A COMPARISON OF EARLYWOOD AND LATEWOOD TRACHEID LENGTHS OF LOBLOLLY PINE

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ABSTRACT

Literature reports on the relationship of earlywood and latewood tracheid length within individual growth rings of pine trees are contradictory and confusing. Latewood tracheids have been reported to be longer or shorter than, and the same length as, earlywood tracheids. This study compares earlywood and latewood tracheids of both juvenile and mature wood of trees in a loblolly pine plantation (phase 1) and reports tracheid length variation from first-formed earlywood to last-formed latewood at several sampling locations of one tree (phase 2).

For the plantation-grown trees, earlywood and latewood were compared for ring 5 (juvenile wood) and ring 15 (mature wood) of 18 trees. In juvenile wood, first-formed earlywood cells were shorter than either last-formed earlywood or latewood tracheids. There was, however, little difference between last-formed earlywood and latewood. In mature wood, first-formed earlywood and last-formed latewood tracheids were the same average length. However, both earlywood and latewood tracheids formed near the transition zone were slightly longer.

Measurement of tracheids, obtained by macerating serial microtome sections taken from earlywood to latewood of individual rings (phase 2), revealed large variations of tracheid length within rings. In some rings, tracheid length increased from earlywood to latewood, in others it decreased, and in others it was unchanged.

The conclusion is that tracheid length is neither consistently longer nor shorter in the latewood portion of loblolly pine growth rings.

Keywords: Earlywood tracheid length, latewood tracheid length, loblolly pine, cambial activity, tracheid diameter, cells per growth file.

INTRODUCTION

Several researchers have reported that latewood tracheids of the genus *Pinus* are longer than earlywood tracheids. An Australian team found that latewood tracheids of scotch pine were longer than earlywood tracheids (Bisset and Dadswell 1950). Similar results were reported for loblolly pine (Kramer 1957; McMillin 1968), for slash pine (Taras 1965) and for shortleaf pine (McGinnes 1963). A more recent study reported contradictory findings. In an early study of longleaf pine, the earlywood tracheids were reported to be longer than latewood tracheids (Gerry 1916). In a study of loblolly pine, no difference in the length of earlywood and latewood tracheids was found (Jackson and Morse 1965). Recently it has been shown that latewood tracheids of longleaf pine are not significantly longer than earlywood tracheids (Rousso 1979).

A reason for such diverse findings may have been the absence of an unbiased method of selecting tracheids for measurement. Since thin-walled earlywood tracheids are more easily damaged than thick-walled latewood tracheids, it is possible that broken earlywood tracheids were measured. Also, if bent tracheids were not measured or were measured inaccurately, a random sample may not have been taken.

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The objective of this research was to determine whether a difference in tracheid length exists between earlywood and latewood tracheids within an individual growth increment of loblolly pine (*Pinus taeda* L.). If there are no differences, future measurement studies could ignore earlywood tracheids, which are more difficult to measure than latewood tracheids.

PROCEDURE

Phase 1

One-inch discs were removed from the top of the first pulpwood stick (5½ feet above groundline) of eighteen trees in a 21-year-old plantation in Mideast Mississippi that was being thinned for pulpwood. Blocks including the fifth and fifteenth rings were removed from each disc. Blocks were removed along a radius other than the long or short radius of eccentric discs to avoid compression wood zones. Blocks were mounted in a sliding microtome, and two-hundred micrometer-thick tangential sections were removed from first earlywood, last earlywood, first latewood and last latewood tissue. Blocks were positioned carefully to assure that only tissue from the selected sampling region was included in the microtome section.

Microtome sections were macerated by Franklin's method (Franklin 1945). Tracheid lengths were measured by the method described by Taylor (Taylor 1975).

Phase 2

Samples were removed from rings 5, 10, and 20 at sampling heights of 5 feet and 20 feet in one felled loblolly pine tree. Sample rings were sliced into 400-micrometer-thick tangential sections from first earlywood through last latewood. Sections were macerated and measured as described in Phase 1.

