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Phenotypic Variation in Specific Gravity and Fiber Length of Cherrybark Oak

Ten randomly selected trees in each of three stands in west Tennessee and in central Mississippi were sampled to study variation in wood properties important in genetic improvement. Specific gravity ranged from 0.533 to 0.693, and averaged 0.601. Tree-to-tree differences within stands accounted for most of the variation. Variance between stands and within trees was moderate. Correlation of ring width and specific gravity for the entire sample had a coefficient of 0.32; coefficients for individual stands ranged from 0.22 to 0.59. Fiber lengths of samples from the 20–21st rings and the 38–39th rings ranged from 1.08 to 1.98 mm; grand mean was 1.49 mm. Variation among stands and trees was statistically significant. While area effects were statistically nonsignificant, they accounted for the second largest component of variance. Samples within trees accounted for the third largest component, and the contribution of stands ranked last. Fiber length was only slightly correlated with ring width. Variation patterns for both characters indicate that field selection of breeding material should be by individual trees.

Keywords: Density · Fiber dimensions · Fiber length · Physical properties · *Quercus* · *Quercus falcata** · Variations

KNOWLEDGE of variation in oakwood properties that are related to pulp yield and quality is essential in genetic improvement research. Two important properties that can be studied easily are specific gravity and fiber length. This paper reports a study made to develop a guide to field selection of breeding material in cherrybark oak (*Quercus falcata* var. *pagodaefolia* Ell.).

METHODS

Transects 30 ft wide were established in three separate natural stands at each of two locations: (1) the Hatchie River bottom in Haywood County, western Tennessee, and (2) the Brown Loam Hills in Warren County, west-central Mississippi. The first 10 trees on each transect were sampled. Cherrybark oak made up 30–50% of the stands, and sampled trees on a single transect were within 100 yards of each other. Most of the trees were 40–60 years old but in two Tennessee stands some were 80–100.

Two cores 12 mm in diameter were taken at breast height from opposite sides of each tree. Annual rings of cores from the same tree were matched; then, cores were cut into segments of 10 rings each, beginning at the pith. Segment length was measured and the specific gravity of each segment was determined by the maximum-moisture technique (*1*). Specific gravity determinations began at the 10th ring, a point at which samples from the two cores were available from nearly all trees.

Variation in specific gravity of segments representing rings 10–19, 20–29, 30–39, and 40–49 was partitioned by analyses of covariance. (Specific gravity of rings 50–90 was determined for the few older trees, but the number of samples was small and therefore the variance in these values was not analyzed.) Since specific gravity was correlated positively with growth rate, ring width was the independent variable in covariance analyses. Coefficients for components of variance were computed with procedures outlined by Anderson and Bancroft (*2*) for sampling designs with unequal subsample numbers. The model is considered random, and all factors were tested at the 0.05 level of probability. Variance components were computed from adjusted mean squares.

For determinations of fiber length, wood samples were macerated and fibers stained and mounted by methods described for cottonwood (*3*). The only departure from the cottonwood technique was use of a 48-hr maceration period. Sample means were based on measurement of 50 whole fibers at 50×.

Fibers were first sampled in single rings at 10-ring intervals in 10 trees to determine patterns of variation within trees. Patterns within sampled trees having vigorous early growth were qualitatively similar to those reported for oak (*4, 5*). There was a relatively rapid increase in fiber length between rings 10 and 30, then a leveling off. A few very old trees reverted to short fibers in their last rings. On the basis of this sample, we decided to study variation among trees by combining samples of the 20th and 21st rings, and of the 38th and 39th. Sample values were analyzed as described above for specific gravity.

RESULTS

Specific Gravity

Specific gravity of individual samples ranged from 0.533 to 0.693 within the span of 10 to 50 rings from the pith. In the few older trees that were sampled, specific gravity between the 50- and 90-year rings averaged slightly lower (range 0.49–0.65) than for younger wood. Means for stands and geographic areas are presented in Table I.

The coefficient of correlation between ring width (1–9 mm) and specific gravity for the entire sample was 0.32; coefficients for individual stands ranged from 0.22 to 0.59. All were statistically significant at the 0.05 level. The slight decrease in specific gravity with ring number (Table I) was thus related to a general decrease in ring width as trees aged. Paul (*6*) made a similar observation in a study of oaks. While such decrease is apparent in averages, there was considerable variation in growth patterns among stands and trees. Some trees subjected to juvenile

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Table I. Summary of Means: Specific Gravity, Fiber Length, and Ring Width of Cherrybark Oak

Number of rings from pith	Grand mean	Area mean		Stand mean[a]					
		Miss.	*Tenn.*	*Miss. 1*	*Miss. 2*	*Miss. 3*	*Tenn. 4*	*Tenn. 5*	*Tenn. 6*
				Specific Gravity					
10–19	0.608	0.613	0.601	0.599(6)	0.619(4)	0.619(4)	0.591(4)	0.588(2)	0.623(4)
20–29	0.609	0.608	0.610	0.598(5)	0.610(5)	0.614(4)	0.602(4)	0.598(3)	0.627(3)
30–39	0.598	0.595	0.601	0.584(4)	0.606(4)	0.599(4)	0.587(4)	0.602(3)	0.620(4)
40–49	0.593	0.593	0.593	0.582(4)	0.600(4)	...	0.578(3)	0.599(4)	0.612(4)
				Fiber Length, mm					
20–21	1.46	1.58	1.35	1.59(5)	1.52(5)	1.62(4)	1.33(4)	1.29(3)	1.43(4)
38–39	1.53	1.58	1.48	1.61(4)	1.50(5)	1.62(4)	1.50(4)	1.45(3)	1.49(4)

[a] Numbers in parentheses are average ring widths in millimeters.

suppression exhibited maximum growth rates in middle age, and in these boles specific gravity increased over time (Table I, stand 5). Within age groups, growth × specific gravity correlations were lower:

Annual Ring	*r*
10–19	0.24*
20–29	0.17
30–39	0.26*
40–49	0.22

The asterisks indicate values statistically significant at the 0.05 level.

