PATTERNS OF GENETIC VARIATION AMONG TEN-YEAR-OLD OPEN-POLLINATED MID-SOUTH SEED SOURCES OF AMERICAN SYCAMORE [1/]

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Abstract.--One-year-old seedlings of 96 open-pollinated American sycamore (Platanus occidentalis L.) families from 16 seed sources in AL, MS, LA, and AR were planted in a compact family design in south-central LA in 1976. Seed source and family components of genetic variation were significant for height, dbh, volume, and stem canker infection, and would allow for substantial gains through source and family-within-source selection. The best 9 families (top 10%) came from the two Mississippi river sources closest to the plantation. The means for these families in this plantation were better than the plantation mean by 2.1 m for ht, 2.4 cm for dbh, 26.6 cu decimeters for volume, 14% for survival, and 29% less for stem canker infection at age 10 years.

Additional keywords: geographic variation, progeny testing.

INTRODUCTION

American sycamore is a common bottomland hardwood widely distributed throughout the eastern half of the United States. Until recently its commercial value was limited to package veneer, factory and box lumber, and furniture (Putnam et al 1960). However in the early 1970's sycamore was proposed as an excellent species for short- rotation production of biomass for energy and paper pulp (Steinbeck et al 1972). Research has included investigation of genetic variation available to increase growth and yield in plantations.

In Louisiana, sycamore is one of several hardwood species planted to convert old bottomland fields to commercially productive forests. Such conversion has recently increased, resulting in a demand for genetically improved sycamore seedlings. This study provides information needed to implement a program of selection which should result in an increase in volume production of sycamore at a time of increasing demand for hardwood fiber in Louisiana and neighboring states.

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MATERIALS AND METHODS

Site Description

Location - The study was established on the Thistlethwaite Wildlife Management Area, four miles northeast of Washington, LA (latitude 30°40' N, longitude 92°0' W) (Figure 1), in the Red River Region of the Lower Mississippi River Delta.

Soil - The soil is a Dundee silty clay loam, a member of the fine-silty, mixed, thermic family of Aeric Ochraqualfs (Murphy et al 1986). It is a level, somewhat poorly drained, and medium in fertility alluvial soil located just off the bank of Bayou Wauksha. Having been in cultivation for over 20 years, the soil is moderately compacted, and contains a plowpan at a depth of about 25 cm.

Based on the species composition of surrounding timber stands, the site is best suited for cherrybark oak (Quercus falcata var. pagodifolia Ell.) and sweetgum (Liquidambar styraciflua L.). According to Broadfoot (1976) the site index of sycamore for a Dundee silty clay loam ranges from 29 to 35 m in 50 years.

Figure 1. Location of seed sources and planting test site used to evaluate variation of ten-year-old American sycamore characteristics.

Plantation Description

Genetic Material - Sixteen seed sources from the Mid-South region (Figure 1) were tested at this site as part of a cooperative study. Dr. S. B. Land, Jr., Mississippi State University, provided the genetic material. Table 1 contains a description of each seed source location. Seed was collected from two stands at each seed source and from three open-pollinated parent trees per stand (six trees per seed source) making a total of 96 families tested. No selection criteria were used during seed collection. Seedlings were grown at the Winona Nursery of the Mississippi Forestry Commission.

Experimental Design - The plantation was laid out as a compact family design, a split-plot within a randomized complete block design. Seed sources were blocked within each of six replications, and three-tree row plots for each family were randomly placed within their source block.

Establishment and Maintenance - In March, 1976, 1-0 seedlings were planted on 3m x 3m spacing using KBC bars. No site preparation was necessary as the seedlings were planted on soybean stubble. Weed control consisted of discing between trees twice each year during the first two years and mowing twice each year during the next two years. No thinning was applied in the plantation.

Table 1. Location of seed sources used to study genetic variation of ten-year-old American sycamore characteristics.

Source Code	State	County/ Parish	River Drainage	Lat. (North)	Long. (West)
S	AR	Grant and Saline	Saline	34°25'	98°38'
H	AR and MS	Phillips and Coahoma	Mississippi	34°27'	90°40'
T	MS	Marshall	Tallahatchie	34°35'	89°29'
I	MS	Itawamba	Tombigbee	34°22'	88°26'
C	AR	Drew	Saline	33°28'	91°54'
G	MS	Bolivar	Mississippi	33°37'	91°09'
K	MS	Attala	Big Black	33°34'	89°58'
L	AL	Pickens	Tombigbee	33°16'	88°18'
O	LA	Catahoula	Ouachita	31°52'	91°54'
N	MS	Jefferson	Mississippi	31°47'	91°15'
J	MS	Copiah	Pearl	32°26'	90°15'
A	AL	Choctaw and Marengo	Tombigbee	32°15'	87°28'
F	LA	Pt. Coupee and W. Feliciana	Mississippi	30°53'	91°38'
B	LA and MS	Washington and Pearl River	Pearl	30°46'	89°50'
P	MS	George	Pascagoula	30°48'	88°43'
M	AL	Baldwin	Tombigbee	30°57'	87°55'

