JUVENILE-MATURE CORRELATIONS IN SYCAMORE

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Abstract.--Genetic and simple correlations for five seed traits, two nursery traits, and four early field traits were made with fifth year DBH, height, dry weight, and volume in a sycamore progeny test. Germination value and first year root-collar diameter were identified as potential early selection traits for increasing gain per unit time in fifth-year volume. Families that showed good rank stability over time were also observed as stable over progeny test locations. Selection for both stability and performance may be the most desirable strategy for advanced-generation breeding programs.

Additional keywords: *Platanus occidentalis,* early selection, stability.

Correlations between juvenile and mature traits are receiving increased consideration from tree breeders because of the economics of shortening breeding cycles and increasing gain per unit time. Since genetic correlations between early and mature traits are rarely perfect, correlated gain from indirect selection on early traits for improvement of mature traits is usually less than gain from direct selection on mature traits for a given breeding cycle. However, increased gain per unit time has been demonstrated where several breeding cycles can be carried out in the time required for one cycle of direct selection (McKinley and Lowe, 1986). Savings in cultural and mensurational costs can also be realized from selection of juvenile traits as opposed to mature traits.

Mature traits may be volume or dry weight at three to ten years of age in short-rotation energy crops. Juvenile traits would therefore be seed, nursery, and early field observations. The time saved in early selection for a short-rotation breeding program is small compared to a traditional breeding program but may result in considerable savings in expense of field testing the progeny (Land et al., 1987).

Genetic and simple correlations for early selection of sycamore *(Platanus occidentalis)* biomass production are presented. Seed, nursery seedling, and outplanted seedling traits are correlated with three- and five-year DBH, height, dry weight, and volume. Stability of family ranks over time, traits, and locations and losses due to early selection are examined. A potential breeding strategy is suggested.

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MATERIALS AND METHODS

A large open-pollinated sycamore progeny test and a separate seed-trait study with 79 families in common were used to derive correlations between early selection and biomass traits. The 79 families represent 16 source selections made from four latitudinal transects across eastern Arkansas and Louisiana, Mississippi. and western Alabama (Figure 1). They number 18. 20. 20, and 21 families respectively from the northern to the southern transect.

Figure 1. Locations of seed sources and planting sites used in the sycamore progeny test.

Open-Pollinated Progeny Test

The progeny test was established at four locations in Mississippi (Figure 1). A description of these sites and the early genetic estimates from the study are given by Land (1981). Two planting years, six randomized block replications per year, and three individual trees per family plot are represented at each of the progeny test locations. There is an average of 140 trees per family composing each correlation between family performance for juvenile and mature traits. Thus, family and within family sample sizes are sufficiently large to minimize problems associated with sampling error (Lambeth. 1983). The study also has the advantage of correlating family performance over different planting locations.

Traits chosen from the progeny test for use in the correlation study were nursery root-collar diameter, nursery height. first-year (in the field) height. first-year root-collar diameter, third-year DBH, third-year height. fifth-year DBH, fifth-year height, fifth-year stem plus limb dry weight, and fifth-year stem volume.

Seed Trait Study

The families for the seed trait study were taken from the same mother-tree seed collections as those used for the progeny test. Germination counts were taken on 100 seed from each of three individual trees per family for the first, second, third, fifth, seventh, ninth, fourteenth, and twenty-first days in a germination chamber. Numbers of ungerminated seed and percent full seeds were also determined. A germination value (GV), to measure in one statistic both speed and completeness of germination was calculated for each family using the following formula (Czabator, 1962):

GV = Mean daily germination (MDG) * Peak value (PV),

where MDG = total number of seed germinated, divided by the total length of the germination period (21 days), and

PV = the maximum value of the cumulative percent germination for each day of the trial divided by the corresponding number of days from the beginning of the trial.

Unpublished data on seedball diameter and weight, weight of clean seed per seedball, and weight of 100 seed per seedball were also used for two replications of five seedballs per family. These seed and seedball traits were correlated with the progeny test traits.

Correlations

Because seed trait and progeny test studies were separate in nature (i.e. seeds were not traced from the germination chamber to the field, and experimental designs of the studies differed), clean genetic correlations from one analysis of covariance table could not be obtained. Product-moment and rank correlations (Sokal and Rolf, 1969) were calculated and considered to be composed of genetic, maternal, and common environment effects. Analyses of covariance on family means were performed for combinations of nursery and field traits in the progeny test. Components of covariance were estimated by equating actual with expected mean products, and genetic correlation estimates were obtained from those components.

Performance Levels

Performance level (PL) (North Carolina State University-Industry Cooperative, 1979) measures a family's position in the distribution for a particular trait in a given environment:

PL = (FM - (GM - (2 * STD))) / ((GM + (2 * STD)) - (GM - (2 * STD)))

where FM = family mean
GM = grand mean
STD = standard deviation.

