Genetics of wood and bark Characteristics of Eucalyptus viminalis

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Abstract

Thirteen open-pollinated families of *Eucalyptus viminalis* were used to estimate narrow sense heritabilities for wood specific gravity, wood moisture content, bark specific gravity, fiber length, cell wall thickness, fiber diameter and lumen diameter. The respective values calculated on family means were 0.61, 0.52, 0.55, 0.42, 0.94, 0.82 and 0.71.

There was considerable variation among trees and families for the seven characteristics studied. The mean values obtained were: wood specific gravity (0.48), wood moisture content (135 percent), bark specific gravity (0.30), fiber length (0.64 mm), cell wall thickness (4.37 μm), fiber diameter (15.04 μm), and lumen diameter (6.32 μm).

Genetic correlations among the traits were found to be greater than phenotypic correlations. Most of the significant phenotypic correlation coefficients were of traits with low genotypic correlations.

Wood moisture content, bark specific gravity and lumen diameter were the only three characteristics that are of value in predicting wood specific gravity. Wood moisture content was the best single correlate of wood specific gravity.

Key words: E. viminalis, wood specific gravity, moisture content, fiber length, cell wall thickness, fiber diameter, lumen diameter, heritability, phenotypic correlation, genotypic correlation.

Zusammenfassung

Dreizehn frei abgeblühte Familien von *Eucalyptus viminalis* wurden dazu verwendet, die Heritabilitäten im engeren Sinne für das spezifische Gewicht des Holzes, den Feuchtigkeitsgehalt des Holzes, das spezifische Gewicht der Rinde, die Faserlänge, die Zellwanddicke, den Faser- und Lumendurchmesser zu schätzen. Die betreffenden, auf die Familienmittel bezogenen Werte waren: 0.61, 0.52, 0.55, 0.42, 0.94, 0.82 und 0.71.

Sowohl zwischen Einzelbäumen, als auch zwischen Familien war für die sieben beobachteten Hauptmerkmale eine beträchtliche Variation festzustellen. Die erhaltenen Mittelwerte waren für das spezifische Gewicht des Holzes 0.48, den Feuchtigkeitsgehalt des Holzes 135%, das spezifische Gewicht der Rinde 0.30, die Faserlänge 0.64 mm, die Zellwanddicke 4.37 μm, den Faserdurchmesser 15.04 μm und den Lumendurchmesser 6.32 μm.

Genetische Korrelationen zwischen den Merkmalen stellten sich als größer heraus, als die phänotypischen. Die meisten der signifikanten, phänotypischen Korrelationskoeffizienten zeigten geringe genotypische Korrelationen.

Der Feuchtigkeitsgehalt des Holzes, das spezifische Gewicht der Rinde und der Lumendurchmesser waren die einzigen drei Merkmale, die für die Einschätzung des spezifischen Gewichts des Holzes Bedeutung haben. Der Feuchtigkeitsgehalt des Holzes war das beste Einzelkorrelat des spezifischen Gewichtes des Holzes.

Introduction

Growth of southern United States hardwoods exceeds drain by a ratio of two to one. Despite that favorable ratio, availability of the resource in the South Atlantic and Gulf Coastal States is limited because the greatest inventory of hardwoods occurs in bottomland forest types. There is thus a need to identify species that will exhibit rapid growth, tolerance to pests, and desired wood properties for upland sites which are accessible during all seasons of the year. Based on experience in other parts of the world, selected species of *Eucalyptus* appear to have that potential.

The first recorded attempt to introduce fast-growing *Eucalyptus* species from Australia to the southern United States was in 1878 (Schory, 1962). The attempts were sufficiently successful at latitudes south of 28°N to create interest in growing some of the species for forestry use. In 1959 the Florida Forests Foundation began an extensive program to screen species for use in the prairie grasslands of south-central Florida. That project, which subsequently became a working unit of the Southeastern Forest Experiment Station of the U. S. Forest Service, identified *E. grandis, E. robusta, E. tereticornis* and *E. camaldulensis* as the species having greatest potential.

In 1971 members of the N. C. State University-Industry Cooperative Hardwood Research Program, with landholdings throughout the Southeast, began a search for species and sources of *Eucalyptus* having acceptable cold tolerance, adaptability, resistance to pests, and acceptable wood properties. Species identified for potential use within a zone 100 miles inland from the Gulf Coast and extending northward to Charleston, South Carolina include *E. viminalis, E. nova-anglica, E. macarthurii* and *E. camphora* (Hunt and Zobel, 1978).