RESULTS

Data relative to the number and size of tracheids in individual growth increments are reported in Tables 1 and 2. Obvious differences from ring 5 (Table 1) and ring 15 (Table 2) are:

1. More periclinal divisions took place in the cambium during the fifth growth increment than during the fifteenth growth increment. An average of 134 earlywood tracheids were formed in growth increment 5 but only 28 were formed in growth increment 15.
2. Tracheids are considerably longer in growth increment 15 than in growth increment 5. Within growth increments the radial diameter of latewood tracheids is much less than earlywood tracheid diameter.

These relationships are well known and are obvious without measurement.

Within individual rings, differences in the length of tracheids and interrelationships of tracheid sizes are not obvious. In the juvenile wood of growth increment 5, the first-formed earlywood tracheids were shorter (2.85 mm) than last-formed earlywood tracheids (3.10 mm) or latewood tracheids (3.14 mm) (Table 1). Average length of tracheids in growth increment 15 was the same (4.05 mm) for the first-formed earlywood and last-formed latewood (Table 2). However, both ear-

TABLE 1. *Average tracheid length and cambial activity in the fifth growth increment of a loblolly pine.*

Tree no.	Earlywood				Latewood			
	Tracheid length		Radial tracheid diam. (mm)	No. cells	Tracheid length		Radial tracheid diam. (mm)	No. cells
	First earlywood (mm)	Last earlywood (mm)			First latewood (mm)	Last latewood (mm)		
1	2.72	3.19	40.4	126	2.85	2.76	24.7	38
2	2.78	2.84	43.6	202	3.00	2.94	21.4	44
3	2.80	2.94	43.6	186	3.02	2.97	25.7	46
4	2.83	2.74	41.1	168	2.70	2.50	24.1	44
5	2.70	3.19	43.3	42	3.30	3.14	30.3	64
6	2.84	2.96	46.6	148	3.09	2.96	25.2	42
7	2.16	2.46	40.2	142	2.68	2.71	28.9	62
8	2.46	2.69	40.4	170	3.22	3.24	22.8	40
9	2.92	3.08	44.2	134	3.48	3.33	25.4	37
10	3.42	3.81	43.2	88	3.82	3.68	22.9	24
11	3.02	3.05	44.5	181	3.17	3.08	28.5	46
12	2.99	3.64	46.1	145	3.18	4.26	23.9	38
13	2.50	2.86	42.5	143	2.88	2.48	27.0	54
14	3.09	3.36	48.9	138	3.15	3.30	27.9	61
15	2.72	3.07	48.6	97	3.39	3.20	27.6	62
16	2.81	3.30	44.2	151	2.78	2.85	26.5	40
17	3.40	3.42	46.9	64	3.78	3.70	26.8	50
18	3.18	3.21	37.9	92	3.08	3.42	28.0	49
Avg.	2.85	3.10	43.8	134	3.14	3.14	26.3	47

TABLE 2. *Average tracheid length and cambial activity in the fifteenth growth increment of a loblolly pine.*

Tree no.	Earlywood				Latewood			
	Tracheid length		Radial tracheid diam. (mm)	No. cells	Tracheid length		Radial tracheid diam. (mm)	No. cells
	First earlywood (mm)	Last earlywood (mm)			First latewood (mm)	Last latewood (mm)		
1	4.22	4.46	45.6	16	4.54	4.27	24.8	45
2	3.64	4.06	45.0	54	3.77	3.70	21.1	62
3	4.60	4.85	50.5	18	4.49	4.33	28.0	41
4	3.90	4.20	50.6	18	4.39	4.41	30.8	62
5	3.72	3.76	48.1	36	3.55	3.64	25.1	63
6	4.05	4.57	49.0	21	4.58	4.40	30.2	34
7	3.74	3.54	47.9	24	3.98	3.70	29.0	42
8	3.92	4.19	35.6	18	3.68	3.66	24.3	35
9	3.80	4.32	47.8	40	4.37	3.81	28.4	63
10	3.98	4.38	43.8	34	4.42	4.20	25.6	32
11	3.88	4.10	44.2	26	4.14	3.74	27.0	64
12	4.01	4.07	45.5	22	4.33	3.99	28.0	64
13	4.50	4.12	43.8	16	4.50	4.18	26.6	47
14	4.49	4.84	50.7	15	4.64	4.80	26.5	46
15	4.38	4.49	61.9	26	4.19	4.34	26.7	43
16	3.46	3.96	49.0	31	4.04	3.56	38.3	23
17	4.61	4.62	43.0	34	4.34	4.20	28.0	50
18	3.92	4.12	41.0	52	4.14	4.00	27.2	68
Avg.	4.05	4.26	46.8	28	4.23	4.05	27.5	49

