DIFFERENCES IN THE WOOD OF LODGEPOLE PINE IN ALBERTA

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ABSTRACT

Significant tree-to-tree differences in both specific gravity and tracheid length were found in lodgepole pine trees growing in the mountains of western Alberta. No geographic variations of the properties were observed, but within geographic growth zones, trees growing at lower elevations had longer tracheids. Within the stem, specific gravity decreased as height above ground increased. The relationship of age (rings from pith) and specific gravity was different at different sampling heights within stems. At all heights tracheid length increased with age.

Keywords: Tracheid length, specific gravity, lodgepole pine.

Lodgepole pine (*Pinus contorta* Dougl. ex Loud.) grows in the mountainous section of western Alberta (Fig. 1). It occurs in pure stands, often quite dense, or in mixed stands on a wide variety of sites. Of the 68.6 billion cubic feet in North America, 45.6 billion cubic feet are in Canada (Summitt and Sliker, 1980). In Alberta, lodgepole pine grows on high, well-drained ridges and on moist sites at lower elevations.

Lodgepole pine is one of the major timber species of Alberta. It is sawn into construction lumber and planing mill products, veneered for making structural plywood, and used extensively for pulping. It is one of the native species being planted throughout the forested areas. Its form and growth characteristics, when properly managed, recommend it as a species useful to future generations.

This article reports on an investigation into the difference in specific gravity (a property associated with the strength of timber and yield of pulp) and tracheid length (a property associated with the quality of paper products). These properties were examined throughout the range of lodgepole pine in Alberta, and within individual trees from the bottom of the stem to the crown and from the pith to the bark. Such information is useful in characterizing the wood of lodgepole pine in the province of Alberta. It should be used to evaluate the existing timber supply and to indicate the variations available for selection in tree improvement programs.

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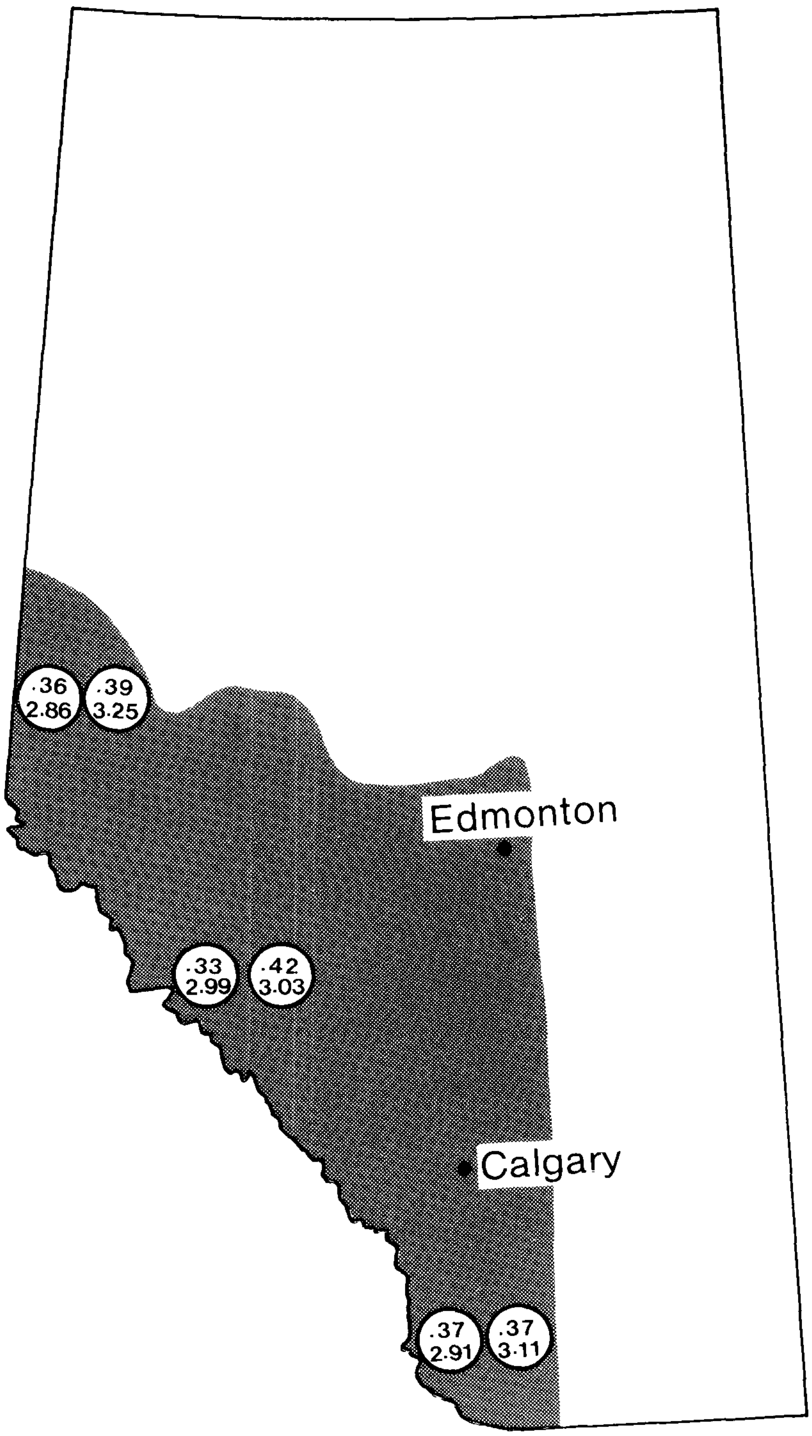

