Geographic Variation in Sycamore (Platanus occidentalis L.)

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Abstract

Geographic variation in American sycamore *(Platanus occidentalis* L.) was investigated along two transects — one along the Atlantic Coast from North Carolina to Florida and one down the Mississippi River Valley from Illinois to Louisiana.

Height at 5 years was fairly well-correlated with latitude of origin along the Atlantic Coast transect, but, except for the slow-growing southern Illinois trees, the Mississippi River Valley transect showed a random pattern of variation in height. Seed source × planting location interaction for height was much smaller than the average seed-source effect over all plantings. Significant differences in height among half-sib families within seed sources were shown in about one-third of the geographic seed sources.

Timing of leaf fall at the end of the growing season proved to be under strong genetic control. A smooth cline was demonstrated at all planting sites where the trait was observed. It was well-correlated with latitude of seed origin along both the Atlantic Coast and Mississippi River transects. Seed source × planting location interaction was negligible.

Key words: Provenance tests, genecology.

Zusammenfassung

Die geographische Variation von *Platanus occidentalis* L. ist anhand zweier Transekte, von denen einer entlang der Atlantikküste von Nord-Carolina bis Florida und der andere das Mississippital hinunter von Illinois bis Lousiana lief, untersucht worden.

Entlang des Transekts an der Atlantikküste war die Höhe im Alter von fünf Jahren gut mit dem Breitengrad der Herkunft korreliert. Die Saatgutherkünfte entlang des Mississippital-Transekts zeigten aber, mit Ausnahme der langsam wachsenden Bäume aus dem südlichen Illinois, ein zufälliges Variationsmuster. Für die Baumhöhe war die Interaktion Saatgutherkunft × Versuchsort viel geringer als der durchschnittliche Herkunftseffekt über alle Versuchsorte.

Der Zeitpunkt des Laubfalls am Ende der Vegetationsperiode hat sich als genetisch streng kontrolliert erwiesen. Ein gleichmäßiger Klin wurde an allen Versuchsorten, wo dieses Merkmal beobachtet wurde, festgestellt. Entlang beider Transekte ergab sich eine gute Korrelation mit dem Breitengrad der Saatgutherkunft. Die Interaktion Saatgutherkunft × Versuchsort war unbedeutend.

Zwischen Halbgeschwisterfamilien innerhalb von Saatgutherkünften wurden in ungefähr einem Drittel der Absaaten signifikante Unterschiede im Höhenwachstum gefunden.

Introduction

American sycamore *(Platanus occidentalis* L.) is a prominent component of the eastern deciduous forest. It is widely utilized for forest products and is also valued as an ornamental in both rural and urban environments. Since the early 1970's it has become a favored species in short-rotation "biomass farms" (Steinbeck *et al.*, 1972). Approximately 800 ha of sycamore are planted annually in conventional reforestation programs in the southeastern United States and genetic improvement programs are in progress (Malac and Heeren, 1979; Texas For. Serv., 1982).

A disease complex involving *Ceratocystis fimbriata* (Ell. and Halst.) and *Botryodiplodia theobromae* Pat. has been a major factor constraining widespread use of sycamore in

