Chairman: Henry D. Gerhold

DIVERSITY IN JAPANESE LARCH FROM DIFFERENT PROVENANCES STUDIED IN MARYLAND[1]

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INTRODUCTION

Japanese larch, *Larix leptolepis* (Sieb. and Zucc., Gordon), is native to the central sections of Honshu Island, Japan. It grows in a small range at altitudes of 3500 to 9000 feet. Some reports suggest that one form of this species has been located in the Kiangsi Province of China (Schoenike, 1961).

Karamatsu, as Japanese larch is called in its native range, is a beautiful ornamental tree as well as a valuable timber species. On favorable sites it grows more rapidly than other conifers, and attains height of over 120 feet. British yield tables indicate that in 50 years Japanese larch may grow to 80 feet in height and over a foot in diameter at breast height (Stone, 1957). Rapid growth rate and resistance to canker, *Dacyscypha willkommii*, are the main factors favoring the extensive planting of Japanese larch in Europe.

More recently, this larch has become a popular tree for planting in the eastern United States, particularly in New York State. In some years, up to 100,000 Japanese larches have been planted in Maryland.

The genus Larix includes a total of 15 species or varieties of larch. Among them, Japanese larch is one of the most rapidly growing species. In New Hampshire, Japanese larch of unknown origin has grown as rapidly as the best strains of European larch (Genys, 1960). Similar results were obtained in central Maryland where, among five species of larches, some strains of Japanese larch were the most productive (Genys, 1968). Past experiments also have shown that the performance of Japanese larch is dependent on its geographic origin (Farnsworth et al., 1971; Hattemer, 1968 and 1969; Langner, 1958 and 1961; Langner and Stern, 1965; Maschning, 1968; Schönbach et al., 1966; Stairs, 1965). Consequently, there is an opportunity to select better than average strains for practical use.

This report is based on 16 populations of Japanese larch, studied at two locations in Maryland. The major objective was to learn which seed sources may be most promising for planting. Since this experiment was a part of an international study, the Maryland results are compatible for comparison with results in other states and in other countries.

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METHODS

This experiment is part of a large project initiated by Dr. W. Langner of West Germany (Langner, 1958). Seedlots from 25 native stands of Japanese larch were collected in 1956 by Dr. Iwakawa of the Forest Experiment Station, Meguro, Japan. Each stand was represented by seeds from two to ten trees, and all pertinent details have been recorded on each provenance.

The Maryland study included trees from 16 provenances in seven major distribution areas (Fig. 1, Table 1). The seedlings for this experiment were obtained with the cooperation of several scientists. Dr. Frederick Klaehn, then working in Syracuse, New York, received 25 seedlots from Dr. Langner of Germany, and shared them with Dr. J. W. Wright, of Michigan State University. Three-year-old seedlings, grown in Lansing, Michigan, were offered for the studies in Maryland.

Two plantations were established in the spring of 1962. One experimental area (PDM) is located on the rolling Piedmont Plateau (elevation 1i50 feet), with a growing season of about 170 days. This plantation is 20 miles west of Baltimore, in Carroll County, Maryland. The second plantation (MTS) was established in Garrett County on Negro Mountain near Grantsville on the Allegheny Plateau (elevation 2500 feet), with a growing season of about 130 days.

The Piedmont Plateau experiment included 15 different populations planted at random in three randomized blocks. On the Allegheny Plateau, 12 populations were planted in four randomized blocks. In each block, each strain was represented by square 4-tree plots with the trees spaced 71 x 71.

In both plantations, survival counts were made one year after planting (in 1963), as well as during the subsequent years. In the Alleghenies, heights of trees were measured in the fall of 1967, and an attack by larch sawfly, *Pristiphora erichsonii* (Hartig) was studied in the summer of 1968.

