Predicted Genotypic Gain from Cottonwood Clonal Tests

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Eastern cottonwood (Populus deltoides Bartr.) is an excellent candidate for planting and intensive culture in southern bottom lands at least partly because of its high potential for genetic improvement. To realize that potential quickly, efficient and reliable clonal tests must be designed. The purpose of these tests should be first to select the best clones from a large number being observed and then to reliably predict how well the selections will perform on sites that are likely to be planted. Information presented here should help in designing adequate tests.

If clones are tested on too few sites or for too short a time, the merits of the selections may be exaggerated. Testing on too many sites, however, exhausts resources that could more profitably be allocated to other phases of the breeding program. Evaluating for too many years prior to release deprives growers of potential profits. To decide how many sites to test on and for what length of time, a breeder must have reliable estimates of genotypic variance, genotype X environment interaction variance, and correlations between measurements taken at different ages. Environment is meant here to include both site and weather conditions.

Genotype X environment interactions in cottonwood have been studied. Farmer (1970) found significant interactions for growth characters and wood properties. Curlin (1967) found strong clone X fertilizer interactions for height, diameter, and volume, but not specific gravity. Farmer and Wilcox (1968) did not find significant clone X site interaction for height, diameter, or specific gravity in 1-year-old cottonwood. Significant interaction was found in field studies by Randall and Mohn (1969) and Mohn and Randall (1973) on two sites near the extremes of cottonwood productivity for the lower Mississippi Valley. In both studies, one site was typical of those where cottonwood is commercially grown and the other was marginal at best for cottonwood production. Estimates of genotype X site interaction, therefore, may have been near maximum. Effects of planting site and year were not combined as they are in the present study, however.

Few studies have been published about genotype X planting year interaction. Mohn and Randall (1973) found no clone X planting year interaction in cottonwood for either 3-year height or diameter.

In the current study, each planting was made in a different year, thus completely confounding site and planting year. Cottonwood site index (30-year base) for the three test sites ranged from 90 to 122. All would be acceptable for commercial planting.

Methods

The three environments for the study were Wickliffe in Ballard County, Kentucky, planted in 1965; Morrison in Hickman County, Kentucky, planted in 1966; and Conran in New Madrid County, Missouri, planted in 1967. At each location 50 clones were planted, but not all were common to each location. Some clones were omitted from the analysis due to poor survival. Thirty-two clones which were common to the three plantings are considered in the current analysis. These include a number from the USDA Forest Service breeding program at Stoneville, Mississippi, and from the Armstrong Cork Company program at Wickliffe, Kentucky.

Two ramets were planted per plot at a 10- by 10-foot spacing. Plots were replicated four times at each location in randomized complete block designs. Unrooted 20-inch cuttings were planted in February or March. Planting and cultural procedures outlined by McKnight (1970) were followed. Height, diameter, and specific gravity were measured at the times shown in Table 1.

Table 1. — Ages at which characters were measured.

Character	Planting site and age Wickliffe	Morrison	Conran
		Years	
Height	1, 2, 3, 5	1, 2	1, 3
Diameter	3, 5	2, 4	3
Specific gravity	5	4	3

Table 2.—Mean (X), error variance (σ^2), interaction variance (σ^2_{gn}), genetic variance (σ^2), heritability (h^2) and genotypic gain ($\Delta M/\overline{x}$) for height, diameter, and specific gravity for combined data over three sites and averages for single sites.

Data in group	$\overline{x}$	σ^2	σ^2_{gn}	σ^2		h^2		$\Delta M/\overline{x}$	
	Combined	Combined	Combined	Combined	Average	Combined	Average	Combined	Average
Height (feet) 1/	21.98	5.56	1.45	2.26	3.70	.24	.38	9	12
DBH (inch) 2/	3.10	.33	.11	.21	.33	.33	.47	21	21
Specific gravity 2/	.34	.00016	.00001	.00030	.00031	.63	.72	8	8

1)Height was measured at ages 3, 2, and 3 years, respectively at Wickliffe, Morrison, and Conran.

2)Diameter and specific gravity were measured at ages 5, 4, and 3 years, respectively at Wickliffe, Morrison, and Conran.

