GEOGRAPHIC VARIATION OF SWEETGUM

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Abstract.--A range-wide sweetgum (Liquidambar styraciflua) provenance study was established in 1966 to assess the variation in survival, growth and quality traits associated with differences among trees in stands, among stands, and among geographic sources.

Seed were collected from five trees from each of two stands from each of 14 sources across the south and southeastern United States. Outplantings were established in each of the 14 seed source areas.

Fourth year results indicate that tree to tree differences are sufficiently great to warrant a mass selection program for genetic improvement of the species. However, the greatest source of difference was among stands, indicating that greatest genetic gains could be obtained by selecting the best stands and then selecting the best trees from those stands. Although the trend is not strong, there is evidence that Coastal Plain sources are superior to Piedmont sources when planted in the Coastal Plain. When planted in the Piedmont, Coastal Plain sources perform equally well as the local sources but are more susceptible to environmental extremes.

During the past 15 years great advancement has been made in the application of tree improvement principles to southern pine silviculture. However, progress with southern hardwood tree improvement has lagged. Only now are we realizing results from basic variation studies of commercially important hardwood species.

To develop a sound breeding program for any species one must have a fundamental knowledge of the variation of economically important characteristics and how these characteristics are genetically controlled. Seed source testing is a meaningful beginning to understanding the pattern of variation. Seed source tests can also help delineate seed collection zones. For a species as widely distributed as sweetgum (Liquidambar styraciflua L.), there exists, in all probability, inherent differences between populations; these differences can dictate the choice of seed adapted to a particular area. Normally, the local seed source is best because it contains trees adapted to the local environmental conditions. However, in large scale forestry, a sufficient supply of suitable local seed may not always be available, resulting in the necessity of obtaining seed from a distant source.

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A Southwide sweetgum seed source study was established in 1967, under the direction of the N. C. State University - Industry Hardwood Research Program. The objectives of the study were:

1. To determine within stand, between stand, the geographic variation in growth rate, tree form, wood specific gravity, and fiber length from 14 sweetgum sources in the Southeast;

2. To differentiate performance and growth of these sources when established in the environmental conditions of other sources;

3. To indicate desirable sources of sweetgum for planting and, when local seed is unavailable, guide the selection of alternative sources;

4. To establish heritabilities of growth, form, and wood properties through parent-progeny correlations and to determine the changes in heritability estimates when the same material is grown under a variety of environments.

Assessment of height growth after the 4th growing season in the field has resulted in information pertaining to objectives 2, 3, and part of 1 which is discussed in this presentation.

METHODS AND MATERIALS

Seed were collected from natural sweetgum stands from seven transects across the Southeast. The first five transects were divided into Coastal and Piedmont zones, the first four being orientated east-west and the fifth north-south. The sixth and seventh transects are oriented east-west (northeast-southwest), comparing sources of the Mississippi Delta to the Louisiana upland and the Sabine River drainage to the Neches River drainage of eastern Texas (Fig. 1).

Within each collection zone seed were obtained from five mother trees in each of two stands (2 stands/collection zone x 2 zones/transect x 7 transects x 5 trees per stand = 140 parent trees.) Assuming that sweetgum management of the future would be on the better sites, seed sources were obtained from average or better sites. A listing of seed sources is shown in Table 1.

Seed collections were made in 1964 and 1965, sown in the nursery in 1966 and outplanted in the field in Spring, 1967. An outplanting was established in each of the 14 collection zones. Good sites were selected for the outplantings as sweetgum management will most likely be restricted to the better sites (Table I).

Each outplanting included seedlings from the immediate transect plus seedlings from the two adjacent transects. The most northerly plantation included seedlings from the most western transect and vice versa so that all plantations included seedlings from three transects.

Seedlings were planted in 12-tree row plots by mother tree. The five mother-tree seed lots from each stand were planted together as a unit with randomization of seed lots in each unit. The mother tree units were randomized within each of 6 replications. To date, four of the outplantings have been abandoned (4-A, 4-B, 6-B, and 7-B) due mainly to poor survival, leaving 10 from which the 1970-71 measurements were obtained.