FIG. 1. Location of lodgepole pine study stands in the natural range of the species (shaded area) in Alberta. Numbers are average specific gravity (top number) and tracheid lengths of mature wood of ten sample trees from each stand.

TABLE 1. *Location and average growth data for 10 trees in sample stands.*

Stand no.	Forest	Elevation (meters)	Age (rings at 1.5 m)	Height (meters)	Diameter (centimeters)
1	Bow-Crow	1,341	101	20.2	28
2	Bow-Crow	1,768	78	18.6	28
3	Edson	1,067	94	21.6	28
4	Edson	1,402	77	18.2	30
5	Grande Prairie	914	77	23.7	29
6	Grande Prairie	1,372	110	19.6	29

PROCEDURE

Two sample stands were selected in each of three provincial forests (Bow-Crow, Edson, and Grande Prairie) within the natural range of lodgepole pine (Fig. 1). In each area one stand was selected at a high elevation and another at a low elevation. Within each stand, ten sample trees, with no visible evidence of disease or damage, were selected for property evaluations. Sample trees were dominant or codominant trees with straight, nonleaning stems and normal crowns. Within each stand, all sample trees were growing on the same macro-site with no large differences in slope, aspect, or soil characteristics. However, they were separated by a minimum of 100 meters to decrease the likelihood of including siblings in the sample.

A large (11-mm) increment core, intact from pith to bark, was removed from the southern radius at breast height of each sample tree. The core was divided into four segments, containing growth increments: 1–10, 11–20, 21–30, and 31 to the bark.

The specific gravity and average ring width of growth rings were measured for each segment. Specific gravity was determined on a green volume and oven-dry weight basis. Green volume was determined by immersion as described in U.S. Forest Products Laboratory Technical Note B-14 (revised Oct. 1956). After volume measurements were made, segments were dried, weighed, extracted, redried, and reweighed. Extraction was accomplished by a Soxhlet treatment consisting of 8-h elution in a solution of equal parts alcohol-benzene, followed by 8-h elution in ethyl alcohol. Alcohol and water soluble extractives were removed by boiling for 8 h in a large volume of water.

TABLE 2. *Average extractive-free specific gravity at breast height with standard deviations ( ) for portions of cores from each stand.*

Stand no.	Growth rings included in core portion			
	1–10	11–20	21–30	30–Bark
1	0.36 (.02)	0.34 (.02)	0.35 (.02)	0.37 (.03)
2	0.36 (.02)	0.36 (.02)	0.37 (.04)	0.37 (.03)
3	0.36 (.03)	0.38 (.04)	0.40 (.03)	0.42 (.05)
4	0.32 (.02)	0.32 (.02)	0.33 (.02)	0.33 (.02)
5	0.36 (.03)	0.37 (.03)	0.39 (.04)	0.39 (.05)
6	0.35 (.02)	0.34 (.02)	0.35 (.02)	0.36 (.02)

TABLE 3. *Extractive-free specific gravity values and analysis of variance table for mature wood (rings 31 to bark) of individuals trees in study stands.*

Tree no.	Stand					
	1	2	3	4	5	6
1	0.39	0.40	0.45	0.33	0.33	0.40
2	0.33	0.39	0.40	0.32	0.38	0.37
3	0.36	0.34	0.41	0.33	0.44	0.36
4	0.36	0.35	0.50	0.34	0.35	0.35
5	0.35	0.34	0.36	0.32	0.39	0.36
6	0.36	0.33	0.40	0.32	0.41	0.35
7	0.39	0.36	0.37	0.32	0.37	0.35
8	0.40	0.39	0.38	0.33	0.50	0.32
9	0.36	0.39	0.48	0.35	0.38	0.39
10	0.39	0.38	0.41	0.37	0.33	0.36
Average	0.37	0.37	0.42	0.33	0.39	0.36

Source	d.f.	S.S.	M.S.	F.
Among stands	5	0.0391571		
Forests	2	0.00033375	0.000166875	0.01 N.S.
Areas	3	0.03882335	0.012941117	11.18**
Within stands	54	0.0624871	0.001157169	
TOTAL	59	0.1016442		

Tracheid length measurements were made on latewood tracheids of mature wood. A composite sample was prepared from the wood of rings 31–35 and another composite from the outer five rings of each core. The length of fifty whole, latewood tracheids of macerated tissue selected in an unbiased manner (Taylor 1975) were measured.