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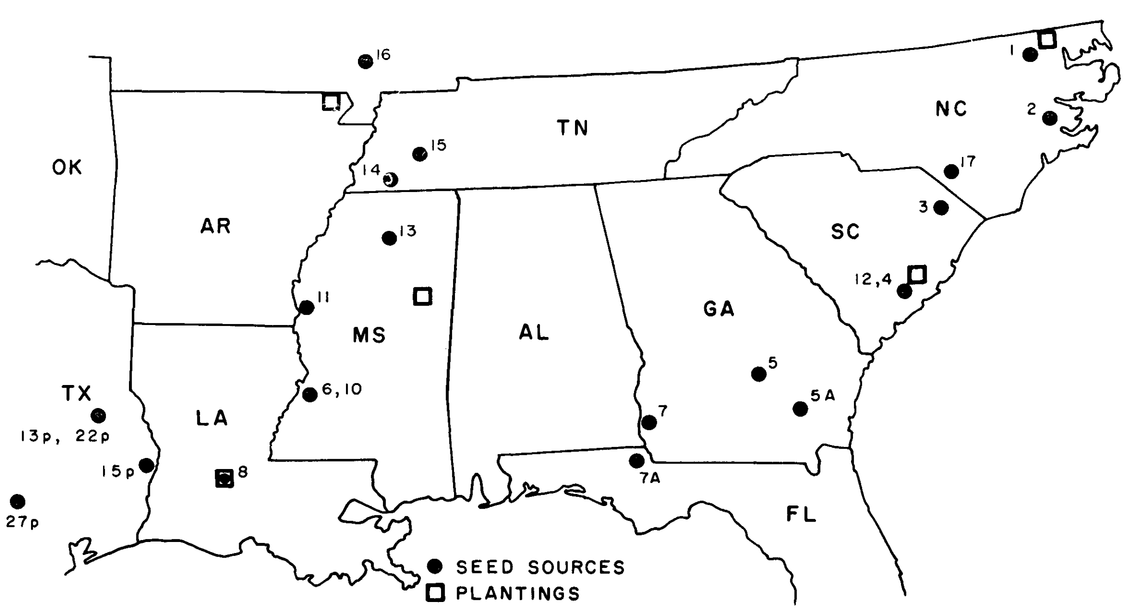

Figure 1. — Seed sources and plantings for a provenance test of sycamore in the southeastern United States.

plantations in the southeastern United States (RICKETTS, 1975; FILER *et al.*, 1975; COOPER *et al.*, 1977).

A study was designed in the late 1960's to investigate geographic variation in sycamore in the southeastern United States. Seed collections were made and plantings were established along two transects, one along the Atlantic Coast from northeastern North Carolina to western Florida and the other down the Mississippi River Valley from southern Illinois to southern Louisiana. Of nine plantings, five survived and grew well enough to provide usable data through the fifth growing season.

Materials and Methods

Seed was collected from 10 trees in each of the areas shown as seed sources in *Figure 1.* These areas are grouped into two rough transects; one primarily along the Atlantic Coast, and the other mostly within the Mississippi River Valley. Identity of the 10 half-sib families from each area was maintained throughout the study. Selection criteria for individual trees were undemanding - average phenotypes were sought. The only specification was that individual trees be separated by at least 200 yards to minimize relatedness. However, the Western Gulf Forest Tree Improvement Program (WGFTIP) contributed four seed lots from trees in their program. Phenotypic selection criteria were stringent for these trees.

Plantations were established along the same Atlantic Coast and Mississippi River Valley transects that been sampled by the seed collections. Seed for the central Mississippi planting was collected in 1967 and the plantation established in 1970. Seed for the northeastern Arkansas, North Carolina, and South Carolina plantings was collected in 1970 and the plantations established in 1972, 1975, and 1975, respectively. Seed for the southeastern Louisiana planting was collected in 1974 and the plantation established in 1976. In most cases, the trees selected in 1967 were relocated and used for the 1970 and 1974 seed collections. All stock was grown for 1 year in a nursery on the Harrison Experimental Forest in southern Mississippi and planted in bare-root condition. A compact-family block design was used (WRIGHT, 1976), with 4-tree, half-sib family, row-plots grouped into 10 (or fewer) row plots that represented a particular seed collection area. Six replications were established in South Carolina, six in Arkansas, seven in North Carolina, eight in Louisiana, and nine in Mississippi. Spacing in the different plantations varied between 2.4 × 2.4 m and 3.0 × 2.4 m. The Louisiana and Arkansas sites were on old fields that had been used for soybeans the previous year, the North Carolina site was recently cleared and bedded forest land, and the South Carolina and Mississippi sites were old cultivated fields that had not been used for agriculture for many years. All appeared to be fertile, promising, hardwood sites. The Louisiana, Arkansas, and South Carolina sites were alluvial floodplains, the Mississippi site was an interior flatwoods soil, and the North Carolina site had supported mixed hardwoods with a site index of 26 to 27 m at 50 years. The North Carolina site was fertilized after the first and fourth years with about 225 kg/ha NH_4NO_3. All sites were cultivated several times during the first three growing seasons to keep weeds at a minimum.

