GEOGRAPHIC VARIATION OF GROWTH AND WOOD PROPERTIES IN JAPANESE LARCH IN SOUTHWESTERN LOWER MICHIGAN [1]

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ABSTRACT--Growth and wood characteristics at age 10 from planting were assessed on the 22 seedlots of Japanese larch outplanted in the Kellogg Forest, Augusta, Michigan using a randomized complete block design. Results did not indicate any geographic trends for most traits studied but did suggest the operation of genetic drift and inbreeding. Fast growing seedlots continued to perform well in southwestern Lower Michigan. Recommends that seed for plantings in the Lake States area should be from the Mt. Nantai area in the northeast species range.

Japanese larch (*Larix leptolepis* (Sieb. et Zucc.) Gordon) is one of the most important economic species of Japan. It is found in the subalpine regions of Central Japan and attains sizes up to 30 meters in height and 1 meter in diameter (Japan For. Tech. Assoc. 1964). The wood is heavy, decay resistant, holds nails well, and pulps readily using the sulfate process. The species is extensively used for reforestation outside its natural range in northern Japan, Europe, the United States, and Canada because it grows fast and is valued for ornamental uses. It can be propagated readily from cuttings collected from young trees (Chandler 1967).

The natural range of Japanese larch is small (about 200 kilometers square, from 900 to 2,500 meters in elevation) and is composed of several genetically isolated small populations, the largest being several kilometers across and the smallest a hectare or so in size (Wright 1962). Considerable improvement of this species can be expected through a careful selection and breeding program because previous studies indicated that there were significant differences in growth performance. These include

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studies conducted in Minnesota (Pauley et al. 1965), Wisconsin (Lester 1964), Midwest (Farnsworth et al. 1972), New York (Stairs 1966), Maryland (Genys 1972), and Germany (Langner 1958 and 1961; Hattemer 1968 and 1969; Langner and Stern 1965).

The study reported here consisted of 22 seed sources of Japanese larch grown at the Kellogg Experiment Forest, Augusta, Michigan. The objectives were to continue to assess the growth performance, to collect new genetic information on the geographic variation pattern of wood properties, and to analyze the growth-wood properties relationships.

MATERIAL AND METHODS

The study was initiated by Dr. W. Langner of Germany. Seed was collected from 25 natural stands throughout the species range by the Japanese Government Forest Experiment Station, Meguro, Tokyo, Japan, in 1956. Each seedlot consisted of seed from several trees per stand. The seed was sent to branch stations of the Government Forest Experiment Station in Japan; Institut fuer Forstgenetik and Forstpflanzenzuechtung, Schmalenbeck, Germany; State University of New York College of Forestry at Syracuse; and Michigan State University, East Lansing, Michigan.

Michigan State University seeded 22 seedlots (table 1, fig. 1) in the research nursery at East Lansing on May 14, 1959. A randomized complete block design was used; extra seed was broadcast in a separate block to provide planting material for field tests.

In 1961, 2-0 seedlings were lifted and used for the establishment of the Kellogg study. A randomized complete block design with 22 4-tree plots in each of the 10 replications, and 2.4 by 2.4 meter spacing was used. Dead trees were replaced with 3-0 stock at the end of the first growing season. Amitrol-T was used for weed control.

The Kellogg plantation (MSFG 1-61) was one of the 17 test plantations established throughout the north-central States. The ground was relatively level with sandy loam soils. Survival at Kellogg was among the best when assessed in 1962 and 1967 (88 and 74 percent, respectively).

I measured total height to the nearest 7.6 centimeters (1/4 foot) and diameter at 0.3 meter (1 foot) from the ground to the nearest 1/4 centimeter(0.1 inch) on the two tallest trees per plot on August 5-6, 1971. Seedlot means were used as items in statistical analysis for the two growth traits studied.

I also extracted a 0.5 cm increment core at 1 foot above ground from the north side of the largest tree on each plot. After the debarking, the 1969 growth increment was removed from the core sample and split radially into two halves, one for the study of specific gravity and the other for tracheid length.