Eucalyptus viminalis Labill. is the most promising species identified from the study. Because of its potential as an exotic in the South, it has been necessary to study the species extensively with respect to its wood and fiber characteristics. The objectives of this study were: Determine the variation pattern of certain wood and fiber characteristics in *Eucalyptus viminalis;* estimate variance components of the characteristics under consideration; estimate heritability values of these characteristics; determine the relationships, if any, that exist among the characteristics; and determine which of the other characteristics can be used to predict wood specific gravity.

Materials and Methods

Thirteen open-pollinated families of *Eucalyptus viminalis* were harvested in March, 1978 at 35 months of age for determination of wood properties. The trees were grown in southwestern Georgia by International Paper Company at a spacing of 2.7 x 2.7 m in 25-tree square plots of a replicated design. The trees, growing on 70 site index quality land for *Pinus taeda* at base year 25, averaged about 8 meters tall and 6.5 cm diameter outside bark at breast height (1.3 meters above ground level) at time of harvest. Wood samples were taken at breast height from 5 trees in each of 3 replications for each of the 13 half-sib families. Two 2-inch disks of wood were obtained, one with the bark peeled and the other with the bark intact. Each disk was labeled and sealed in plastic bags for transport to the cold room, where they were kept until time of processing.

In the laboratory each disk of wood was split through the pith to form two halves to allow for an estimate of error at the one sample point on the tree bole. Specific gravities were determined by the water displacement method used

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by the N. C. State Tree Improvement Program. Wood specific gravity was determined from the peeled wood sample, while bark specific gravity was determined from the sample with bark intact. Calculation of the respective values was by the ratio:

$$\text{Specific gravity} = \frac{\text{oven dry weight of sample}}{\text{green volume of sample}}$$

Wood moisture content was determined from the data obtained from wood specific gravity determination. It was calculated by the ratio:

$$\text{Wood moisture content} = \frac{\text{air weight of green wood sample} - \text{oven-dry weight of the sample}}{\text{oven-dry weight of the wood sample}} \times 100\%$$

To determine fiber dimensions, a thin transverse section was taken from each wood sample. Macerating, staining, and preservation of the fibers were done by the method used by the N. C. State Tree Improvement Program.

From the macerated wood samples, slides were prepared using glycerin and water as media to measure lengths of 20 unbroken fibers from each sample. With lumen diameter, cell wall thickness and fiber diameter, only glycerin was used as the medium, and a scaled light microscope with a specifically designed fiber micrometer eyepiece was used to take simultaneous radial measurements.

All analyses were done using basic computer language for SAS as given by BARR, *et al.* (1976).

Results and Discussion

The results of the analyses of variance and the range of values for the seven characteristics examined are presented in *tables 1* and *2*, respectively. The variation among trees within a family for wood specific gravity, wood moisture content, bark specific gravity, fiber length, fiber diameter, lumen diameter, and cell wall thickness contributed appreciably to the total phenotypic variation existing for the respective characteristics *(Table 3)*. Except for fiber length and wood moisture content, significant differences also occured among the 13 half-sib families *(Tables 1* and *3)*. The significant variation among trees within families, coupled with similar findings by other investigators (Anon., 1976; DAVIDSON, 1973; JETT and ZOBEL, 1975), indicates that good genetic gains are possible from a moderate selection program involving these characteristics.

The average values for the seven characteristics were: Wood specific gravity, .48; wood moisture content, 135 percent; bark specific gravity, .30; fiber length, .64 mm; cell wall thickness, 4.37 μm; fiber diameter, 15.04 μm; and lumen diameter, 6.32 μm. The seven characteristics were under moderate to strong genetic control. Narrow sense heritabilities for individual trees and family heritabilities for each of the seven characteristics are presented in *table 4*. Single-tree heritability for fiber length was low compared to reported values for other tree species. For 13-year-old clonal material of *Pinus radiata*, DADSWELL, *et al.* (1961) reported a gross heritability of 0.73, whereas narrow sense heritabilities ranging between 0.57 and 0.97 were reported by GOGGANS (1962, 1964) for 7- and 8-year-old open-pollinated progenies of *Pinus taeda*. The low heritability value estimated from this study may be due to differences in fiber length between pines and eucalypts and between

Table 1. — One-way analysis of variance for seven wood and bark characteristics of *E. viminalis* a/