Measurements of height and tree quality or form were made at 3 and 5 years after planting in the field and d.b.h. was measured at 5 years. Fall leaf shed was observed in November 1977, in the South Carolina, North Carolina, and Arkansas plantings. The proportion of foliage that had fallen from each tree by that date was estimated. Tree quality — a composite of stem straightness, crown shape, and number and angle of branches — was quantified by establishing five grades (1 = best, 5 = poorest). Each tree was scored by a quick, visual estimate.

ANOVA was first used to determine if there were differences at age 5 years among families from each of the sources represented in the five plantings. Degrees of freedom for a typical analysis of data from a single seed collection area in the North Carolina planting, for example, were: replications = 6, families = 9, error = 54. The experimental unit was the mean of the 4-tree family plots. Values were calculated for missing plots; augmented means were used thereafter in the analysis of data combined from more than one planting, and adjustments were made to the treatment sums of squares and degrees of freedom for error (YATES, 1933). Source means, which were based on 40-tree plots, were more precise than family means within sources, which were based on 4-tree plots.

Various confounding influences prevented comprehensive analysis of seed source ×planting location and family × planting location interactions. All seed sources were not represented at all planting locations and all the seed for the study was not collected the same year. Also, the same

Table 1. — Average fifth-year height (in meters) of 22 seed sources of sycamore in five planting locations.

Seed Source		Planting Location[1]				
ID	Location	Northeast NC	Northeast SC	Northeast AR	Central MS	South LA
				Atlantic Coast Transect		
1	Northeast NC	4.5ab[2][3]	5.7ab	3.5 bc	5.2 bc	-
2	East-central NC	3.9 c	5.0 b	3.0 d	4.8 cd	3.1 e
17	Southeast NC	-	-	-	Δ4.8 cd	-
3	Northeast SC	4.3 bc	Δ5.7ab	Δ2.9 d	5.7 b	Δ3.4 de
4	Northeast SC	-	-	-	5.4 b	-
12	East SC	Δ4.7a	5.9ab	4.3 b	-	4.4abc
5	Central GA	-	-	4.1 b	5.5 b	4.3abc
5A	Central GA	-	-	-	6.0a	-
7	Southwest GA	-	-	3.9 b	Δ6.3a	4.6ab
7A	Northwest FL	-	-	-	6.2a	-
				Mississippi Valley Transect		
16	South IL	4.1 bc	Δ5.7ab	Δ3.5 bc	4.5 d	3.5 de
15	West TN	4.4abc	6.1a	4.0 b	5.5 b	Δ4.2 bc
14	Southwest TN	-	-	Δ3.6 bc	-	-
13	North MS	4.6ab	6.1a	Δ4.1 b	5.4 b	4.2 bc
11	West-central MS	4.5ab	6.0a	3.9 b	5.6 b	Δ3.8 cd
10	Southwest MS	4.8a	5.6ab	Δ3.4 bc	Δ5.3 b	-
6	Southwest MS	-	-	-	-	4.9a
8	South LA	-	Δ5.2ab	Δ3.8 b	Δ5.7 b	4.5ab
13P	East TX	-	-	3.8 bc	-	-
15P	East TX	-	-	Δ4.6a	-	-
22P	East TX	-	-	4.0 b	-	-
27P	East TX	-	-	4.2 b	-	-

1/ NC = North Carolina, SC = South Carolina, AR = Arkansas, MS =Mississippi, LA = Louisiana, GA = Georgia, FL = Florida, IL = Illinois, TN = Tennessee, TX = Texas.