Fig. 1. Parent tree and seed collection locations (★):

Sweetgum Seed Source Study

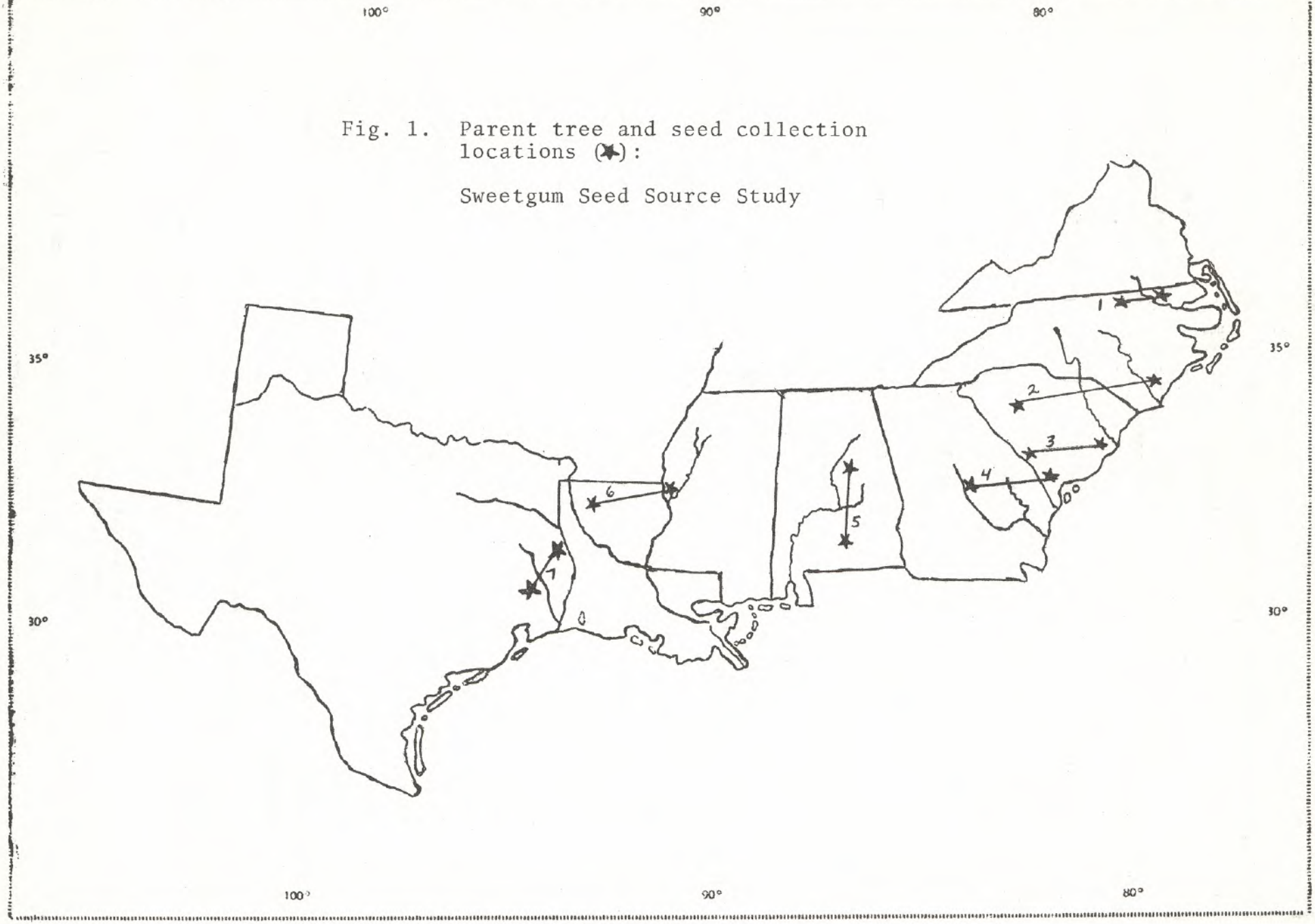

Table 1. Seed Collection and outplanting locations

Source Code[1/]	Exact Source	Approx. lati-tude	Out-planting	Approximate Location of Outplanting
1A1	Halifax County, N. C.	36°20'	1A	Bertie County, N. C.
1A2	Bertie County, N. C.	"	"	"
1B1	Granville County, N. C.	36°20'	1B	Greensville County, Va.
1B2	Granville County, N. C.	"	"	"
2A1	Bladen County, N. C.	34°40'	2A	Elizabethtown, N. C.
2A2	Bladen County, N. C.	"	"	"
2B1	Newberry County, S. C.	34°30'	2B	Clinton, S. C.
2B2	Newberry County, S. C.	"	"	"
3A1	Georgetown County	33°15'	3A	Georgetown County, S. C
3A2	Georgetown County, S. C.	"	"	"
3BI	Saluda County, S. C.	33°15'	3B	Edgefield County, S. C.
3B2	Saluda County, S. C.	"	"	"
4A1	Allendale County, S. C.	33°00'	4A	Allendale County, S. C.
4A2	Allendale County, S. C.	"	"	"
4B1	Bibb County, Ga.	33°00'	4B	Twiggs County, Ga.
4B2	Monroe County, Ga.	"	"	"
5A1	Barbour County, Ala.	31°30'	5A	Butler County, Ala.
5A2	Monroe County, Ala.	"	"	"
5B1	Coosa County, Ala.	33°15'	5B	Tallapoosa County
5B2	Clay County, Ala.	"	"	"
6A1	Warren County, Miss.	32°30'	6A	Jefferson County, Miss.
6A2	Warren County, Miss.	"	"	"
6B1	Bienville Parish, La.	32°30'	6B	Bienville Parish, La.
6B2	Winn Parish, La.	"	"	"
7A1	Sabine County, Texas	31°15'	7A	Zwolle, La.
7A2	Sabine County,Texas	"	"	"
7B1	Angelina County, Texas	31°15'	7B	Neches River, Texas
7B2	Angelina County, Texas	"	"	"

The code for the sweetgum seed source test is:

Four digit number.
First digit - A number corresponding to the transect number. One being the northeasternmost and seven the southwesternmost.
Second digit- A letter, either A or B. A connotates a coastal source and B a Piedmont source.
Third digit - A number differentiating one of two stands representing the collection location.
Fourth digit - Tree number - Five trees were chosen as half-sib family parents in each stand.
