SYCAMORE SEED AND SEEDLING TRAITS- -
EARLY SELECTION CRITERIA?

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Abstract.--American Sycamore (Platanus occidentalis Lj) is a candidate species for short-rotation energy plantations in the southern United Statesj Seed and seedling characteristics may provide early selection criteria for genetic improvement in these short-rotation systems. Five experiments with twelve open-pollinated families were used to determine genetic and product-moment correlations and to identify the best traitsj Rate of germination, as expressed by "peak value", and root growth potential of one-year-old seedlings (before planting in the field) were correlated with dry weights, number and growth of sprouts, and bud characteristics after one growing season in the fieldj

Keywords: Platanus occidentalis, early selection, root collar diameter, APA, genetic correlation, root growth potential.

INTRODUCTION

Acceptance of short-rotation energy plantations of woody crop species in the United States can be enhanced by increased productivity from these plantations, provided costs are kept low. These short-rotation plantations (three to five years) represent a unique forest cropping system for geneticists, since the harvested product can be more influenced by the quality of the forest reproductive material planted (seeds, seedlings, or vegetation propagules) than is experienced for longer-rotation systemsj Manipulations of the environmental, genetic, and physiological factors affecting the quality, and thus future productivity, of these forest reproductive materials may provide lower cost practices for increasing productivity than do many cultural activities that are done after plantingj

American sycamore (Platanus occidentalis Lj) is a candidate species for short-rotation energy plantations in the southern United Statesj Early indirect selection at the seed or seedling stage would save the costs of expensive field progeny tests. Results from germination, germinator, nursery, greenhouse, and field tests were used to address three questions basic to short-rotation genetic studies: (1) can the effects of variable seedling density in the nursery bed be separated from genetic effects for family root collar diameter, (2) how important is root collar size as an indirect measure

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of various growth and root characteristics in the field, and (3) are seed and seedling characteristics genetically correlated with root collar diameter and early field performance?

METHODS

Test Designs and Measurements

Data were used from twelve open-pollinated sycamore families that were common to germination, germinator, nursery, greenhouse, and field tests.

The germination test consisted of four replications of 50 seeds each from each open-pollinated family seed lot. The seeds were placed on Kimpack medium in germination incubators, and germination was measured over a 21-day period under a temperature-light regime of eight hours of light at 30°C and sixteen hours of dark at 20°C.

The germinator test was arranged in a randomized complete block design with four replications and 50 seeds per family plot within each replication. Seeds were placed at a 3.7-by-3.7cm spacing on Stultz white germination paper in a germinator. Measurements were taken for germination and hypocotyl lengths on eleven dates over a 97-day period. Light and temperature regimes were the same as for the germination test.

Seeds in the nursery test were planted in a 1.2-m-wide by 30.5-m-long nursery bed. A randomized complete block design with three replications and border rows was used. Each family plot within a replication consisted of 96 planting spots spaced at 10-by-10 cm on eight rows across the bed by 12 columns along the bed. Three to four seeds were planted at each spot and thinned to one after measurement of survival on the 33rd day after planting. Seedling heights and root collar diameters were measured at monthly intervals from June to January (58 to 264 days after planting).

Twenty seedlings from each family in the nursery were lifted on the 264th day, measured for root characteristics, and planted in four-liter containers of sand on ground-heating mats under mist and supplemental lighting in a greenhouse. A completely random experimental design was used. Five of the 20 seedlings per family were chosen to have 8-10 mm root-collar diameters and were designated for "border" containers. The other 15 seedlings per family were selected to have five with "large" root collars (12-mm diameter), five with "medium" root collars (9-mm), and five with "small" root collars (6-mm). These were used to test family and root collar size effects on root growth potential (RGP). RGP was measured as the number of short (1.0-2.5 cm), medium (2.5-5.0 cm), and long (>5.0 cm) new white roots after 21 days in the greenhouse.

The 240 seedlings from the RGP study were transplanted from the greenhouse to a field site in mid February (300-day-old seedlings). The same completely random design was used. Measurements of survival and growth were taken in May. After one year in the field, the seedlings (now two-years-old from seed) were dug up and measured for root and stem dimensions and for dry weights.

Calculations

APA-Adjusted Nursery Root Collar Diameters Family differences in root collar diameter at time of lifting from the nursery bed were adjusted for differences in seedling density by using a geometrically derived covariable, "area potentially available" (APA)j The APA index was calculated for each seedling using a Fortran computer program developed by Nance and Grissom (1988). The procedure involves the geometric construction of unweighted polygons that circumscribe each seedlingj Sides of the polygons are placed half way between the subject seedling and its nearest competitors. The area of the polygon is calculated to determine the area potentially available for growth of the seedling. A detailed explanation of the APA formulation is given in Nance et al. (1987). Analyses of variance for both APA-adjusted and unadjusted root collar diameters were conductedj

Peak Value Peak value (PV), a measure of rate of germination, was calculated after Czabator (1962):

PV = peak value, 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.