TABLE 3. *Average length of tracheids at sampling points across individual growth increments from earlywood (sampling point 1) to latewood (millimeters).*

Sampling height (ft.)	Ring no.	Sampling point															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
5	5	2.4	2.6	2.4	2.6	2.7	2.2	2.2	2.4	2.4	2.7	2.8	3.0	3.0	3.0		
5	10	2.9	2.8	2.8	3.1	3.1	3.1	2.8	3.0	3.3	3.3	3.4	3.2	3.2	3.4	3.3	
5	20	3.7	3.7	3.6	4.0	3.6	3.4	3.4	3.6	3.6	3.4	3.3					
20	5	3.3	3.2	3.0	2.9	3.2	3.1	3.2	3.6	3.4	3.3	3.7	3.6	3.8	3.9	3.9	3.8
20	10	4.6	4.6	4.2	4.5	4.5	4.2	4.8	4.4	4.5							
20	20	5.1	4.9	5.1	4.9	4.6	4.8	4.8	5.0	4.8							

lywood and latewood tracheids near the transition were longer than those formed near the margins of growth increments. This result confirms a similar report of Jackson and Morse that the longest tracheids are near the middle of the growth increment of loblolly, slash, and shortleaf pine (Jackson and Morse 1965). Paired "t" test comparisons of average tracheid lengths of the eighteen trees revealed that: the shorter average length (2.85 mm) of first-formed earlywood tracheids in growth increment 5 was statistically significant, but the average lengths of tracheids from the other sampling locations were not significantly different from each other. For growth increment 15, first-formed earlywood tracheids were significantly shorter than tracheids formed near the transition zone, but the same length as the last-formed latewood tracheids.

Such data are difficult to interpret in regard to the objective of comparing earlywood and latewood tracheids within growth increments. In juvenile wood (growth increment 5), first earlywood tracheids are shorter than latewood tracheids, but not all earlywood tracheids (last-formed tracheids) are shorter. In mature wood (growth increment 15), the fact that tracheids near the transition zone are longer than tracheids near the ring margins confuses the relationship between earlywood and latewood tracheid length.

Phase 2 was undertaken to determine, in more detail, the tracheid length variation across rings. The average length of tracheids at each sampling point across sample rings is reported in Table 3. The average length of fibers from adjacent sampling points was quite variable. This variation was much greater than that observed for hardwood fibers (Taylor 1976). Such variation in tracheid length may be related to favorable growth periods during the growing season. When conditions favor growth in number of cells, the differentiating cells may also have a favorable environment for elongation and diameter increase.

Linear regression curves fitted to the data of Table 3 illustrate that latewood tracheids may be either longer or shorter than earlywood tracheids (Fig. 1). In juvenile wood (regression lines A and B, Fig. 1), latewood tracheids were longer than earlywood tracheids at both sampling heights. Latewood tracheids were longer than earlywood tracheids at height 5 feet in ring 10 (regression line C, Fig. 1), but not significantly different at height 20 feet (regression line D, Fig. 1). In mature wood, ring 20, latewood tracheids tended to be shorter than earlywood tracheids (regression lines E and F, Fig. 1).

