SPECIFIC GRAVITY AS A SELECTION CRITERION IN SYCAMORE

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Abstract.--Specific gravity, fiber length, and fiber, vessel and ray volumes were measured at DBH in the second growth ring of coppiced sycamore (Platanus occidentalis L.) from a progeny test in the Georgia Piedmont. From these measurements, the means, phenotypic standard deviations, heritabilities and genetic correlations were determined to estimate the effects of selection for high specific gravity on sycamore wood properties. Results indicate that substantial gain in specific gravity could be made by mass selection in the progeny test accompanied by increases in ray and fiber content and decreases in vessel content. Changes in tissue proportions are probably too small to seriously affect pulping characteristics of the wood. Fiber length would be virtually unchanged by selection for specific gravity.

Additional keywords: Platanus occidentalis, heritability, genetic correlation, fiber length, fiber volume, vessel volume, ray volume.

INTRODUCTION

In recent years there has been an upsurge in the planting of hardwoods for utilization as pulp and as a possible source of fuel. Sycamore is one species being given considerable attention because of its fast growth rate and coppicing ability.

With large scale planting genetic improvement for biomass production becomes justified. Results from a Georgia Piedmont indicate that moderate genetic gains are possible by selecting for volume and high specific gravity. (Webb et. al., 1973).

Selection for specific gravity may be accompanied by changes in the anatomical characteristics of wood. In hardwoods, this is because the major tissues of the wood, rays, vessels and fibers differ greatly in their specific gravities (Taylor, 1969a). Increases in ray and fiber volumes and decreases in vessel volume are associated with increases in specific gravity. (Taylor, 1969b; Taylor and Wooten, 1973). On a phenotypic basis, variation in sycamore specific gravity is due more to differences in relative tissue volumes than thickness of fiber walls. This is in contrast to southern pines where increases in specific gravity are associated with increases in tracheid wall thickness (Van Buijtenen et. al., 1968).

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If the relationship between specific gravity and tissue proportions is inherited, selection for specific gravity will result in greater ray and fiber and lesser vessel proportions. And, if these changes are large, high specific gravity selections may produce poor quality paper since a high volume of rays and a low volume of vessels may be detrimental (Horn, 1978; Marton and Agarwal, 1969).

It is the purpose of this study to determine what changes in wood properties can be expected from selection for high specific gravity in sycamore, and, if these changes are likely to affect paper properties.

MATERIALS AND METHODS

Plantation Site, Design, and Treatment.--The progeny test used in this experiment is located on the Oconee River bottom near Scull Shoals in Greene County in the Georgia Piedmont. It consists of 64 wind-pollinated families of sycamore from the Greene and adjacent, Clarke and Oglethorpe Counties. Plantation design was randomized complete block with six replicates and four-tree square plots. Spacing was 1.25m x 1.25m (4 x 4 feet).

The trees were planted as 1-0 seedlings in March, 1968, and the shoots harvested in the winter of 1971 (Webb et. *al.,* 1973). Samples for this research were taken from the subsequent coppice growth.

Sample Selection.--Twenty-four families were chosen at random from the forty-six in which at least two trees survived in each replication. Two trees were then randomly selected within each. Since multiple sprouts were often present, the sprout displaying height dominance was selected for sampling.

Measurements.--The wood samples were stem segments taken at a height of 4.5 ft. The second growth ring of each segment was used for all measurements of proportionate tissue volumes, fiber length, and specific gravity. Proportionate tissue volume was estimated utilizing a Leitz six-spindle integrating stage according to the method outlined by Smith (1967) and percentage volumes for rays, fibers, and vessels were calculated. Fiber length was measured by projecting macerated fiber onto a sampling grid. Specific gravity was determined as oven dry weight divided by green volume determined by immersion.

Statistical Analysis

Each trait was subjected to analysis of variance to determine if family effects were significant and to estimate variance components for heritability calculations. Analysis of the randomized complete block design indicated no replicate effects. The data was then reanalyzed using the completely randomized model:

measured character = mean + family effect + error.

An analysis of covariance was performed according to Becker (1975) in order to estimate genetic correlation between each pair of traits.

Phenotypic correlations were also calculated.