Source of Variation	Degrees of Freedom	MEAN SQUARE: Wood Specific Gravity	Wood Moisture Content	Bark Specific Gravity	Fiber Length	Cell Wall Thickness	Fiber Diameter	Lumen Diameter
Replication	2	.00313	369.583	.00238	.0000998	.8698	4.515	.145
Family	12	.00795*	1044.151	.00659*	.00692	4.2176**	9.282**	3.973**
Family x Replication	24	.00314*	505.143*	.00300**	.00403*	.2756**	1.705	1.167*
Tree (Family x Replication)	146	.00165**	271.725**	.00104**	.00224**	.1151**	1.194**	.730**
Sample (Tree x Replication x Family)	195	.000065	51.641	.0000701	.000210	.0418	0.464	.272

a/ ** Statistically significant at 1% level
*Statistically significant at 5% level

Table 2. — Mean value and range of tree and family values of wood and bark characteristics of *E. viminalis*

Characteristic	Mean	Individual tree range	Family range
Wood specific gravity	0.48	0.40 - 0.57	0.45 - 0.50
Wood moisture content (%)	135	106 - 167	127 - 145
Bark specific gravity	0.30	0.25 - 0.42	0.28 - 0.33
Fiber length (mm)	0.64	0.52 - 0.73	0.61 - 0.67
Cell wall thickness (μm)	4.37	2.87 - 6.05	3.97 - 5.31
Fiber diameter (μm)	15.04	9.27 -17.85	14.31 -16.12
Lumen diameter (μm)	6.32	4.36 - 8.82	5.50 - 6.74

Table 3. — Percent contribution by trees and families to total phenotypic variation for seven wood and bark characteristics of *E. viminalis*

Characteristic	Trees (%)	Families (%)
Wood specific gravity	67.88	13.72
Wood moisture content	54.21	8.85
Bark specific gravity	55.84	13.72
Fiber length	67.63	6.45
Cell wall thickness	16.23	58.17
Fiber diameter	32.23	22.29
Lumen diameter	35.89	14.65

Table 4. — **Heritability estimates of seven wood and bark characteristics of *E. viminalis* a/**

Characteristic	Single-tree Heritability	Family Heritability
Wood specific gravity	0.55 (0.35)	0.61 (0.39)
Wood moisture content	0.35 (0.28)	0.52 (0.40)
Bark specific gravity	0.55 (0.40)	0.55 (0.39)
Fiber length	0.12 (0.25)	0.42 (0.41)
Cell wall thickness	2.33 (0.94)	0.94 (0.38)
Fiber diameter	0.89 (0.42)	0.82 (0.38)
Lumen diameter	0.59 (0.32)	0.71 (0.39)

a/Standard error of estimate in parentheses

juvenile and mature wood of the different species. Fiber length increases with age of the tree, leading to an increase in genetic variance which in turn leads to a probable increase in heritability (GOGGANS, 1962). Since expected response to selection is a function of both heritability and variability, the low heritability value for fiber length will be offset to an extent by the large variation to make the characteristic similarly responsive to selection as the other characteristics.

For wood specific gravity, wood moisture content, fiber length and lumen diameter, family heritability was greater than the corresponding single-tree heritability (*Table 4*). Since single-tree heritability for these characteristics was high and similar to the corresponding family heritability, mass selection will be expected to be superior to family selection in the genetic improvement of these characteristics. This result occurs because of the greater variability among trees within a family than among families, which created a higher selection differential for mass selection.

Family heritability and single-tree heritability were the same (0.55) for bark specific gravity. Mass selection is thus favored over family selection in the genetic manipulation of the characteristic because of the reasons stated for wood specific gravity, wood moisture content, fiber length, and lumen diameter. The greater single-tree heritability (for cell wall thickness), and both the greater variability within than among families and the greater heritability from single-tree than from family calculations (for fiber diameter), indicate that mass selection will result in better improvement of these characteristics than family selection.

Table 5. — **Phenotypic correlation matrix of seven wood and bark characteristics of *E. viminalis* a/**

Characteristics	WSG	WMC	BSG	FL	CWT	FD	LD
Wood specific gravity (WSG)	1.000						
Wood moisture content (WMC)	-0.876**	1.000					
Bark specific gravity (BSG)	0.276**	-0.233**	1.000				
Fiber length (FL)	0.026	-0.024	-0.111*	1.000			
Cell wall thickness (CWT)	0.225**	-0.201**	0.337**	-0.157**	1.000		
Fiber diameter (FD)	-0.048	0.046	0.132**	-0.034	0.605**	1.000	
Lumen diameter (LD)	-0.334**	0.289**	-0.257**	0.161**	-0.418**	0.358**	1.000

a/ ** Statistically significant at 1% level
*Statistically significant at 5% level

Table 6. — **Correlation matrix of family means and genotypic correlations of seven wood and bark characteristics of *E. viminalis* a/**