Performance levels from different locations are averaged to obtain a single PL value for each family and trait. These values range from 0 to 100, with 50 representing a performance level of an average family.

PL values were used in the present study to make adjustments in family performance over varying environments in the progeny test. The Vicksburg progeny test site (location 4, Figure 1) produced site means that were sometimes twice as large as any other site, so that family averages across sites would be biased by performance at this site.

Product-moment correlations of all traits were made on the performance level of each family for that trait as opposed to the measured trait itself.

RESULTS AND DISCUSSION

Correlations

Product-moment correlations between seed traits and third and fifth-year progeny test traits were only significant for germination value and percent full seeds (Table 1). Germination value was significantly correlated with DBH, volume, and dry weight; however it was not correlated with height. Percent full seeds gave significant correlations with third- and fifth-year DBH only. Consistent correlations of 0.3 for germination value were considered to be quite good, since other early selection studies (Robinson et al., 1984; Lambeth et al., 1982) have indicated insignificant seed trait correlations with field traits. Germination value may be a better measure of seed vigor than the traditionally used germination percent or rate, and therefore, correlated well with seedling and mature plant vigor.

Table 1.--Product-moment correlations between the seed study and progeny test for performance level traits for 79 sycamore families.

Biomass Rotation Trait	Germi-nation Value	% Full Seeds	Seedball			
			Diameter	Dry Wt.	Wt. of Clean Seed	Wt. of 100 Seed
3rd-Year DBH	0.327**	0.243*	-0.086	0.037	0.050	0.073
3rd-Year Height	0.157	0.063	-0.081	-0.007	0.005	0.038
5th-Year DBH	0.338**	0.221*	-0.158	-0.132	-0.156	-0.172
5th-Year Height	0.159	0.039	-0.225*	-0.173	-0.166	0.062
5th-Year Stem/ Limb Dry Wt.	0.305**	0.166	-0.177	-0.149	-0.169	-0.161
5th-Year Stem Volume	0.310**	0.173	-0.175	-0.147	-0.167	-0.161

* Significant at the 0.5 level
** Significant at the 0.1 level or above

All seedball traits (Table 1) and nursery root-collar diameter (Table 2) were usually not correlated with field traits. A tendency for the estimates to be negative was noted. Negative correlations for root-collar diameters in the greenhouse with fifth-year height, diameter, and volume in the field has been reported by Robinson at al. (1984) for loblolly pine. The negative relationships are thus far unexplained.

Family mean nursery height did not correlate well with any trait measured in the field, but first-year root-collar diameter and height were strongly correlated with third- and fifth-year measurements in the field (Table 2). This pattern of weak nursery and strong early field correlations suggests that either strong family by microenvironment interactions in the nursery bed or maternal effects are influencing family performance. A study currently underway will make reciprocal controlled pollinations among selected individuals from this progeny test to determine the role of maternal effects on early selection (Land at al., 1986).

Table 2.--Estimates of genetic correlations and product-moment correlations (in parentheses) between early and three- and five-year performance level traits from a sycamore progeny test.

Biomass Rotation Trait	Nursery Root Collar	Nursery Height	1st-Year Root Collar	1st-Year Height	3rd-Year DBH	3rd-Year Height
3rd-Year DBH	-0.335 (-0.012)	0.257 (0.219)**	0.617 (0.631)**	0.638 (0.630)**	-	-
3rd-Year Height	-0.420 (-0.079)	0.136 (0.150)	0.194 (0.395)**	0.638 (0.631)**	-	-
5th-Year DBH	-0.178 (-0.010)	0.161 (0.134)	0.641 (0.578)**	0.630 (0.517)**	0.973 (0.920)**	0.715 (0.756)**
5th-Year Height	-0.471 (-0.123)	0.096 (0.099)	0.335 (0.393)**	0.761 (0.563)**	0.830 (0.790)**	0.891 (0.888)**
5th-Year Stem/ Limb Dry Wt.	-0.072 (-0.004)	0.265 (0.164)	0.721 (0.565)**	0.829 (0.557)**	1.019 (0.903)**	0.804 (0.793)**
5th-Year Stem Volume	-0.076 (-0.013)	0.084 (0.167)	0.727 (0.564)**	0.841 (0.561)**	1.029 (0.911)**	0.803 (0.797)**

** Significant at the .01 level or above

The strong correlations between first-year, third-year and fifth-year measurements in the field indicate that four years could be cut from the short rotation biomass breeding cycle. Land (1981) showed that even for correlations above 0.9 dramatic increases in selection intensities must be made to compensate for the differences between indirect and direct gains. However, a savings of four years in a short rotation program could affect gain per unit time by (1) allowing early identification of genotypes to place in accelerated breeding facilities and by (2) identifying genotypes for vegetative propagation of planting stock for clonal forestry at an age when the material is still easy to root.