2/ Means followed by the same letter (within a planting location) are not significantly different at the 0.05 percent level according to Duncan's New Multiple Range Test.

3/ Significant variation among families within source is indicated by "Δ".

trees were not always used at a given collection point in the 1967, 1970, and 1974 seed collections. Therefore, balanced subsets of the data had to be used to approximate genotype × environment (GE) interactions.

Results

Height. — Height at 5 years was fairly well-correlated with latitude of origin along the Atlantic Coast transect, with the exception of the trees from northeast North Carolina that grew somewhat faster than expected (*Table 1*). The latitude-height correlation along the Atlantic Coast transect was best expressed in the plantings in the Carolinas and southern Louisiana and most poorly expressed in the northeast Arkansas planting where the slowest growth occurred.

In the Mississippi River Valley portion of the test the trees of southern Illinois origin were distinctly slower growing wherever planted, but the pattern of variation was essentially random among the collections for western Tennesse to southern Louisiana. The WGFTIP Texas trees, whose parents were select phenotypes, performed relatively well in northeast Arkansas, the only place they were tested. One Texas source in particular, 15P, was significantly taller than any other source in the Arkansas plant-

Table 2. — A balanced subset of the fifth-year height data showing seed source, planting location effects, and their interaction.

Seed Source		Planting location 1/						Analysis of variance 3/		
		Eastern NC	Eastern SC	Northeast AR	Central MS	South LA	X̄ 2/		d.f.	Mean Square
		Height (m)								
2	East-central NC	3.9	5.0	3.0	4.8	3.1	4.0 c	Locations	4	264.31*
								Reps/loc	31	11.45
3	North-east SC	4.3	5.7	2.9	5.7	3.4	4.0 c	Seed source	5	35.72*
								Loc x SS 3/	20	1.75
16	South IL	4.1	5.7	3.5	4.5	3.5	4.1 bc	SS x reps/loc	155	1.69
15	West TN	4.4	6.1	4.0	5.5	4.2	4.8a			
13	North MS	4.6	6.1	3.6	5.4	4.2	4.9a			
11	West-central MS	4.5	6.0	3.9	5.6	3.8	4.6ab			
Average		4.3	5.7	3.4	5.2	3.7	4.4			

1/ See *Table 1* for explanation of abbreviations.
2/ Means within this column followed by the same letter do not differ significantly at the 0.05 level of significance.
3/ blks = blocks; loc = planting locations; SS = seed source; * indicates significance at the 0.05 percent level.

Table 3. — A balanced subset of the data showing family × planting-location interaction for fifth-year height (in m) of families in three seed sources.

Seed Source	Planting location 1/	Family mean within seed source 2/											Analysis of variance		
		2	3	4	5	6	7	9	11	12	13	X̄		d.f.	Mean Square
1 Northeast NC	AR	3.8	3.5	3.7	3.8	3.5	3.2	3.4	3.4	3.5	3.7	3.5	Locations	2	70.01*
	NC	4.6	4.6	4.8	4.6	4.7	4.4	4.3	4.5	4.4	4.2	4.5	Reps/loc	16	5.95
	SC	6.3	5.8	5.5	5.4	6.0	5.4	5.6	5.6	5.8	5.6	5.7	Families	9	0.49
													Loc x fams	18	0.23
													Fams x reps/loc	154	0.31
	X̄	4.9	4.6	4.6	4.6	4.7	4.3	4.5	4.5	4.5	4.5	4.6			
		Family mean within seed source 2/													
		1	2	3	7	8	9	11				X̄			
2 East-central NC	AR	3.1	2.9	3.4	3.0	2.7	3.1	3.1				3.1	Locations	2	45.35*
	NC	3.9	4.2	4.0	4.2	4.3	4.0	3.6				4.0	Reps/loc	16	3.34
	SC	5.2	5.5	5.9	4.8	4.9	5.6	4.9				5.1	Families	6	0.31
													Loc x fams	12	0.42
													Fams x reps/loc	126	0.32
	X̄	4.1	4.2	4.2	4.0	4.0	4.2	3.8				4.1			
		Family mean within seed source 2/													
		1	2	3	4	5	6	7	8	9	10	X̄			
11 West-central MS	AR	3.8	4.2	4.0	3.6	3.8	4.2	4.0	3.8	4.1	3.8	3.9	Locations	2	73.08*
	NC	4.3	4.8	4.5	4.3	4.4	4.6	4.7	4.6	4.3	4.3	4.5	Reps/loc	16	1.77
	SC	6.0	6.6	5.9	6.0	6.3	5.8	6.6	5.8	5.4	5.9	3.3	Families	9	0.71
													Loc x fams	18	0.31
													Fams x reps/loc	139	0.30
	X̄	4.7	5.2	4.8	4.6	4.8	4.9	5.1	4.7	4.6	4.7	4.8			