To evaluate variations within stems, six trees were felled and short bolts were removed from heights 1.5, 4, 7, 10, 13, and 16 meters. Two cross-sectional discs were cut from the bolts at these heights. Specific gravity was determined from 10-degree, pith-to-bark wedges along each cardinal direction from one disc at each height. Specific gravity was determined on a green volume and dry weight basis for extractive-free wood as described for increment core segments.

From the southern radius of a second disc at each sampling height, wedge sections including growth rings 1–5, 6–10, 11–15, 16–20, 21–25, 26–30, 31–40, 41–60, and rings beyond 60 were removed. The specific gravity of each isolated section was individually determined after extraction as described for core segments. Following specific gravity measurement, the latewood of rings 3, 8, 13, 18, 28, 40, and 60 was dissected and the lengths of fifty tracheids were measured (Taylor 1975).

RESULTS AND DISCUSSION

Physical data about sample stands are reported in Table 1. Differences in elevation between stands in each forest were similar. Elevations differed widely between forests, because lodgepole pine grows at higher elevations in southern Alberta than it does further north in the province (Fig. 1).

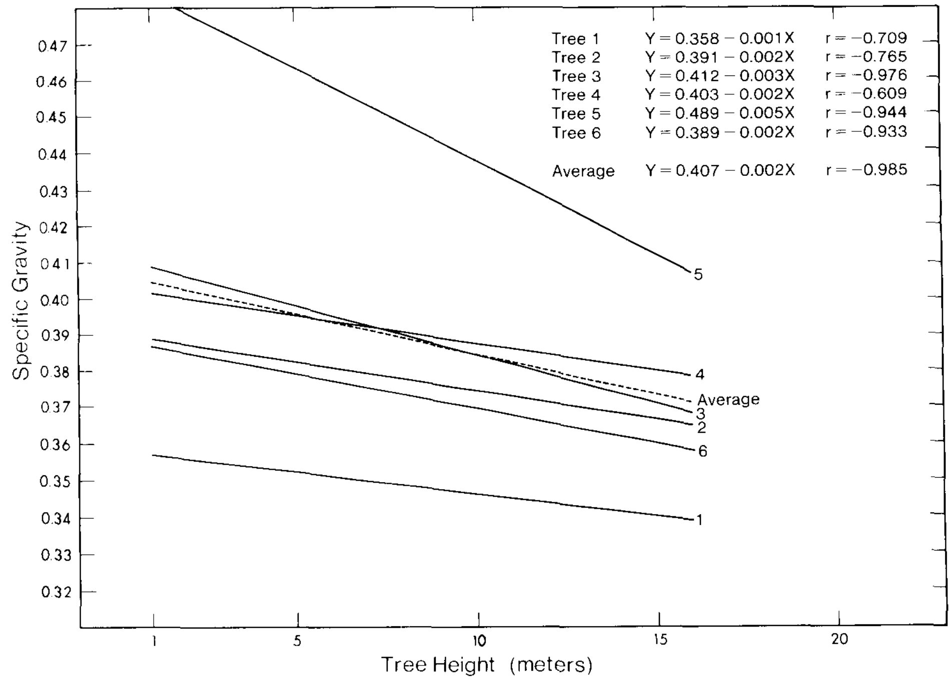

FIG. 2. Relationship between tree height and specific gravity for six lodgepole pine trees.

Variation among stands

Average specific gravity values of core segments for each sample stand are reported in Table 2. There is a trend for specific gravity to increase from juvenile wood near the pith to mature wood in the outer portion of the tree stem. Specific gravity values of mature wood (ring 31 to the bark) for individual trees were quite variable from tree to tree (Table 3). Analysis of variance indicates that the average differences in mature wood specific gravity values do not differ significantly be-

TABLE 4. *Average length of tracheids in growth increments 31–35 and the five annual increments nearest the bark of each tree in the six sample stands. Tabulated values are averages of fifty tracheids.*

Growth increments 31–35 for stand						Five growth increments nearest bark for stand					
1	2	3	4	5	6	1	2	3	4	5	6
Millimeters											
2.98	2.36	2.69	2.73	2.70	2.38	3.48	2.60	2.78	3.02	3.10	2.91
2.22	2.15	2.75	2.78	2.38	2.60	2.92	2.91	3.14	3.00	2.89	3.05
2.70	2.45	2.72	3.01	2.72	2.53	2.64	3.14	2.84	3.30	3.32	2.68
2.37	2.10	3.22	2.82	2.89	2.55	2.80	2.42	3.35	3.01	3.02	3.08
2.68	3.10	2.65	2.82	3.28	2.81	3.14	3.25	3.07	3.20	3.64	3.49
2.64	2.86	2.80	2.40	2.94	2.56	3.14	3.32	2.96	2.94	3.60	2.42
2.30	2.11	2.68	2.90	3.24	2.41	3.15	3.16	2.83	2.93	3.54	2.50
2.36	2.23	2.69	2.58	2.64	2.16	3.22	2.74	2.80	2.64	3.00	2.58
2.77	1.96	2.75	2.58	2.66	2.71	3.30	2.88	3.34	2.73	2.98	2.86
2.46	1.79	2.77	2.89	2.54	2.60	3.31	2.66	3.14	3.14	3.37	3.00
2.55	2.31	2.77	2.75	2.80	2.53	3.11	2.91	3.03	2.99	3.25	2.86

