GEOGRAPHIC VARIATION IN SPECIFIC GRAVITY AMONG JAPANESE LARCH FROM DIFFERENT PROVENANCES

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ABSTRACT

Genetic variation in wood specific gravity is reported for Japanese larch from twenty seed sources at age 17 years from planting in central New Brunswick, Canada. Information on native tamarack and European larch is also presented. Differences in mean specific gravity among provenances of Japanese larch (range 0.385 to 0.417) are highly significant. Specific gravity is not correlated with 12-year height, specific gravity of trees of the same provenances growing in Michigan, or with latitude, or elevation of the provenances. There is a weak but significant negative correlation between specific gravity and tree diameter at 1.3 m. Provenance × environment interaction in respect to specific gravity is high, making it difficult to identify provenances that will be superior over a wide area.

Keywords: Japanese larch, *Larix leptolepis*, provenance, specific gravity, genetic variation.

INTRODUCTION

Japanese larch, *Larix leptolepis* (Sieb. et Zucc.) Gordon, is endemic to the island of Honshu, Japan, where it occurs as a component of the subalpine forests in small, isolated populations at elevations of 900 to 2,500 m (Farnsworth et al. 1972). The species is of economic importance within its native range and has found favor as an exotic in many parts of the world. Cook (1971) expounds on many of the positive attributes of the genus *Larix*, e.g., ease of propagation, precocity of flowering, genetic variability, desirable stem and branch form, and rapid growth. He states that volume growth of the best provenances of Japanese larch will exceed that of commonly planted northeastern North American conifers by a ratio of more than two to one.

Much of the information on genetic variability of the species is derived from a cooperative range-wide provenance study organized by Dr. W. Langner, Institute für Forstgenetik und Forstpflanzüchtung, Schmalenbek, West Germany. Seeds were collected in 1956 from twenty-five native stands selected by personnel of the Government Forest Experiment Station, Meguro, Tokyo, Japan. Dr. Langner distributed the seeds to cooperators throughout the world, where they were used to establish provenance trials. One of these trials was planted at the Acadia Forest Experiment Station (AFES), near Fredericton, New Brunswick.

Results from these trials indicate that Japanese larch is genetically highly variable with respect to growth rate and most other characteristics that have been studied, i.e., stem form, time of flushing, frost damage, time of leaf fall, insect damage, and flowering (see Farnsworth et al. 1972 for review). Much less information is available on genetic variation in wood characteristics. Lee (1975) reported significant differences in specific gravity, but not in tracheid length, among twenty-two of "Langner's" seed sources, growing in Michigan at age 10 years from planting. Mean specific gravity for provenances ranged from 0.366 to 0.441, a difference of 20% or the equivalent of 75 kg/m³ of wood. No information is available on the magnitude of provenance × environment interaction with respect to wood specific gravity in Japanese larch.

In this article, we will report on genetic variation in wood specific gravity among twenty of "Langner's" seed sources growing in central New Brunswick and compare our findings with those of Lee (1975), who used similar methods to determine specific gravity of the same populations growing in Michigan. In addition, we have included comparative information on native tamarack, *Larix laricina* (Du Roi) K. Koch and European larch, *Larix decidua* Mill.

MATERIALS AND METHODS

Seeds from twenty-five Japanese larch provenances (Fig. 1) obtained from Dr. W. Langner, as well as seeds from three European larch and two tamarack provenances, were sown in unreplicated nursery plots at the Acadia Forest Experiment Station in the spring of 1959. All seedlings were raised as 2+1 transplants.

Seedlings from twenty of the twenty-five Japanese larch, three European larch, and two tamarack provenances were field planted in the spring of 1962. Pertinent information on these provenances is presented in Table 1. The planting site was a recent mixed wood clearcut from which logging debris had been removed, and was considered to be fresh and moderately fertile. The experimental design was randomized block with 7- × 7-tree square plots planted at 3- × 3-m spacing and replicated three times. Two rows of tamarack were planted around each of the three replicates and a single row was planted around each plot.

In the fall of 1978, at the end of 17 growing seasons from planting, 4.3-mm increment cores were taken at 1.3-m height from ten random trees per plot for each provenance in each of the three blocks. All cores were taken from the south side and extended through the width of the bole. An attempt was made to sample only clear wood by avoiding obvious knots or wounds. The cores were placed in plastic straws marked according to direction, wrapped with plastic film, and stored at −5 C until required.

Each core was divided in the center, producing a north and a south section. Inside bark diameter was determined from increment cores. Measurements of cores that did not dissect the pith were adjusted by aligning the annual rings with a drawing of a series of concentric circles that simulated the annual rings on a stem cross section. Diameter equalled twice the distance from the center to the outer end of the core. Cores containing branch wood or exhibiting an unusual amount of warping were discarded.

