RELATIONSHIP OF SPECIFIC GRAVITY AND TRACHEID LENGTH TO GROWTH RATE AND PROVENANCE IN SCOTCH PINE

Donald Dorn[1/]

INTRODUCTION

Fiber length and specific gravity of wood have long been subjects of investigation because of the economic importance of these characteristics to the wood-using industries. Although the paper industry still generally prefers wood with long fibers and high specific gravity because of their favorable effects on strength and yield, some of today's specialized wood products may call for wood with other characteristics. If we are to grow wood in the future with "tailor-made" attributes, we need to know to what extent these are determined by inheritance and by environment. Comparing wood from trees of one provenance or seed source with that from another provenance may give a gross indication of the extent to which wood quality is inherited because trees within provenances are more closely related than those between provenances. Echols (1958) found that Scotch pine trees from different provenances produced wood with significantly different values for specific gravity and tracheid length. This raised the further question as to what extent this was due to growth rate, since the provenances did have significantly different growth rates. The investigation herein reported was undertaken to study the relative effects of provenance and growth rate upon fiber length and specific gravity of Scotch pine, in order to suggest ways of controlling these variables.

REVIEW OF LITERATURE

The amount of published material dealing with tracheid length and specific gravity is prodigious and covers a period of over 100 years. Investigations show a pattern for fiber length within single growth rings. Although there is disagreement whether summerwood tracheids are significantly longer than springwood tracheids, it is agreed that the difference, if it exists, is small. The length of tracheids, as related to position within the tree, was studied by Sanio (1872) working with Scotch pine. He discovered a definite predictable pattern of tracheid length related to position within the tree. This same pattern has since been confirmed for conifers generally. For accurate comparisons of tracheid lengths among trees, it is thus necessary to obtain samples from the same position in each tree.

[1/] Held jointly with the Committee on Forest Tree Breeding in Canada.

Forester, U. S. Forest Service, Warren, Pa.

There is disagreement among investigators concerning the effect of growth rate upon tracheid length, but many have found that increased height growth results in increased tracheid length.

Several studies have suggested the possibility of genetical control of wood properties. Zobel (1961) concluded that, of all wood properties studied, tracheid length seemed to be the most strongly inherited. But, he pointed out that a large tree-to-tree variation within a species range does not prove that the variation is due to genetic influence. Echols (1958) found significant differences among different provenances, but it was impossible to say how much of the difference in tracheid length was due to growth rate.

Specific gravity has also been found to vary among provenances and with position in the tree. The relative effects of environment and inheritance upon specific gravity are still topics for argument despite the vast amount of literature written about this subject.

MATERIALS AND METHODS

The wood samples used in this study were obtained from a plantation established I in 1940 as an International Union of Forest Research Organizations (IUFRO) sponsored provenance test of Scotch pine in New York. Thirty-five seedlots, each representing a different provenance, were planted in single row plots of approximately 50 trees per row in each of three replicates. The same and additional provenances were planted in New Hampshire in 1942 as part of the same provenance test. The New Hampshire plantation was utilized by Echols (1958) in his study of Scotch pine wood characteristics.

In the winter of 1964-65, the Forest Research Unit of the New York State Conservation Department made a mechanical thinning in one of the replicates. To provide a determination of specific gravity, ten seed sources and ten of the cut trees within each seed source were selected. Tracheid length values were taken from ten trees in each of five sources. The provenances were chosen to provide a regular latitudinal gradient with a wide north-south distribution. The five largest and five smallest trees within each provenance were selected to study the effect of growth rate differences within provenances. The latitude of the provenances and sample tree data are shown in table 1.

Table 1. -- DBH and height means arranged according to provenance and growth rate.