RESULTS AND DISCUSSION

Phenotypic and genetic parameters.--The phenotypic population parameters of wood properties measured in the Scull Shoals progeny test are presented in Table 1. In general the mean values are similar to those reported from other populations. For specific gravity the average of 0.40 compares favorably to 0.41 in wood of similar age from natural Mississippi stands (Schmitt and Wilcox, 1968) and another Georgia Piedmont stand (Saucier and Ike, 1969). Likewise at a comparable height and age similar fiber lengths were found in Mississippi trees (Taylor and Wooten, 1973) and the Schull Shoals trees.

Table 1.--Means, phenotypic standard deviations and coefficients of variation (CV) of wood properties from Scull Shoals progeny test.

Trait[1/]	$\bar{X}$	σ_P	CV
Specific Gravity	.40	.02	.05
Ray Volume (%)	11.1	1.55	.14
Vessel Volume (%)	32.2	3.29	.10
Fiber Volume (%)	53.4	3.34	.06
Fiber Length (MM)	1.55	.05	.03

1/ Volumes are percent of total wood volume.

Ray, vessel and fiber volumes reported in Table 1 are precent of total wood volume. The sum of these volumes averages 96.7%. The remainder is primarily axial parenchyma. Other studies of wood tissue volumes have shown somewhat higher proportions of ray volumes than our 11.1%; Saucier and Ike (1969) reported 25%, Taylor (1976) 19%, and Myer (1922) 19%. These higher values may be attributed, in part, to inclusion of axial parenchyma in their ray volume fractions. Vessel and fiber volumes were similar between this and the other studies.

Variability for each wood trait is presented in terms of phenotypic standard deviation and coefficient of variation. By either expression it is apparent that wood tissue volumes exhibit a large amount of variation compared to specific gravity or fiber length. Schmitt and Wilcox (1969) concluded that selection for fiber length was not merited because of insufficient variation. On the other hand, they and Lee (1972) suggested that selection for specific gravity might be profitable.

Although specific gravity and fiber length were less variable than the tissue volumes, they were more highly heritable (Table 2). In fact, the calculated heritabilities for specific gravity and fiber length were greater than one. This may be due to the fact that individuals in a family could be more closely related than half-sibs as was assumed in the calculation. This is probable since families represent open pollinated collections from mother trees in several natural stands. The high heritabilities may also occur because of imprecise variance estimates. This is indicated by the widths of the 95% confidence intervals

(Table 2). Confidence intervals presented here have been truncated at 1.00 and 0.00 since we have no confidence that heritabilities fall outside this range. All traits are considered to have a significant genetic component ($h^2 > 0$) since family means were statistically significantly different for each trait (Table 3).

Table 2.--Single tree heritabilities for wood properties.

Trait[1/]	H^2	H^2 95% CI
Specific Gravity	1.10	.59-1.00
Ray Volume	.67	.29-1.00
Vessel Volume	.35	.07- .86
Fiber Volume	.21	.00- .66
Fiber Length	1.40	.87-1.00

1/ Volumes are percent of total wood volume.

Table 3.--Family F values for wood properties.

Traits	"F" ratios for families
Ray Volume	3.42**
Fiber Volume	1.67*
Vessel Volume	2.14**
Specific Gravity	5.41**
Fiber Length	7.66**

* significant at α = .05
** significant at α = .01

Ray and fiber volumes have strong positive correlations and should increase with selection for high specific gravity. Conversely, vessel volume is negatively correlated and will decrease with selection for high specific gravity. Fiber length is poorly correlated with specific gravity (Table 4).

Table 4.--Genetic correlations between specific gravity and other wood properties.

Trait[1/]	Correlation Coefficient[2/]
Ray Volume	+.50
Vessel Volume	-.87
Fiber Volume	+.52
Fiber Length	+.06

1/ Volumes are percent of total wood volume.

2/ Standard errors of the genetic correlations range between .20 and .30.

Selection for high specific gravity.--The progress made by mass selection for high specific gravity in the Scull Shoals progeny test is given by gain = $i\sigma_p h_I^2$ (i = intensity of selection, σ_p = standard deviation of trees in the progeny test and h_I^2 = individual tree heritability calculated in the progeny test). By selecting the thirty trees with the greatest specific gravity from those 1224 surviving individuals, $i = 2.4$ (Becker, 1975). The genetic gain would be 0.05, or an increase of 12% (Table 5). For this calculation a heritability of 1.00 was assumed.