Table 1.--Origin data for the *Larix leptolepis* provenances

Schmalenbeck No. (MSFG No.)	North latitude	East longitude	Elev.	Mean annual temp.	Mean annual precipitation
	(degrees)	(degrees)	(m)	(°C)	(mm)
Mt. Fuji					
1 (111)	35.4	138.7	1,320	6.2	1,820
2 (112)	35.4	138.7	1,760	5.0	1,760
Mt. Azusa					
4 (114)	36.0	138.7	1,500	6.5	1,360
Yatsuga Mountains					
5 (115)	36.0	138.4	1,780	6.1	1,550
6 (116)	36.0	138.4	1,750	5.4	1,480
7 (117)	36.1	138.3	1,600	5.1	1,430
8 (118)	36.0	138.3	1,700	5.4	1,700
9 (119)	35.9	138.3	1,450	6.8	1,560
10 (120)	35.9	138.3	1,750	6.1	1,330
Akaishi Mountains					
11 (121)	35.8	138.2	1,500	6.5	1,720
12 (122)	35.4	138.1	2,000	4.0	2,840
Mt. Nantai					
13 (123)	36.8	139.4	1,360	5.5	2,250
14 (124)	36.8	139.4	1,490	6.8	2,470
15 (125)	36.8	139.5	1,700	5.3	2,590
Mt. Shirane					
16 (126)	36.6	138.5	1,750	4.3	1,800
Mt. Asama					
17 (127)	36.4	138.5	1,900	3.2	1,890
18 (128)	36.4	138.6	1,420	6.2	1,400
19 (129)	36.4	138.5	1,700	4.3	1,570
Mt. Komaga					
23 (133)	35.8	137.9	1,820	3.2	2,380
Hida Mountains					
22 (132)	36.4	137.7	1,380	5.6	1,670
24 (134)	35.9	137.6	1,380	6.9	2,130
25 (135)	36.1	137.7	1,920	3.3	2,300