1/ See *Tables 1* and *2* for explanation of most abbreviations; fam = families; ns = not significant at 0.05 percent level.
2/ There was no significance (0.05 level) among family means at any of the planting locations.

ing. Phenotypic selection and geographic effect are confounded in the case of the Texas families, but this result speaks well for the WGFTIP selection procedures used for sycamore.

Analysis of a balanced subset of height data from six widely distributed seed sources common to five planting location showed seed source × planting location interaction to be much smaller than the significant seed source effect *(Table 2).* This is particularly noteworthy in that the east-west span of these seed sources and plantings is quite large — nearly 1,600 km.

Various imbalances dictated that determination of family × planting location effects be restricted to balanced subsets of the data. Three seed sources fulfilled the necessary requirements (*Table 3*) and each included 7 to 10 families planted at 3 locations. However, family × planting location interaction over the three locations was small and not significant in any of the three sources.

ANOVA of the height data from the nine individual source plantings in the balanced subset (three sources × three locations) in *Table 3* showed no instances of significant differences among families in any of the three sources. With the increaese in precision and degrees of freedom associated with combined location analysis, significance was attained among the 10 families in seed source 11 but not among the families of seed sources 1 and 2.

Additional evidence of significant family effects can be observed in *Table 1*. Of the 60 ANOVA's run on data from an individual source within a single planting, 18 sources showed significant differences among families. Two seed sources, number 3 from northeast South Carolina and number 8 from south Louisiana, showed significant differences among families at three of the five planting locations. This raised the question of whether certain families in these two sources maintained their rank over all planting locations. Results in seed source 8 (south Louisiana) were inconclusive because of a lack of common families, but families in seed source 3 (northeast South Carolina) were consistent from planting to planting (*Table 4*).

Timing of leaf fall. — Sycamore trees from southern seed sources tend to hold their leaves later into the fall than those from the more northern provenances *(Table 5).* A smooth cline was demonstrated at the three planting sites where the trait was observed and leaf fall was well-correlated with latitude of seed origin along both the Atlantic Coast and Mississippi River transects. Selection pressure for this trait has obviously been intense, and the trait is under very strong genetic control. Seed source × planting location interaction was negligible.

Table 4. — Families in seed source 3 (northeast South Carolina) ordered on the basis of fifth-year height in five plantings[1].

Planting Location[2]				
NC	SC	AR	MS	LA
-----	-----	family	-----	-----
3[2]	1	4	3	2
1	5	3	1	7
4	4	7	2	1
2	8	1		6
7		2		11
5		8		13
10		9		4
9		10		5
8		5		8
		6		

[1]/ Tallest families at top of *table*, shortest at bottom.
[2]/ See *Table 1* for explanation. of abbreviations.

Table 5. — Proportion of leaves that fell by the measurement data in November 1977; 20 seed sources of sycamore at 3 planting locations.

