

VARIATION OF CELLULAR PROPORTIONS IN SWEETGUM AND THEIR RELATION TO OTHER WOOD PROPERTIES¹

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ABSTRACT

Sweetgum trees from natural stands in Louisiana were sampled along both vertical and radial gradients. From these samples, within-tree variation of cellular proportion has been established. Overall means indicate that vessels comprise 56.6% of the wood, fibers comprise 25.2% of the wood, and parenchyma comprises 18.1% of the wood. Regression analyses using fiber or vessel proportion provided curves that offer predictive capacities with high precision. In sweetgum, fiber proportion generally increases, and vessel proportion generally decreases with increasing height while parenchyma proportion remains relatively unchanged. The same trends were observed in later years of deposition.

Keywords: Sweetgum, *Liquidambar styraciflua*, cellular proportion, fibers, vessels, parenchyma.

INTRODUCTION

Variation in xylem composition exists among and within tree species (Taylor and Wooten 1973). Of the few published reports quantifying cellular proportions in hardwoods, none involve sweetgum (*Liquidambar styraciflua* L.). Changes in vessel and fiber proportions with increased sampling height were significant for pecan (*Carya illinoensis* (Wangenh) Koch), sycamore (*Plantanus occidentalis* L.), willow (*Salix nigra* Marsh), and yellow poplar (*Liriodendron tulipifera* L.) (Taylor 1968; Taylor 1969a, b; Taylor and Wooten 1973; Wooten and Taylor 1968). However, corresponding changes in fiber or vessel volume with increasing sample height were not significant in willow oak (*Quercus phellos* L.) and sugarberry (*Celtis laevigata* Willd.) (Taylor 1971; Taylor and Wooten 1968).

Significant variation that exists in tissue composition is usually in accord with the following generalizations: (1) vessel volume will increase and fiber volume decrease with increasing height, with ray volume fluctuating in both directions (depending on species), and (2) vessel volume will increase, and fiber volume decrease, with ray volume remaining constant with increasing age (Taylor and Wooten 1973).

The purpose of this study was to: (1) evaluate the variation in cellular proportion within the wood of sweetgum, and (2) determine if measured fluctuations in cellular proportions were related to other wood properties.

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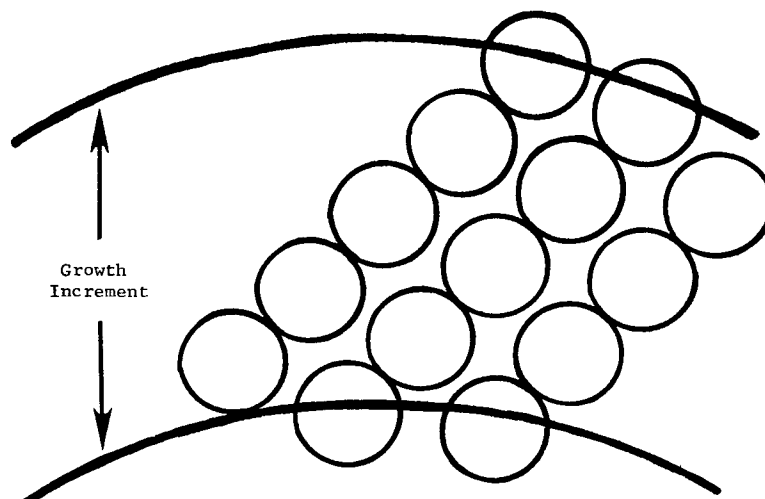


FIG. 1. Arrangement of point count fields superimposed on annual ring sections.

MATERIALS AND METHODS

Field sampling

Samples were taken from trees growing on three upland and three bottomland sites in Louisiana. On each of these sites, three dominant or co-dominant trees were selected for analysis. Before felling, directional axes were marked on each bole. After felling, tags were attached along one directional axis of the stem at 1.2-m intervals starting at the base (15.2 cm above the ground) and proceeding to the top of tree. A 7.6-cm-wide disc was removed at each tagged interval (Ezell 1978).