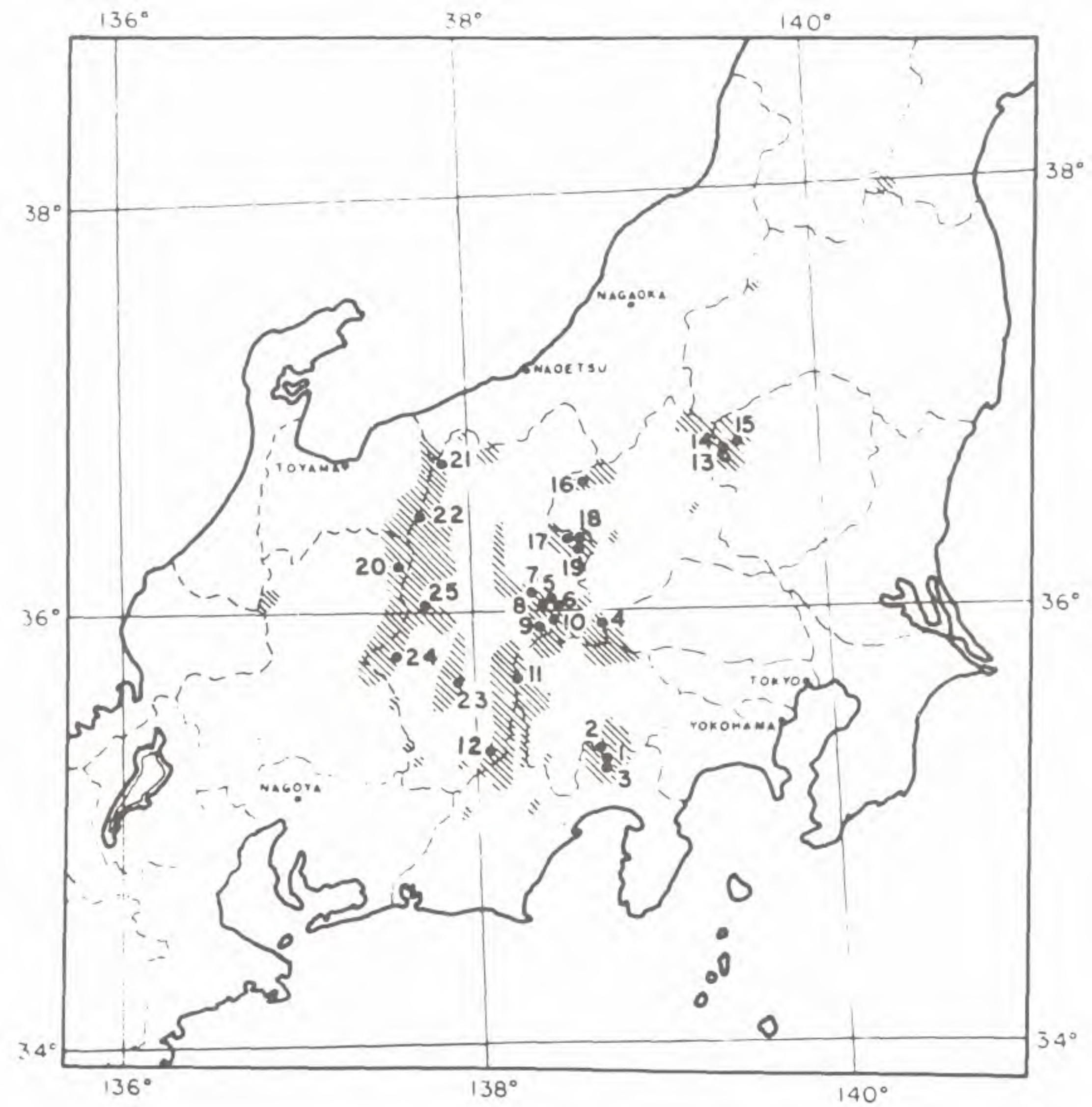

Figure 1.--Natural range (shaded) and location (numbered dots) of seedlots of Larix leptolepis after Farnsworth et al. (1972).

Alcohol-benzene extractives were removed because their presence tends to overestimate specific gravity (Taras and Saucier 1967). The specific gravity was determined following Smith's recommendation (1954).

Wood fibers were macerated in an equal mixture of glacial acetic acid and 30 percent hydrogen peroxide at 50-55°C for 72 hours. After several changes with distilled water, the macerated fibers (tracheids) were stained with 1 percent Bismarck Brown Y aqueous solution overnight and then mounted on slides. No dehydration or cover glass was used (Echols 1969), but fibers were measured directly to the nearest millimeter with 90 X magnification under the Bausch and Lomb No. 2700 projector.3 They were then converted back to the actual tracheid length. Mean lengths of 20 tracheids were used as items in statistical analysis.

In the analysis of variance of growth and wood data, the degrees of freedom were 21, 9, and 189 for provenances, replication and error, respectively. However, there were 16 missing plots; the error term degrees of freedom were reduced accordingly. Rank correlation (d.f. = 20) was used to study the relations among growth, wood, and origin data of parent stands.

VARIATION IN GROWTH TRAITS

Height Growth

The between-seedlot differences in total height were significant at the 1 percent level (table 2). At age 10 after planting, seedlot 15 from Mt. Nantai continued to outgrow others.

Significant differences in juvenile height growth among 25 provenances were also reported by Langner (1961) at Schmalenbeck, North Germany, and by Hattemer (1968, 1969) at 13 localities throughout Germany; by Farnsworth *et al*. (1972) on the 18 test sites in north-central United States using 7 and 22 of the seedlots; By Lester (1964) who observed 6 seedlots in Wisconsin; by Stairs (1966) in New York (20 seed sources); and by Genys (1972) in Maryland (16 seedlots). All these studies were part of the international Japanese larch provenance testing program.