Seed Source		Planting Location[1]		
ID	Location	Northeast NC	Northeast SC	Northeast AR
		Atlantic Coast Transect		
1	Northeast NC	Δ89.6a[2][3]	75.9 bc	97.5abc
2	East-central NC	91.4a	75.1 bc	98.7ab
17	Southeast NC	-	-	-
3	Northeast SC	81.0 c	67.6 bc	92.4abcdef
4	Northeast SC	-	-	-
12	East SC	84.1 bc	53.5 d	Δ91.7 b def
5	Central GA	-	-	92.8ab def
7	Southwest GA	-	-	90.0 ef
		Mississippi Valley Transect		
16	South IL	Δ93.3a	Δ91.3a	99.0a
15	West TN	87.6ab	Δ65.8 c	96.6abcd
14	Southwest TN	-	-	98.0abc
13	North MS	Δ87.7ab	77.4 b	98.0abc
11	West-central MS	74.2 d	Δ53.2 d	Δ93.9ab de
10	Southwest MS	Δ63.4 e	Δ31.1 e	Δ88.4 efg
6	Southwest MS	-	-	-
8	South LA	-	32.2 e	82.9 g
13P	East TX	-	-	Δ87.2 fg
15P	East TX	-	-	87.2a fg
22P	East TX	-	-	90.9 cdef
27P	East TX	-	-	90.1 def

[1]/ See *Table 1* for explanation of abbreviations.
[2]/ Means followed by the same letter (within a planting location) are not significantly different at the 0.05 percent level according to Duncan's New Multiple Range Test.
[3]/ Significant variation among families within source is indicated by "Δ".

There was also considerable variation among half-sib families within sources. Statistically significant differences among families were demonstrated in one-third of the seed source × planting location analyses shown in *Table 5*. It is interesting that so much tree-to-tree variation remains within local populations even after the intense selection pressure exerted on the population by the broad-ranging forces of climate and photoperiod.

Family × planting location interaction was statistically significant in one of the three seed source × planting location combinations where the data were adequately balanced for analysis. This effect is presumably of a random nature. No systematic interaction of certain families with specific sites was evident.

Quality score. — This trait, though based on a subjectively graded score, is quite useful when selecting individual trees or families in replicated field tests. It is, however, more accurate at assessing variation within individual plantings than between plantings. An observer quickly forms a mental image of the mean and range of variation in "quality score" for a given planting, but it is difficult to carry over the attributes of a given score from one planting to another. For this reason, little credence should be given to the differences in quality score among plantings shown here. Differences among and within seed sources within single plantings, on the other hand, are probably quite accurate. Statistically significant differences were demonstrated in two of the four plantings where this trait was observed (*Table 6*). There was no geographic pattern to the variation. This is not surprising, as there seems to be little survival value that can be attributed to stem form and crown characteristics in an area that receives as little snow and ice as the southeastern United States. The Texas seed sources produced somewhat straighter, more finely-crowned trees than the other seed sources. This could very well have been due to the selection procedures employed by the WGFTIP. They seem to have been as effective here as they were for growth rate.

Table 6. — Fifth year quality (1 = best, 5 = poorest); 22 seed sources of sycamore at 4 planting locations.