IUFRO no.	Latitude	Growth rate	DBH	Height	IUFRO no.	Latitude	Growth rate	DM	Height
30	60°40'	slow	3.6	22.4	41	50°51'	slow	4.9	30.4
		fast	5.4	30.6			fast	6.9	40.7
49	57°46'	slow	3.5	22.6	23	49°20'	slow	5.7	33.3
		fast	5.4	28.8			fast	7.2	40.2
32	55°38'	slow	4.7	30.6	35	48°55'	slow	5.9	32.2
		fast	7.7	39.9			fast	8.0	42.0
37	53°13'	slow	4.8	30.9	34	47°24'	slow	3.7	25.1
		fast	7.8	41.3			fast	5.0	30.9
55	51°15'	slow	4.4	28.1	25	46°38'	slow	4.9	31.5
		fast	7.4	36.8			fast	7.0	39.5
Average of ten provenances							slow	4.6	28.7
							fast	6.8	37.1

The wood samples were all taken at breast height and were divided into 5-year growth segments to study age effects. Specific gravity was obtained using the maximum moisture method developed by Smith (1954). Mean tracheid length of each sample was calculated from 50 or more macerated tracheids mounted on slides, and projected on a horizontal screen for measurement.

RESULTS

Comparisons of the mean tracheid length were made of the fastest and slowest grown trees within and between the fastest grown provenance and the slowest grown provenance. The same comparisons were made for specific gravity. As shown in tables 2 and 3, every comparison showed a nonsignificant difference at the 5% level.

Table 2. -- Student's t-test of average tracheid length of fast and slow grown trees within and between the fastest grown provenance (55) and the slowest grown provenance (30).

Comparisons: IUFRO seed source no. and growth rate within source		Average tracheid length (mm) (m		Difference (mm)	-
A	B	A	B		
55 fast	55 slow	3.02	2.88	.14	1.293 NS
30 fast	30 slow	2.93	2.74	.19	1.601 NS
55 fast	30 fast	3.02	2.93	.09	0.825 NS
55 fast	30 slow	3.02	2.74	.28	2.108 NS
55 slow	30 fast	2.88	2.93	.05	0.552 NS
55 slow	30 slow	2.88	2.74	.14	1.186 NS

With 8 df. t = 2.306 significant at 5% level.

Table 3. -- Student's t-test of average specific gravity of fast and slow grown trees within and between the fastest grown provenance (35) and the slowest grown provenance (49).

Comparisons: IUFRO seed source no. and growth rate within source		Average specific gravity		Difference (mm)	-
A	B	A	B		
35 fast	35 slow	.348	.358	.010	0.937 NS
49 fast	49 slow	.372	.370	.002	0.118 NS
35 fast	49 fast	.348	.372	.024	1.809 NS
35 fast	49 slow	.348	.370	.022	1.316 NS
35 slow	49 fast	.358	.372	.014	1.230 NS
35 slow	49 slow	.358	.370	.012	0.786 NS

With 8 df. t = 2.306 significant at 5% level.

Two analyses of variance of tracheid length (using all growth segments and excluding the first five-year segment to reduce the effect of corewood) revealed effects significant at the 0.1% level due to provenance and age (table 4), while growth rate without reference to age or provenance had no significant effect. Tracheid lengths showed progressive decrease in length from south to north in the same ranking as the latitude of the provenances. The interaction of provenance and growth rate when the first 5-year growth segments were excluded was significant at the 0.1% level. All other interactions were nonsignificant.

Table 4. -- Analysis of variance of tracheid length.

Source of variation	Including all growth segments			Excluding first 5-year growth segment		
	df	MS	F	df	MS	F
Provenance (A)	4	.4579	4.45***	4	.5600	5.47***
Cambium age (B)	3	19.2052	186.82***	2	6.3500	62.07***
Growth rate (C)	1	.1463	1.42 NS	1	.0300	<1 NS
A X B	12	.1399	1.36 NS	8	.0612	<1 NS
A X C	4	.2986	2.90 NS	4	.4475	4.37***
B X C	3	.0833	<1 NS	2	.0800	<1 NS
A X B X C	12	.1009	<1 NS	8	.0575	<1 NS
Error	160	.1028		120	.1023	
Total	199			149		

*** Indicates significance at the 0.1% level.

Similar analyses for specific gravity showed that provenance and age caused variance significant at the 0.1% level. Growth rate also showed an effect significan at the 5% level when all growth segments were included and at the 0.1% level when the first 5-year growth segments were excluded (table 5). Interactions of provenance and age with growth were found to be significant at the 0.1% level. Other interactions were nonsignificant.