1/ The source only includes the first three numbers of the code.

RESULTS

Total height growth after four growing seasons in the field was assessed separately for each of the 10 plantations. Analyses of variance (Table 6) and means were computed to discern important differences attributable to geographic source (transects and physiographic regions), stands and trees (families) within stands. Combined analyses were not attempted because of the substantial imbalance encountered between plantings, however, general trends are apparent from the overview of the 10 distinct analyses.

Transects - In general, differences in height growth associated with transects were unimportant and not detectable within the regions defined by the 3-transect comparison (Tables 4 and 6). The results were inconclusive when the most southern source was included in the most northern plantation and when the most northern source was included in the most southern plantation. In plantation 1A, the Coastal Plain plantation of the most northern transect (Bertie Co., N. C.), families from stand 7A2 (Sabine Parish, La.) averaged about a foot taller than the plantation average. At the companion Piedmont plantation (1B), where the difference in height growth between tallest and shortest sources was less than one foot, the 7A2 source was only average (Table 3).

A detailed examination of plantation 2B (Newberry, S. C.) was conducted to determine the effect of frost on several sources represented in that plantation. The sources from Alabama, Mississippi, Louisiana, and Texas suffered considerably more damage than the local ones from North Carolina and South Carolina (Table 2).

From these results it appears that we can collect seed for a given area from within a 3-transect region without fear of growth loss but that we should not move the extreme southern sources as far north as South Carolina.