Seed Source		Planting Location[1]			
ID	Location	Northeast NC	Northeast SC	Northeast AR	Central MS
			Atlantic Coast Transect		
1	Northeast NC	4.2a [2][3]	3.1a	3.4abc	3.2 bc
2	East-central NC	4.4a	3.1a	3.6 c	Δ3.2 bc
17	Southeast NC	-	-	-	3.2 bc
3	Northeast SC	4.2a	Δ3.2a	3.5 bc	3.1ab
4	Northeast SC	-	-	-	Δ3.3 c
12	East SC	4.2a	3.0a	3.2a	-
5	Central GA	-	-	3.2a	3.2 bc
5A	Central GA	-	-	-	3.0a
7	Southwest GA	-	-	Δ3.3ab	3.0a
7A	Northwest FL	-	-	-	Δ3.1ab
			Mississippi Valley Transect		
16	South IL	4.2a	3.0a	Δ3.4abc	3.2 bc
15	West TN	4.3a	2.8a	3.4abc	3.1ab
14	Southwest TN	-	-	3.2a	-
13	North MS	4.1a	2.8a	3.4abc	3.1ab
11	West-central MS	4.2a	2.9a	Δ3.3ab	3.1ab
10	Southwest MS	4.3a	Δ2.6a	Δ3.3ab	3.1ab
6	Southwest MS	-	-	-	-
8	South LA	-	2.9a	Δ3.3ab	3.1ab
13P	East TX	-	-	Δ3.1a	-
15P	East TX	-	-	3.1a	-
22P	East TX	-	-	3.2a	-
27P	East TX	-	-	3.3ab	-

[1]/ See *Table 1* for explanation of abbreviations.
[2]/ Means followed by the same letter (within a planting location) are not significantly different at the 0.05 percent level according to Duncan's New Multiple Range Test.
[3]/ Significant variation among families within source is indicated "Δ".

Seed source × planting location and family × planting location interactions were both small. Family variation within individual seed sources was sizable, however. Eleven of the 49 seed source × planting location combinations in *Table 6* demonstrated significant differences.

Discussion and Conclusions

The data presented on timing of leaf shed in the fall demonstrate a well-developed pattern of genetic variation in sycamore in response to geographic features of the environment. Apparently, the adaptive value of the trait is crucial enough to survival, and the selection pressure strong enough, to effect genetic change. Schmitt and Webb (1971) found data of foliation in the spring to be under similarly strong genetic control in sycamore when seed was collected along a north-south transect through Georgia and then planted in southern Mississippi. Trees from south Georgia foliated about 10 days earlier than those from the southern Appalachians.

Growth rate, the trait of principal value to a genetic improvement program, also demonstrated considerable genetic differentiation over the study area. Although this variation is not as distinct nor as well-correlated with latitude as the timing of leaf shed, a pattern can be seen from this and other provenance tests of sycamore in the lower Mississippi River valley.

Nebgen and Lowe (1982) tested sycamore from southern Arkansas to southern Louisiana and southeastern Texas (latitude 33°45' to 30°00') and found no differences in growth rate. Land (1981) sampled sycamore throughout Mississippi and parts of adjacent states (latitude 34°30' to 30°30') and found no conclusive latitudinal correlation with height when his plantings were 4 years old. He did find, however, a trend of increasing volume (height and diameter combined) with decreasing latitude along the Mississippi River. Ferguson *et al.* (1977) found very clear evidence of the latitudinal effect on height growth in plantings established from sycamore collections along the Mississippi River from near New Madrid, Missouri (latitude 36°25'), to Vidalia, Louisiana (latitude 31°25'). Land (1981) also demonstrated a longitudinal effect in his study area. Sycamore from near the Mississippi River generally had greater 4-year volume than trees originating at the same latitude but up to 240 km east or west of the river. As in Land's test, the present study does not show a linear trend of increasing height growth with decreasing latitude of origin within the 640 km span from northern to southern Mississippi, but as in Ferguson's test, a collection from above 36° latitude (in the present study southern Illinois at 37°37') produced trees that were distinctly slower growing than those originating from western Tennessee or further south.

The present study shows a clinal relationship between height and latitude of origin along the Atlantic Coast transect. Schmitt and Webb (1971) also demonstrated this relationship along a north-south transect through Georgia along the Chattahoochee River.

In summary then, the relationship between height growth and latitude of seed origin is well-established throughout the southeastern United States range of sycamore, but a perturbation to the cline apparently exists in and around the lower Mississippi River Valley. Evolution in the broad fertile floodplain of the river may have resulted in faster-growing populations than on the adjacent uplands and floodplains of the smaller rivers. The lack of a cline along the lower Mississippi may also be the result of constant migration of genes down river.

