SEED SOURCE VARIATION IN TRACHEID LENGTH AND SPECIFIC GRAVITY OF FIVE-YEAR-OLD JACK PINE SEEDLINGS

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Jack pine *(Pinus banksiana* Lamb.) is widely used in Lake States reforestation because of its ability to make rapid early growth on relatively infertile sites. It is a major pulpwood producing species. Since the quality and yield of pulp are so strongly influenced by tracheid length and specific gravity, information on genetic variation in these characteristics would be useful in planning future jack pine tree improvement programs.

This study was done to: 1) measure tracheid length and specific gravity variation by seed source in the juvenile wood of jack pine; and 2) develop a basis for comparing wood quality variation by seed source in young seedlings with that in mature trees.

Material and Methods

A jack pine seed source test was established in the Hugo Sauer Nursery near Rhinelander, Wisconsin, in spring 1962. This test was initiated by Mr. M. Hoist of the Petawawa Forest Experiment Station, Chalk River, Ontario, Canada. He arranged for the collection of seed from 100 natural jack pine stands located over the entire range of the species. The seed collections were distributed among a number of cooperators in Canada and the United States. Ninety-two of the collections are represented in the Rhinelander planting.

The seed was sown in a 5-replicate randomized complete block design. Ten contiguous seed spots of each source are contained in each replication. Each spot was randomly thinned to three seedlings at the beginning of the second growing season and to one seedling at the beginning of the third growing season. Chemical weed control, fertilization, and irrigation promoted vigorous growth.

At the end of the 1966 (fifth) growing season when the test was to be terminated, 34 sources were selected for measurements of tracheid length and specific gravity (fig. 1). For each source, 5 trees of each of the 5 replications were sampled; i.e., 25 trees per seed source or a total of 850 trees.

After considering concepts discussed by Richardson (1961) and Dinwoodie (1961), we decided that, to compare trees, wood samples must be taken at a common internode and common growth ring for all trees. Thus all samples were taken from the center of the lowest 1964 internode (jack pine is multinodal). A piece of the main stem 3 to 5 centimeters long was cut from each tree and debarked. The entire cross-section (1964, 1965, and 1966 wood) was used for specific gravity determination, but only the outermost portion of the 1966 summerwood for tracheid length determination.

Specific gravity was computed as the ratio of ovendry weight to green volume (in metric units). Green volume was measured by the water-immersion method, and oven-dry weight was measured after drying the samples in a 105°C oven for 48 hours.

Small slivers were then chipped off around the outermost portion of the 1966 summerwood and put into vials containing equal volumes of 10-percent chromic acid and 10-percent nitric acid (Jeffrey's reagent). After about 26 hours, the macerated material was washed by decanting it several times with tap water. The tracheids were then mounted on temporary slides, and 30 to 40 whole tracheids per slide were measured by projecting the slides on a wall-mounted screen with a microprojector. Two of the replications were measured at magnifications of about 350 to 1; the other three at magnifications of 400 to 1. The magnification was recalibrated at least twice a day, and the microprojector was never moved unless an entire replication had been completed.

All the samples in this study were kept separate by nursery replicate. That is, the samples for an entire replicate were collected, weighed, dried, reweighed, macerated, and measured in random order before the next replicate was started. Thus, any variation due to experimental techniques would appear in analysis as between-replicate differences and would not seriously affect seed source comparisons.