Laboratory sampling

A section was removed along the eastern axis of sample discs up to and including the sample taken from a height of 16.8 m of each tree, and measurements were taken from samples at 2.4-m intervals (example: base, 2.4 m level, 4.8 m level, etc.). The growth rings deposited in 1974, 1970, 1965, 1960, 1955, and 1950 were used for all tissue cell-type measurements.

Growth rings to be examined were first saturated with water. A smooth surface was prepared on the cross-sectional facet of the ring using a razor blade, and the sample was stained with 1% aqueous acridine orange. Selected growth rings were subsequently examined using 100 \times magnification on a Leitz Ortholux II microscope. This instrument contained the proper light source and filter system for indirect fluorescence microscopy.

Measurements of cellular proportions were made according to a method described by Taylor (1971), which involves a point count technique using a Zeiss integrating eyepiece with Graticule I (Test-Point Graduation). The eyepiece is equipped with a grid system of 25 points asymmetrically arranged within a circle. This grid system was superimposed upon the magnified section and the number of test points coincident with each tissue type (vessels, fibers, or parenchyma)

TABLE 1. Average fiber proportion for all sample years in intensively sampled trees.

Area	Subarea	Year of deposition						\bar{x}
		1950	1955	1960	1965	1970	1974	
		percent						
1 ^a	U ¹	25.9	26.9	26.4	26.2	27.8	29.7	27.2
1	B ²	21.3	22.4	22.8	23.4	23.8	23.3	22.8
2 ^b	U	25.7	26.1	26.1	27.1	27.3	25.7	26.3
2	B	23.2	23.9	25.9	25.9	25.1	24.4	24.7
3 ^c	U	27.0	24.9	25.3	25.4	23.5	24.7	25.1
3	B	22.9	24.0	23.5	26.4	25.2	28.0	25.0
\bar{x}	(all)	24.3	24.7	25.0	25.7	25.5	26.0	25.2

¹ Upland.² Bottomland.^a Kisatchie National Forest (west of Alexandria, LA).^b Lee Memorial Forest (east of Franklinton, LA).^c Idlewild Exp. Stn. (Clinton, LA) and Ben Hur Farm (Baton Rouge, LA).

TABLE 2. Average vessel proportion for all sample years in intensively sampled trees.

Area	Subarea	Year of deposition						\bar{x}
		1950	1955	1960	1965	1970	1974	
		percent						
1 ^a	U ¹	54.8	54.3	55.2	56.3	54.0	50.8	54.2
1	B ²	60.3	59.5	58.8	58.5	58.6	57.2	58.8
2 ^b	U	57.1	56.4	56.8	55.3	54.6	56.2	56.1
2	B	58.5	57.7	56.2	56.4	57.2	57.7	57.3
3 ^c	U	53.3	57.4	56.7	56.9	58.9	57.3	56.8
3	B	58.7	57.3	57.5	55.4	56.1	53.1	56.4
\bar{x}	(all)	57.1	57.1	56.9	56.5	56.6	55.4	56.6

¹ Upland.² Bottomland.^a Kisatchie National Forest (west of Alexandria, LA).^b Lee Memorial Forest (east of Franklinton, LA).^c Idlewild Exp. Stn. (Clinton, LA) and Ben Hur Farm (Baton Rouge, LA).

TABLE 3. Average parenchyma proportion for all sample years in intensively sampled trees.

Area	Subarea	Year of deposition						\bar{x}
		1950	1955	1960	1965	1970	1974	
		percent						
1 ^a	U ¹	19.3	18.8	18.4	17.4	17.4	17.9	18.2
1	B ²	18.5	18.2	18.4	18.1	17.5	18.1	18.1
2 ^b	U	17.2	17.6	17.1	17.6	18.1	18.0	17.6
2	B	18.3	18.3	17.9	17.6	17.7	17.9	18.0
3 ^c	U	19.7	17.7	17.9	17.6	17.7	17.9	18.1
3	B	18.5	18.7	19.0	18.1	18.7	18.8	18.6
\bar{x}	(all)	18.6	18.2	18.1	17.7	17.8	18.1	18.1

¹ Upland.² Bottomland.^a Kisatchie National Forest (west of Alexandria, LA).^b Lee Memorial Forest (east of Franklinton, LA).^c Idlewild Exp. Stn. (Clinton, LA) and Ben Hur Farm (Baton Rouge, LA).