Table 5. -- Analysis of variance of specific gravity.

Source of variation	Including all growth segments			Excluding first 5-year growth segment		
	df	MS	F	df	MS	F
Provenance (A)	9	.00400	4.30***	9	.00511	5.32***
Cambium age (B)	3	.06833	73.47***	2	.05650	58.85***
Growth rate (C)	1	.00500	5.38	1	.01000	10.42***
A X B	27	.00074	<1 NS	18	.00028	<1 NS
A X C	9	.00367	3.95***	9	.00289	3.01***
B X C	3	.00467	5.02	2	.00450	4.69
A X B X C	27	.00067	<1 NS	18	.00111	1.16 NS
Error	320	.00093		240	.00096	
Total	399			299		

*** Indicates significance at the 0.1% level.

DISCUSSION AND CONCLUSIONS

The investigation showed that cambium age at the point of sampling has a highly significant effect on both tracheid length and specific gravity in Scotch pine. This point has been confirmed for conifers generally by many investigators during the course of years ranging from Sanio (1872) to the most recent study. Both tracheid lengths and specific gravity increase from the pith to the bark. The wood formed within the first five to seven years from the pith is termed core wood or juvenile wood and has tracheid lengths and specific gravities up to 50% less than wood formed at later years.

Total height growth and mean tracheid length had a correlation coefficient significant at the 1% level. However, this study showed that the correlation of growth rate with tracheid length was caused by differing tracheid lengths among different provenances and not by growth rate per se. Zobel (1961) concluded that, of all the wood properties studied, tracheid length seems to be the most strongly inherited, enabling considerable improvement through selection; the results of the study herein reported further confirm this observation.

The apparent contradictions between the analysis of variance that showed a significant difference due to provenance and the t-test that showed nonsignificant differences may be explained. Five provenances were used in the analysis of variance where the t-test, being a comparison, used only two -- the fastest growing one and slowest growing one. It is readily conceivable that significant differences in tracheid length do not exist between the fastest and slowest growing sources, even though they do exist among some of the other sources, used in this study. This is apparently the situation in this case. This adds further weight to the conclusion that provenance, not growth rate, exerts the most influence on tracheid length.

The results of the specific gravity measurements and analyses were less conclusive. Specific gravity differences were significant both between fast- and slow-grown wood and among different provenances. The relative proportion of variance due to seed source or to growth rate can only be resolved by additional studies in which wood grown at many different rates within each source is analyzed. The significant interaction of growth rate with provenance and with age suggests that growth rate affects specific gravity more in some provenances than others and more during certain periods of the tree's life.

Although this study has shown statistically significant differences between provenances, the estimates obtained are not precise in relation to the genetic gains possible through further selection and breeding within or between sources. Nevertheless, the broad indicators mandate for selection of the faster growing provenances and within these, the fastest growing trees. The loss in specific gravity with increased growth rate may be countered by the increased volume, or through within-source selection for high specific gravity among fast-growing trees. The possibility for establishing a generality in regard to specific gravity was restricted by significant interactions with provenance and cambium age. The data for fiber length were not so encumbered and clearly suggested selection for increased growth rate. An additional question remains of economic biological parameters. The answer to this question can only come from detailed analysis of the commercial utilization for the species; such a study should include biological, economic, managerial, and utilization considerations. Obviously, a very small percentage increase in growth rate or pulp yield would have important economic considerations in a major species like Douglas fir or loblolly pine. In a minor species like Scotch pine, the tree breeder will require additional guidelines to suggest meaningful differences in growth rate and wood quality.

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