TECHNICAL SESSION

Geographic Variation in Specific Gravity and Three Fiber Characteristics of Sweetgum

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In mid-1964, at the Annual Advisory Committee Meeting of the North Carolina State-Industry Co-operative Hardwood Research Program, participants in the Program endorsed plans for a major seed source study involving sweetgum over that part of its range from northeastern North Carolina to eastern Texas. Such a study has been established. It includes as one of its component parts the use of seed trees whose individuality is described and maintained throughout the life of the study from the the nursery phases of the work through the out-plantings and on to final results at some time in the future.

No study of this breadth and complexity is undertaken lightly. Sweetgum, in terms of where and how it grows, its uses, and the quantities consumed, is the most important single hardwood species in the United States. Its uses cover the range of quality aesthetics from fine face veneer through box lumber and dunnage to pulpwood. It grows almost everywhere, though not necessarily well. Furthermore, it appears to be amenable to management and manipulation, both genetically and silviculturally. In short, sweetgum is a tree species and a timber commodity very much worth studying from the standpoint of variation, whatever may be its cause. The investigation reported here covers possible provenencial variations in certain wood characteristics that bear importantly on its utilization.

Sample Collections

It has been mentioned that the N. C. State-Industry Sweetgum Provenance Study extends geographically from North Carolina to Texas. Within this broad region, seven collection transects distributed more or less uniformly over the area were arbitrarily selected. Typically, each transect contained a collection point within a major river drainage in the Coastal Plain and a companion collection point in the Piedmont. One transect, however, consisted of a collection point in the Mississippi River Delta near Vicksburg, Mississippi, and a companion location in the north-central pine uplands of Louisiana, near Hodge. The last transect, in East Texas, consisted of two collection points, one along the Neches and the other near the Sabine River. There is, rather obviously, little physiographical differentiation between these two points. Figure 1 indicates generally the collection locations for seed and wood samples for the study.

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Within each collection location, two sweetgum stands were selected on average to good sites for the species and sufficiently distant from each other to eliminate the likelihood of common parentage. Then within each stand, five of the better dominant or codominant trees were selected as sample trees; as with stands, these trees were far enough apart to reduce chance s that any two might have originated as sprouts from the same root system. There we re, thus, seven transects, two physiographies per transect, two stands per physiographical location, and five trees per stand, or a total of 140 sample trees.

From each of the 140 trees, sufficient fruits were collected to produce seed and seedlings for the necessary outplantings. Two 10 mm. increment cores were extracted from each sample tree at approximately breast height and at points 180° apart on the circumference of the stem. These cores were shipped immediately to Raleigh for specific gravity and fiber characteristics determination.

Sample Measurements

The 10 mm. increment core samples were maintained moist and cold in Raleigh until sectioning, treating, and measuring. Each core was, first, divided into three segments. The first began at the pith and extended through the first ten annual rings; the second began with the eleventh and continued through the twentieth rings; and the third included the rest of the core. Specific gravity was determined for each of these core segments on a green volume-oven dry weight basis, with volume being measured by the water-displacement method. The two determinations for any particular segment were averaged to obtain an expression of specific gravity for that segment.

Following measurements of specific gravity, the fifteenth and thirtieth annual rings of one core from each tree were determined as carefully as possible, excised, and chemically macerated to separate the fibers using Franklin's method (1) Measurements of length to the nearest 0.1 mm. were made on 40 unbroken fibers for ,each annual ring sample for each core. Measurements of cell wall thickness and total fiber diameter were determined from 10 fibers to the nearest ocular micrometer graduation, with a magnification of 450x. These measurements were then converted to microns.

Analysis of Data

In keeping with the main objectives of the overall study, the principal matters of interest in our wood and fiber characterization work were the variations that exist between trees and between stands in each of the two physiographies, Coastal Plain and Piedmont, on each of the seven transects from North Carolina to Texas. The data, averaged by stand, are shown in Table 1. Sweetgum fibers average about 2 mm. in length, and weighted specific gravity at breast height approaches 0.50, which checks closely with other measurements of these characteristics.

A series of analyses of variance were run for all of the characters measured. Some of these results are presented here.

Specific Gravity Variation: Between-Trees

Variation studies in other species, pine and hardwood, have routinely indicated significant specific gravity differences between trees in a given stand. While there was no reason to suspect anything different from the data collected here, the dual coring of each sample tree enabled an analysis of variance using within-tree gravity variation as the error term. Only the outer-segment data --- from the 21st annual ring on--- were used, for the first analysis. Specific gravity of this portion of the core would be more truly representative of tre.e specific gravity at breast height than would similar information for the other segments. A nested classification was used in the analysis of variance, with cores in trees being used to test trees in stands and stands in provenances; with stands being used to test provenances in transects; and with provenances being used to test transects.

