GENETIC PERFORMANCE AND EARLY-AGE SELECTION WITHIN A TEN-YEAR OLD MID-WEST SYCAMORE PROGENY TEST

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Abstract --Geographic seed source adaptability, family performance and early-age selection were investigated in a ten-year-old open-pollinated American sycamore test located in southern Illinois. Low genetic (r_g = 0.06) and phenotypic correlations (r = 0.44) between age-1 height and age-10 volume indicate the uselessness of age-1 height as a correlated selection trait. Large genetic (r_g = 0.96) and phenotypic correlations (r = 0.73) between age-6 height and age-10 volume suggest the use of age-6 height as early-age selection trait. Estimates of indirect gain for age-10 volume obtained through coefficients of genetic prediction (CGP) and correlated response (CR) were highest from selection of age-7 height (e.g. CGP = .131, CR = 18.0%). In terms of genetic gain per unit of time age-6 height provided the optimal selection differential for age-10 volume.

The Alabama and South Carolina seed sources were taller than the Kentucky source at age 1. This ranking was reversed by age 2 and has held stable through age 10. The Kentucky source produced the highest total volume, yielding approximately 11 percent more volume per acre than the Alabama source and 20 percent more than the South Carolina source.

Keywords: *Platanus occidentalis* L., early-age selection, coefficient of genetic prediction, correlated response.

INTRODUCTION

Increased genetic gains per unit of time will result from early-age selection of sycamore (*Platanus occidentalis* L.). Rapid juvenile growth culminating in a 15-year pulpwood rotation is expected when sycamore is grown on rich alluvial soils. Short rotations accentuate the need for effective early-age selection strategies. Various methods have been used to determine effective early-age selection by many authors including Foster (1986a), Loo and others (1984), Lambeth and others (1983), and Squillace and Gansel (1974). Two methods, correlated response (CR) (Falconer 1960) and coefficients of genetic prediction (CGP) (Baradat 1976), were used in quantifying early-age selection efficacy. Increasing the efficacy of early-age selection in sycamore also provides the breeder the option of clonal propagation. Thus, shorter test duration, increased gains per unit of time, and the ability to clonally propagate selections emphasize the necessity for early-age selection in sycamore.

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The purpose of this study was to determine seed source differences, genetic variability among families and provide information on optimal selection age.

METHODS

Open-pollinated seed from 27 sycamore mother trees was collected and grown at the Kentucky State Nursery, Gilbertsville, Kentucky during 1977. Mother tree collections were grouped into three geographic sources: South Carolina Coastal Plain (SC), central Alabama (AL), and west Kentucky, west Tennessee and southern Illinois (KY). Seedlings were outplanted as 1-0 stock on a secondary bottomland tract in Pulaski Co., Illinois. The area was formerly timbered, logged in 1976, site prepared in 1977, and row-marked and slit at a spacing of 11 x 11 feet in December 1977. The Soil Conservation Service described the test site soils as Bonnie and Belknap silt loams. They are deep but poorly drained soils derived from sediments washed off of loess uplands. The test was planted on April 3, 1978. The test design was a randomized complete block consisting of six blocks, three geographic source groups, a total of 27 open-pollinated families, and 10 tree row-plots (Table 1). Families were grouped by seed source to facilitate estimates of volume on a per acre basis.

Total height was measured at ages 1, 6, 7, and 10, while diameter at breast height was taken at ages 7 and 10. Individual total tree volumes (ft^3) were calculated for ages 7 and 10 using the equation volume = .00252 (D^2H), where D = diameter breast height and H = total height, developed by Belanger (1973) for plantation-grown sycamore.

Analysis of variance and multivariate analysis of variance were done on an individual tree basis for all traits. Variance components were estimated by equating mean squares or mean cross products with expected mean squares. Geographic source effects were considered to be fixed while all other effects were considered to be random.

Table 1. Analysis of variance and expected mean squares for the 1978 Sycamore Test.

