R. E. FARMER, JR.
and J. R. WILCOX

Specific Gravity Variation in a Lower Mississippi Valley Cottonwood Population

Specific gravity varied from 0.32 to 0.46, averaging 0.38. Most of the variation was associated with individual trees; samples within locations accounted for a smaller, but statistically significant, portion of the variation. Variation between locations was not significant. It was concluded that individual high-density trees should be sought throughout the population. Wood near the cambium was more dense than that near the pith or middle of stems; this position effect was influenced by location and samples within locations. Relatively low correlations between density of juvenile and more recently formed wood indicate that selection for specific gravity at an early age may not be efficient. A slight negative relationship was observed between specific gravity and mean annual diameter increment.

Keywords: *Populus deltoides* · Populus · Hardwoods · Density · Growth · Tissues (plant) · Plant anatomy · Wood structure

A KNOWLEDGE of phenotypic variation in specific gravity of cottonwood (*Populus deltoides* Bartr.) is essential in planning improvement programs and inheritance studies. To collect such data, stands were sampled in two general areas about 150 miles apart on the Mississippi River. One area was approximately 5 miles south of Clarksdale, Miss., the other was 10 miles north of Vicksburg. In each area, four 30-ft-wide transects were established within 4 miles of each other. All were in pure stands of cottonwood on reasonably uniform, but different, sites. The first 10 trees on each transect were selected for sampling. They ranged from 21 to 23 years in age and from 9 to 20 in. dbh; mean dbh was 14 in.

Two cores 11 mm in diameter were taken from opposite sides of each tree 3 ft from the base. They were immediately placed in water-filled test tubes and stored at 38°F. Specific gravity of three 2-cm^3 samples from each of the two cores was determined by dividing ovendry weight by green volume. One 2-cm^3 sample was taken adjacent to the pith, one midway between pith and cambium, and one adjacent to the cambium. Since variance between opposite cores was minimal, the mean of the two cores at each position was used in the analysis of data. The design and method of analysis is outlined in Table I.

RESULTS AND DISCUSSION

Variation

Mean sample specific gravity for individual trees varied significantly (0.01 level) from 0.320 to 0.461, a range slightly less than that reported for cottonwood in Illinois by Walters and Bruckman (*1*). Similar ranges have been reported for aspen by van Buijtenen *et al.* (*2*) and Valentine (*3*). The mean for the total sample was 0.380, a figure close to other published means (*1, 4, 5*).

R. E. FARMER, JR.,† and J. R. WILCOX,‡ Southern Forest Experiment Station, Forest Service, U. S. Dept. of Agriculture.

† Present address: Southern Hardwoods Laboratory, maintained at Stoneville, Miss., in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

‡ Present address: The Institute of Forest Genetics, Gulfport, Miss.

Variance components, based on estimated mean squares, were calculated for locations, transects, and trees:

Source	*Variance component*
Location	0.000106
Transects	0.000235
Trees	0.000466

Most of the observed variation was among trees. A smaller, but statistically significant, component was associated with transects; means for transects within the Vicksburg location varied significantly from 0.362 to 0.409, while at Clarksdale, transect variance was not significant. The smallest component, not statistically significant, was associated with locations.

Variation between locations and transects probably is largely a reflection of site differences, which are believed to be greater between stands and locations than between individual trees within transects; on a given transect trees were within a radius of 200 ft on an apparently uniform site. Within-transect environmental variation not directly associated with site quality (e.g., competitive effects) may have significantly influenced specific gravity; nevertheless, the data suggest that, pending results from heritability studies, individual high-density trees should be selected throughout the entire population. The minimal variation between cores from a single tree, mentioned previously, indicates that single-core samples may be adequate.

Growth-Specific Gravity Relationship

Mean annual diameter increment of individual trees varied from 0.41 to 0.96 in. It had a slight, but insignificant, negative correlation with mean tree specific gravity ($r = -0.20$). This finding is in agreement with some previous observations in cottonwood, the aspens, and hybrid poplars (*1, 6–8*). However, Cech *et al.* (*9*) and Kennedy

Table I. Analysis of Variance for Specific Gravity with Estimated Mean Squares for Locations, Transects, and Trees