Characteristics	WSG	WMC	BSG	FL	CWT	FD	LD
Wood specific gravity (WSG)	1.000						
Wood moisture content (WMC)	-0.966** (-0.988) b/	1.000					
Bark specific gravity (BSG)	0.467 (0.533)	-0.340 (-0.379)	1.000				
Fiber length (FL)	0.061 (0.079)	-0.067 (-0.093)	-0.336 (-0.445)	1.000			
Cell wall thickness (CWT)	0.343 0.376	-0.329 (-0.371)	0.674* (0.751)	-0.227 (-0.266)	1.000		
Fiber diameter (FD)	0.242 (0.331)	-0.184 (-0.265)	0.491 (0.589)	-0.110 (-0.145)	0.898** (0.950)	1.000	
Lumen diameter (LD)	-0.388 (-0.467	0.423 (0.458)	-0.728** (-0.873)	0.410 (0.524)	-0.763** (-0.843)	-0.417 (-0.629)	1.000

a/ ** Statistically significant at 1% level
* Statistically significant at 5% level
b/ Genotypic correlation in parentheses

Correlations

The phenotypic and genotypic correlation coefficients between all possible pairs of the seven characteristics are presented in *tables 5* and *6*, respectively. Since specific gravity is the only wood property directly considered in most selection programs, only relationships of specific gravity with the other characteristics investigated will be discussed.

In all cases, genotypic correlations were greater than the corresponding phenotypic correlations. In most cases where phenotypic correlations were statistically significant, the corresponding genotypic correlations were not statistically significant. This is probably due to the small number of families involved, leading to small degrees of freedom in the case of genotypic correlation. And since the degrees of freedom play a part in determining whether or not a correlation coefficient is significant, it cannot be that there is no genotypic correlation between any pair of characteristics with a significant phenotypic correlation coefficient. Moreover, it has been suggested that only the sign and relative size of a genotypic correlation need be considered, as genotypic correlation coefficients usually have high standard errors of estimate (GOGGANS, 1964). Thus it could be concluded that the genes controlling these characteristics have pleiotropic effect.

An inverse relationship exists between wood specific gravity and both wood moisture content and lumen diameter (*Tables 5* and *6*). This relationship suggests that wood specific gravity decreases with increasing lumen diameter and wood moisture content.

There was a positive correlation of wood specific gravity with bark specific gravity. This relationship indicates that wood specific gravity of a tree can be predicted if the bark specific gravity of the tree is known.

There was a highly significant, though small, positive correlation between wood specific gravity and cell wall thickness. The suggestion is that any genetic manipulation of wood specific gravity will result in a corresponding change in cell wall thickness.

There was no apparent relationship of wood specific gravity with fiber length and fiber diameter. Conflicting reports have been presented on the relationships (*e. g.*, GOGGANS, 1964; RESLER, 1978; VAN BUIJTENEN *et al.*, 1961; ZOBEL *et al.*, 1969). Because of the conflicting reports and because significant relationships did not materialize in this study, genetic improvement of wood specific gravity may not necessarily lead to a change in fiber length and fiber diameter of *E.viminalis.*

Regression

The regression analysis, with wood specific gravity as the dependent variable and the other characteristics as independent variables, showed that wood moisture content was the single most important characteristic that could be used to predict wood specific gravity. The regression equation developed was:

$$WSG = .7587 - .002100\ WMC$$

Where WSG = wood specific gravity
WMC = wood moisture content

The R-square statistic was 0.77 and was highly significant. The error mean square was .000269 with 388 degrees of freedom.

When wood specific gravity was regressed on all other characteristics and a stepwise regression used, wood moisture content (WMC), bark specific gravity (BSG), and lumen diameter (LD) were the only characteristics that proved significantly useful in predicting wood specific gravity. The regression equation obtained was:

$$WSG = .7467 - .002013\ WMC + .06990\ BSG - .003260\ LD$$

It contained a highly significant R-square statistic of 0.78 and an error mean square of .000258 with 386 degrees of freedom. When wood specific gravity was regressed on cell wall thickness (CWT) alone, the regression equation developed was:

$$WSG = .4033 + .0163\ CWT$$

The regression had an error mean sqare of .0011 with 388 degrees of freedom. The R-square statistic (0.05), though small, was highly significant and indicates that cell wall thickness can be used as an index of wood specific gravity.

Summary and Conclusions

The amount of variation and the magnitude of narrow sense heritability estimated for the various wood and fiber characteristics indicate that significant genetic gains can be realized through a moderately intensive selection program.