Physiographic region - Examination of the means for Coastal Plain and Piedmont sources reveals some evidence that the Coastal sources are superior to the Piedmont sources when planted in the Coastal Plain (Table 5). When planted in the Piedmont, Coastal Plain sources performed equally as well as the local sources; however, it is suspected that the Coastal Plain sources are more susceptible to environmental extremes as indicated by the frost damage encountered at Newberry, S. C. No statistical differences between regions were found (Table 6).

Stand - The greatest source of variation in height growth was attributed to the stand component (Table 6). This result is similar to that found for wood specific gravity of the parent trees of this study (Johnson and McElwee, 1967). Studies on sycamore have also shown the stand component of variation to be greater than the tree-to-tree differences within stands (Schmitt and Webb, 1971; Lee, 1973; Schmitt and Wilcox, 1969). Such large differences among stands imply that the greatest genetic gain can be obtained by first locating the best stands and then locating the best trees within these stands. Since it would be very difficult to select the best stands with respect to growth without actually testing, a possible approach would be to relax selection so that the best trees in many natural stands could be evaluated, followed by intensive selection in the resulting foundation populations, as suggested by Schmitt and Wilcox (1969). This approach is similar to the mother tree studies being

Table 2. Cold Damage to Several Sweetgum Sources
Planted in Newberry, S. C.

Source	Averages by Source Extent of damage*	% Infected
Halifax and Bertie Cos., N. C.	.18	2.0
Granville Co., N. C.	.24	2.4
Bladen Co., N. C.	.50	4.8
Newberry Co., S. C.	.22	2.2
Georgetown, S. C.	.69	6.7
Saluda Co., S. C.	.55	4.0
Barbour and Monroe Cos., Ala.	1.0	14.0
Coosa and Clay Cos., Ala.	.6	6.0
Warren Co., Miss.	1.0	14.0
Bienville and Winn Parishes, La.	2.0	30.0
Sabine Co., Texas	2.0	2.0
Angelina Co., Texas	2.0	27.5

* Extent of damage was recorded according to the following code:

None = 0

Light = top 1/4 **or** less of tree killed = 1

Moderate = top 1/4 - 1/2 of tree killed = 2

Heavy = Killed to ground or nearly so = 3

Table 3. HEIGHT MEANS (IN FEET AND TENTHS) BY STAND FOR EACH PLANTATION

Plantation	1A Coastal, N.C.		1B Piedmont, N.C.		2A Coastal, N.C.		2B Piedmont, S.C.		3A Coastal, S.C.	
	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.
	7A2	7.6	2B2	3.2	1A1	3.0	2B2	10.0	4B1	5.2
	2A1	7.1	2A1	3.0	2A1	3.0	2A2	9.6	2A1	5.1
	2A2	6.9	1A1	2.8	1B2	2.7	3B1	9.2	4A2	4.8
	1B2	6.8	1B1	2.8	3B1	2.7	1B2	9.2	3B1	4.6
	2B2	6.7	2A2	2.8	3A2	2.6	3A2	9.1	3A2	4.5
	7B2	6.6	1A2	2.7	1A2	2.6	1A1	8.8	4A1	4.5
	1A2	6.6	1B2	2.7	2A2	2.6	2A1	8.7	3A1	4.3
	7A1	6.5	2B1	2.6	2B2	2.4	3A1	8.6	2A2	4.2
	1A1	6.4	7A2	2.6	3A1	2.4	1A2	8.4	2B1	4.0
	1B1	6.4	7A1	2.4	1B1	2.3	1B1	8.2	3B2	3.9
	2B1	6.3	7B1	2.4	2B1	2.2	2B1	8.2		
	7B1	5.9								