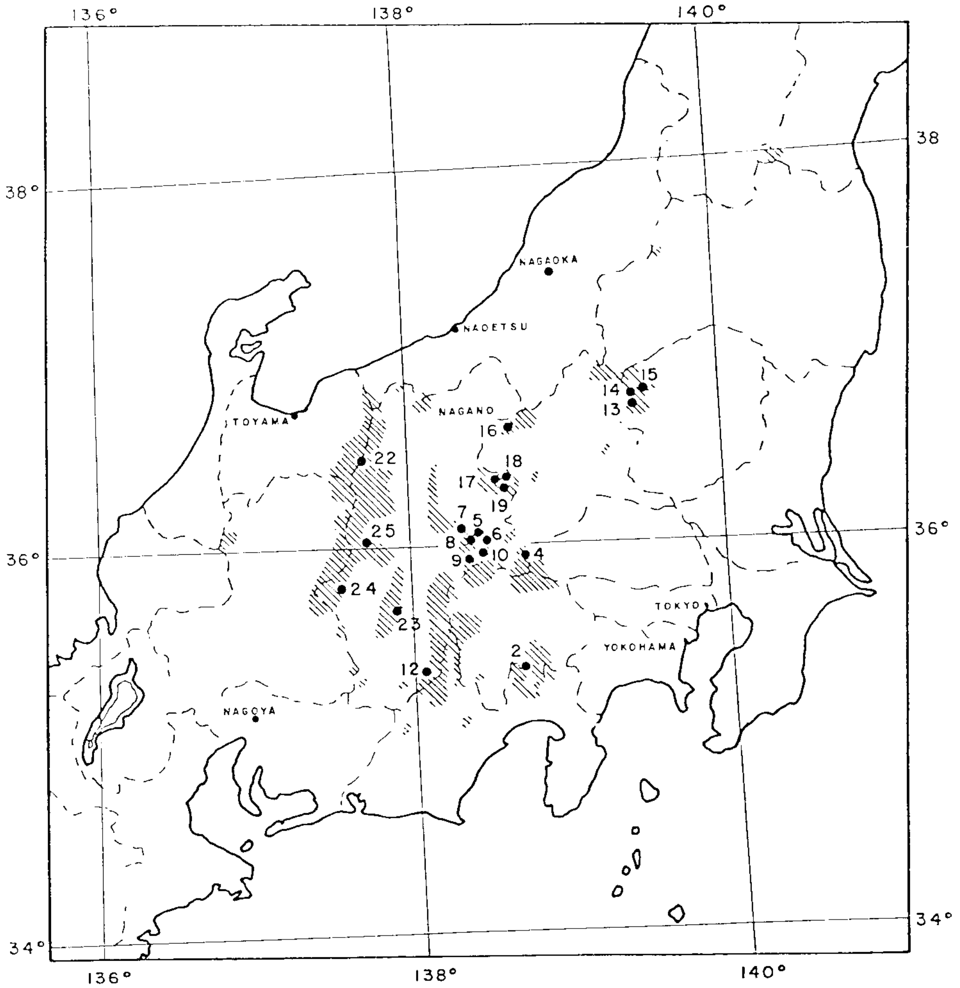

FIG. 1. Natural range (shaded) of Japanese larch in central Honshu, Japan, and location (dots with Schmalenbeck numbers) of stands from which seed was collected (from Farnsworth et al. 1972).

Specific gravity for each core section was determined by the maximum moisture content method described by Smith (1955). Analysis of variance for specific gravity of twenty Japanese larch provenances was performed.

Correlation coefficients among specific gravity, diameter inside bark at 1.3 m, height at 12 years, specific gravity of the same provenances growing in Michigan (Lee 1975), provenance elevation and provenance latitude, were computed.

RESULTS AND DISCUSSION

Specific gravity is the most widely used characteristic to evaluate wood quality in tree improvement programs (Zobel 1964). It is, of course, only one of several characteristics used for the overall evaluation of individual trees or populations of trees. The mean specific gravities of wood sampled in this study are presented in Table 1. Japanese larch has a mean specific gravity of 0.401 with provenance

TABLE 1. *Location of parental stands and, specific gravity and growth characteristics of Japanese and European larch and tamarack of different provenances.*

Schmalenbeck no. (MS no.)	Latitude °north	Elevation (m)	Specific gravity*	Diameter at 1.3 m (cm)	Height (12 years) (m)	Specific gravity (from Lee 1975)
L. leptolepis						
Mt. Fuji						
2 (386)	35.4	1,760	0.414a*	12.34	7.67	0.424
Mt. Azusa						
4 (388)	36.0	1,500	0.399b	15.14	8.63	0.392
Yatsuga Mts.						
5 (389)	36.0	1,780	0.390c	15.16	8.71	0.388
6 (390)	36.0	1,750	0.399b	13.64	7.79	0.374
7 (391)	36.1	1,600	0.402a	14.54	8.43	0.405
8 (392)	36.0	1,700	0.405a	13.26	8.10	0.404
9 (393)	35.9	1,450	0.396b	14.36	7.65	0.378
10 (394)	35.9	1,750	0.399b	14.51	8.25	0.399
Akaishi Mts.						
12 (396)	35.4	2,000	0.385c	15.28	8.06	0.393
Mt. Nantai						
13 (397)	36.8	1,360	0.398b	13.71	7.88	0.398
14 (398)	36.8	1,490	0.403a	13.73	7.94	0.386
15 (399)	36.8	1,700	0.409a	13.03	7.93	0.405
Mt. Shirane						
16 (400)	36.6	1,750	0.408a	14.97	8.68	0.403
Mt. Asama						
17 (401)	36.4	1,900	0.403a	14.09	8.71	0.390
18 (402)	36.4	1,420	0.402a	13.22	7.56	0.405
19 (403)	36.4	1,700	0.395b	11.64	6.19	0.413
Mt. Komaga						
23 (407)	35.8	1,820	0.394b	15.14	8.72	0.441
Hida Mts.						
22 (406)	36.4	1,380	0.417a	13.79	8.00	0.411
24 (408)	35.9	1,380	0.386c	14.90	8.68	0.379
25 (409)	36.1	1,920	0.409a	14.24	8.79	0.366
L. decidua						
Eastern Alps						
(382)	—	1,260	0.391	12.34	6.88	
(383)	—	1,760	0.401	12.22	6.84	
Poland						
(381)	—	810	0.399	11.86	6.95	
L. laricina						
New York						
(380)	—	—	0.410	12.52	7.72	
Prince Edward Is.						
(379)	—	30	0.411	11.06	7.12	