Selection of sycamore seed from different geographic areas for reforestation in the southeastern United States must depend as much upon resistance to the cankering disease mentioned earlier as it does upon growth rate and cold resistance. Plantings of the present study escaped infection for five years but evidence indicates that plantings anywhere in the southeastern United States are at risk. Use of proper geographic seed sources offers a means of minimizing damage from the disease. Using seed from slightly south of the intended planting site has been recommended as trees of southern origin have performed better than those of northern origin in several tests (COOPER *et al.*, 1977; COGGESHALL *et al.*, 1981).

Seed collection and planting zones. — Most provenance tests of sycamore in the southeastern United States are young, but trends are emerging, and at least tentative seed collection areas and planting zones can be proposed at this point. The growth trait in the present study, 5-year height, does not show close adaptive matching of genotype and environment over short distances in the southern Coastal Plain. Trees from southern Georgia and Louisiana were moved about 800 km north in the present study and suffered no obvious cold damage. In fact they were the fastest growing of the seed sources tested in the northern plantings, just as they were in plantings where they were the local seed source. This is not to recommend that such seed movement be done — GE interaction may be better expressed as the tests mature and better sample the vicissitudes of their environments. Given the present state of knowledge, a reasonable rule of thumb would be to collect seed up to 250 to 300 km south of the intended planting sites for planting south of the 34th parallel of latitude (northern boundary of Mississippi). This would be conservative enough to avoid cold damage, and it would take advantage of the generally faster growth rate of trees of southern origin. Most important, it would minimize the risk of incurring stem canker disease.

Most provenance tests of sycamore, including the present one, have shown substantial amounts of heritable tree-to-tree variation in growth rate within the provenances sampled. Genetic improvement through selection and progeny testing would most likely proceed at a rapid rate in sycamore if commitment to this task were to be made by forest industry and other firms that plant sycamore. Material from tests such as those reported here are logical starting points for such improvement programs, as selection has already been carried on for one complete generation.

Literature Cited

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Stand-Volume Prediction of Improved Trees Based on the Realized Gain in Progeny Tests of HINOKI (Chamaecyparis obtusa Endl.)

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Summary

Stand-volume prediction based strictly on the realized gain in thirteen progeny-tests of HINOKI (*Chamaecyparis obtusa* ENDL.) were made by using a reciprocal-equation of yield-density effect connected with site-index curves. In this study, height-growth superiorities of plus-tree progenies over commercial-checks are regarded as the realized gain of correlated-responses by plus-tree tree selection, and it is found to be equivalent in the mathematical form to the site-index formula if its standard-deviation equation is derived from within stand variation of individual tree height.

2.6% increase in site-index of improved trees at the base age of forty years was calculated based on the 5.7% gain in progeny-tests at five years old, and it is expected to bring 6 to 8% increase in stand volume for this species. Then the proof of this estimate as the lower-limit value was given in relation to the difference between heritability and coheritability used to express the correlated response found in progeny-tests. Furthermore, a possibility of over-estimation on future breeding gain which was reported by other scientists with the use of conventional site-index formulae was pointed out by contrasting the standard-deviation curve of between stands height variation with that of within stand variation.

Key words: Plus-tree selection, progeny test, genetic gain, correlated response, yield-density effect, stand-volume prediction, site index curves.

Zusammenfassung

Auf der Grundlage der realisierten Züchtungsfortschritte in 13 Nachkommenschaftsprüfungen bei Hinoki (*Chamaecyparis obtusa* ENDL.) wurden Voraussagen über das Bestandesvolumen gemacht. Dabei wurden in Verbindung mit Bonitäts-Index-Kurven eine reziproke Gleichung des Ertragsdichteeffektes benutzt. In dieser Studie wird die Überlegenheit im Höhenwachstum von Plusbaum-Nachkommenschaften über kommerzielle Vergleichsproben als der

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