Source	d.f.	Expected Mean Squares
Block	(b-1)	
Geographic Sources	(s-1)	$\sigma_w^2 + n\sigma_{BF/S}^2 + bn\sigma_{F/S}^2 + fn\sigma_{BXS}^2 + bfn\theta_S$
Block*Geo. Sources	(b-1)(s-1)	$\sigma_w^2 + n\sigma_{BF/S}^2 + fn\sigma_{BXS}^2$
Family/Geo. Sources	(f-1)s	$\sigma_w^2 + n\sigma_{BF/S}^2 + bn\sigma_{F/S}^2$
Block*Family/Geo.Sources	(b-1)(f-1)s	$\sigma_w^2 + n\sigma_{BF/S}^2$
Error	bsf(n-1)	σ_w^2

Estimates of narrow-sense heritabilities and genetic and phenotypic correlations were calculated from the estimated components of variance and covariance (Becker 1975). Coefficients of genetic prediction (CGP) were derived from procedures outlined in Baradat (1976) and van Buijtenen and Tuskan (1986). The indirect gains estimated by the correlated response (CR) were derived from Falconer (1960).

RESULTS AND DISCUSSION

Test survival has remained fairly stable from age 2 (91%) through age 10 (90%). Total height at ages 1, 2, 6, 7 and 10 for the entire test averaged 4.7, 24 29, and 46 ft., respectively. Average dbh and volume were 3.8 in. and 1.17 ft', respectively at age 7 and 5.4 in. and 3.61 ft^3, respectively at age 10. The overall slower growth of this test, relative to growth expected on alluvial soils, is indicative of less favorable soil moisture and lower fertility of secondary bottoms.

No significant survival differences were detected among the three sources through time. At age 10 all three sources averaged approximately 90 percent survival. Age-1 height of the SC source (4.8 ft.) was slightly taller than the AL (4.7 ft.) and KY (4.6 ft.) sources, however by age 10 this pattern was reversed. Average height, dbh, and volume at age 10 were greater for the KY source (47 ft., 5.6 in. and 4.0 ft^3) followed by the AL (46 ft., 5.4 in. and 3.6 ft^3) and SC (45 ft., 5.1 in. and 3.2 ft^3) sources, respectively.

Knowledge of performance of various geographic seed sources within the mid-west is imperative in defining seed source limitations. Seed source differences were nonsignificant for height at all ages. However, seed source differences were shown for dbh and volume at ages 7 and 10. Non-significant seed source differences for height at all ages contrasts with what Schmitt and Webb reported (1971), showing significant seed source effects for age-3 height in a sycamore progeny test in Mississippi. However, Land (1981), Nebgen and Lowe (1985), and Wells and Toliver (1987) found no evidence of seed source effect for height growth of sycamore. Near optimal alluvial site conditions, including the moderating effect of a large riverine system, such as the Mississippi River, seems to allow greater movement of seed sources. In contrast, secondary bottom-land sites, such as this test site, are less favorable and result in poor growth of sources adapted to milder climates. The excellent performance of the near local KY source indicates that for the southern Illinois area seed movement should be restricted to within 100 miles south of the planting site.

Highly significant differences among families-within-seed sources were shown for height at all ages (Table 2). This component of variation increased as age increased accounting for 5.4 percent of the total variation at age 1 and 7.0 percent at age 10. The block by family-within-seed source components were fairly large and highly significant for all traits at all ages. Tree-to-tree differences accounted for most of the variation associated with all traits through age 10. Tree-to-tree differences were lower for height than either dbh or volume.

Table 2. Variance components, percent of total variation (in parentheses) and significance levels for all traits .

Traits	Family/Source	Block X Family/Source	Within Plot
Age 1 Height	0.0184nsa/(1.6)	0.1036** (9.1)	1.0207 (89.3)
Age 6 Height	0.5433**b/(5.4)	1.3957** (13.9)	8.0819 (80.7)
Age 7 Height	0.6191** (5.9)	1.3771** (13.0)	8.5769 (81.1)
Age 10 Height	1.2811** (7.0)	2.0043** (10.9)	15.0328 (82.1)
Age 7 DBH	0.0220* (2.8)	0.0579** (7.4)	0.7021 (89.8)
Age 10 DBH	0.0191ns (1.5)	0.0330* (2.6)	1.2117 (95.9)
Age 7 Volume	0.0129* (2.9)	0.0390** (8.8)	0.3913 (88.3)
Age 10 Volume	0.0556" (2.0)	0.1160** (4.1)	2.6429 (93.9)

a/ns = non-significance at the .05 level of probabillty.
/ * = Significant at the .05 level of probability;   = significant at the .01 level of probability.

