A NOTE ON WITHIN-TREE VARIATION OF SPECIFIC GRAVITY IN SWEETGUM (*LIQUIDAMBAR STYRACIFLUA* L.)[1]

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(Received 13 August 1979)

ABSTRACT

Both radial and vertical variations of specific gravity within trees for sweetgum were analyzed. Upland and bottomland sites were studied. Six different sites (three upland and three bottomland) were selected; three dominant or codominant trees per site were chosen. In general, specific gravity was found to be a highly variable property of sweetgum wood. It fluctuates with both height and year of deposition, but the patterns were not consistent either within or among trees.

Keywords: Specific gravity variation, radial variation, height variation, site influence on specific gravity.

INTRODUCTION

Specific gravity is perhaps the most studied property of wood. This property has been found to be a highly heritable trait in conifers and can be used as a direct indicator of pulp yields (Zobel 1977). When these facts are considered in conjunction with current utilization strategies, it is easy to understand why specific gravity has been evaluated more extensively in conifers than in hardwoods.

Specific gravity of selected hardwood species has been receiving increased attention. However, the scope of basic data has not kept abreast of the increased need for a better understanding of wood properties of some of the more important hardwood species.

Sweetgum (*Liquidambar styraciflua* L.) specific gravity ranges from 0.428 to 0.607 (Carpenter and Hopkins 1966) with an average of 0.496 for the "green" moisture content (Panshin and deZeeuw 1970) and 0.530 for the oven-dry condition (Forest Products Lab 1964). This species also exhibits important sources of variation, both within and between trees.

Research dealing with sweetgum seedlings has yielded consistent results in the evaluation of specific gravity variations (Winstead 1972; Randel and Winstead 1976). However, sweetgum research dealing with stems past the sapling stage is

[1] This manuscript has been approved as Texas Agricultural Experiment Station No. TA 14545. The data for this manuscript were collected while Ezell was a Research Associate with the School of Forestry and Wildlife Management at Louisiana State University.

Wood and Fiber, 12(2), 1980, pp. 80–87

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not as conclusive. Carpenter and Hopkins (1966) found significant differences in specific gravity due to sample height within the stem. Hunter and Goggans (1968) reported significant variation between points at the same sampling height, and Webb (1964) noted significant variation between growth rings within a single height. Conversely, Jett and Zobel (1975) found no change in specific gravity between juvenile and mature wood.

This research deals with the variation of specific gravity within the tree. Both radial and vertical gradients are considered.

MATERIALS AND METHODS

Three dominant or codominant sweetgum trees were selected for analysis on six different sites. Of the eighteen total trees, nine were from upland sites and nine were from bottomland sites. A disc was removed at 1.2-m intervals from each tree starting at the base (15.24 cm above ground level) and proceeding to the top of the stem. A complete description of field sampling is contained in Ezell (1977).

Specific gravity was determined for sample sections taken from the western directional axis of each disc. By utilizing sections from uniform locations in each tree, potential error due to alteration of sample location around the stem was removed.

The growth rings that had been deposited in the years 1974, 1970, 1965, 1960, and subsequent intervals of five years were used for all specific gravity measurements. These growth rings were determined by ocular count along a fresh cross-sectional surface. Rings selected for measurement were isolated from adjacent rings. Size of the sample varied both within and between rings due to variable growth patterns.

Specific gravity was measured according to the maximum moisture content method as described by Smith (1954). Samples were first dried for 96 h in a 105 C oven. Periods of time for both drying and soaking were reduced by the small size of the samples. After drying, each sample was weighed to the nearest 0.1 mg. The oven-dry samples were then placed in a large desiccator and subjected to 28 inches of vacuum pressure. Before releasing the vacuum, the desiccator was filled with water. To ensure total saturation, the samples were allowed to soak for at least 96 h with intermittent vacuum pressure. No final weight measurements were recorded until fluctuations in sample weight were less than one percent as determined by weighings on successive days.

The ratio of maximum moisture weight: oven-dry weight (Mm:Mo) was then calculated and specific gravity derived directly from the table constructed by Fogg (1967). If the Mm:Mo ratio was not within the realm of the table, the specific gravity was calculated from the equation given by Smith (1954).

