# VARIATION IN JUVENILE GROWTH AND WOOD PROPERTIES IN HALF-SIB COTTONWOOD FAMILIES

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Maximum early gains in the genetic improvement of eastern cottonwood *(Populus deltoides* Bartr.) in the lower Mississippi Valley are most likely to be achieved through identification and commercial vegetative propagation of superior genotypes. A relatively simple improvement program having this goal might include evaluation of progeny from phenotypically superior mother-trees followed by clonal tests of outstanding juvenile phenotypes selected from progeny. Such an approach is being used in the first phase of the cottonwood improvement program at the Southern Forest Experiment Station. This paper describes a short-term one-parent progeny test conducted under nursery conditions to provide data on juvenile variation.

## Methods

Twenty-five 20- to 30-year-old female trees were chosen for their phenotypic superiority in size and form; all occurred in stands along the Mississippi River between Clarksdale and Vicksburg, Mississippi. Seed collected from the trees in June 1962 was sowed in 4-inch peat pots filled with a standard potting mixture (sand: peat :loam, 1:1:1). Resulting seedlings were grown for 1 month in greenhouses. In early August potted plants were transferred to a nursery site characterized by a Commerce silt loam soil. The 25 families were planted in a randomized block design with 10 replications of 18-tree row plots. Rows were 3 feet apart, plants were 2 feet apart within rows, and a 2-row border was planted around the test. Seedlings were irrigated immediately after they were planted and re-irrigated and cultivated as necessary during the balance of the summer.

Total height and diameter at 1.5 inches above the soil surface were recorded in December 1962. The seedlings were then clearcut at groundline, and a second season's growth on the rootstocks was observed. This cutting was necessary because the plants were spaced so closely and grew so fast that they might have become stagnated during the second year. After growth resumed in the spring, clumps of sprouts were thinned to one stem.

At the end of the second growing season, total height and diameter at 1 foot above the soil surface were measured on all trees. Specific gravity and fiber length were evaluated from wood samples taken at the base of the first six trees in each plot. Specific gravity was determined from the green volume and oven-dry weight. For fiber-length determinations, six 1-mm.-wide slivers were cut in matchstick-like form from the outer portion of each wood sample. The slivers were macerated in a 1:1 mixture of glacial acetic acid and 30-percent hydrogen peroxide at 50° C. for 36 hours. The macerated, bleached fibers were washed in distilled water, stained for 15 minutes in a Bismarck Brown solution (1 gm. stain in 100 ml. of 50% ETOH, filtered) and mounted in a 1.5-percent agar solution on glass slides. Sixty fibers per sample were measured with a modified ampliscope (Echols 1959; Wilcox *et al.* 1964) at 52 X, and the sample mean was used as the unit of analysis.

Specific gravity and fiber length of wood samples from parent trees were also determined by the above techniques. Two cores 11 mm. in diameter were taken from each tree. Specific gravities of whole cores were measured and fiber samples were taken in the last growth ring.

Data were analyzed as outlined in table 1. Because of unequal numbers of trees per plot, an approximation of the within-plot variance was computed from individual-tree data in every tenth plot, and the harmonic mean of plants per plot was used to convert this value to the appropriate scale for comparison with other mean squares. Narrow-sense heritability values were calculated, using the formula in table 1. Family means were compared through use of Harter's (1960) values for Duncan's new multiple range test.

## Results

Mean family height growth varied significantly (0.01 level) from 3.1 to 4.6 feet in 1962 and from 11.9 to 14.2 feet in 1963. Heights of individuals ranged from 0.8 to 6.8 feet in 1962 and from 4.6 to 21.1 feet in 1963.

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Table 1.--Analysis of variance and narrow-sense heritabilities for several characters in a cottonwood one-parent progeny test

| Item | df | | Height 1962 | Height 1963 | Diameter 1962 | Diameter 1963 | Specific gravity | Fiber Length | Estimated mean square |
|---|---|---|---|---|---|---|---|---|---|
| Source of variation | df | | | | | | | | |
| | | | | | MEAN SQUARE | | | | |
| Replications (R) | 9 | | 0.7456 | 92.8262 | 8.9700 | 4.572844 | 0.064489 | 0.083456 | |
| Families (F) | 24 | (1) | 2.0517 | 3.3640 | 19.8058 | .300779 | .008279 | .023846 | $\sigma^2_W + K\sigma^2_{RF} + RK\sigma^2_F$ |
| Replications X Families | 1/ 215 | (2) | .1233 | 1.2359 | 2.9407 | .116167 | .001437 | .005358 | $\sigma^2_W + K\sigma^2_{RF}$ |
| Within plot (W) | | (3) | .0401 | .2794 | .5272 | .063520 | .000452 | .002287 | $\sigma^2_W$ |
| | | | | | VARIANCE COMPONENT | | | | |
| $\sigma^2_F = (MS_1 - MS_2)/RK$ | | | .0140 | .0130 | .1016 | .003077 | .000114 | .000308 | |
| $\sigma^2_{RF} = (MS_2 - MS_3)/K$ | | | .0060 | .0583 | .1454 | .008774 | .000164 | .000512 | |
| $\sigma^2_W = MS_3$ | | | .0401 | .2794 | .5272 | .063520 | .000452 | .002287 | |
| K= harmonic mean of plants per plot | | | | | | | | | |
| | | | | | HERITABILITY | | | | |
| $h^2 = \frac{4\sigma^2_F}{\sigma^2_F + \sigma^2_{RF} + \sigma^2_W}$ | | | .93 | .35 | .52 | .16 | .62 | .40 | |

1/ Reduced by 1 because of 1 missing plot.