Characteristics Studied

Tenth-year-measurements were taken during February - March,1986, and Included diameter at breast height (0.1 inches) and total height (ft). A visual estimate was made on the percentage of stem length that had been killed by sycamore stem canker. This stem disease was believed to be caused primarily by two canker fungi, Ceratocystis fimbriata Ellis and Halst. and Botryodiplodia theobromae Pat. (Cooper et al 1977). Stem volume inside bark (i.b.) was calculated using the following equation from Land (1982):

$$\text{Volume} = 2.26 + .0335 \times (\text{dbh}^2 \times \text{ht})$$

where volume = stem volume i.b. in cubic decimeters (cu dm); dbh = diameter at breast height in cm; and ht = total height in m.

Statistical Analysis

Tests of significance for sources of variation were done on a plot mean basis using the glm procedure of Statistical Analysis System (SAS Institute, Inc. 1985). All sources of variation were assumed to be random. Influence of seed source latitude on sycamore characteristics was evaluated by separating seed source variation into variation among the four latitudinal transects (Figure 1) and variation within the transects. When F-tests were significant Duncan's multiple range test, (alpha = .05) was used to separate means. Genetic variance estimates were calculated using mean squares from analysis of variance.

RESULTS AND DISCUSSION

Plantation Averages

Height at age 10 yrs averaged 9.56 m. Average dbh was 10.4 cm and, stem volume inside bark averaged 45 cu dm. Survival was 80% at age 10 and 30% of the plantation was infected by stem canker fungi. Stem cankers killed an average of 70% of the height and 48% of volume i.b. on infected trees. Half of the trees infected by stem canker were dead at age 10. Death from stem cankers accounted for 72% of the total mortality in the plantation during the first 10 years. Thus, survival was heavily dependent on stem canker resistance and additional mortality will most likely occur as Land (1982) found that most trees die within two years of stem canker formation. Smaller, weaker trees in this plantation had the greatest stem canker infection. No disease was found on the largest trees, 15 to 19 cm in dbh. To reduce the influence of cankers, only heights and volumes of healthy trees were used and dbh was used for analysis only when trees had 20 percent or more of their stem length alive.

Analysis of Variance

A ranking of the genetic components indicates that seed source variation was greater than family variation, which was greater than stand variation (Table 2). With the exception of survival, stand variation within seed source was low and considered to be unimportant. Stand variance for survival was significant but there was no family variance. Environmental variation (rep) and G x E variation (rep x seed source) were significant for height, dbh and volume. Only genetic components of variation were significant for stem canker infection supporting the conclusion that all trees have been exposed to the disease.

Table 2. Estimated values and significance levels of variance components (σ^2) in a ten-year-old American sycamore progeny test near Washington, LA.

Source of Variation	Characteristic at age 10 years: Height (m)	DBH (cm)	Volume i.b. (cu dm)	Survival (%)	Stem Canker Infection(%)
Genetic variation estimates (σ^2)					
Seed Source (P)	.984**	.881**	95.0**	220.7**	715.3**
Latitude(L)	.299	.162	0	252.8**	732.1**
Source/L	.681**	.661**	89.8**	21.1	66.6*
Stand (S)/P	0	.097	8.0	31.9*	1.2
Family (F)/SP	.117**	.331**	20.3**	0	82.1**
Environmental and G x E variation estimates (σ^2)					
Rep (R)	.401**	.496**	36.3**	8.1	16.0
P x R	.659**	.877**	71.2**	22.6	31.8
L x R	.182*	.077	17.8	20.9*	3.0
S/L x R	.504**	.839**	55.0**	3.6	29.5
S/P x R	.019	.198	20.0	22.6	1.6
Error	1.011	2.636	195.7	429.4	504.7

** = significant at the .01 level of probability
* = significant at the .05 level of probability

Seed Source Variation

Latitude of seed source explained most of the variation in percent infection by stem cankers (Table 2). Southern sources were more resistant to infection while sources from the northern most latitude were highly susceptible. Forty to 80% of Arkansas and northern Mississippi source trees (H,I,S,T) were infected by stem canker by age 10 (Table 3). The same trend was found by Land (1982) on a test site at Vicksburg, MS, containing the same seed sources. In both studies, resistance to stem canker infection was

found in sources from southeastern LA and along the lower portion of the Mississippi river. The best two seed sources at age 10 were F (West Feliciana Parish, LA) and N (Jefferson County, MS) for height, dbh, and volume (Table 3). They were also lowest in percent of trees with stem canker infection. Both sources were located along the Mississippi River and were the closest to the test site. They were 1.8 m (19%) taller than the plantation average in height and 2.0 cm (20%) larger in dbh. These two sources on average produced 22 cu dm (49%) more volume per tree, had 16% better survival and had 29% less stem canker infection. Seed sources F and N were also the best in growth and stem canker resistance when tested at a site near Vicksburg, MS (Land 1982). Similar performance of sources at the two sites indicates that the source G x E interaction is not very strong.