RESULTS AND DISCUSSION

Average values for all sample years and sample heights are presented in Tables 1 and 2. There was no apparent trend in the occurrence of maximum or minimum average specific gravity with respect to sample height or year of deposition.

Specific gravity in this study was generally in agreement with comparable values reported in earlier work on sweetgum. Deviations from previous reports were

TABLE 1. *Average specific gravity for all radial sampling points at each sample height in sample trees.*

Area	Sub-area	Tree	Height (ft.)											
			Base	4	8	12	16	20	24	28	32	36	40	44
1[a]	U[1]	1	0.511	0.480	0.478	0.481	0.496	0.491	0.535	0.504	0.469	0.483	0.557	0.495
1	U	2	0.518	0.478	0.476	0.464	0.474	0.473	0.492	0.497	0.524	0.489	0.480	0.602
1	U	3	0.495	0.524	0.492	0.488	0.486	0.502	0.536	0.422	0.476	0.484	0.528	0.508
1	B[2]	1	0.497	0.461	0.464	0.460	0.457	0.466	0.458	0.490	0.462	0.456	0.514	0.467
1	B	2	0.453	0.438	0.433	0.432	0.477	0.464	0.459	0.457	0.443	0.459	0.483	0.440
1	B	3	0.472	0.441	0.431	0.430	0.426	0.425	0.453	0.439	0.447	0.463	0.447	0.434
2[b]	U	1	0.515	0.480	0.450	0.451	0.449	0.457	0.470	0.458	0.478	0.491	0.477	0.479
2	U	2	0.499	0.458	0.457	0.436	0.414	0.443	0.457	0.449	0.477	0.465	0.465	0.447
2	U	3	0.496	0.466	0.454	0.453	0.483	0.456	0.492	0.470	0.570	0.488	0.496	0.485
2	B	1	0.482	0.465	0.461	0.440	0.490	0.449	0.467	0.450	0.446	0.448	0.453	0.456
2	B	2	0.485	0.474	0.453	0.466	0.448	0.477	0.471	0.477	0.495	0.480	0.484	0.496
2	B	3	0.451	0.442	0.433	0.421	0.463	0.460	0.442	0.431	0.435	0.529	0.545	0.460
3[c]	U	1	0.467	0.454	0.439	0.488	0.426	0.438	0.464	0.425	0.424	0.580	0.472	0.488
3	U	2	0.526	0.490	0.481	0.466	0.494	0.477	0.463	0.462	0.482	0.470	0.469	0.495
3	U	3	0.535	0.448	0.478	0.438	0.459	0.477	0.506	0.466	0.457	0.463	0.450	0.455
3	B	1	0.402	0.490	0.471	0.450	0.442	0.420	0.408	0.427	0.465	0.468	0.477	0.459
3	B	2	0.491	0.455	0.445	0.456	0.446	0.448	0.482	0.443	0.425	0.444	0.421	0.441
3	B	3	0.504	0.494	0.495	0.493	0.504	0.482	0.481	0.523	0.491	0.509	0.482	0.458

TABLE 1. *Continued.*

Area	Sub-area	Tree	Height (ft.) 48	52	56	60	64	68	72	76	80	84	88	92	96
1[a]	U[1]	1	0.460	0.515	0.601	0.489	0.487	0.458							
1	U	2	0.477	0.481	0.485	0.464	0.459	0.466							
1	U	3	0.496	0.487	0.480	0.487	0.536								
1	B[2]	1	0.483	0.484	0.483	0.490	0.493	0.547	0.498	0.499	0.501	0.489			
1	B	2	0.450	0.443	0.475	0.479	0.523	0.510	0.463	0.486					
1	B	3	0.432	0.435	0.431	0.449	0.424	0.456	0.448	0.392	0.477		0.457	0.536	
2[b]	U	1	0.474	0.551	0.517	0.484	0.476	0.509	0.478	0.510	0.493	0.479	0.492	0.495	0.534
2	U	2	0.503	0.505	0.494	0.480	0.534	0.533	0.495	0.481	0.469	0.459			
2	U	3	0.487	0.483	0.559	0.510	0.504	0.567	0.522	0.510	0.466				
2	B	1	0.516	0.496	0.488	0.440	0.485	0.426							
2	B	2	0.524	0.502	0.498	0.512	0.490	0.487	0.492	0.536	0.492	0.531			
2	B	3	0.500	0.466	0.586	0.457	0.514	0.430	0.497	0.464	0.462				
3[c]	U	1	0.432	0.482	0.479	0.451	0.464								
3	U	2	0.478	0.451	0.460	0.470	0.514	0.419							
3	U	3	0.469	0.462	0.460	0.460									
3	B	1	0.407	0.469	0.561	0.470	0.490								
3	B	2	0.492	0.473	0.481	0.466	0.448	0.415	0.524						
3	B	3	0.517	0.501	0.501										