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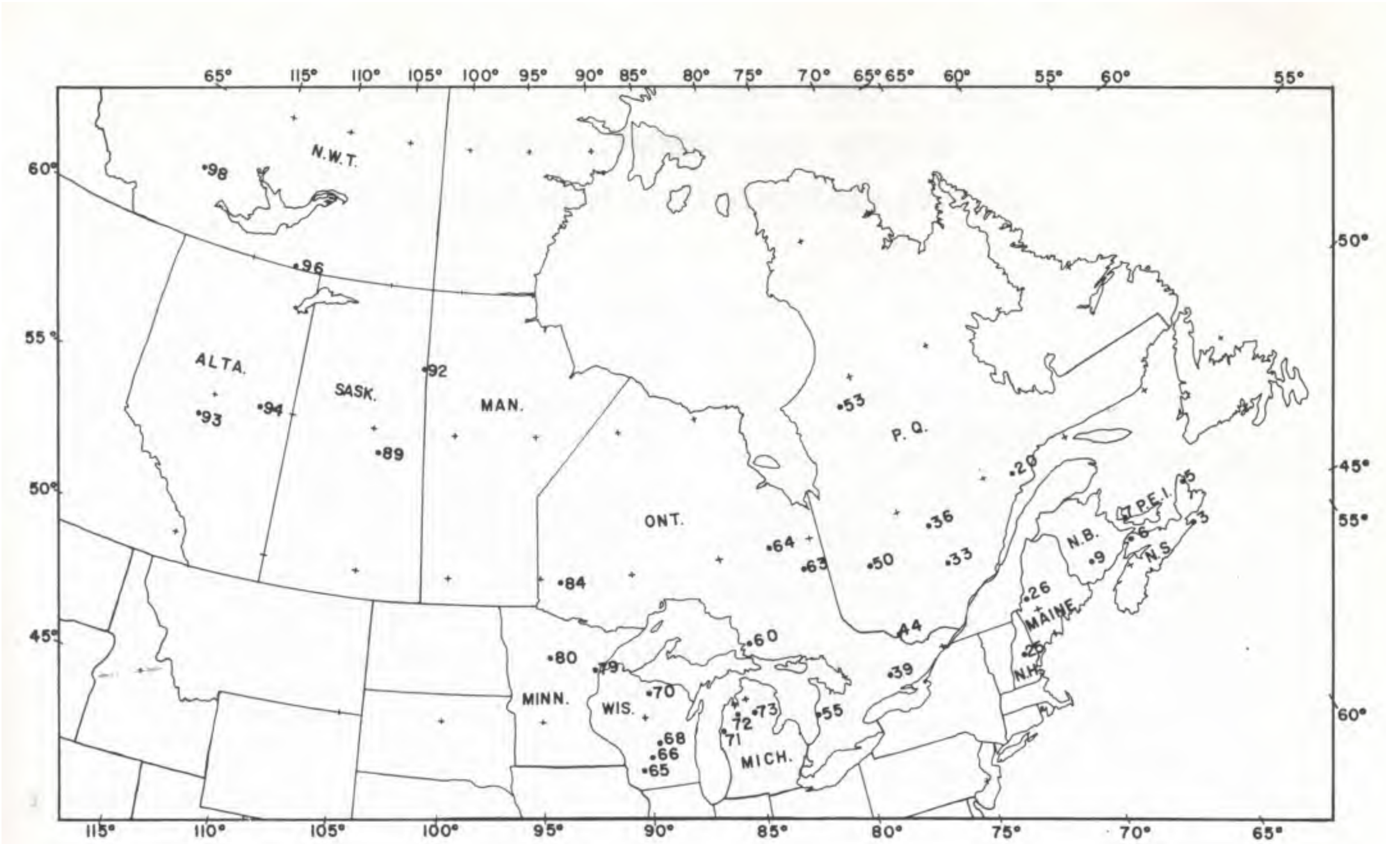

FIGURE 1. — Location of the 34 jack pine seed sources used in the measurement of tracheid length and specific gravity.

Results

There are real differences among seed sources in both tracheid length and specific gravity (tables 1 and 2). The mean tracheid length for all sources was 1.38 mm. The source from Fife Lake, Mich., had the longest tracheids; they averaged 1.62 mm — about 17 percent greater than the mean. The source from Reindeer Lake, Saskatchewan, had the shortest mean tracheid length — 1.12 mm or about 18 percent below the overall mean.

Considering only the nine seed sources from the Lake States, the mean tracheid length was 1.50 mm and ranged from 1.44 to 1.62 mm. The mean tracheid length for the Cloquet, Minnesota, source was 1.45 mm. This agrees well with a study by Kribs (1928) of natural-grown jack pine at Cloquet wherein the tracheid length of 3-year-old wood, one foot above the ground, averaged about 1.42 mm (interpolated from Krib's data).

The variation in specific gravity was less than that of tracheid length. Mean specific gravity for all sources was 0.350. The source at Reindeer Lake, Saskatchewan, had the highest specific gravity — 11 percent above the overall average — and the source at Fort Coulonge, P.Q., had the lowest — 8 percent below average. The average specific gravity of the nine Lake States sources was 0.339, and there were no significant differences between these seed sources.

In this material, strong positive correlations exist between mean seed source tracheid length, 1964 diameter inside bark, and 1964 shoot length (table 3). Strong negative correlations exist between mean seed source specific gravity and tracheid length, diameter inside bark in 1964, and 1964 shoot length.

Covariance analyses (table 4) indicated that seed source differences in tracheid length could not be entirely accounted for by variation in diameter inside bark or 1964 shoot length. Because of the high correlation between 1964 shoot length and the diameter inside bark, the effects of these two variables on tracheid length could not be evaluated independently. Specific gravity differences were also not entirely related to diameter and hence rate of growth.