Source of variation	*df*	*Mean square*	*Expected mean square*
Locations (L)	1	0.021414 N.S.	$\sigma_E^2 + p\sigma_{R(T)(L)}^2 + pr\sigma_{T(L)}^2 + prt\Sigma\,\alpha^2/(l-1)$
Transects (T) in locations	6	0.008703[a]	$\sigma_E^2 + p\sigma_{R(T)(L)}^2 + pr\sigma_{T(L)}^2$
Trees (R) in transects in locations	72	0.001644[a]	$\sigma_E^2 + p\sigma_{R(T)(L)}^2$
Positions (P)	2	0.009482[a]	....
Positions × locations	2	0.003624[b]	....
Positions × transects/locations	12	0.000630[a]	....
Positions × trees/transects/locations	144	0.000247	σ_E^2

[a] Significant at the 0.01 level. $\sigma_E^2 = p/(p-1)\sigma_{PR(T)(L)}^2$
[b] Significant at the 0.05 level.
NOTE: Locations and positions of samples from each core were considered fixed effects. All other effects were considered random.

Reprinted from **Tappi**, The Journal of the Technical Association of the Pulp and Paper Industry,
Vol. 49, No. 5, May 1966.

and Smith (*10*) working with *P. trichocarpa*, and van Buijtenen *et al.* (*2*) working with *P. tremuloides*, have noted significant negative correlations between growth rate and specific gravity. Brown and Valentine (*11*) observed both positive and negative correlations between ring width and specific gravity in natural *P. tremuloides* clones. This variance in reports suggests the existence of a major unaccounted-for influence, perhaps genetic, that may mask a straightforward growth-density relationship in a sample such as from the Mississippi study. In this regard, Cech *et al.* (*9*) have reported a significant effect of clone independent of growth rate.

Position in Tree

Specific gravity averaged 0.375 near the pith, 0.373 at the middle of cores, and 0.393 at the cambium. The pith and middle samples differed from the outer samples at the 0.01 level of significance. Increase in density toward the outer bole has been observed in aspen by Brown and Valentine (*11*).

Position effect varied with location and transect. Thus, within the Clarksdale location the middle section of the core had the lowest mean specific gravity (significant at 0.01 level, by Duncan's multiple range test) in two of the four transects. Within the Vicksburg location the internal segment had the lowest mean specific gravity (0.01 level) in two of the four transects. In the two remaining transects at each location the inner and middle segments did not differ. These significant interactions of position with location and transect are probably indicative of environmental effects that may alter the pattern of variation within stems.

Correlation coefficients describe relationships between specific gravity of different positions in the tree:

Relationship	*r value*
Inner vs. middle segment	0.64[a]
Inner vs. outer segment	0.61[a]
Middle vs. outer segment	0.82[a]

[a] Significant at 0.01 level.

About 36% of the variation in specific gravity at the midsection and the outer section of the core was accounted for by variation at the inner section. Approximately 67% of the variation at the outer position of the core was accounted for by variation at the midsection. The relatively low correlation between the density of inner and outer sections of cores suggests that selection for specific gravity at an early age (1–5 years) may not be efficient.

LITERATURE CITED

1. Walters, C. S. and Bruckman, G., *Jnl. Forestry* **63**: 182 (1965).
2. van Buijtenen, J. P., Einspahr, D. W., and Joranson, P. N., *Tappi* **42**: 819 (1959).
3. Valentine, F. A., *Northeast. Forest Tree Impr. Conf. Proc.* **9**: 17 (1962).
4. Food and Agriculture Organization of the United Nations. "Poplars in Forestry and Land Use," Forestry and Forest Prod. Study 12, 1958.
5. Paul, B. H., *U. S. Dept. Agr. Tech. Bul.* **1288** (1963).
6. Göhre, K., *Abhandl. Deut. Akad. Landw-Wiss.* (Berlin) **44**: 51 (1960); *Forestry Abs.* **21**: 4896 (1960).
7. Johnson, L. P. V., *Canad. Jnl. Res.* **20**: 28 (1942).
8. Lenz, O., *Centralanstalt Forstl. Versuchsw.* **30**: 9 (1954).
9. Cech, M. Y., Kennedy, R. W., and Smith, J. H. G., *Tappi* **43**: 857 (1960).
10. Kennedy, R. W., and Smith, J. H. G., *Pulp Paper Mag. Can.* **60**: T35 (1959).
11. Brown, Ian R. and Valentine, F. A., *Northeast. Forest Tree Impr. Conf. Proc.* **10**: 25 (1963).

RECEIVED Nov. 9, 1965. Presented at the 3rd Forest Biology Conference of the Technical Association of the Pulp and Paper Industry, held in Madison, Wis., Nov. 1-3, 1965.