Correlations Product-moment correlations of family means were calculated between 20 selected field traits and 38 selected germinator, nursery,and greenhouse traits. Since the germinator and nursery test designs differed from the greenhouse and field design, clean genetic correlations could not be determined between early seed and seedling traits and later field traitsj However, the product-moment correlations serve as measures of the intensity of associations between the traits and are considered to be composed of genetic, maternal, and common environment effectsj

Genetic Correlations Genetic correlations were calculated for those pairs of field and greenhouse traits that showed significant product-moment correlationsj Each pair of traits was measured on the same individual seedling that was lifted from the nursery bed, planted in a container in the greenhouse, and later transplanted to the fieldj

Components necessary to calculate the genetic correlations were acquired from analyses of variance and covariance on the half-sib families. Genetic correlations were calculated as:

$$r_G = \frac{COV_{xy}}{\sqrt{VAR_x * VAR_y}}$$

where VAR and COV refer to the components of variance and covariance for half-sib families and x and y to a field trait and greenhouse trait.

RESULTS AND DISCUSSION

Nursery Bed Root Collar Diameter (RCD)

Families were significantly different for unadjusted RCD and not different for APA-adjusted RCD (Table 1). Competition among nursery seedlings for available root growth space was considered an important factor in RCD differencesj Where localized seedling density varied, performance was biased toward seedlings that had less root competition and more available root growth spacej Individuals within a family were planted in block plots within replicationsj When empty spots occurred within a block many seedlings of the same family benefitedj Families with low percent-germination had large diameter seedlingsj The effect of increased available area is removed in the APA-adjusted analysis, and families no longer exhibited significant differences in RCDj The significant unadjusted family differences indicated that RCD was under environmental rather than genetic control.

Table 1. Analysis of variance for root collar diameter at time of nursery lifting for both unadjusted and APA-adjusted modelsj

Source of Variation	DF	Unadjusted MS	Unadjusted F-test	Adjusted MS	Adjusted F-test
APA (covariable)	1			0.9424	16.37**
Rep	2	12.8929	71.38**	2.8632	6.44**
Fam	11	1.2478	2.88**	0.4816	1.08
Rep*Fam	22	0.4327	2.40**	0.4429	5.73**
Within plot (Error)	1180	0.1806		0.0776	

*Significant at the 0.05 levelj
**Significant at the 0.01 levelj

The sequential mean square F-test for the APA covariable implies that APA alone can account for a significant amount of variation in RCD. Variation in seedling density due to mortality in the nursery bed has long been a problem in analyzing nursery experiments. The APA covariable analysis was useful in accounting for variation due to inconsistent spacing, and it should be tried in other nursery studies.

The replication-by-family interaction terms were significant in both unadjusted and adjusted analysesj Family rank changes across replications were observed, but three of the 12 families did show rank stabilityj

Seed and Seedling Correlations

Peak value (PV) for germination of open-pollinated seed lots is significantly correlated with first-year field growth, crown growth potential (bud characteristics), and biomass (dry weight) (Table 2). PV is a measure of a seed lot's general vigor, and in this case seed vigor has correlated well with early plant performance in the fieldj Identifying families with good PV may allow early identification of genotypes to place in an accelerated breeding programj

Greenhouse root growth potential (RGP) traits and number of medium lateral roots produced in the nursery correlated well with number and growth of secondary buds, number of total apical buds, and growth of all buds in the field test. These results suggest that the above and below ground numbers of potential lateral meristems (or branching pattern) may be reflections of each

Table 2. Significant product-moment correlations between germination, nursery, greenhouse, and field traits for 12 open-pollinated sycamore families.

	Germination Trait	Greenhouse RGP Traits No. of New Roots			Nursery
Field Trait	Peak Value	Long	Medium	Short	Medium Lateral Roots
Stem Dry Weight	0.596*	-.096	.035	-.008	.032
Root Dry Weight	0.738**	-.026	.125	.099	.279
Total Dry Weight	0.683**	-.071	.075	.037	.137
Growth Secondary Buds (3 months)	0.805**	0.590*	0.818**	0.821**	0.678**
No. Secondary Buds (1 year)	0.586*	0.529	0.711**	0.805**	0.641*
Length of Topmost Sprout (3 months)	-0.714**	-.219	-.454	-.333	-.514
No. Total Apical Buds/ Tree (1 year)	0.560*	.527	.717**	.817**	.614*
Growth All Buds/Tree (1 year)	0.778**	.543	.700**	.702**	.489
Root Volume (1 year)	0.624*	-.120	.002	.019	.112

* Significant at the 0.05 level.
** Significant at the 0.01 level.

other. RGP traits might be useful for early identification of families that will produce large crowns and more photosynthetic area.

Root Collar Class

Analyses of variance on 35 nursery, greenhouse, and field traits resulted in 25 analyses for which root collar class had a significant effect (Table 3). Significant family effects were also found for eleven of these traits, but in no case was there a significant family-by-root-collar-class interaction. These results support the hypotheses that (1) RCD is the single most important morphological measure of early growth potential and (2) genetic differences in growth potential exist for seedlings of the same RCD. Effective early selection in the nursery will require either (1) equal growing space per seedling or (2) evaluation of only seedlings having the same root collar class.

Table 3. Nursery, greenhouse, and field traits that showed significant root collar class (RCC) or family differences.