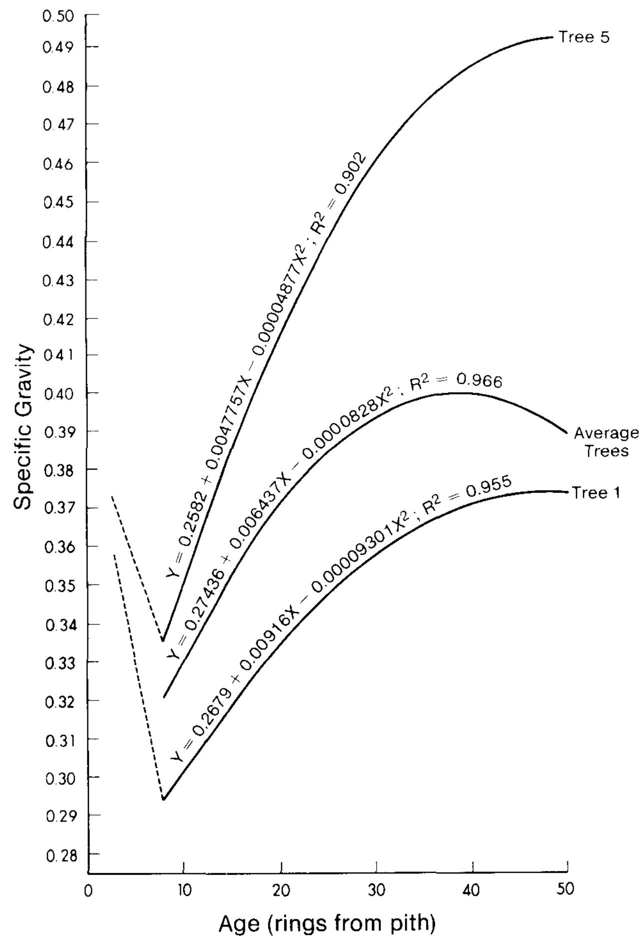

FIG. 3. Relationship between age (rings from pith) and specific gravity for the highest and lowest specific gravity trees and the average of the four intermediate specific gravity trees at 1.5 meters above ground. Curvilinear regressions were fitted to the data for the sample rings from ring 8 to ring 60. Actual specific gravity values for ring 3 are plotted and connected to the appropriate curve by a dotted line.

tween forests. However, there are significant differences (0.01 level) in mature wood specific gravity from stand to stand within forests. Values ranged from a high of 0.42 for stand 3 to a low of 0.33 for stand 4 of the Edson forest (Table 3).

Mature wood tracheids from each forest sampled were approximately the same length (Table 4). The wood taken from lower elevation stands had the longest tracheids (Fig. 1 and Table 4). Statistical analysis of the data in Table 4 showed that these differences were significant at the 1% level for tracheids in outer rings and significant at the 5% level for tracheids of growth rings 31–35.

Data of Table 4 also showed that outerwood tracheids (3.02 mm) were approximately 15% longer than tracheids of rings 31–35 (2.61 mm). This relationship of increased tracheid length in outerwood was confirmed and clarified by the incremental values of individual trees reported in the next section.