Plantation	3B Piedmont, S.C.		5A Coastal,Ala.		5B Piedmont,Ala.		6A Upper Coastal Miss.		7A Upper Coastal Texas	
	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.
	2A1	5.8	6B2	6.7	6B1	5.7	6B2	6.3	7A2	6.3
	4B1	5.2	5A2	6.2	4A1	5.7	6A1	6.0	6B2	6.1
	2B2	5.0	6A2	5.7	4A2	5.6	7A2	5.9	6B1	6.1
	3B1	5.0	5BI	5.7	5A2	5.6	7B2	5.8	7A1	6.0
	3B2	5.0	4B1	5.6	4B2	5.5	5A2	5.7	7B1	6.0
	4A1	4.9	6A1	5.5	6B2	5.1	6A2	5.6	1B2	5.9
	3A2	4.7	4A2	5.4	4B1	4.6	6B1	5.6	7B2	5.9
	2B1	4.6	5A1	5.4	6A1	4.5	7A1	5.6	1A2	5.8
	4A2	4.5	5B2	5.4	6A2	4.4	5A1	5.5	1A1	5.6
	2A2	4.4	6B1	5.4	5B1	4.4	5B1	5.4	6A1	5.6
	3A1	4.1	4B2	5.2	5A1	4.2	7B1	5.4	1B1	5.4
			4A1	4.5	5B2	4.2	5B2	5.0	6A2	5.3

Table 4. Ht. means by transect at each plantation (in ft. and tenths)

	Plantations				
	1A Coastal N. C.	1B Piedmont N. C.	2A Coastal N. C.	2B Piedmont S. C.	3A Coastal S. C.
Transect	1 - 6.6	1 - 2.8	1 - 2.6	1 - 8.6	2 - 4.5
Transect	2 - 6.7	2 - 2.9	2 - 2.6	2 - 9.1	3 - 4.3
Transect	7 - 6.8	7 - 2.5	3 - 2.6	3 - 9.0	4 - 4.7

	3B Piedmont S. C.	5A Coastal Ala.	5B Piedmont Ala.	6A Upper Coastal Miss.	7A Upper Coasta Texas
Transect	2 - 5.0	4 - 5.2	4 - 5.3	5 - 5.4	1 - 5.7
Transect	3 - 4.7	5 - 5.7	5 - 4.6	6 - 5.9	6 - 5.8
Transect	4 - 4.9	6 - 5.8	6 - 5.0	7 - 5.7	7 - 6.0

Table 5. Ht. means (in feet and tenths) by physiographic region at each plantation

	1A Coastal N. C.	1B Piedmont N. C.	2A Coastal N.C.	2B Piedmont S.C.	3A Coastal S.C.
Coastal Plain	6.8	2.8	2.8	8.9	4.6
Piedmont	6.5	2.8	2.4	8.9	4.2

	3B Piedmont S. C.	5A Coastal Ala.	5B Piedmont Ala.	6A Upper Coastal Miss.	7A Upper Coastal Texas
Coastal Plain	4.8	5.5	5.0	5.7	5.8
Piedmont	4.9	5.6	4.9	5.6	5.9

Table 6. Analyses of variance of four year total height growth computed separately by planting.

Plantation	1A N. C. Coastal D.F.	M. S.	1B N. C. Piedmont D.F.	M.S.	2A N. C. Coastal D.F.	M.S.	2B S.C. Piedmont D.F.	M.S.	3A S.C. Coastal D.F.	M.S.
Replications	5		5		5		4		5	
Geographic source		4.45	5	1.63	5	2.38	5	2.75	5	2.36
lat. transects	2	0.60	2	3.75	2	0.48	2	4.96	2	0.24
physiographic region	1	10.06	1	0.03	1	5.72	1	0.25	1	6.44
trans x region	2	5.48	2	0.62	2	2.60	2	1.79	2	2.50
Stands/source	6	2.55	5	0.74	5	1.41**	5	8.86**	4	4.38**
Family/stands	41	1.56**	38	0.37	37	0.16	37	2.42	32	1.00**
Error	260	.88	240	0.35	235	0.28	188	2.13	200	0.49