Traits	Study Mean	Significance Family	Significance RCC	Significance Family*RCC
Nursery				
Nursery height (cm) day 58	7.7	**	**	NS
Nursery height (cm) day 93	31.5	**	**	NS
Nursery height (cm) day 120	51.8	**	**	NS
Nursery height (cm) day 156	77.7	NS	**	NS
Nursery hegith (cm) day 181	79.7	NS	**	NS
Nursery RCD (mm) when lifted	9.2	NS	**	NS
Root vol. (ml) when lifted	21.7	NS	**	NS
No. medium lat. roots-lifted	3.8	NS	**	NS
No. large lat. roots-lifted	1.1	NS	**	NS
Taproot length (cm)-lifted	28.9	*	**	NS
Greenhouse				
No. long new roots 21-days	4.8	++	NS	NS
No. medium new roots 21-days	12.7	**	NS	NS
No. small new roots 21-days	25.5	NS	NS	NS
Field				
Total no. sprouts/tree	8.5	**	**	NS
Length top sprout (cm)-May[a/]	21.3	NS	**	NS
Growth sprouts/tree (cm)-May	12.6	**	**	NS
Height (cm)-Jan.[b/]	98.1	NS	**	NS
Groundline diam. (mm)-Jan.	16.8	NS	**	NS
Total no. apical buds/tree-Jan.	7.2	**	**	NS
No. 2° apical buds/tree-Jan.	5.9	**	**	NS
Tot, growth (cm) 2° buds	104.5	NS	**	NS
No. large lateral roots-Jan.	1.3	NS	**	NS
No. small lateral roots-Jan.	5.8	*	**	NS
Tot. no. lat. roots @20cm radius	8.7	NS	**	NS
Stem dry wt.(gm)-Jan.	47.4	NS	**	NS
Root dry wt.(gm)-Jan.	40.5	NS	**	NS
Severe dieback (0=no,1=yes)-Jan.	0.2	NS	**	NS
Slight dieback (0=no.1=yes)-Jan.	0.7	NS	**	NS

[a/]Third month in the field (15-months-old).
[b/]Twelfth month in the field (2-years-old).
++ Significant at the 0.07 level.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

Genetic Correlations

The number and growth of sprouts (elongation of buds) and number of total and secondary apical buds in the field all showed strong genetic correlations with root growth potential (Table 4). No correlation was found between primary apical buds and RGP, however. These results suggest that some families are allocating more of their first-year growth to limbs than others. In subsequent years those families with a larger crown size would possess a greater photosynthetic surface area. Like the product-moment correlations, the genetic correlations indicate that families with high RGP's may build larger crowns faster than those with lower RGP's, even though primary bud growth (first-year height growth) may not differ.

Table 4. Genetic correlations for measures of root growth potential (RGP) and taproot length with first-year field performance of 12 open-pollinated sycamore families.

Field Trait by Greenhouse Trait	Genetic Correlation
No. Sprouts/Tree (after 3 months) by	
Taproot length (day 264)	-0.764
No. of long (>5 cm) new roots (day 21)	0.990
No. of medium (2.5-5.0 cm) new roots (day 21)	0.966
No. of short (1.0-2.5 cm) new roots (day 21)	1.138
Growth all sprouts/tree (after 3 months) by	
No. of long (>5 cm) new roots (day 21)	0.953
No. of medium (2.5-5.0 cm) new roots (day 21)	0.970
No. of short (1.0-2.5 cm) new roots (day 21)	1.093
Total No. Apical buds/tree (after 1 year) by	
No. of long (>5 cm) new roots (day 21)	0.852
No. of medium (2.5-5.0 cm) new roots (day 21)	1.002
No. of short (1.0-2.5 cm) new roots (day 21)	1.374
No. secondary apical buds/tree (after 1 year) by	
No. of long (>5 cm) new roots (day 21)	0.834
No. of medium (2.5-5.0 cm) new roots (day 21)	0.976
No. of short (1.0-2.5 cm) new roots (day 21)	1.339

Taproot growth showed a strong negative genetic correlation (-0.764) with the number of sprouts per tree. This could be the result of some families diverting energy from bud development to taproot elongation.

SUMMARY AND CONCLUSIONS

1. Family differences in seedling root collar diameters (RCD) are interpreted to be a result of differences in seedling density in the nursery bed, rather than genetic differences. The "area potentially available" (APA) for each seedling appears to be a useful measure of localized

nursery bed density, and it is a promising tool for future nursery experiments.

2. Root collar diameter was the most important morphological measure of early field performance potential. However, family differences in root morphology, root growth potential, and field performance for seedlings of the same root collar class were also found. Effective early selection in the nursery for genetic improvement will require equal growing space per seedling or use of seedlings of equal root collar class.

3. Large positive genetic correlations suggest that families with high RGP's are more likely to build large crowns faster and produce more photosynthetic area than those with lower RGP's.

4. Czabator's peak value for germination of open-pollinated family seed lots was highly and positively correlated with eight first-year field traits. This seed trait may allow early screening to reduce the number of families that are progeny tested for short-rotation energy programs.

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