Table 3. Seed source means for American sycamore characteristics in a ten-year-old progeny test near Washington, LA.

Seed Source	Characteristic at age 10 years 1/ Height (m)	DBH (cm)	Volume ib (cu dm)	Survival (%)	Stem Canker Infection(%)
N	11.51a	12.35a	66.2a	90.7ab	0.9a
F	11.24ab	12.45a	67.8a	97.2a	0.0a
B	10.84b	11.25b	53.0bc	89.8ab	1.9s
G	10.10c	11.38b	54.6b	87.2ab	21.2cd
A	9.94cd	10.56bc	45.7cd	92.6a	27.8de
O	9.74cde	11.36b	49.3b	92.6a	5.2ab
K	9.43def	9.94cde	39.4def	89.2ab	23.7d
P	9.40def	9.98cde	38.6def	92.5a	16.1bcd
J	9.32ef	10.40cd	41.0de	93.9a	3.5a
T	8.94fg	9.29ef	36.7ef	65.8c	71.9i
M	8.93fg	9.53def	35.3ef	89.2ab	11.8ac
C	8.47gh	9.39ef	33.6ef	80.6b	44.4f
H	8.35hi	9.89cde	37.9def	64.8c	55.7h
L	8.28hi	9.26ef	33.6ef	79.6b	35.2ef
S	7.85i	8.95fg	31.0f	41.7d	80.6i
I	6.41j	8.22g	21.0g	42.5d	80.0i
Plantation Average	9.56	10.36	45.0	80.6	29.9

1/ Seed source means followed by different letters within a characteristic were significantly different at alpha = .05 (Duncans multiple range test).

Family Variation

Family means at age 10 ranged from 4.6 to 12.0 m for height; 5.2 to 14.6 cm for dbh; 17 to 92 cu dm for volume i.b. per tree; and 8 to 100% for survival. Of the 96 families 12 had 100% survival. No canker infections were found in 28 families while 3 families from seed source I, Itawamba County, MS, had 100% infection. When the above 28 disease-free families

were tested at Vicksburg, MS (Land 1982) 12 had some trees with stem cankers. In addition, 10 disease-free families at Vicksburg had some diseased trees in this study. This suggests there may be a strong family G x E interaction in sycamore resistance and/or pathogen virility relative to plantation location.

The best nine families (top 10%) in height (Table 4) came from the best two seed sources, F and N. The mean performance of these nine families was greater than the plantation average by 2.1 m in height, 2.4 cm in dbh, 6.6 cu dm in volume i.b. per tree, and 14% in survival. In addition, these families had 29% less stem canker infection.

Table 4. Characteristic values of the best 9 families (top 10%) in a ten-year-old American sycamore progeny test in south-central LA.

Family Description			Characteristic at age 10 years				
Source	Stand	Family	Height (m)	DBH (cm)	Vol. i.b. (cu dm)	Survival (%)	Stem Canker Infect.(%)
F	1	1	11.96	14.55	91.86	100.0	0
F	1	8	11.76	13.26	76.25	100.0	0
N	2	4	11.71	13.47	78.07	88.9	5.6
F	2	4	11.67	12.76	72.73	83.3	0
N	1	10	11.63	12.29	66.52	100.0	0
N	2	8	11.56	11.88	59.85	94.4	0
F	2	1	11.55	11.98	65.07	100.0	0
N	2	1	11.44	12.83	70.16	94.4	0
N	1	5	11.48	12.14	64.28	94.4	0
Top Families Average			11.64	12.80	71.64	95.1	.6
Plantation Average			9.56	10.36	45.02	80.6	29.9
Difference			2.08	2.44	26.62	14.5	-29.3

CONCLUSIONS

Source of seed for seedlings can be very important when planting sycamore in Louisiana, particularly relative to stem canker disease resistance. Substantial gains in survival, height, diameter, volume, and stem canker resistance can be obtained in south-central Louisiana if sycamore seed is collected from sources in the lower Mississippi river valley (Natchez, MS and south). Further gains can be attained if family-within- source selection is performed.

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