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Each character was subjected to analysis of variance by individual environment, and significance was determined at the 0.05 level. Error variances were examined for homogeneity, and certain analyses were combined over environments. It was necessary to combine data taken at different ages because measurements were not taken at the same ages at each environment. In most cases mean growth for the ages combined was approximately the same. In the combined analysis, the genotype × environment component of variance was confounded with age of material. The combined analyses are listed in *Table 2*.

Broad-sense heritabilities were computed on a plot-mean basis as suggested by NAMKOONG *et al.* (1966) to conform with other published reports on cottonwood heritabilities. For single sites, heritability (h^2) was determined as:

$$\frac{\sigma_g^2}{\sigma_g^2 + \sigma_e^2}$$

Heritability over sites was computed as:

$$\frac{\sigma_g^2}{\sigma_g^2 + \sigma_{gn}^2 + \sigma_e^2}$$

where σ_g^2 is the genotypic variance, σ_{gn}^2 is the genotypic × environment interaction variance, and σ_e^2 is the error variance.

The best clones from this study will be propagated for further testing and for commercial use. Therefore, broad-sense heritability (ratio of total genotypic variance to phenotypic variance) is appropriate in predicting gain from selection. A common formula for predicting gain (ΔM) from selection is $\Delta M = i\, h^2 \sigma_p$ where i is the intensity of selection and σ_p is the square root of the phenotypic variance (FALCONER, 1966).

Since selection will be based on clone means, h^2 and σ_p must be expressed on a clone-mean basis for inclusion in the predicted gain formula. For a single location on a clone-mean basis, $h^2 = \frac{\sigma_g^2}{\sigma_g^2 + \frac{\sigma_e^2}{r}}$ and $\sigma_p^2 = \sigma_g^2 + \frac{\sigma_e^2}{r}$; therefore $\Delta M = i \frac{\sigma_g^2}{\sqrt{\sigma_g^2 + \frac{\sigma_e^2}{r}}}$.

For more than one location, on a clone-mean basis, $h^2 = \frac{\sigma_g^2}{\sigma_g^2 + \frac{\sigma_{gn}^2}{n} + \frac{\sigma_e^2}{rn}}$ and $\sigma_p^2 = \sigma_g^2 + \frac{\sigma_{gn}^2}{n} + \frac{\sigma_e^2}{rn}$; therefore $\Delta M = i \frac{\sigma_g^2}{\sqrt{\sigma_g^2 + \frac{\sigma_{gn}^2}{n} + \frac{\sigma_e^2}{rn}}}$ where n is the number of locations and r is the number of replications. If the upper 12½ percent (4/32) of the clones are to be saved, i will be 1.583 (BECKER, 1967).

Phenotypic correlations among characters measured at the Morrison and Wickliffe sites were computed from clone means.

Results and Discussion

Clones differed significantly for each character measured in every individual and combined analysis. From the combined analyses, environmental effects and clone-environment interactions were significant for all characters except specific gravity. The lowest mean specific gravity occurred at the site where growth was most rapid. The genotype × environment component of variance was as large as the genotypic component for age 1 height; it was approximately one-half as large as the genotypic component for each of the growth characters measured at later ages (*Table 2*). The genotype × environment component was essentially zero for specific gravity. Only for age 1 height was the genotype × environment variance sufficiently large to cause the average of the three individual location estimates of expected genotypic gain to be appreciably higher than the estimate from the combined analysis.

Growth characters were highly correlated (*Table 3*), indicating that height and diameter growth can be substantially improved simultaneously. Since specific gravity was only measured on 10 clones, correlations between specific gravity and growth characters were not computed.

Table 3. — Phenotypic correlations for height and diameter at Wickliffe and Morrison.[1]

Character and age	Wickliffe Height, age 5	 DBH, age 5	Morrison DBH, age 4
Height (feet)			
age 1	.68	.61	.42
2	.78	.78	.68
3	.91	.89	
5		.87	
Diameter (inches)			
age 2			.89
3		.96	

[1] All correlations are significant at 0.05 level.

Estimates of genotype × site interactions by MOHN and RANDALL (1973) and RANDALL and MOHN (1969) at latitude 33-1/2° north may have been too large, because of the wide contrast in productivity of the test sites. The present study was done all on soils that are recommended for cottonwood planting, and site differences were not as large. Use of data from trees of different age but comparable size could have reduced the magnitude of our genotype × environment interaction estimates. In all three studies, however, the estimates of genotype × environment variance for most growth characters were approximately one-half as large as those for genotypic variance. Therefore, it appears that the estimates in all cases were reasonable. In our study, genotype × environment interaction variance for height was as large as genotypic variance at age 1, then decreased progressively. Perhaps that difference was caused by variations in weather and first-year cultural techniques.