Patterns of variation were generally similar in all four age groups (Table II). Variance attributable to area was nonsignificant, overall means for the two locations both being 0.602. Stands within areas accounted for significant variation in the three youngest groups, and tree-to-tree variation was significant in all analyses. Variance components were largest for trees within stands, next largest for samples within trees, and smallest for stands within areas. In the analysis of the 20–29th rings, the within-tree variance component was larger than the tree component, an exception to the general pattern.

Relationships between juvenile and mature wood, which are important in selection, were studied through correlation analyses. Specific gravity of rings 10 through 19 was only moderately correlated with that of rings with higher numbers:

Ring Correlation	*r*
10–19 × 30–39	0.50*
10–19 × 40–49	0.37*

The *r* values are statistically significant at the 0.05 level.

Fiber Length

Mean length of fibers in samples ranged from 1.08 to 1.98 mm; means for the 20–21st and the 38–39th rings were, respectively, 1.46 and 1.53 mm (Table I). Fiber length was only slightly correlated with ring width in the sampled rings (r = 0.17, 0.27) but, since the correlation was significant in the samples of the 20–21st rings, covariance analyses were made. The results (Table II) were similar in most respects to those for specific gravity. Variation among stands and trees was significant in both sample groups. While area effects were nonsignificant, they accounted for the second largest component of variance; only variance due to trees within stands was larger. Samples within trees accounted for the third largest component of variance, and the contribution of stands ranked last. The correlation between fiber lengths in the 20–21st rings and those in the 38–39th rings had a coefficient of 0.66.

In trees that had grown rapidly there was little increase in fiber length between the 20th and 40th rings, i.e., by 20 years, fiber length had reached maximum. In trees that had been suppressed while young (stands 4 and 5), fiber length increased between the 20th and 40th rings. This relationship suggests that, in oak, increases in fiber length from the pith outward may be at least partly a function of distance from the pith (i.e., number of cambial generations). As noted by Dinwoodie (*7*) in studies of other species, both age and distance from pith may influence cell length, but their relative significance varies with distance from the pith.

DISCUSSION

The range of specific gravity variation observed in this study is similar to that noted by Paul and Marts (*8*) in a sample of cherrybark oak trees from a single stand. It is slightly greater than the range reported for a group of red oak species by Paul (*6*). The positive relationship between ring width (or percent latewood) and specific gravity in southern oaks has been observed by Hamilton (*4*), Paul (*6*), Paul and Marts (*8*), and others. In our sample, however, growth rate accounted

Table II. Summary of Analyses of Covariance: Specific Gravity and Fiber Length Adjusted for Ring Width

Source of variation	Specific gravity								Fiber length				Expected mean squares
	10–19 years		*20–29 years*		*30–39 years*		*40–49 years*		*20–21 years*		*38–39 years*		
	df	*$\overline{M}$ square*	*df*	*$\overline{M}$ square*	*df*	*$\overline{M}$ square*	*df*	*$\overline{M}$ square*	*df*	*$\overline{M}$ square*	*df*	*$\overline{M}$ square*	
Area (A)	1	0.000354	1	0.000108	1	0.001696	1	0.000057	1	0.541700	1	0.240000	$\sigma_e^2 + s\sigma_T^2 + st\sigma_R^2 + str\sigma_A^2$
Stands/areas (R)	4	0.004534*	4	0.002891*	4	0.003124*	3	0.001513	4	0.079900*	4	0.043900*	$\sigma_e^2 + s\sigma_T^2 + st\sigma_R^2$
Trees/stands (T)	54	0.000639*	54	0.000828*	46	0.000721*	27	0.001091*	54	0.023330*	46	0.016891*	$\sigma_e^2 + s\sigma_T^2$
Samples/trees (S)	45	0.000147	54	0.000324	51	0.000180	31	0.000173	54	0.005292	51	0.004028	σ_e^2
					Variance Components								
V_A^2		±0.0		±0.0		±0.0		±0.0		0.008373		0.004142	
V_R^2		0.000225		0.000108		0.000140		0.000047		0.002953		0.001576	
V_T^2		0.000293		0.000264		0.000273		0.000466		0.009444		0.006496	
V_S^2		0.000147		0.000324		0.000180		0.000173		0.005292		0.004028	

NOTE: Asterisks indicate values statistically significant at the 0.05 level.

for a relatively small percentage of the specific gravity variation (4–36%, depending on stand). Most of the variation, after adjustment for growth rate, was related to differences among trees and among samples within trees. Thus, phenotypic variation followed a pattern which has now been observed in a number of hardwood species (*9–12*). The range of this variation provides considerable opportunity for selection.

Since tree-to-tree variation was broad within stands, and stand and geographic-area variance was small, it appears that much of the variation in specific gravity may have a genetic basis. Given this pattern of variation, field selection for specific gravity should be by individual trees. The appreciable within-tree variance indicates that selection should be based on at least two whole cores per tree.

With some modifications, these conclusions are applicable to selection for fiber length. The only difference in variation patterns of specific gravity and fiber length was the existence of an area component of variance for fiber length. This area effect, however, was probably related to differences in growth patterns of stands, since fiber length appears to be related to both distance from pith and ring number. Some of the tree-to-tree variance in the sample may also have resulted from the same ring being at different distances from pith in individual trees. Ideally, therefore, selection for long fibers, if warranted, should be made in rapidly grown stands of fairly uniform age. Evaluation must take into account distance from pith, ring number, and tree's growth pattern.

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