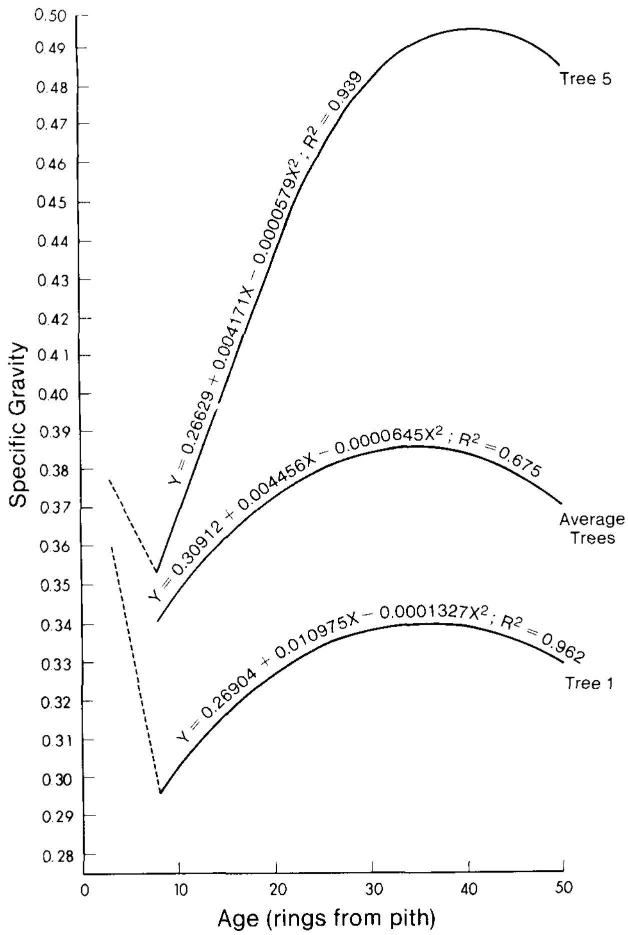

FIG. 4. Relationship between age (rings from pith) and specific gravity for the highest and lowest specific gravity trees and the average of the four intermediate specific gravity trees at 4 meters above ground. Curvilinear regressions were fitted to the data for the sample rings from ring 8 to ring 60. Actual specific gravity values for ring 3 are plotted and connected to the appropriate curve by a dotted line.

Variation within trees

The average specific gravity of the four wedges from each sampling height was used as an estimate of specific gravity at that height. No weighting was considered necessary because each wedge represented nearly equal portions of the total disc. In each of the six sample trees, specific gravity tended to decrease as height above ground increased. The relationship is highly linear (Fig. 2); although some trees have much higher specific gravity than others, the effect of height on specific gravity is similar for each tree, as indicated by the similar slope of regression lines. An investigation of the specific gravity/height relationship of lodgepole pine in the United States reported the same trend (Okkonen et al. 1972), and a survey

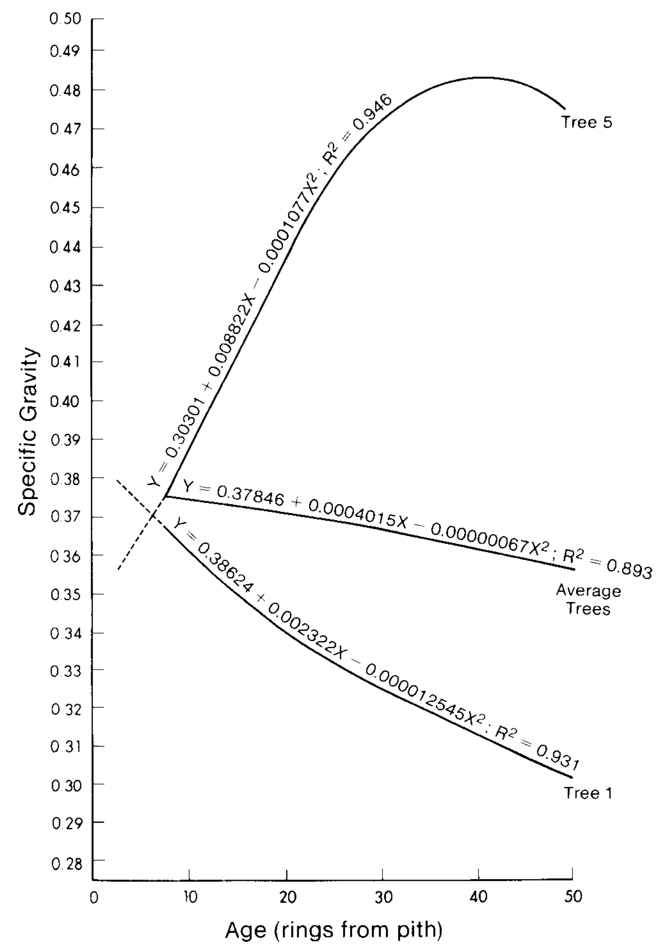

FIG. 5. Relationship between age (rings from pith) and specific gravity for the highest and lowest specific gravity trees and the average of the four intermediate specific gravity trees at 7 meters above ground. Curvilinear regressions were fitted to the data for the sample rings from 8 to ring 60. Actual specific gravity values for ring 3 are plotted and connected to the appropriate curve by a dotted line.

of 36 lodgepole pines in British Columbia produced similar regression curves (Heger 1974).

The relationship between specific gravity and growth rings was quite complex for the six trees studied. At most sampling heights, specific gravity decreased from the 5-ring segment nearest the pith to the segment containing growth rings 6–10. This is similar to the decrease in specific gravity in rings near the pith of *Eucalyptus grandis* (Taylor 1973). At breast-height and at 4 meters, the general pattern (after the decrease in rings near the pith) was for specific gravity to increase to a maximum between rings 30 and 50. This pattern was found in all trees (Figs. 3 and 4). At a sampling height of 7 meters, however, the lowest specific gravity tree (tree 1) and the average specific gravity trees decreased in specific gravity from pith to bark (Fig. 5). The trend of decreasing specific gravity