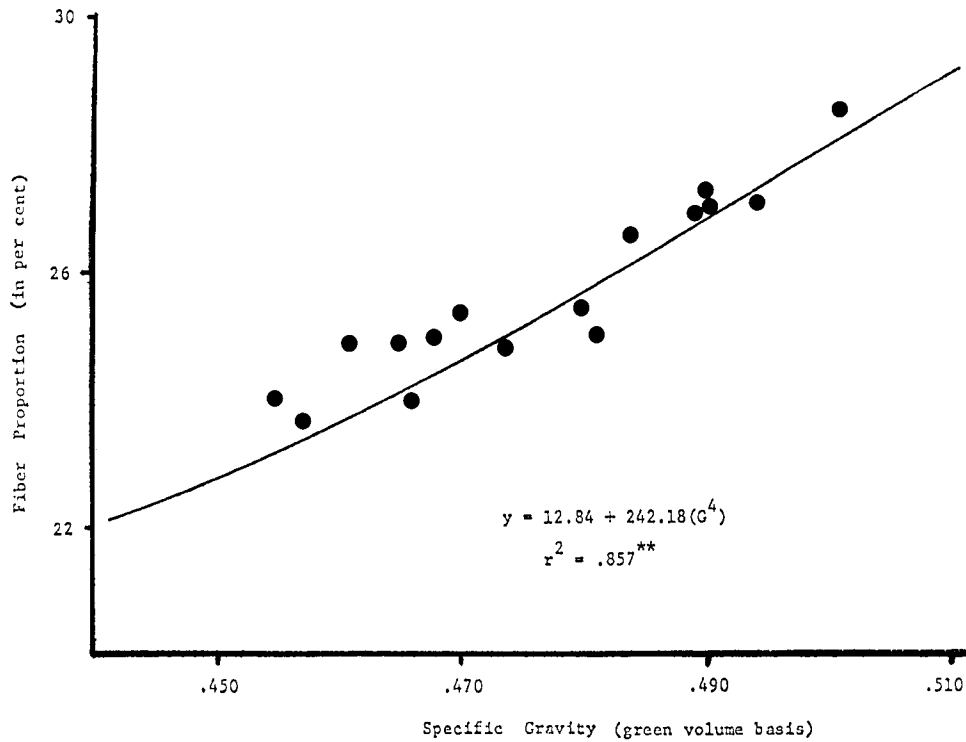


FIG. 2. Regression curve for fiber proportion vs. specific gravity (G).

was recorded. In the present study both longitudinal and ray parenchyma were recorded as parenchyma.

Radial and tangential gradients of cell types within each growth increment were avoided by arranging the examination fields along a transect aligned at 45 degrees to the direction of growth (Fig. 1). The number of sample points was determined according to a technique described by Quirk (1975), with a total of 200 points counted within each growth ring.

RESULTS AND DISCUSSION

Average values from tissue cell type measurements are found in Tables 1, 2, and 3. Inspection of these tables indicates that fiber and vessel proportions are more variable than the proportion of parenchyma.

Relative proportions of cellular elements were correlated with fiber length, specific gravity, height, and year of deposition. Results indicate that the correlation coefficients of wood element proportion to specific gravity are higher than the similar coefficients between element proportions and any other variable. Vessel and fiber proportions follow the same pattern of height and year of deposition variation as specific gravity, with vessel proportion being negatively correlated, and fiber proportion being positively correlated, to specific gravity. Specific gravity generally increases with increasing height and later years of deposition (Ezell 1977).

TABLE 4. *Correlation coefficients for the relationship of fiber proportion to other wood properties for all samples.*

	Year of deposition					
	1950	1955	1960	1965	1970	1974
Avg. fiber length	0.190*	0.020	-0.016	0.036	0.078	0.036
Avg. specific gravity	0.949**	0.932**	0.913**	0.953**	0.957**	0.952**
% vessel	-0.871**	-0.851**	-0.848**	-0.873**	-0.877**	-0.923**
% paren.	0.010	-0.016	-0.067	-0.027	-0.116	-0.010

* Significant at 0.05 level.