* Data followed by different letters fall into different, discrete, nonoverlapping groups (Gates and Bilbro 1978).

TABLE 2. *Results of analysis of variance for wood specific gravity based on 20 provenances of Japanese larch.*

Source	d.f.	SS	MS	F
Replications	2	0.0109	0.00546	6.66**
Provenances	19	0.0650	0.00342	4.17**
Direction, north vs. south	1	0.0125	0.01254	14.75**
Replication × Provenance	38	0.0780	0.00207	2.44**
Error	1,027	0.845	0.00082	

** $P = 0.01$.

means ranging from 0.385 to 0.417. All sources of variation including differences among provenances are highly significant (Table 2). The mean specific gravities for the two native larch provenances and for the three European larch provenances are 0.411 and 0.397, respectively, and fall well within the range of provenance means of Japanese larch.

Increment cores, although widely used to evaluate specific gravity, do not provide an accurate estimate of whole tree specific gravity. Juvenile wood has a lower specific gravity than mature wood and an increment core is composed of a disproportionately high amount of juvenile wood. Smith and Wahlgren (1971) suggest that closer approximation of merchantable bole specific gravity can be obtained from the outer half of a core than from the whole core. It is thus evident that our estimates of wood specific gravity are low.

In this study, we used increment cores to provide estimates of relative specific gravity for several provenances. Although less tenuous when used in this sense, the method still has some drawbacks. If, as Isebrands and Hunt (1975) suggest, juvenile wood of larch is confined to the inner ten annual rings, cores from trees exhibiting rapid growth in height would contain relatively less juvenile wood than ones from slow-growing trees of the same age, i.e., at 1.3 m a rapid-growing tree would have one or two more annual rings. Despite the fact that cores from rapid-growing trees contained relatively less juvenile wood, there was a weak, but significant, negative correlation between specific gravity and tree diameter (Table 3). Nevertheless, variation in specific gravity among provenances is such that provenances characterized by rapid growth and high specific gravity can be identified, e.g. MS 409 and MS 400.

Specific gravity is not correlated with 12-year height, or with latitude or elevation of the provenances. This finding is in agreement with others (Stairs 1965;

TABLE 3. *Correlation coefficients among wood, growth and environment variables.*

Variable	X_1	X_2	X_3	X_4	X_5	X_6
X_1 Specific gravity, AFES	1.000	−0.447*	−0.037	0.219	−0.213	0.313
X_2 Diameter 1.3 m		1.000	0.806**	−0.257	0.090	−0.273*
X_3 Height 12 years			1.000	−0.208	0.047	−0.171
X_4 Specific gravity, Michigan				1.000	0.305*	−0.026
X_5 Elevation m					1.000	−0.329
X_6 Latitude °N						1.000

* $P = 0.05$.
** $P = 0.01$.

Genys 1971; Farnsworth et al. 1972; Lee 1975) who reported an absence of clear-cut geographic patterns of genetic variation in this species.

There is a small, but highly significant, difference in specific gravity between cores from the north (0.404) and south (0.398) sides of the trees. It is probable that this north-south difference relates to differences in compression wood associated with stem lean or sweep produced by prevailing winds. It emphasizes the need for uniform sampling techniques.

The absence of a correlation between specific gravity of trees growing at AFES and trees of the same provenances growing in Michigan (Lee 1975) is disappointing, but not unexpected. Evidently, provenance × environment interaction in Japanese larch is high for many characteristics (Genys 1972; Farnsworth et al. 1972; Hattemer 1969), including wood specific gravity. For this reason, it is not possible to identify provenances that can be expected to have outstanding performance over a wide range of environments. Rather, it will be necessary to determine the best provenance for each environment.

Based on specific gravity, diameter, and 12-year height, the provenances recommended for central New Brunswick are MS 409 from 1920 m in the Hida Mountains and MS 400 from 1750 m on Mt. Shirane. Provenances MS 407, MS 389 and MS 401 are also satisfactory.

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