Despite it's narrow species range, variation in height growth was large. At age 10 from planting, seedlot means varied from 540 to 714 cm, a difference of 32 percent. This is roughly equivalent to 300 kg/m ^{3} or 20 lbs/ft ^{3} (62.4 lbs. x (1.32 - 1.00)) more wood production. The corresponding values obtained for eastern white pine (*Pinus strobus* L.)

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[3] Mention of trade names does not constitute endorsement of the product by the USDA Forest Service.

Table 2.--Growth and wood properties of 22 Larix leptolepis provances at age 12 from seed in southwestern Lower Michigan

Origin No., Mountain of origin	Height	Diameter at stump height	Height/ diameter ratio	Specific gravity	Tracheid length	Index wood 1/ production
	(cm)	(cm)	(cm/cm)	(number)	(mm)	(number)
1 Fuji	663	11.7	57	0.400	2.08	1.05
2 Fuji	674	12.0	56	.424	2.11	1.19
4 Azusa	696	12.9	54	.392	2.17	1.31
5 Yatsuga	714	12.2	59	.388	2.12	1.18
6 Yatsuga	670	12.3	54	.374	2.06	1.09
7 Yatsuga	693	12.5	55	.405	2.07	1.27
8 Yatsuga	600	10.4	58	.404	2.08	.76
9 Yatsuga	673	12.1	56	.378	2.09	1.08
10 Yatsuga	683	12.6	54	.399	2.07	1.25
11 Akaishi	594	10.0	59	.412	2.13	.71
12 Akaishi	615	10.9	56	.393	2.13	.83
13 Nantai	636	11.4	56	.398	2.06	.95
14 Nantai	686	12.9	53	.386	2.03	1.27
15 Nantai	714	12.6	57	.405	2.13	1.32
16 Shirane	609	10.8	56	.403	1.99	.83
17 Asama	673	12.3	55	.390	2.00	1.14
18 Asama	655	11.1	59	.405	2.08	.95
19 Asama	540	9.5	57	.413	1.98	.58
23 Komaga	600	10.4	58	.441	2.05	.83
22 Hida	649	11.2	58	.411	2.06	.96
24 Hida	626	11.9	53	.379	2.03	.97
25 Hida	600	11.5	52	.366	2.04	.84
Mean	647	11.6	56	0.398	2.07	1.02
F	3.26**	2.49**	1.58*	1.79*	1.27	--

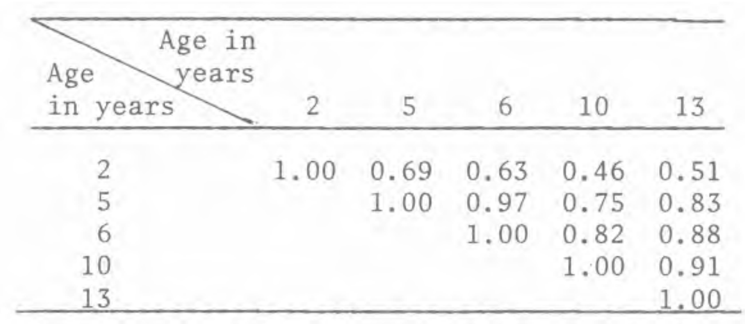
1/ $\text{Index} = \frac{\text{Height}}{\text{Mean Height}} \times \frac{(\text{Diameter})^2}{(\text{Mean Diameter})^2} \times \frac{\text{Specific Gravity}}{\text{Mean Specific Gravity}}$

and European black pine (Pinus nigra Arnold) from the same Kellogg Experiment Forest were 23 and 34 percent, respectively (Lee 1974, Lee and Wright 1975). These three species are test planted in the same general area with a high degree of precision as reflected in the small-sized (2.45 to 3.88 percent) coefficients of variability (the standard deviation to mean ratio).

The correlations between growth rate and the latitude, altitude, and mean annual precipitation at localities of parent stand were not significant.