** Significant at 0.01 level.

Relationship of fiber proportions to other wood properties

Results from the correlation of fiber proportion to other wood properties are presented in Table 4. Fiber proportion was significantly related to average fiber length in only one sample year (1950, $r = 0.190$, $P \leq 0.05$). This lack of significance is in disagreement with the work of Taylor (1971) and Taylor and Wooten (1973), who found a constant significant negative correlation between fiber length and fiber proportion in sugarberry. In contrast, only one negative correlation could be detected in the present study (1960, $r = -0.016$). This discrepancy could be due to the fact that sugarberry is ring-porous, whereas sweetgum is diffuse porous.

Fiber proportion is highly significantly related to all other variables (Table 4). Coefficients ranged from 0.913, $P \leq 0.01$ to 0.957, $P \leq 0.01$ in correlations between fiber proportions and average specific gravity. Since specific gravity is directly dependent on the amount of cell-wall material and the bulk of cell-wall material is found in fibers, high coefficients are not unusual. However, earlier reports have never reported coefficients with this overall level of significance for any other species.

Fiber proportion has highly significant negative correlations to vessel proportion (-0.848 , $P \leq 0.01$ to -0.923 , $P \leq 0.01$) and parenchyma proportion (-0.376 , $P \leq 0.01$ to -0.511 , $P \leq 0.01$). These coefficients are to be expected, as the increase in one cell type must necessarily result in the decrease of at least one other cell type for all species (Taylor and Wooten 1973).

Results from the regression analysis of fiber proportion and specific gravity are

TABLE 5. *Correlation coefficients for the relationship of vessel proportion to other wood properties for all samples.*

	Year of deposition					
	1950	1955	1960	1965	1970	1974
Avg. fiber length	-0.145	-0.076	-0.093	-0.110	-0.161**	-0.074
\bar{x} Avg. specific gravity	-0.838**	-0.797**	-0.799**	-0.837**	-0.850**	-0.875**
% g fibers	-0.871**	-0.851**	-0.848**	-0.873**	-0.877**	-0.923**
% paren.	-0.500**	-0.511**	-0.473**	-0.464**	-0.376**	-0.376**

* Significant at 0.05 level.

** Significant at 0.01 level.

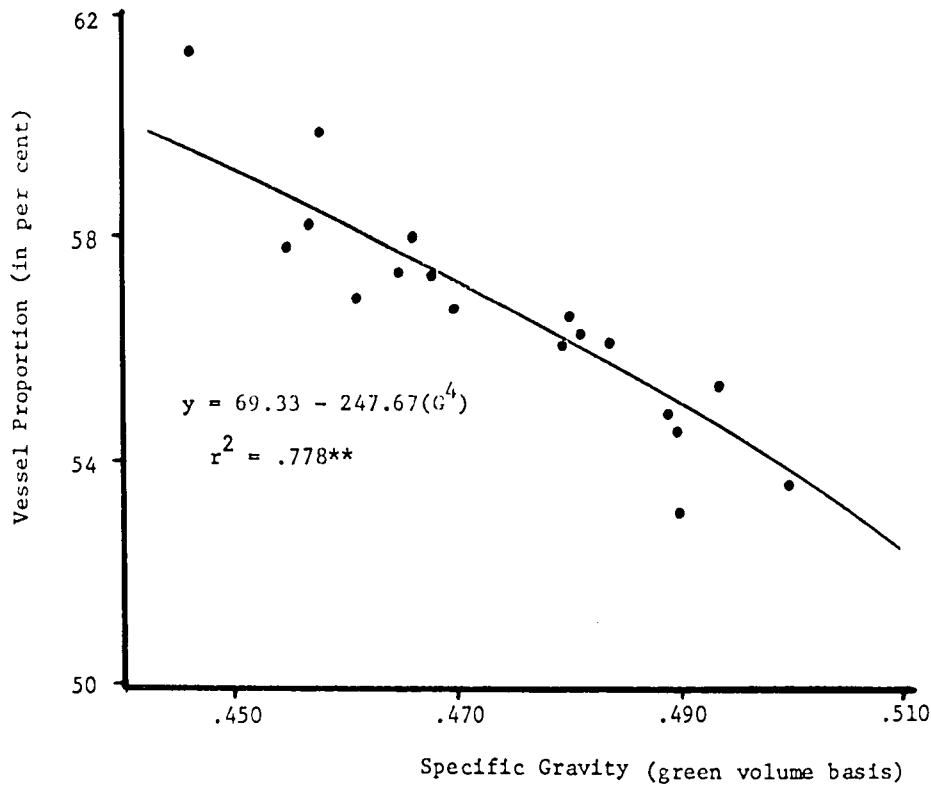


FIG. 3. Regression curve for vessel proportion vs. specific gravity (G).