Family heritabilities were higher than single-tree heritabilities for wood specific gravity, wood moisture content, fiber length and lumen diameter while they were equal for bark specific gravity; single-tree heritabilities exceeded family heritabilities for cell wall thickness and fiber diameter. In all cases it is concluded that mass selection is superior to family selection in the genetic manipulation of the characteristics as the variation among trees for all the characteristics is great enough to offset low single-tree heritability.

Genotypic correlation coefficients were consistently greater than the corresponding phenotypic correlation coefficients, although the former were in most cases nonsignificant because of the small number of degrees of freedom. A negative correlation was found between wood specific gravity and wood moisture content and between wood specific gravity and lumen diameter. There was a positive correlation between wood specific gravity and bark specific gravity and between wood specific gravity and cell wall thickness. Hence, an increase in wood specific gravity would likely result in a decrease in wood moisture content and lumen diameter. A similar increase in wood specific gravity would likely result in a positive change in bark specific gravity and cell wall thickness.

No apparent relationship was found between wood specific gravity and fiber length and between wood specific gravity and fiber diameter. Wood moisture content was the best single predictor of wood specific gravity, while wood moisture content, bark specific gravity and lumen diameter combined gave the best predictor model. Cell wall thickness, though its effect is small, can be used as an index of wood specific gravity.

Generally the 35-month-old *E. viminalis* trees examined had a higher average wood specific gravity (0.48) than trees of similar age of some hardwood species indigenous to the South. Although eucalypt fibers are shorter than those of most indigenous hardwood species, higher wood specific gravity may offset any reduction in quality of pulp associated with short fibers. Coupled with its fast growth rate, frost-hardiness, good form, general resistance to pests, and acceptable wood properties, *E. viminalis* has definite potential for use in the Coastal Plain of the southeastern United States.

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Studies in Populus ciliata Wall. ex Royle. II Phenotypic variation in natural stands[1])

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Summary

Natural variation studies were conducted in *Populus ciliata* Wall. ex Royle to determine the range of phenotypic variation in Simla, Kulu and Chamba regions of Himachal Pradesh. The characters studied were height, diameter (D. B. H.), taper, specific gravity and fiber length. These were subjected to analysis of co-variance to eliminate the effect of age on phenotypic variants. Diameter was found to be strongly affected by age. Correlation studies carried out between height and diameter, diameter and specific gravity, height and fibre length, specific gravity and fibre length and hight and taper showed variable values in different provenances. Strong correlations were observed between height and diameter. Under closer spacing the ratio of clear bole to total height was found to be higher and showed positive correlations with height. The species in general revealed a low magnitude of genetic variation among the natural stands.

Key words: Populus ciliata, phenotypic variation, taper, specific gravity, co-variance, correlations.

Zusammenfassung

Bei *Populus ciliata* Wall. ex Royle wurden Studien zur natürlichen Variation durchgeführt, um den Rang der phänotypischen Variation in den Simla, Kulu und Chamba Regionen von Himachal Pradesh zu bestimmen. Die untersuchten Merkmale waren Höhe, Durchmesser in Brusthöhe, Stammform, spezifisches Gewicht des Holzes und Faserlänge. Um den Effekt des Alters zu eliminieren, wurden diese Merkmale einer Kovarianzanalyse unterworfen. Es wurde gefunden, daß Alter und Durchmesser in enger Beziehung stehen. Durchgeführte Korrelationsrechnungen zwischen Höhe und Durchmesser, Durchmesser und Holzdichte, Höhe und Faserlänge, Holzdichte und Faserlänge sowie Höhe und Stammform zeigten variable Werte bei verschiedenen Herkünften. Enge Korrelationen wurden zwischen Höhe und Durchmesser beobachtet. Bei geringerem Abstand der Bäume war die astfreie Stammlänge im Verhältnis zur Gesamthöhe größer und mit der Höhe positiv korreliert. Allgemein zeigte die Art eine geringe genetische Variation zwischen natürlichen Beständen.

Introduction

The phenotypic variation in any natural stand may be due to genetic/environmental factors and/or interactions between them. The knowledge of relative influence of these factors is, therefore, a pre-requisite in planning any improvement programme of a species and also to copy nature by replicating superior clones under intensive cultural techniques. In an earlier communication Khosla *et al.* (1979) studied the phenotypic variation in male and female trees of *Populus ciliata*. Here, in the present investigations it is contemplated to determine the range of phenotypic variability in the natural stands of the species as met in mixed deciduous forest, Western mixed coniferous forest and West Himalayan Oak/fir forest types.

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