If the 32 clones from the present study were regrown on a large number of sites of which the current three sites were a random sample, it is predicted that the best four would be 9 percent taller, 21 percent larger in diameter, or 8 percent higher in specific gravity than averages of the 32 clones.

When genotypes are tested at only one location, the interaction of genotypes and environments is inseparable from the genetic effects. If the interaction is large, genetic gain will be overestimated. From our study, the overestimate of genotypic gains from single sites was excessive only for first-year height. With later height, diameter, and specific gravity measurements, estimates of genotypic gain from single sites were only slightly larger than gains computed over locations.

Genotype × environment interaction had little effect on estimates of genotypic gain, except for first-year height.

Additional locations, therefore, are beneficial primarily because they provide more precise estimates of clone means.

Since there was essentially no genotype × environment interaction for specific gravity and the estimated genotypic response was similar at each location, it appears that little can be gained by measuring specific gravity at more than one location.

Summary

Among 32 cottonwood clones tested at three locations, the genotype × environment component of variance was as large as the genotypic component for age 1 height. At later ages, it was approximately half as large as the genotypic component for height and diameter. No such interaction was found for specific gravity. Only for age 1 height did the genotype × environment interaction cause the average of the three individual location estimates of expected genotypic gain to appreciably exceed the estimate from the combined analysis. Growth characters were closely correlated. Selecting the best 4 of 32 clones would give predicted genotypic gains of 9 percent in height, 21 percent in diameter, or 8 percent in specific gravity.

Key words: Populus deltoides, genotype × environment interaction, heritability.

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Effect of Annual Leader Pruning on Cone Production and Crown Development of Grafted Douglas-fir

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Introduction

Grafted ramets of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) in Oregon and Washington seed orchards commonly grow 2 to 4 feet in height each year. As a result, upper crowns of 14- to 16-year-old grafts are already difficult to reach and manage. Insect and disease control, controlled pollination, and operation of overhead irrigation systems are difficut. Climbing to collect cones of orchard trees which might have structurally weak graft unions is dangerous. Therefore, Douglas-fir seed orchardists would like to restrict tree leader growth even at the expense of some cone production.

Several methods for limiting or evading the tree height problem have been tried on *Pinus* species in the southern pine area of the United States. Tree shearing or pruning studies (van Buijtenen and Brown, 1963) and tree shakers and mobile vacuum machines (North Carolina State University, 1970) have been tested under their orchard conditions. Tree shakers have not been used in Douglas-fir orchards because of the branch and leader damage which occurs during shaking. Also, there have been no adequate tests to prove that bole damage does not occur when the trees are reshaken each crop year. The vacuum machine technique of picking up seed from the ground has not been tested in the Douglas-fir region and would presently be unsuitable unless orchards had more thorough ground clean-up and maintenance programs. Chemical control of leader growth, as proposed by Sachs *et al.*, 1970, is not favored for seed orchards because of potential mutagenetic effects on the reproductive buds and the developing seeds.

Reduction of tree height by leader pruning is an alternative, but Douglas-fir orchardists presently have little information concerning its use. Crown pruning was tested on *Pinus taeda*, and the resulting cone production from pruned trees was generally disappointing (van Buijtenen and Brown, 1963). Crown shearing of a Christmas tree plantation shows that Douglas-fir is easily shaped (Douglass, 1964). But trees of this size are generally too young to produce adequate numbers of cones and of no use in evaluating shearing effects on cone production. Personal observations of Douglas-fir trees growing under telephone and electric power lines in Oregon indicate that cones are produced on leader- and crown-sheared trees. But how the frequency of crops and number of cones produced by pruned trees compare with unpruned trees growing in similar areas is not known.

The following study was established in 1965 to determine the effect of leader pruning on cone production and crown shape.

Materials and Methods

Leaders were pruned annually to 1.0 or 1.5 feet above the top whorl of branches. From 1965 to 1970, succulent leaders (about 90—95% elongated) were pruned in July, and lignified leaders (fully elongated), in September. Single stem trees were desired, so lateral branches were trimmed

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