Major investigations of both plantations were undertaken in the fall of 1970, 9 years after planting, when the trees were 12 years old from seed. Data were collected on heights, diameters, and stem quality. Analysis of variance for data from the Allegheny plantation followed the randomized blocks design. However, the Piedmont plantation had many missing trees and missing plots. For analysis of variance, this plantation was considered a completely randomized block with unequal group sizes, and each tree was considered as a plot. A similar analysis was used to interpret the data on attack by larch sawfly. The degrees of freedom for both types of analyses follow:

Source of variation	Alleghenies		Piedmont
	df(a)	df(b)	df(a)
Total	47	173	92
Among blocks	3	--	--
Among strains	11	11	14
Error	33	162	78

df(a) = degrees of freedom for growth data
df(b) = degrees of freedom for individual trees attacked by larch sawfly

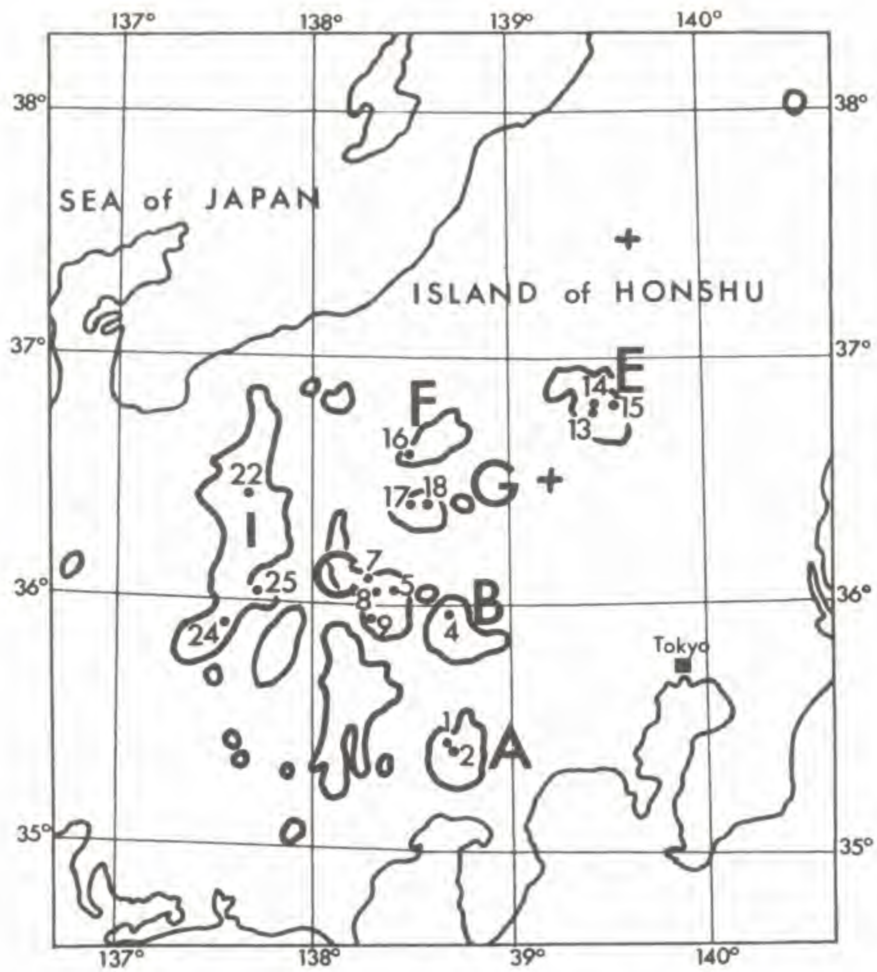

Figure 1. Natural range of Japanese larch (*Larix leptolepis*) in the central section of Honshu Island, Japan. Capitol letters indicate different regions; numbered dots show provenances of populations studied in Maryland. A map by Maschning, 1968, has been used as a reference for this outline.

Table 1. -- Data on origin of 16 populations of Japanese larch (*L. leptolepis*) studied in Maryland. Provenances were listed by the numbers used by Langner, 1961.

