in sources only 10-15 miles apart. Because adjacent sources rarely respond in the same way, there is no reason to believe there are groups or subzones of desirable sources. Conservative judgment, then, would have to be that performance of the progeny of the five trees sampled in each source represents no larger population than just those five trees. Thus, selection of individual parent trees should probably be at random over the entire optimum seed collection zone rather than in smaller areas.

This and other studies indicate that the best way to find superior sweetgum families is to progeny test random selections rather than search intensively for superior phenotypes. Cooper (1975) found no difference in height growth in the progeny of sweetgum trees intensively selected for height and the progeny of nearby comparison trees. An efficient selection system for fast growth would involve collecting seed from many average or better phenotypes from throughout the optimum zone and establishing a progeny test within the planting zone. The number of parent trees selected should be limited only by the seed collection workload and the size of the progeny test that can be handled.

LITERATURE CITED

Cooper, D. T. 1975. Performance of open-pollinated sweetgum progenies on contrasting sites in the Mississippi delta. Proc. IUFRO Hardwood Progeny Test Meeting, Knoxville, Tennessee.

Panse, V. G., and P. V. Sukhatme. 1954. Statistical methods for agricultural workers. Indian Counc. Agric. Res., New Delhi, 361 p.

Sprague, J. and R. J. Weir. 1973. Geographic variation of sweetgum. Proc. South. For. Tree Improv. Conf. 12:169-180.

Squillace, A. E. and J. F. Kraus. 1959. Early results of a seed source study of slash pine in Georgia and Florida. Fifth South. Proc. South. For. Tree Improv. Conf. 5:21-34.

Texas Forest Service. 1975. 23rd progress report of cooperative forest tree improvement program. For. Genet. Lab, Texas For. Serv., College Station, Texas. 23 p.

Yates, F. 1933. The analysis of replicated experiments when the field results are incomplete. Emp. J. Exp. Agric. 1:129-142.