In general, the more northerly sources had the slowest growth rate and therefore the highest

Table 1. — Mean tracheid length, specific gravity, 1964 shoot length, and 1964 shoot diameter inside bark of 34 jack pine seed sources

Number and location	Tracheid length	Specific gravity	1964 shoot length 1/	Diameter (inside bark) 2/
	Mm		Cm	Mm
03 Durell Island, N.S.	1.13	.384	14.4	14.6
05 Neils Harbor, N.S.	1.17	.376	21.2	15.7
06 Thomson Station, N.S.	1.38	.338	31.2	21.6
07 East Bideford, P.E.I.	1.46	.339	29.6	21.5
09 Grand Lake, N.B.	1.35	.351	32.7	22.1
20 Toulnoustook River, P.Q.	1.38	.348	27.8	20.2
25 Welch Mt., N.H.	1.31	.349	31.1	21.7
26 Spencer Lake, Maine	1.41	.337	31.7	22.8
33 Lake Valade, P.Q.	1.39	.338	28.2	23.3
36 Ducharme River, P.Q.	1.38	.351	27.3	22.6
39 Twin Lakes, Ont.	1.46	.347	35.5	24.7
44 Fort Coulonge, P.Q.	1.47	.321	43.1	26.2
50 Lac Villebon, P.Q.	1.39	.345	26.6	22.6
53 Kanaaupscow Lake, P.Q.	1.19	.379	10.4	12.6
55 Clark Point, Ont.	1.46	.350	29.8	23.0
60 Goulais River, Ont.	1.44	.341	31.3	23.3
63 Nellie Lake, Ont.	1.41	.335	28.6	21.9
64 Smoky Falls, Ont.	1.35	.363	20.3	18.4
65 Lone Rock, Wis.	1.45	.337	45.6	27.6
66 Wisconsin Dells, Wis.	1.55	.337	46.9	26.9
68 Waupaca, Wis.	1.51	.334	48.6	27.4
70 Nokomis, Wis.	1.47	.341	42.5	24.8
71 Freesoil, Mich.	1.49	.341	44.7	26.9
72 Fife Lake, Mich.	1.62	.340	46.8	26.2
73 Marl Lake, Mich.	1.51	.337	45.1	25.7
79 Cloquet, Minn.	1.45	.338	42.0	25.4
80 Cass Lake, Minn.	1.47	.343	39.8	25.8
84 Vermillion Bay, Ont.	1.39	.345	32.7	23.1
89 Nipekamew River, Sask.	1.28	.366	19.2	17.4
92 Reindeer Lake, Sask.	1.12	.389	11.0	11.9
93 Whitecourt, Alta.	1.30	.361	19.1	18.5
94 Lac la Biche, Alta.	1.32	.354	21.4	19.3
96 Fort Smith, N.W.T.	1.18	.368	12.5	13.3
98 Fort Simpson, N.W.T.	1.13	.375	11.5	12.9
Mean	1.38	.350	30.3	21.5
$S_{\bar{x}}$	.036	.0052	2.70	1.09

1/ Measured in the nursery to the nearest centimeter.
2/ Measured to the nearest millimeter.

specific gravity and shortest tracheids. There was one notable exception: The two sources from eastern Novia Scotia — relatively low-latitude sources for jack pine — were among the slowest growing. Sources from Wisconsin and Michigan were among the fastest growing and seemed taller as a group than those from southern Ontario, New Brunswick, Quebec, and New England to the east. The data suggest several east-west discontinuities in the jack pine population, but this may be the result of the low number of widely spaced seed sources used in this investigation. Any conclusions regarding population structure of jack pine must await the analysis of the growth data for all 92 sources in the major study.

Table 2. — Summary of analyses of variance of tracheid length, specific gravity, 1964 shoot length, and 1964 shoot diameter inside bark

Item	Source of variation: Replication	Seed source	Error
Degrees of freedom	4	33	132
Mean squares for:			
Tracheid length	.0552	.0789 **	.0065
Specific gravity	.00020	.00132 **	.00014
1964 shoot length	248.55	661.50 **	36.45
Diameter inside bark (1964 shoot)	54.42	105.74 **	5.91

** Significantly different at the 1-percent level

Table 3. — Correlation coefficients (r) between mean tracheid length, specific gravity, 1964 shoot length, and 1964 shoot diameter inside bark for 34 seed sources[1]

Characteristic	Tracheid length	1964 shoot length	Diameter i.b. (1964 shoot)	Specific gravity
Tracheid length	1.00	.91	.94	-.89
1964 shoot length		1.00	.96	-.85
Diameter inside bark (1964 shoot)			1.00	-.91
Specific gravity				1.00

1/ All values significant at the 1-percent level with 32 degrees of freedom.