found in Fig. 2. The strength of this relation involving fiber proportion could be a tremendous asset to future sweetgum specific gravity studies. Valuable time could be saved in laboratory analysis by quickly determining the proportion of fibers in the sample and then deriving the specific gravity. While some precision would be lost in this type of operation, savings in time might prove worthwhile.

Relationship of vessel proportion to other wood properties

Results from the correlation of vessel proportion to other wood properties are found in Table 5. Only one correlation between vessel proportion and fiber length is significant (-0.161 , $P \leq 0.05$). All correlations of this type have negative coefficients, which is interesting in comparison to work on sugarberry that constantly revealed significant positive coefficients for the same correlation (Taylor 1971; Taylor and Wooten 1973). Again, the fact that one species is ring-porous and the other diffuse porous may account for the reversal in results.

All correlations between vessel proportion and specific gravity are negative and highly significant, ranging from -0.797 , $P \leq 0.01$ to -0.875 , $P \leq 0.01$. These correlations represent a deviation from work on other species both in the nature of the correlation and the significance thereof (Taylor 1971; Taylor and Wooten 1973). Correlations to proportions of other cell types were always negative and highly significant, as was expected for reasons discussed earlier.

TABLE 6. Correlation coefficients for the comparison of parenchyma proportion to other wood properties.

	Year of deposition					
	1950	1955	1960	1965	1970	1974
Avg. fiber length	-0.040	0.113	0.201**	0.159**	0.184**	0.105
Avg. specific gravity	0.030	-0.013	-0.015	-0.016	-0.088	-0.019
% vessel	-0.500**	-0.511**	-0.473**	-0.464**	-0.376**	-0.376**
% fibers	0.010	-0.016	-0.067	-0.027	-0.116	-0.010

** Significant at 0.01 level.

Results from the regression analysis of vessel proportion and specific gravity are found in Fig. 3 and provide a useful predictive measure ($r^2 = 0.778$, $P \leq 0.01$). The negative association between the variables is expected because of the fact that the increase in proportion of relatively thin-walled vessel elements will decrease specific gravity, since specific gravity is directly related to the amount of cell-wall material per unit area.

Relationship of parenchyma proportion to other wood properties

The proportion of parenchyma is the most uniform of the three cell types measured, and correlations are notably different (Table 6). Even though variable, the overall relationship between parenchyma proportion and fiber length was positive. These results are in general agreement with earlier work and reflect the fact that parenchyma is the most constant cell type (in proportion) for all species examined.

There is no apparent relationship between parenchyma proportion and specific gravity. Coefficients ranged from -0.088 to 0.030 and are very similar to those reported for sugarberry (Taylor 1971). Results from the regression analysis of parenchyma proportion and specific gravity are not statistically significant.

Overall, correlations and regressions involving parenchyma proportion and other wood properties seem restricted by the fact that parenchyma is a very constant cellular component of wood, while other wood properties are highly variable.

SUMMARY

Variation in the cellular proportion of sweetgum wood has been established. This variation will constitute a portion of the basis of a later manuscript that will compare differences between sweetgum growing on upland and bottomland sites. Vessels comprise 53–60% of the wood, fibers comprise 21–28% of the wood, and parenchyma is the most consistent proportion with 17–19% of the wood. Fiber and vessel proportions are strongly related to specific gravity, and regression analyses have provided curves that offer predictive capacities with high precision. Variation of the proportions does not conform to previous generalizations. In sweetgum, fiber proportion generally increases, and vessel proportion generally decreases with increasing height, while parenchyma proportion remains relatively unchanged. The same relationship is true for later years of deposition.

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