Similar results have also been reported by Pauley et al. 1965; Lester 1964; Farnsworth et al. 1972; Langner 1961; Schonbach et al. 1966, and Genys 1972). Fast growing seedlots were from the northern as well as the southern species range and, likewise, from low as well as high altitudes. However, I observed a distinct geographic trend between the 1971 height growth, longitude, and the mean annual temperature at seed origin. The rank correlation coefficients were 0.497 and 0.514; both significant at the 5 percent level. Schonbach et al. (1966) also observed a clearcut correlation between early frost resistance and the time of growth cessation. This suggests that clinal variation patterns in height growth essentially are temperature related; trees from the species' eastern range and from localities where mean annual temperatures are high grew faster and suffered less from the early autumnal frost.

Professor Jonathan W. Wright of Michigan State University generously furnished the 1974 height data (13 years after planting). Therefore, it was possible to compute the following age-age correlations.



Age in years \ Age in years	2	5	6	10	13
2	1.00	0.69	0.63	0.46	0.51
5		1.00	0.97	0.75	0.83
6			1.00	0.82	0.88
10				1.00	0.91
13					1.00

The rank correlation coefficients were all statistically significant at the 1 percent level; however, they tended to decrease as the plantation grew older. In general, fast growing seedlots at two years of age were still growing well at age 13, but some changes in the growth pattern have occurred. For example, seedlot 15 from Mt. Nantai ranked fifth in 1963 at age 2. It was the top performer in 1964, when it was 60 percent taller than the slowest growing seedlot. In 1966 (age 5) it was 70 percent taller than the shortest seedlot. This figure dropped to 37 in 1967 and to 32 percent in 1971; by 1974 - 13 years from seed - seedlot 15 ranked sixth. The story is somewhat similar to that of the southern Appalachian seedlots in eastern white pine (Lee 1974). Therefore, continued observation on the growth pattern is necessary because changes in relative height may continue to occur in the future.

It is important to determine the genotype x environment interactions for each provenance. My study was based on a single plantation and provided no information. However, according to Wright (1962), the Germany-Michigan correlation in height data was low. Provenances that were fast-growing in Germany were not necessarily good in Michigan. Langner and

Stern (1965) attributed the absence of a growth relation to severe winters in Michigan. In the recent study by Farnsworth et al. (1972), there were 7 common seedlots represented in 18 plantations throughout the north-central United States. They reported a strong genotype x environment interaction in height performance. Seedlot 15 was tallest at most test sites but grew poorly in Nebraska and Ohio. The interaction was described as unintelligible. Hattemer (1969) was not able to explain genotype x environment interactions in height growth of Japanese larch. This means that the tallest seedlots in one plantation may not be the best in other plantations.

However, Genys (1972) found that Maryland growth data were more strongly correlated to data from Germany than to data from north-central United States." His study was based on 16 different seed sources.

Diameter Growth 1 Ft. Above Ground

There were significant (1 percent level) differences in diameter growth among the 22 seed sources (table 2). No geographic pattern was observed. The rank correlation coefficients between the diameter and origin data were weak.

The range in seedlot means varied from 9.5 to 12.9 cm, a difference of 36 percent. This range was far smaller than that observed at the two Maryland test plantations (Genys 1972). However, Genys' and my data are similar in one respect--both have established a strong positive height-diameter correlation (r = 0.720 in my study). The two growth traits may be inherited together.

The between-seedlot differences in the height-to-diameter ratios (cm/cm) were significant at the 5 percent level (table 2). A seedlot having a high h/d ratio is more desirable because it has less stem tamper.

The h/d ratios were correlated with the 1971 height and diameter. Both correlation coefficients were insignificant (r = 0.170 and -0.297, respectively).

DIFFERENCES IN WOOD QUALITY

Specific gravity and tracheid length are the most extensively studied wood properties, both are under moderate to strong genetic control (Smith 1967, Zobel 1961); thus, significant gains can be expected through selection breeding. The wood characteristics of Japanese larch are not well known and information based on rangewide material is not available.