[1] Upland.
[2] Bottomland.
[a] Kisatchie.
[b] Lee Forest.
[c] Idlewild-Ben Hur.

TABLE 2. *Average specific gravity for all sample years in intensively sampled trees (all sample heights).*

Area	Sub-area	Tree	1974	1970	1965	1960	1955	1950	1945	1940
1[a]	U[1]	1	0.530	0.512	0.492	0.487	0.496	0.491	0.472	0.485
1	U	2	0.510	0.492	0.476	0.474	0.499	0.480	0.519	0.545
1	U	3	0.519	0.510	0.479	0.472	0.478	0.480	0.570	0.522
1	B[2]	1	0.508	0.487	0.484	0.474	0.477	0.458	0.456	0.451
1	B	2	0.471	0.469	0.462	0.454	0.451	0.444	0.458	0.465
1	B	3	0.448	0.444	0.457	0.450	0.443	0.431	0.404	0.403
2[b]	U	1	0.465	0.479	0.483	0.479	0.464	0.448	0.467	0.486
2	U	2	0.470	0.510	0.485	0.474	0.482	0.483	0.458	0.449
2	U	3	0.521	0.496	0.490	0.480	0.494	0.486	0.457	0.440
2	B	1	0.453	0.463	0.477	0.471	0.473	0.457	0.443	0.453
2	B	2	0.507	0.477	0.479	0.487	0.472	0.456	0.471	0.479
2	B	3	0.438	0.484	0.490	0.481	0.450	0.447	0.461	0.436
3[c]	U	1	0.430	0.408	0.470	0.467	0.487	0.504	0.470	0.491
3	U	2	0.494	0.487	0.480	0.472	0.470	0.476	0.469	0.452
3	U	3	0.472	0.465	0.473	0.484	0.441	0.473	0.499	0.491
3	B	1	0.465	0.480	0.456	0.438	0.452	0.438	0.447	0.421
3	B	2	0.460	0.457	0.469	0.435	0.462	0.456	0.445	0.451
3	B	3	0.553	0.487	0.509	0.481	0.457	0.449	0.491	0.478

Area	Sub-area	Tree	1935	1930	1925	1920	1915	1910	1905	1900
1	U[1]	1	0.444							
1	U	2								
1	U	3								
1	B[2]	1	0.451	0.464	0.462					
1	B	2	0.442	0.438	0.445	0.432				
1	B	3	0.412	0.464						
2	U	1	0.493	0.469	0.486	0.482	0.520	0.514		
2	U	2	0.448	0.422	0.437	0.432	0.441	0.454	0.502	
2	U	3	0.467	0.482	0.497					
2	B	1	0.465	0.458	0.461	0.475	0.528	0.554		
2	B	2	0.478							
2	B	3	0.419	0.446	0.416	0.459	0.485	0.462	0.484	0.448
3	U	1	0.499							
3	U	2								
3	U	3								
3	B	1	0.443							
3	B	2	0.461							
3	B	3								

[1] Upland.
[2] Bottomland.
[a] Kisatchie.
[b] Lee Forest.
[c] Idlewild-Ben Hur.

of individual sample nature, such as a single growth ring or sample height. When overall averages are considered, no great discrepancy was detected.