Correlation of diameter growth (expressed as number of cells produced by the

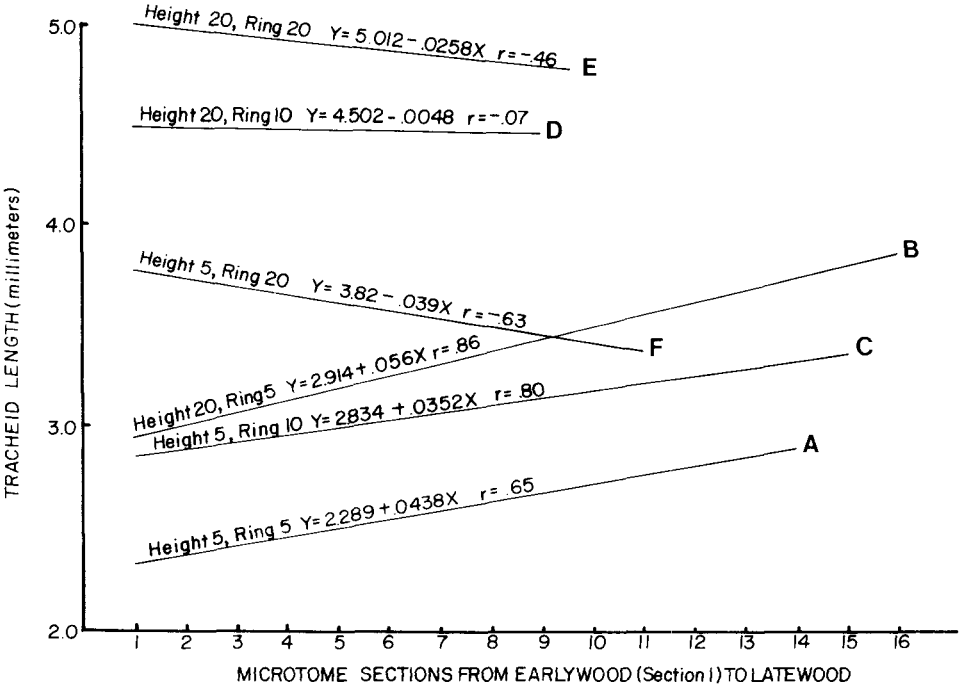

FIG. 1. Linear regression curves for tracheid lengths from earlywood to latewood of individual rings at heights of 5 and 20 feet.

cambium or the average radial diameter of cells) for the eighteen trees studied in phase 1 showed few strong relationships between growth and tracheid length (Table 4). Radial diameter of earlywood tracheids was positively correlated to earlywood tracheid length, but the radial diameter of latewood tracheids was negatively correlated to latewood tracheid length at most sampling points. The

TABLE 4. *Correlation of growth parameters in juvenile and mature wood.*

Dependent variable	Independent variable	Correlation coefficient	
		Ring 5	Ring 15
EARLYWOOD			
Radial tracheid diameter	No. cells per radial file	0.091	0.182
Radial tracheid diameter	First earlywood tracheid length	0.333	0.185
Radial tracheid diameter	Second earlywood tracheid length	0.392	0.235
No. cells per radial file	First earlywood tracheid length	−0.350	−0.472*
No. cells per radial file	Second earlywood tracheid length	−0.496*	−0.301
LATEWOOD			
Radial tracheid diameter	No. cells per radial file	0.759**	0.378
Radial tracheid diameter	First latewood tracheid length	−0.069	0.211
Radial tracheid diameter	Last latewood tracheid length	−0.134	−0.051
No. cells per radial file	First latewood tracheid length	−0.221	−0.162
No. cells per radial file	Last latewood tracheid length	−0.269	−0.123

* Indicates significance at the 5% level.
** Indicates significance at the 1% level.

number of cells produced by the cambium was negatively correlated with tracheid length in both earlywood and latewood. Although only two of these correlation coefficients were statistically significant, the consistent negative correlation suggests that cells differentiating from a rapidly dividing cambium do not elongate as much as cells produced by a more slowly dividing cambium. Other authors have reported that as ring width increases in gymnosperms, the tracheid length decreases (Chalk 1930; Helander 1933; Misra 1939; Hata 1949; Bisset et al. 1951; Wardrop 1951; Nylinder and Hagglund 1954; Schultze-Dewitz 1959; and Elliott 1960).

CONCLUSIONS

Earlywood tracheids are not consistently longer or shorter than latewood tracheids of loblolly pine.

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