Family and individual tree heritabilities for height increased from age 1 to age 10 (Figure 1). Family heritabilities were consistently larger than individual tree heritabilities. Both family and individual tree heritabilities are somewhat inflated due to the single test site. However, the relative performance continues to widen between the good and poor families and individuals indicating their larger role in the observed total variation. Family and individual heritability estimates for dbh and volume decreased between ages 7 and 10 (Figure 1). Increasing tree-to-tree variation, attributed to microsite variation and the highly variable genotypic response to the early disease incidence, has resulted in decreased heritability estimates.

Genetic and phenotypic correlations decreased as the age difference increased (Figure 1). Genetic correlations for height, dbh and volume were usually larger than phenotypic correlations. Age-1 height was poorly correlated with height, dbh and volume at ages 7 and 10 (Figure 1). However genetic and phenotypic correlations between age-6 height and age-10 height were extremely high. Because these correlations are a comparison of performance within a specific growth phase in particular, the juvenile phase they were expected to be high (Namkoong and Conkle 1976). The low correlations involving age-1 height and later age traits are probably the result of nursery effects and the early disease situation. These effects demonstrate the inefficacy of using age-1 height as a selection trait for gains at age 10. However, correlations between age-6 and age-10 traits were excellent indicating the possible use of it as a selection age.

The CGP calculated between age-1 height and later measurements of height, dbh and volume tend to be low and decrease with increasing age (Figure 1). The CGP between age-1 height and age-10 volume resulted in a value (.004) much lower than the .08 value shown for individual heritability of age-10 volume. The lower CGP indicates that response in age-10 volume from selection of age-10 height would be very low compared to direct selection on age-10 volume. In contrast, the CGP's calculated between traits at ages 6, 7 and 10 were either very

	H1	H6	H7	H10	D7	D10	W	V10
H1	0.36 (0.06)	0.46	0.31	0.40	0.18	0.23	0.01	0.06
H6	0.53	0.63 (0.22)	0.97	0.89	0.91	0.97	0.93	0.96
H7	0.49	0.93	0.65 (0.23)	0.94	0.86	0.92	0.89	0.96
H10	0.37	0.78	0.83	0.71 (0.28)	0.77	0.90	0.82	0.93
D7	0.52	0.82	0.82	0.72	0.51 (0.11)	1.02	0.97	0.93
D10	0.43	0.73	0.74	0.73	0.90	0.40 (0.06)	1.01	0.93
	0.52	0.80	0.80	0.58	0.96	0.83	0.51 (0.12)	1.00
V1 0	0.44	0.73	0.75	0.76	0.90	0.97	0.88	0.48 (0.08)

Figure 1. Additive genetic correlations (above the diagonal), phenotypic correlations (below the diagonal) and family and individual (in parentheses) heritabilities (along the diagonal).

	H1	H6	H7	H10	D7	D10	V7	V10
H1 (.06)		.054	.039	.053	.015	.015	.001	.004
H6 (.22)			.218	.219	.142	.111	.147	.126
H7 (.23)				.241	.137	.109	.147	.131
H10 (.28)					.137	.117	.148	.148
D7 (.11)						.085	.111	.059
D10 (.06)							.085	.064
V7 (.12)								.098
V10 (.08)								

Figure 2. Coefficients of genetic prediction (CGP) and individual tree heritability estimates (in parentheses) for all traits and ages in the 1978 Sycamore Mother Tree Test.

similar or exceeded the estimated heritabilities of the response trait. However, selection based on age-7 height resulted in the highest CGP for volume at age 10. This indirect gain was higher than the CGP calculated for volume at ages 7 and 10. In addition, the CGP computed between age-10 height and volume was higher than age-10 volume heritability. Interestingly, age-10 volume gains resulting from selection of age-10 or age-10 height were larger than those using age-10 dbh or volume. Even the use of age-6 height as the selection trait resulted in greater gains in age-10 volume than selection based on either age-10 dbh and volume. This relationship with height occurs because of the high genetic correlations shown to exist between height at ages 6 and 7 with volume at age 10. In addition, the lower phenotypic covariance for height and volume compared to the phenotypic variance of volume alone also affects this relationship. Thus, the lower environmental effects on phenotypic height relative to phenotypic dbh resulted with a higher CGP with respect to volume.