No significant differences at the 5% level were found in outer wood specific gravity between trees (Table 2). This was so unexpected that a second analysis--- this time using the core segment that contained the 11th through the 20th annual rings--- was run. Patterns of significance were exactly as shown in Table 2 for outer wood: there were highly significant differences between stands, but none between trees. We cannot pretend that these results are fully or perfectly indicative; our sample was only five trees per stand, and the analyses were for single, separate segments of each core. The preponderance of data from other studies strongly suggests the existence of significant tree-to-tree differences in specific gravity. Our data do not confirm significant tree-to-tree variation; we recommend additional, more-intensive studies of this characteristic.

Specific Gravity Variation: Between Stands, Provenances, and Transects

After analyzing between-tree variation in specific gravity, as indicated by the outer-wood

Table 1. Averages by stands for specific gravity, fiber length, width, and wall thickness. Sweetgum Prov. Study

Transect Provenance Stand	Sp. G. 1st 10 rings	Sp. G. 2nd 10 rings	Sp. G. outer rings	Sp. G. weighted	Fiber length 15th yr.	Fiber length 30th yr.	Fiber width 15th yr.	Fiber width 30th yr.	Wall thickness 15th yr.	Wall thickness 30th yr.
					---- mm			microns		
1-A-1	.514	.522	.496	.496	1.87	1.99	27.94	30.70	7.63	8.91
1-A-2	.476	.500	.494	.494	1.74	1.88	28.30	30.72	7.25	7.87
1-B-1	,512	.520	.512	.513	1,93	1.91	30.11	28.66	7.59	7.97
1-B-2	.474	.486	.484	.484	1.92	2.10	29.39	29.82	7.39	8.09
2-A-1	.490	.510	.518	.515	1,94	2.21	26.39	26.87	7.63	8.09
2-A-2	.448	.474	.488	.486	1.77	1.95	26.64	28.92	7.22	7.92
2-8-1	.470	.482	.494	.491	1.87	2.04	27.28	28.60	6.95	8.07
2-8-2	.488	.476	.476	.476	1.86	1.83	27.98	28.61	7.59	8.72
3-A-1	.506	.534	.536	.533	1.92	2.10	28.56	28.99	8.52	9.16
3-A-2	.464	.474	.470	.470	1.80	2.04	29.20	28.90	7.21	8.02
3-B-1	.436	.484	.490	.488	1.80	1.86	28.55	29.56	7.16	8.62
3-B-2	.502	.518	.512	.513	1.60	1.90	26.16	28.72	6.88	8.19
4-A-1										
4-A-2	.496	.496	.504	.502	2.03	2.11	28,38	29.35	7.97	8.36
4-8-1	.444	.460	.466	.465	2.02	2.12	26.32	27.99	7.17	7.55
4-B-2	.462	.492	.502	.499	1.87	1.88	25.40	26.92	7.08	8.62
5-A-1	.460	.488	.494	.492	1.75	1.91	29.33	29.28	8.28	8.74
5-A-2	.500	.526	.508	.509	1.81	1.90	26.97	26.78	7.41	8.44
5-B-1	.484	.496	.500	.499	1,67	1.92	26.95	28,71	7.72	8.33
5-B-2	.506	.504	.500	.501	1.75	1.89	27.06	27.41	7.59	7.96
6-A-1	,550	.558	.550	.553	1.66	1.85	25,38	26.47	7.08	7.86
6-A-2	.464	.478	.492	.489	1.93	2.12	27.50	27.53	7.40	7.86
6-B-1	.472	.488	.484	.484	1.89	1.97	26.75	27.85	6.61	6.81
6-B-2	.476	.474	.484	.486	1.65	1.90	26.03	29.04	6.97	7,25
7-A-1	.480	.490	.496	.494	1.68	1.86	26.28	27,86	6.84	7.93
7-A-2	.482	.494	.484	.485	1.76	1.92	25.92	25.44	6.67	6.95
7-B-1	.468	.478	.498	.491	1.79	1.83	24.07	23.82	8.13	7.87
7-B-2	.466	.480	.492	.496	1.70	1.77	22.84	25.86	7.27	8.13

Table 2. Analysis of variance for outer-wood specific gravity at breast height.

Source	df	MS	F
Total	269 1/		
Transect	6	.00085	.388
Provenances in transects	7	.00219	.584
Stands in provenances in transects	13	.00375	6.048**
Trees in stands	108	.00067	1.081
Error	135	.00062	

1/ One stand of five trees (ten cores) was inadvertently omitted from the sample. Thus, there are 269 df here rather than 279.

** Significant at the 1% level.

of breast-height samples, data from the two increment cores of each tree were combined. Analyses of average specific gravity were then made in terms of each segment and for weighted specific. gravity for the entire tree. Only the analysis for weighted gravity is discussed here.

Again, a nested classification was used, following the order trees in stands in provenances in transects, then stands in provenances in transects, then provenances in transects, and finally transects. The analysis-- Table 3-- shows significant differences only between stands, but at the 1% level. While the analysis of variance of Table 3 is for weighted specific gravity only, the same pattern occurred for specific gravity of each segment.

Table 3. Analysis of variance for weighted specific gravity at breast-height.