Diameter growth (mean for 1962, 0.5 in.; mean for 1963, 1.0 in.) followed the same pattern of broad variation as height, although familial differences were less and family rankings did not change greatly between the 2 years. Differences between replications were a major source of variation in both height and diameter growth, and reflect cottonwood's sensitivity to site differences within the 3-acre test area.

Family means for specific gravity ranged from 0.38 to 0.43 (mean = 0.40); density of individual trees varied from 0.31 to 0.52, a range similar to that observed in natural cottonwood stands of the lower Mississippi Valley. Mean fiber length for families ranged from 0.88 to 0.97 mm (mean = 0.92). The range in fiber length of individual trees (0.74-1.19 mm.) was close to that reported for mature *P. deltoides* (0.85-1.28 mm.) by Boyce and Kaeiser (1961), but greater than the range published by Kennedy and Smith (1959) for *P. trichocarpa* seedlings (0.42-0.60 mm.).

Narrow-sense heritabilities (table 1) for height decreased from 0.93 in 1962 to 0.35 in 1963; heritabilities for 1962 and 1963 diameter growth were 0.52 and 0.16. Specific gravity and fiber length had heritabilities of 0.62 and 0.40.

Narrow-sense heritability estimates were also calculated by regressing progeny mean values for specific gravity and fiber length on maternal parent values and doubling the regression coefficients; a value of 0.18 was obtained for specific gravity and of 0.32 for fiber length. These estimates, especially that for specific gravity, are considerably lower than those obtained by partitioning variance components. This result was not unexpected, since parent trees were growing on a variety of sites along the Mississippi River.

Genetic correlations in table 2, derived from covariance analyses indicate essentially no relationship between specific gravity and either diameter ($r_a = -0.07$) or fiber length ($r_a = 0.18$). There was, however, a strong positive genetic correlation between diameter and fiber length ($r_a = 0.80$) . This relationship between growth rate and fiber length was observed in juvenile P. *trichocarpa* by Kennedy and Smith (1959).

Table 2.--Analysis of covariance and genetic correlations for diameter growth and wood properties in a cottonwood one-parent progeny test

| Item | | | Diameter/ specific gravity | Diameter/ fiber length | Specific gravity/ fiber length |
|---|---|---|---|---|---|
| Source of variation | df | | | | |
| | | | MEAN SQUARE | | |
| Replications (R) | 9 | | -0.529854 | -0.242526 | 0.034092 |
| Families (F) | 24 | (1) | -.008219 | .048867 | .002998 |
| Replications X Families | 1/ 215 | (2) | -.005898 | +.000096 | .000956 |
| Within plot (W) | | (3) | -.000710 | +.002716 | .000161 |
| | | | VARIANCE COMPONENT | | |
| $\sigma^2_F = (MS_1 - MS_2)/RK$ | | | -.000039 | .000769 | .000034 |
| $\sigma^2_{RF} = (MS_2 - MS_3)/K$ | | | -.000865 | 2/ 0.0 | .000132 |
| $\sigma^2_W = MS_3$ | | | -.000710 | +.002716 | .000161 |
| | | | GENETIC CORRELATION | | |
| | | | -.0667 | .7994 | .1818 |

1/ Reduced by 1 because of 1 missing plot.

2/ Considered as 0.0 since within-plot variance exceeded replication X family variance.

## Discussion and Conclusions

The marked differences in heritabilities between the 2 years for height and diameter and between the two methods of calculation for the wood property data illustrate the limitations of the values. They are descriptive statistics for a particular experiment. Only as the experiment is typical of a species or population will the heritabilities be typical; therefore caution is needed in their interpretation and particularly in their extension to other populations.

The narrow-sense heritabilities for growth parameters in 1963 are in the general range reported for juvenile half-sib progeny tests by Matthews *et al.* (1960) and Wright (1963). The difference between height and diameter-growth heritability in 1962 and 1963 may be due to several causes. For one thing, environmental preconditioning in the greenhouse while plants were growing in family blocks may have accentuated 1962 family differences. Second, the difference in competition between 1962 and 1963 may have altered variation patterns. Cutting plants back to root stocks after one season's growth may also have had an effect.

Narrow-sense heritabilities for wood properties in cottonwood have not been reported. Our estimates of 0.62 for density and 0.40 for fiber length are within the range for juvenile conifers (Stonecypher *et al.* 1964; van Buijtenen 1962; Zobel 1961). They indicate opportunity for moderate genetic gain via family selection. Of perhaps greater significance is the strong genetic correlation between diameter and fiber length (ra = 0.80), which indicates that selection for rapid growth will result in a concurrent improvement in fiber length. Other genetic correlations suggest little opportunity of increasing density by selecting for other characters.

Although a high degree of variation in growth is present in our material, lack of data on juvenile-mature correlations suggests the need for extensive selection in nursery tests. In a 10-year study of growth patterns in highly variable progenies of hybrid poplar, Bialobok (1963) found that ranking of individual trees within progenies changed annually for 5 to 7 years. The poorest were easily identified after first-season growth, but within the better stems rearrangement was considerable. Thus, in our material, clonal testing of the top 10 percent of phenotypes in the top 20 percent of families would appear to be a safe and productive procedure at this stage of breeding.

Juvenile cottonwood's rapid growth and sensitivity to minor site differences (both demonstrated in this test) indicate that special care is necessary in the design and conduct of nursery progeny tests. Heterogeneity common to the alluvial soils in the lower Mississippi Valley is thus a major problem in testing. The most accurate results can perhaps be secured with intensive site preparation and culture ( as for agricultural crops) and sensitive experimental designs such as the lattices. At least 4- by 4-foot spacing is desirable if material is to be observed for 2 years.

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