Table 5.--Response of wood properties to phenotypic selection of the 30 densest trees out of 1224 (I = 2.4).

Trait[1/]	Change from mean	
	Absolute Units	%
Specific Gravity	+.05	+12.0
Ray Volume	+1.52	+13.5
Vessel Volume	-4.06	-12.5
Fiber Volume	+1.91	+ 4.0
Fiber Length (MM)	+0.01	+ 0.5

1/ Volumes are in percent of total wood volume.

In selecting for high specific gravity changes in the tissue volumes are also expected because of their strong genetic correlations with specific gravity (designated r_A). However, the amount of that change is also determined by other factors including selection intensity (i), phenotypic standard deviation of the correlated trait (σ_{py}), square root of the specific gravity heritability (h_x) and square root of the correlated trait heritability (h_y). Together the change in the correlated trait (CR_y) = $i\sigma_{py}h_x h_y r_A$. Selecting 30 trees with the densest wood would result in increases of ray and fiber volumes by 1.52 and 1.91 percent of wood volume, respectively, at the expense of vessels which drop by 4.06 percent of wood volume. In other terms progeny of the selected trees would have 4% greater fiber volume, 13.5% greater ray volume and 12.5% lesser vessel volume (Table 4).

Fiber length is little affected by genetic selection for specific gravity.

Practical significance.--On the basis of phenotypic variation Schmitt and Wilcox (1969) and Lee (1972) have suggested selection for specific gravity in sycamore, presumably to increase the yield of pulp per unit volume of wood. From our heritability estimates, and those of Webb et. *al.* (1973), it indeed appears that significant increases in specific gravity and hence pulp yield, could be made by mass selection. (Because of the high heritability family selection has little utility).

Such phenotypic selection would concomitantly result in greater proportions of rays and fibers and less vessel elements. Fiber length would be virtually unaffected, and, unlike pine, it is probable that fiber wall thickness would not be altered since it is poorly correlated with specific gravity. (Taylor, 1976).

Genetic variation in specific gravity, thus, appears to result largely from different proportions of the wood tissue types. The relative proportion of these has been shown to affect the pulping properties of angiospermous wood. Horn (1978) demonstrated that hardwood rays contribute to the fines and that a high percentage of these is detrimental to bursting and tensile strength. In *Quercus alba, Betula papyrifera* and *Populus* fibers were shown to make stronger paper than vessels, but whole pulp produced the best result (Marton and Agarwal, 1965). As yet there is too little information to completely define the relationships between tissue volumes and paper properties, but it does not appear that even very strong selection for specific gravity (selection of the best 0.1% of the population) will result in tissue volume changes (ray volume: + 2.1, fiber volume: + 2.7, vessel volume: -5.8 on a % of wood volume basis) that will greatly alter paper properties (Horn, per. comm.).

Maximizing pulp yield from sycamore plantations depends on increasing volume production as well as specific gravity. Heritabilities for growth variables were about 0.3 from four year old trees in this same progeny test (Webb et. al., 1973), indicating that moderate gains can be expected from selection for volume. However, the genetic correlations between growth parameters and specific gravity were negative, about -0.2. Selection for volume or specific gravity alone would result in losses in the other. The most rapid improvement would be made by joint selection or by selection for stem biomass directly. However selection for stem biomass first requires the development of weight yield tables.

Selection for biomass has taken on a new significance with the current interest in sycamore as potential source of fuel. Here, too, producing maximum dry weight per acre is desirable. The same selected genotypes may therefore serve for energy or fiber production.

Limitations of the results.--Strictly speaking this data and the conclusions drawn from them apply only to wood in the second growth ring of once coppiced sycamore growing in the Scull Shoals progeny test. In addition the heritabilities and hence the predicted gains from selection in this progeny test are somewhat overestimated since the test occurs at only one location (genotype x environment interaction being ignored) and because individuals in a family are more closely related than half-sibs. The results found in this study should be tested in other populations.

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