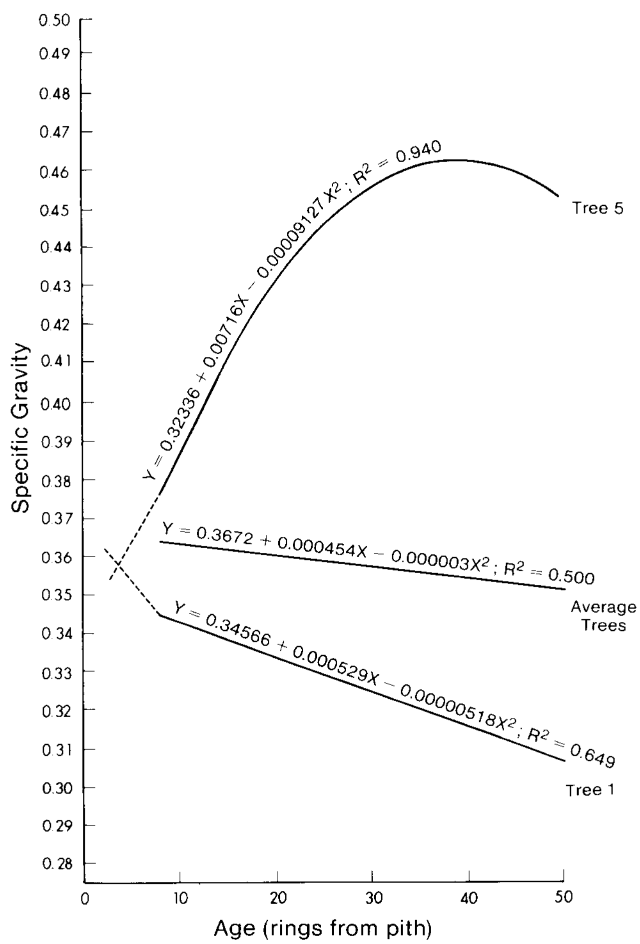

FIG. 6. Relationship between age (rings from pith) and specific gravity for the highest and lowest specific gravity trees and the average of the four intermediate specific gravity trees at 10 meters above ground. Curvilinear regressions were fitted to the data for the sample rings from ring 8 to ring 60. Actual specific gravity values for ring 3 are plotted and connected to the appropriate curve by a dotted line.

with increasing age was found for these trees at all successive heights up the stem (Figs. 6, 7). However, the highest specific gravity tree (tree 5) maintained a curve of increasing specific gravity with increasing age (similar to the breast-height relationship) through a height of 10 meters (Figs. 3, 4, 5, 6, 7). Such a variation pattern as exhibited by tree 5, if heritable, should be a breeding goal of tree improvement programs for lodgepole pine.

Tracheid length was much more consistent from tree-to-tree and height-to-height within trees than specific gravity. For every sampling location, the pattern of length variation conformed to "Sanio's Law"; i.e., tracheid length increased with increasing rings from the pith until a maximum was reached and then increased or decreased slightly through subsequent growth increments (Bailey and

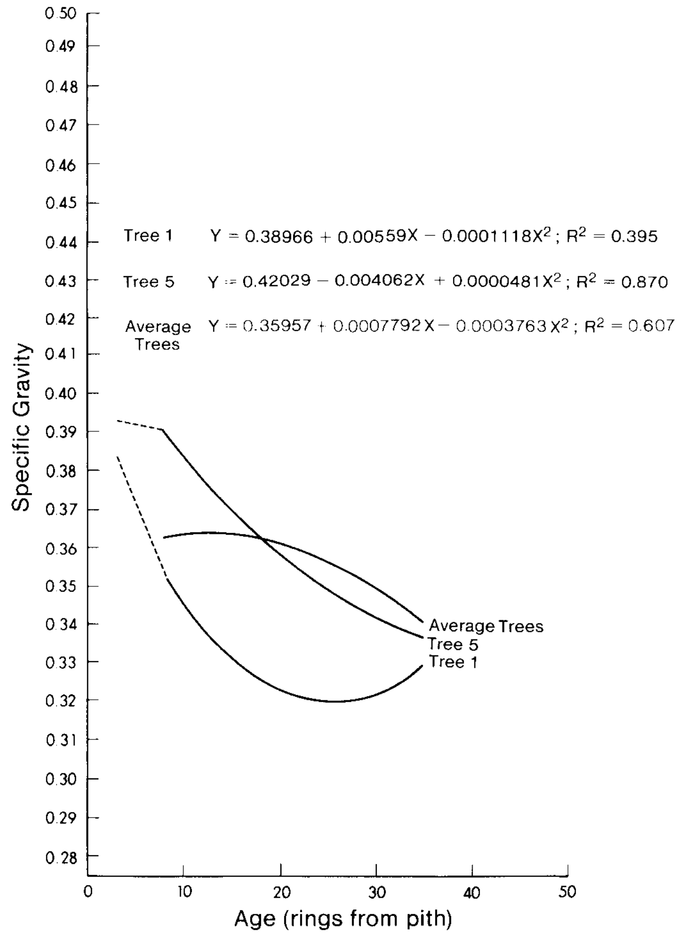

FIG. 7. Relationship between age (rings from pith) and specific gravity for the highest and lowest specific gravity trees and the average of the four intermediate specific gravity trees at 13 meters above ground. Curvilinear regressions were fitted to the data for the sample rings from ring 8 to ring 60. Actual specific gravity values for ring 3 are plotted and connected to the appropriate curve by a dotted line.