Source	df	MS	
Total	134		
Transects	6	.000571	.429
Provenances in transects	7	.001330	.567
Stands in provenances in transects	13	.002346	4.546**
Error	108	.000516	

** Significant at the 1% level.

Fiber Characteristics Variation

A slightly modified approach was used in analyzing the differences in fiber length, width, and wall thickness of the wood samples used in the study. These characters were measured for the 15th and 30th annual rings of one core only from each tree. Thus, it was possible to use the within-ring sum of squares as the error term to evaluate differences between annual rings and between trees; thereafter, the nested classification was again used for stands, provenances, and transects.

The pattern of variation discerned from these analyses was not so regular as was that for specific gravity. Fiber width was found to vary significantly by transects at the 5% level. We suspect this to be a quirk of the data, and not really meaningful. Analyses of variance for the fiber characteristics measured are shown in Table 4. Age of wood, or annual ring, proved to be highly significant as a source of variation, as did trees within stands, for all three of the fiber characteristics measured. Variation between stands was significant only in the case of fiber length.

Correlations

As a second step in analyzing the mass of data that had been collected, correlations were run between certain of the characteristics. The objective here was to shed light on the predictability of a character from another character easier to measure or measurable at an earlier age and to indicate limitations or lack of limitations in selections and breeding for specific wood or fiber characteristics. The correlations should not be

Table 4. Analyses of variance for fiber length, fiber width, and wall thickness.

		Fiber length		Fiber width		Wall thickness	
Source	**df**	**MS**	**F**	**MS**	**F**	**MS**	**F**
Total	269						
Transects	6	0.1839	2.404	68.248	4.644*	3.284	1.431
Provenances	7	0.0765	0.825	14.697	2.361	2.295	1.538
Stands	13	0.0927	4.233**	6.225	1.419	1.492	1.654
Trees	108	0.0219	1.991**	4.388	1.779**	0.902	2.775**
Annual Rings		1.3174	119.7**	70.994	28.789**	33.715	103.738**
Error	134	0.0110		2.466		0.325	

****Significant at* 1% level.
**Significant at* 5% level.

construed as indicating cause and effect.

The correlations that were calculated are as shown the following listing of characters and r-values:

1. Specific gravity 0.10 yr. to weighted r = .662*
2. Specific gravity outer wood to 30th yr. fiber length r = .290
3. Fiber length 15th yr. to 30th yr. r = .766
4. Fiber length to fiber diameter, 30th yr. r = .475*

(*Significant at the 1% level).

Other correlations are available from the basic data. Those shown, however, appear to be the most meaningful in terms of the specified objectives.

DISCUSSION

We are surprised that differences in outer-wood specific gravity prove to be of no statistical significance in light of between-tree variations shown by Webb (6) for sweetgum, by McElwee and Faircloth (3) for tupelo, by Taylor (4), Thorbjornsen (5), and Kellison (2) for yellow-poplar. We suspect this to be a function of the relatively small number of trees per stand that made up the sample. The mass of published data that show significant between-tree differences in wood specific gravity for sweetgum and other hardwoods appears to outweigh the data presented here. The discrepancy between our results and those of other investigators calls for additional definitive investigations.

Lack of significance for specific gravity differences between provenances and between transects is not so perplexing as the non-significance of between-tree differences. The only significant gravity differences were between stands. Analyses of outer-wood specific gravity (Table 2) and weighted specific gravity (Table 3) show the same significance or lack of it for the possible sources of variation.

The highly significant differences in fiber length that show up between the 15th and the 30th annual rings concur with previous reports. In almost every case the outer ring has the longer fiber, which could bear importantly on pulpwood rotation ages. It is gratifying that significant differences exist between trees, particularly since fiber length increases will almost certainly be an important objective in improvement programs. The between-stand differences should not be ignored; they will be of considerable practical importance in tree selections. You will recall Squillace's strong recommendation at this conference that mass selections be made within the best stands on a given site. Within these best stands, individual tree selections will take advantage of the between-tree variation that was found in the fiber length characteristic.

No such complexity exists in the analyses of fiber widths and cell wall thicknesses. Only those differenes between rings and between trees were significant.

The correlations noted previously reveal interesting possibilities for predictions, of wood and fiber characteristics from measurements made relatively early in the life of a sweetgum. For example, weighted breast-height specific gravity of merchantable trees can be determined quite closely from specific gravity of ten-year-old saplings, and fiber length of the 15th annual ring is a strong indicator of fiber length of the 30th ring. Equally interesting and useful are the indications that specific gravity and fiber length of the outer wood are weakly related at best, as are fiber length and fiber diameter at the 30th annual ring. These characteristics, each potentially important in tree improvement programs, are independent of each other. Selections and breeding for specified degrees of one need not result in degradation of quality in the other.

Of most immediate interest and value, however, is the repeated assurance of these data that differences in wood and fiber characteristics over major changes in geography --North Carolina to Texas and Coastal Plain to Piedmont are not statistically significant, and need not, therefore, complicate selection and breeding programs. Other phases of the basic study will reveal in years to come the possible existence and importance of provenances in sweetgum growth and development.

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