Losses From Early Selection

Losses in fifth-year volume performance level from early selection of the best twenty families range from fifteen percent for nursery traits to less than three percent for third-year traits (Table 3). Nursery root-collar diameter, which was negatively correlated to fifth-year volume, correctly identified five out of twenty high volume families. Five is therefore considered as a background count of families identified by chance against which other early selection traits can be compared. Germination value, whose correlation with fifth-year volume was 0.310, correctly identified one-half of the twenty families. The same number was identified by first-year height whose correlation was 0.561. One reason for the improved predictive power of germination value relative to its correlation is that the upper quartile of germination value families were better correlated with fifth-year volume than the lower 59 families. A high upper quartile correlation also played a role in the very impressive six out of ten correctly chosen families for first-year root-collar diameter.

Table 3.--Average performance levels and number of common top families selected for greatest fifth-year stem volume.

Trait	Fifth-year average volume performance level of top 20 families for each trait[a]	Number of families common to top fifth-year stem volume families Out of top 20 Families	10 Families	5 Families
Indirect Selection:				
Germination Value	52	10	3	2
Nursery Root Collar	51	5	2	0
Nursery Height	51	5	1	1
First-year Height	55	10	3	2
First-year Root Collar	55	9	6	1
Third-year DBH	59	16	5	3
Third-year Height	58	14	4	1
Direct Selection:				
Fifth-year Stem Volume	60	20	10	5

a/ A difference of 10 in performance level for fifth-year stem volume roughly translates to a 13% difference in actual volume.

In consideration of both time and minimal losses, germination value and first-year root-collar diameter are the most promising traits for early selection.

Stability of Family Performance

Ranks across traits for the top twenty families in fifth-year volume indicate that two families, F101 and F205, from a southern Louisiana source showed very good rank stability for all traits (Table 4). Other families exhibited good stability for part of the traits. For example, family N109 was stable for all but first-year traits.

Table4. --Ranks for the best twenty fifth—year stem volume families over selected traits.

	Rank out of 79 total families								
	Germi- nation Value	First- year Root Collar	First- year Height	Third- year DBH	Third- year Height	Fifth- year DBH	Fifth- year Height	Fifth- year Stem/Limb Dry Wt.	Fifth- year Vol.
F101	6	2	1	1	2	1	1	1	1 *
N109	2	21	24	3	9	2	2	2	2
B110	20	41	25	12	7	3	8	3	3
N204	4	16	40	17	24	6	7	4	4
B209	27	9	15	2	14	4	15	5	5
N110	12	10	13	15	38	11	9	8	6
P110	80	4	29	13	15	8	11	7	7
M104	55	1	9	28	30	10	6	6	8
N102	51	7	30	7	33	5	23	9	9
F201	17	32	4	4	1	12	4	11	10
L110	45	29	43	9	13	7	19	10	11
F108	23	64	20	10	12	9	5	12	12
P101	25	55	49	29	4	15	3	13	13
P206	67	12	6	11	5	14	10	14	14
A109	5	42	37	5	3	19	21	15	15
N208	8	35	48	19	36	17	14	17	16
C109	46	23	19	16	11	18	29	16	17
F205	18	27	14	8	18	16	18	20	18 *
G106	11	25	46	23	41	13	42	19	19
P201	54	19	11	21	19	24	12	18	20

* Good family rank stability from seed to nursery to field traits

The families that showed rank stability over ages and traits were also stable over progeny test sites (environments). Since it is impossible to directly predict the future rank stability of families, one might indirectly test for stability by ranking families for early traits over environments. The use of a multiple selection index, which would weight stability over environments and productive value, could be used to improve early selection in the next generation, if heritabilities are high. Even when stability over years is not indirectly predicted, it could be measured in the first generation and used to shorten the breeding cycles of the second and third generations.

SUMMARY AND CONCLUSIONS

1. Germination value was moderately correlated to fifth-year volume production. This seed trait could be used to decrease the cost of progeny testing by screening out the worst families before sowing in the nursery or greenhouse.

2. First-year height and root-collar diameter in the progeny test had high genetic correlations with fifth-year volume. These traits could be used in early selection of genotypes for an accelerated breeding program and for vegetative propagation of planting stock.

3. Families that were stable in rank over ages and traits were also stable over progeny test environments. Stability might be used as part of an early Selection program to improve age-age correlations or to reduce genotype-by-site interactions.

4. Two unanswered questions are (a) the importance of maternal effects on early correlations and (b) the magnitude of correlations between seed or nursery traits and field performance at the individual genotype level. A study is underway to answer these questions.

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