Use of increment core sample extracted at the breast height or stump height (1 foot above ground) has been a common practice for the evaluation of wood quality. However, whether the entire increment core (pith to bark) or portion of the core should be used is not known. I found that a single growth increment formed during the same growing season was adequate to show the geographic variation pattern.

The stump height (or breast height)-whole tree values relation was not determined. However, there are numerous studies for pines that indicate a strong correlation between the two values (Wahlgren and Fassnacht 1959).

Specific Gravity

The between-seedlot differences were significant at the 5 percent level (table 2). A single seedlot (Schmalenbeck No. 23) from Mt. Komaga had a higher specific gravity than those from the rest of the species range.

There was no clearcut geographic variation pattern in specific gravity; the correlations between specific gravity and origin data were weak (the rank correlation coefficients were from 0.044 to 0.326). Heavy wood may be characteristic of seedlots from northern as well as from southern localities, or from both high and low altitudes.

Nor was there a significant correlation (r = 0.031) between specific gravity and height growth measured in 1971, 10 years after planting. This is similar to loblolly pine (<u>Pinus taeda</u> L.), for which Matziris and Zobel (1973) attributed only 7.3 percent of the total variation in specific gravity to growth rate (r = 0.271 with 353 degrees of freedom). Selection of fast growing seedlots may not be accompanied by a desirable wood quality. The specific gravity-diameter growth correlation was also nil (r = 0.003) in Japanese larch.

The overall mean for the trunkwood specific gravity was 0.398, comparable to that observed for loblolly pine (Matziris and Zobel 1973). In both studies, juvenile wood was used as the study material. The range in seedlot means varied from 0.366 to 0.441--a difference of 20 percent. This is equivalent to 75 kg more wood/m^3 (4.68 lbs/ft^3). The between-tree range was from 0.311 to 0.525, a difference of 69 percent. The greater between-tree variation was expected; it has been found in eastern white pine and European black pine growing in the same area in Michigan. The larger the variation among individual trees, the faster and more efficient improvement can be made through selection.

Tracheid Length

There were no significant differences in tracheid length among the 22 Japanese larch seed sources.

Bannan (1965) studied fiber morphology for members of several coniferous genera and concluded that species or races growing on favorable sites in general had longer fibers. Although the tracheid-height and the tracheid-diameter correlations were statistically significant (1 percent level) in Japanese larch, they are of little practical importance. Mean tracheid length of the five tallest seedlots was only 0.04 mm longer than that of the five shortest ones.

Overall mean tracheid length was 2.07 mm. The seedlot means ranged from 1.98 to 2.17 mm, a difference of only 10 percent. The between-tree range was from 1.75 to 2.39 mm, a difference of 37 percent. Both ranges were much narrower than those of specific gravity.

The tracheid length-specific gravity correlation was weak (r = 0.370). This was also the case with a number of pine species such as loblolly pine (Jackson and Strickland 1962, Matziris and Zobel 1973), eastern white pine (Lee 1974) and European black pine (Lee and Wright 1975). The two wood properties may be inherited independently.

PRACTICAL APPLICATION

Based on my observations, seed sources from Mt. Nantai in the north-eastern species range should be recommended for planting in the Lake States area. They are tall and grow at least 5 percent taller than the plantation mean (647 cm at age 10 from planting). Trees from Mt. Nantai are efficient wood producers (table 2); they started growth early in the spring (the time of leafing not correlated with the latitude and altitude of seed source according to Yanagisawa 1961), tended to shed off their leaves early, and suffered little damage from winter cold (Farnsworth *et al*. 1972). Schonbach *et al*. (1966) indicated that the resistance to early autumnal frost was closely associated with time of growth cessation. Mt. Nantai is located at a northern latitude; thus, trees from that area lignify early which contributed to frost-damage being less than that found in trees from more southerly seed sources (Yanagisawa 1961). The wood quality of trees from Mt. Nantai is average. Genys (1972) reported that trees from Mt. Nantai are not as susceptible to larch sawfly and offer better stem quality (straightness) when compared to trees growing further south.

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