Shepard 1915). For comparable growth increments, tracheids were quite similar in length at sampling points 1.5, 4, and 10 meters in the stem (Fig. 8). Average tracheid length for top logs would, however, be less than for butt logs because top logs would contain a higher proportion of juvenile wood with shorter tracheids.

Tracheid length variation patterns for the tree with the longest tracheids (tree 6) and shortest tracheids (tree 1) are illustrated in Figs. 9, 10, 11, 12. The tree with long tracheids (tree 6) had much longer tracheids than tree 1 at higher sampling points in the stem (Figs. 11, 12). Statistical analysis showed that there was a significant difference in tracheid length among trees.

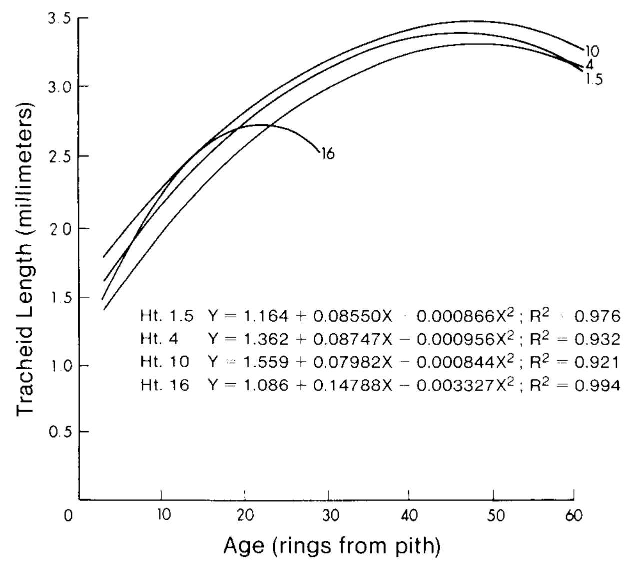

FIG. 8. Relationship between age (rings from pith) and tracheid length at different sampling heights within stems. Curves are averages for sample trees.

Variation among trees

Values for specific gravities of individual trees show large differences among trees in each stand studied (Table 3). Differences among trees have been reported for every species studied in detail. In research of lodgepole pine and other West-

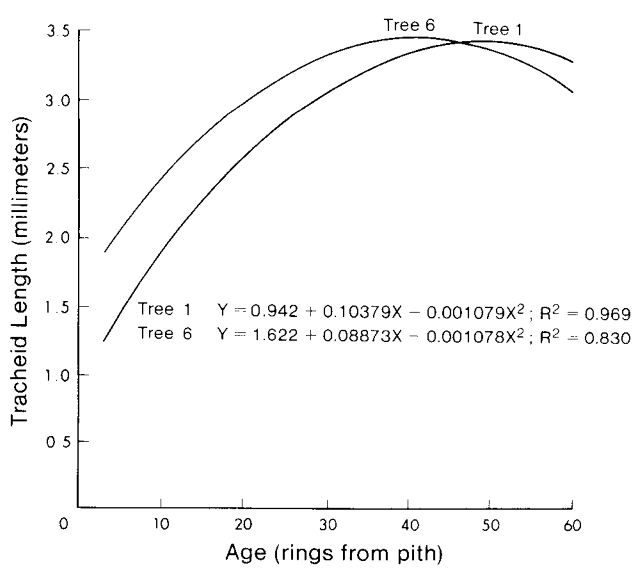

FIG. 9. Relationship between age (rings from pith) and tracheid length for the longest fibered tree (tree 6) and shortest fibered tree (tree 1) at a height of 1.5 meters.

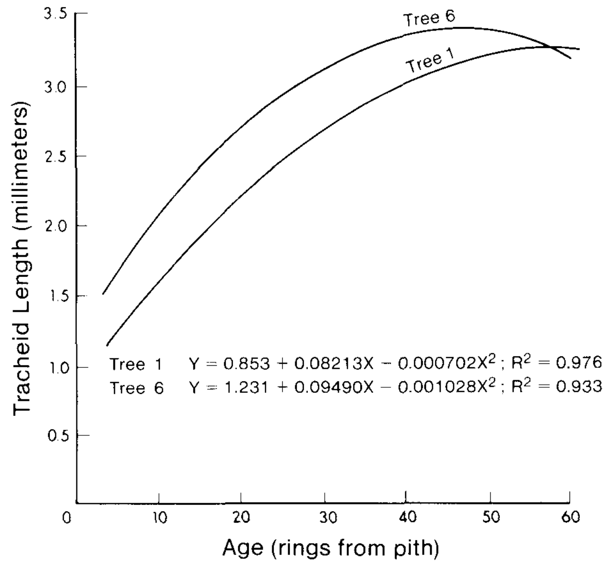

FIG. 10. Relationship between age (rings from pith) and tracheid length for the longest fibered tree (tree 6) and shortest fibered (tree 1) at a height of 4 meters.

ern United States species the between-tree difference was called "tremendous" (Okkonen et al. 1972). The concept of tremendous differences among lodgepole pine trees is supported by the discovery that tree 5 (examined in this study) had an average specific gravity 28% higher than tree 1 (Table 5).