Table 4. — Summary of covariance analyses; all F-values are significant at the 1-percent level

Dependent variable	Independent variable	Seed source F-value
Tracheid length	1964 shoot length	6.33
Tracheid length	Diameter inside bark	5.50
Specific gravity	Diameter inside bark	6.14

Setting the calculated mean squares from our analyses of variance equal to the expected mean square components (of a random effects model) and solving the components, we find that the between-stand genetic component in tracheid length variation is 2.3 times the error component. Since the error component contains the within-stand genetic variation plus measurement errors and within-plot environmental variation, clearly the between-stand genetic variance (for the seed sources represented here) is at least 2.3 times the within-stand genetic variance in tracheid length. Following the same procedure with specific gravity, we find that the between-stand genetic variance is at least 1.7 times the within-stand genetic variance in specific gravity.

Discussion

On the basis of the present study, selection of seed sources for higher specific gravity is apparently not feasible with trees of this age.

There are several reasons for this. First, the overall variation in specific gravity in juvenile wood is too low to allow any meaningful selection. If we eliminate from consideration the slow-growing sources from Nova Scotia and northern Canada and consider only those sources of potential use in a Lake States tree improvement program, we find only one seed source (from Fort Coulonge, P.Q.) that is significantly different from the remaining 22 sources. And this source is significantly lower in specific gravity than the rest. Moreover, the LSD $_{.05}$ is only 4 percent of the overall mean in specific gravity. It seems doubtful that an increased sampling intensity will increase the sensitivity of the test to the point where significantly higher specific gravity sources can be detected among the faster-growing seed sources.

Secondly, although there is a strong negative correlation between specific gravity and growth rate in this juvenile wood, Spurr and Hsuing (1954), after a comprehensive review of the literature, concluded that growth rate had only a minor effect on specific gravity in mature trees. Apparently, as the trees mature, factors other than growth rate assume an increasing importance in determining specific gravity. One such factor is summerwood percent which, in the southern pines (Larson 1957, Schafer 1949, and others), varies independently of growth rate. Attempts to determine the percent of summerwood in the present study were abandoned because of the small amount of summerwood present and because of the presence of false rings in many of the samples. Presumably the specific gravity of wood formed at an age when genetic variation in summerwood percent is evident would be more useful in predicting mature-tree specific gravity than is possible with the specific gravity of 3-year-old material.

The possibility of juvenile selection seems a little brighter for increased tracheid length than for specific gravity. If we consider only the fastest growing sources, we find several that have tracheid lengths significantly different from the others. The literature also suggests that as the trees mature : 1) the average seed source tracheid length will increase; 2) the differences between seed sources will increase; and 3) the source with the highest initial tracheid length may also yield higher tracheid lengths in older trees (Bisset *et al.* 1951, Dadswell and Wardrop 1960, Dinwoodie 1963). However, Dinwoodie's (1963) data on four Sitka spruce (*Picea sitchensis* (Bong.) Carr.) provenances showed that the ranking of the seed sources can shift with age, particularly among sources which did not differ greatly initially.

Thus, while proper seed source selection can result in increased tracheid length, selections based on very young material will probably result in a reduced genetic gain. The magnitude of this loss can only be determined by long-range studies.

Conclusions

1. Jack pine seed sources differ in tracheid length and specific gravity of 3-year-old wood.
2. In material of this age, strong positive correlations exist between mean seed source tracheid length, diameter inside bark, and annual height growth. Strong negative correlations exist between mean seed source specific gravity and tracheid length, diameter inside bark, and annual height growth.
3. With the widely diverse seed sources represented in this study, the between-stand component of genetic variation was much greater than the within-stand variation.
4. Seed sources from northern Canada and eastern Nova Scotia had the slowest growth rate, shortest tracheids, and highest specific gravity. Sources from Minnesota, Wisconsin, and Michigan had the highest growth rate, longest tracheids, and lowest specific gravity.
5. Tracheid length as estimated from 3-year-old wood may give a fair indication of mature-tree tracheid length when a wide range of genetic diversity is under investigation. Specific gravity of 3-year-old material is unlikely to be useful in predicting the density of mature trees.

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