Correlation analyses of sample height with specific gravity produced varied results. Correlation coefficients ranged from strongly positive ($r = 0.732$, $P < 0.01$) to negative ($r = -0.441$, $P < 0.05$) (Table 3). Six of the eighteen intensively-sampled trees had correlation coefficients that were significant. Four trees,

TABLE 3. *Correlation coefficients for the comparison of specific gravity to sample height and year of deposition.*

Area	Sub-area	Tree	Sp. grav. & ht.	Sp. grav. & year
1[a]	U[1]	1	.067	.514
1	U	2	−.091	−.511
1	U	3	.040	−.340
1	B[2]	1	.597**	.819**
1	B	2	.603**	.824**
1	B	3	−.203	.420
2[b]	U	1	.399	−.555*
2	U	2	.569**	.477
2	U	3	.461*	.498
2	B	1	−.071	−.577
2	B	2	.732**	.511
2	B	3	.394	.090
3[c]	U	1	.228	−.732*
3	U	2	−.441	.918**
3	U	3	−.374	−.467
3	B	1	.503*	.798**
3	B	2	.130	.171
3	B	3	−.011	.628*

[1] Upland.
[2] Bottomland.
[a] Kisatchie.
[b] Lee Forest.
[c] Idlewild-Ben Hur.
* Denotes significance at 0.05 level.
** Denotes significance at 0.01 level.

three from bottomland sites, had highly significant ($P < 0.01$) coefficients, and two trees had a significant ($P < 0.05$) coefficient (Table 3).

However, when the data were grouped for analysis, all analyses resulted in positive correlation coefficients. The correlation for trees from bottomland sites was higher ($r = 0.284$, $P < 0.01$) than for trees from upland sites ($r = 0.185$, $P < 0.05$) or for the overall correlation of all trees ($r = 0.227$, $P < .01$).

These correlations provide a more effective evaluation of specific gravity variation with increasing height than the work of Carpenter and Hopkins (1966). They reported a significant difference between heights, but their research was based on only three sample heights per tree. Webb (1964), in his more intensive study utilizing trees from bottomland sites, did not find height to be an important source of variation in sweetgum specific gravity, whereas the highest correlation coefficients in this study were for trees grown on bottomland sites.

One important consideration that arises from the analyses of grouped data is the fact that all correlation coefficients are positive; if, in fact, specific gravity does increase with increasing height, the butt log of sweetgum trees would contain wood of the lowest average specific gravity in the tree. Utilization evaluation could therefore be biased by any judgments based solely on samples from butt logs. Since more of the tree can now be utilized due to technological advances, earlier specific gravity values for a species which were based on samples from the lower portion of the stem may need to be adjusted to include samples from the entire stem.

Correlation analyses were used to evaluate the relationship between specific gravity and year of deposition. Results for individual trees are presented in Table 3. Individual tree correlations are extremely variable, with a range of coefficients from strongly positive ($r = 0.918$, $P < 0.01$) to strongly negative ($r = -0.732$, $P < 0.05$).

Grouping the data did little to clarify this relationship. Group correlations were all positive, and though the coefficient for trees from bottomland sites ($r = 0.161$) was higher than for trees from upland sites ($r = 0.111$), the only significant correlation was for trees from all sites ($r = 0.145$, $P < 0.05$).

Even though the comparison of year of deposition to specific gravity is not completely comparable to an analysis of age or distance from the pith, there are two notable similarities. First, all deal with variation in a radial direction, and second, all compare an increase in one variable (i.e. later years, increasing age, or greater distance from the pith) to fluctuations in specific gravity. In terms of these generalities, restricted comparison to earlier work may be undertaken.

Past research efforts that measured the variation of specific gravity over a radial dimension in sweetgum have yielded variable results. Hunter and Goggans (1968) found both consistent and inconsistent patterns of variation, Jett and Zobel (1975) found no effect of radial position, and Webb (1964) reported a very consistent effect of radial position.

Specific gravity fluctuation over a radial dimension in sweetgum, therefore, appears to be extremely variable, regardless of what radial parameter is used to explain the fluctuation. Based on the results of the analyses in this study, any general statement concerning the effect of year of deposition on specific gravity is inadvisable due to low correlations for groups and extreme variation in correlations from individual trees.

In summary, specific gravity is a highly variable property of sweetgum wood. It fluctuates with height and year of deposition, but the patterns are not consistent within or among trees.

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