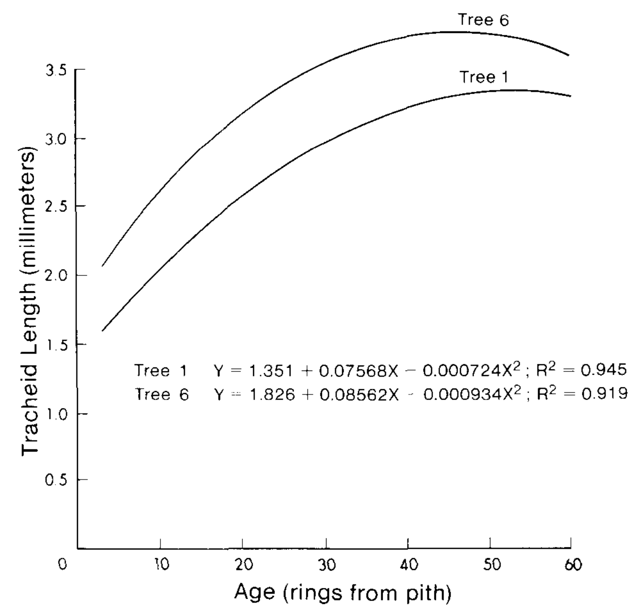

FIG. 11. Relationship between age (rings from pith) and tracheid length from the longest fibered tree (tree 6) and shortest fibered (tree 1) at a height of 10 meters.

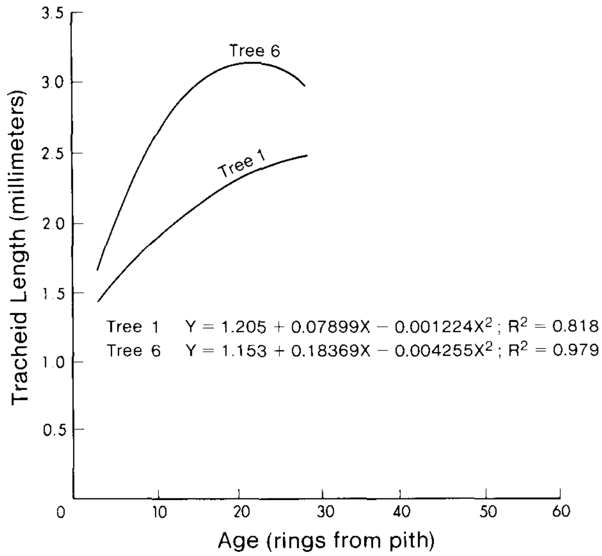

FIG. 12. Relationship between age (rings from pith) and tracheid length for the longest fibered tree (tree 6) and shortest fibered (tree 1) at a height of 16 meters.

Such large differences in specific gravity of lodgepole pine trees growing in the same stands are potentially the most important findings of this study, because they suggest that specific gravity (heritable in most softwood species) may be enhanced through selective breeding of lodgepole pine.

The breast-height samples of mature wood showed large differences in tracheid length among individual trees within study plots (Table 4). Tracheid length data, depicted graphically in Figs. 9–12, show that there are even greater differences in tracheid length among trees at sampling points higher in the stem than at breast height. Such differences are potentially important because in other pines tracheid length is reported to be one of the easiest wood properties to alter in a selective breeding program (Goggans 1964).

TABLE 5. *Unextracted specific gravity (green volume, dry-weight basis) of discs from various sampling heights of individual trees.*

Height (m)	Tree number						Average (6 trees)
	1	2	3	4	5	6	
1.5	0.36	0.40	0.41	0.40	0.47	0.38	0.403
4	0.35	0.38	0.40	0.39	0.48	0.38	0.397
7	0.35	0.37	0.39	0.39	0.46	0.38	0.390
10	0.35	0.38	0.38	0.40	0.44	0.37	0.386
13	0.34	0.38	0.38	0.40	0.41	0.37	0.380
16	0.34	0.36	0.37	0.36	0.41	0.35	0.376
Avg. for tree	0.348	0.378	0.388	0.390	0.445	0.372	

CONCLUSIONS

The results of this study suggest the following conclusions:

1—Neither specific gravity nor tracheid length varies from north to south in Alberta.

2—Within geographic growth zones, trees growing at lower elevation have longer tracheids.

3—Specific gravity of stemwood decreases as height above ground increases.

4—At breast height, specific gravity decreases in rings near the pith and then increases to a maximum in the outer stem.

5—Above 7 meters stem height, specific gravity decreases from pith to bark in most trees. However, some trees exhibit a pattern of increasing specific gravity in rings beyond ring 10 to the bark through a height of 10 meters.

6—Tree-to-tree differences in both specific gravity and tracheid length are statistically significant.

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