Plantation	3B S. C. Piedmont D.F.	M.S.	5A Ala. Coastal D.F.	M.S.	5B Ala. Piedmont D.F.	M.S.	6A Miss. Upper Coastal D.F.	M.S.	7A Texas Upper Coastal D.F.	M.S.
Replications	5		5		5		5		5	
Geographic source	5	3.23	5	7.93	5	9.27	5	3.87	5	2.14
lat. transects	2	2.30	2	12.24	2	10.04	2	5.82	2	2.45
physiographic region	1	1.88	1	4.84	1	0.59	1	2.53	1	0.04
trans x region	2	4.84	2	5.18	2	12.84	2	2.59	2	2.88
Stands/source	5	7.97**	6	6.38**	6	5.83**	6	2.20*	6	1.21
Family/stands	36	0.92	45	1.00	44	0.52	46	0.71	48	0.77*
Error	230	0.96	280	1.73	275	1.29	285	0.66	295	0.54

* - denotes statistical significance at the .95 level of probability

** - denotes statistical significance at the .99 level of probability

conducted by the N. C. State University - industry Hardwood Research Program. the best trees are selected from a very large number of stands and collectively these are tested with open-pollinated progeny. From the progeny, intensive selection for the very best trees in the best families is planned.

Families - Several studies conducted on southern hardwoods have shown that the variation among trees of a species is great enough to warrant mass selection Programs (Roberds, 1965; Wilcox and Farmer, 1967; Kellison, 1971; Weir, 1971; Kitzmiller, 1972 and Sumantakul, 1973). Although the stand component was the Largest source of variation in this sweetgum study there were significant family differences in a few of the plantations and it is felt that family differences are great enough to justify a mass selection program for genetic improvement of the species in the manner described above (Table 6).

SUMMARY AND CONCLUSIONS

1. Differences in height growth associated with transects were not detectable within any given region defined by its 3-transect companions. Therefore, we feel it safe to move sweetgum within a 3-transect region as defined by this study.

2. Results from plantations where the southern-most sources were planted in the northern-most areas of the study and vice versa were inconclusive. However, based on the frost damage encountered in the plantation at Newberry, S. C., we recommend that the Alabama, Mississippi, Louisiana, and Texas sources not be moved as far north as South Carolina.

3. Examination of data reveals that the Coastal sources should be restricted to the Coastal Plains and the Piedmont sources to the Piedmont areas in order to assure maximum survival and growth.

4. The large stand to stand differences indicate that the largest genetic improvement would be obtained by selecting the best trees out of the best stands for use in seed production.

5. Family differences were great enough to warrant a mass selection program as described in this paper.

LITERATURE CITED

Johnson, J. W. and McElwee, R. L. 1967. Geographic variation in specific gravity and three fiber characteristics of sweetgum (Liquidambar styraciflua L.). Proc. 9th Southern Conference on Forest Tree Improvement. pp. 50-55.

Kellison, R. C. 1970. Phenotypic and genotypic variation of yellow-poplar (Liriodendron tulipifera L.) Ph.D. Thesis, School of Forest Resources, N. C. State Univ., Raleigh.112 pp.

Kitzmiller, J. H. 1972. Response of sycamore (Platanus occidentalis L.) families to nitrogen fertilization. Ph.D. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 133pp.

Roberds,J. H. 1965. Patterns of variation in several characteristics of sweetgum (Liquidambar styraciflua L.) in North Carolina. M.S. Thesis School of 'Forest Resources, N. C. State Univ., Raleigh. 62 pp.

Schmidt, D. M. and Webb, C. D. 1971. Georgia sycamore seed sources in Mississippi plantings: Site adaptability a key factor. Proc. 11th Southern Forest Tree Improvement Conference, pp. 113-119.

Schmitt, D. and Wilcox, J. R. 1969. Sycamore (Platanus occidentalis L.) variation in the lower Mississippi Valley. U.S.D.A. Forest Serv., Res. Paper S0-91, 6 pp. South. Forest Exp. Station, New Orleans, La.

Sumantakul, Vichien. 1973. Genetic variation of sycamore (Platanus occidentalis L.) M.S. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 81 pp.

Weir, R. J. 1971. Open-pollinated sycamore (Platanus occidentalis L.) families on pine sites. M.S. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 64 pp.

Wilcox, J. R. and Farmer, R. E. 1967. Variation and inheritance of juvenile characters of eastern cottonwood. Silvae Genetica 16, Heft 5-6:162-164.