Indirect gains for age-10 volume were obtained through the use of the correlated response (CR). Selection for height at age 7 resulted in the highest genetic gain (18%) for age-10 volume (Table 3). Genetic gains per unit of time for age-10 volume showed age-1 height the lowest at 0.15 percent and age-6 height the highest at 1.96 percent (Table 3). The extremely high genetic correlations for height, dbh, and volume among ages 6, 7, and 10 have led to a high correlated response for age-10 volume.

Maximizing genetic gains per unit of time through effective early-age selection has been shown by Foster (1986b) and Rousseau (1987) in eastern cottonwood, and Lambeth and others (1983) in loblolly pine. The higher gains resulting from the selection of height differed from Foster (1986b) and Rousseau (1987) where selections of dbh and volume at earlier ages resulted in much higher gains in volume at later ages. The similarities between CR and CGP calculations affirm that selection of either age-6 or age-7 height would result in approximately identical gains for age-10 volume. Both CR and CGP showed that very little gain would result from selection of age-1 height for age-10 volume. The CR of age-6 height was nearly as high as age-7 due to the high genetic correlations shown for age-6 height and age-10 volume. Although similarities were shown between gains at age-10 volume predicted by CR and CGP based on selection of height at ages 6 and 7, genetic gains per unit of time indicate that selection of age-6 height is more efficient. This selection age is very similar to those identified by Nebgen and Lowe (1985). Because of various factors such as the lack of frequent earlier measurements, few measurement traits, and the present young age of studies we are unable to precisely define the optimal selection age and trait for volume in a pulpwood rotation of sycamore. However, it is evident at this time that age-1 height is not an effective selection trait and that selection at or near age 5 will result in reduction of the generation interval. An additional aspect of early-age selection allows the breeder to approach sycamore improvement from the clonal aspect as well as from the traditional seed orchard method.

Table 3. Correlated response and genetic gains per unit of time for age 10 from selection of other traits.

Selected Trait[a/]	Correlated Response (ft^3)		Genetic Gain Per Unit of Time[b/]
Age 1 Height	0.0207	0.6	0.15
Age 6 Height	0.6355	17.6	1.96
Age 7 Height	0.6498	18.0	1.80
Age 7 DBH	0.4354	12.6	1.26
Age 7 Volume	0.4889	13.5	1.35

[a/]Selection intensity was 5/1360 individuals (i=2.9750).
[w]Unit of time is defined as selection age plus three years.
c/Percent response - Correlated Response (ft^3)/Average age-10 volume (3.61 ft3)
[d/]Percent Gain per Unit of Time - Percent Response/Selection age plus three years

CONCLUSIONS

This study demonstrates the feasibility of early-age selection in sycamore. A shortened generation interval allows for increased gains per unit of time and the possibility of clonal propagation. Large tree-to-tree variation partially resulting from disease susceptibility led to high phenotypic variation which affected the various estimates of genetic parameters. Significant family-within-seed source differences were shown for all traits. However, significant seed source differences were not shown for height at any age. Family and individual tree heritabilities increased with age for height but decreased for dbh and volume.

Genetic and phenotypic correlations were extremely poor for age-1 height with all other traits. Height at ages 6 and 7 were highly correlated with age-10 volume. Coefficients of genetic prediction for age-10 volume were highest for age-7 height. However, selection of age-6 height for gains in age-10 volume were very similar to selection of age-7 height. In terms of gain per unit of time, the optimal selection trait was age-6 height for the response trait of age-10 volume.

The local seed source (KY) proved to be better adapted to the conditions found on the 1978 test site. This is in contrast to reports of southerly seed sources outperforming local material in tests located on alluvial floodplain sites.

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