Prov. No.	Region (Mountain range) Location or Forest, County or City	Northern Latitude	Eastern Longitude	Alti-tude
		--degrees--		meters
	Region A (Mount Fuji)			
1.	Mt. Fuji, Narusawa	35° 26'	138° 41'	1320
2.	Mt. Fuji, Narusawa	35° 24'	138° 43'	1760
	Region B (Mount Azusa)			
4.	Mt. Azusa, Kawakami	35° 57'	138° 43'	1500
	Region C (Yatsuga Mountains)			
5.	Toyosato, Kitamaki	35° 03'	138° 24'	1775
7.	Tateshinayama Sta. For., Teteshina	36° 06'	138° 17'	1600
8.	Kitayama, Yoshino	36° 03'	138 20'	1700
9.	Nishidake Sta. For., Fujimi	35° 56'	138° 19'	1450
	Region E (Mount Nantai)			
13.	Okunikko Sta. For., Nikko City	36° 46'	139° 27'	1360
14.	Okunikko Sta. For., Nikko City	36° 47'	139° 27'	1490
15.	Yashubara Sta. For., Nikko City	36 47'	139° 33'	17[illegible]0
	Region F (Mount Shirane)			
16.	Kumashiroyama Sta. For., Tsumakoi	36° 39'	138° [illegible]9'	1750
	Region G (Mount asama)			
17.	Mizunoto Sta. For., Tsumakoi	36° 24'	138° 29'	1900
18.	Nagakurayama Sta. For., Karuizawa	36° 24'	138° 34'	1425
	Region I (Mount Komaga)			
22.	Takasegawa Sta. For., Omachi	36° 26'	137° 41'	1380
24.	Shikanose Sta. For., Mitake	35° 54'	137° 33'	1380
25.	Akanagi Sta. For., Nakawa	36° 04'	137° 43'	1920

RESULTS

The data on performance of different geographic progenies of Japanese larch studied in Maryland are listed in table 2. Included are survival, heights, diameters, grades of stem quality, and one-year data on percent of branches attacked by larch sawfly. The relationship between the characters studied, and their relationship to latitude, longitude, elevation, temperature, and precipitation is either discussed in the text or expressed by correlation coefficients in table 3. The relationships between the data in Maryland and the results in New York, in the North Central States, and in Germany are also shown in table 3.

Survival

In the Allegheny plantation in western Maryland, 15 percent of the trees had died two months after planting. This mortality, however, was not associated with the different geographic populations (not different at 0.05 level). The following spring (1963), the dead trees were replaced by new specimens. During the next five years, another 18 percent of the trees died. High mortality occurred particularly in the populations from Mount Fuji (Prov. 1) and from Yoshino (Prov. 8). Trees from Region E (Tochigi Prefecture) showed the best survival. No further mortality occurred during the seventh, eighth, and ninth years.

In the plantation on the Piedmont Plateau, central Maryland, mortality was much higher than in the mountains; two months after planting, 36 percent of the trees died. This mortality occurred at random, apparently caused by warm weather and dry soil conditions during the planting season (spring 1962). Two years after planting the mortality increased to 51 percent, and at this time it was distinctly different among populations. Almost all trees of Prov. 2 from Mount Fuji had died, and seed origins from Regions C, G, and I had a high percent of mortality (Table 2).

Survival of the same geographic strains in the mountains and in the Piedmont Plateau showed no significant correlation. Also, the survival rates in Maryland's plantations showed no significant correlations with the nine-year survival rates in Germany. The survival in Garrett County, however, was very significantly correlated (r = .78) with the advance in budset as determined in Germany (Hattemer, 1969). Apparently, some trees may have been injured by early frosts before they formed buds. Also, survival in the mountains was correlated with the general growth rate (r = .67 for height; r = .66 for diameter); this shows that the slow-growing strains were subject to a somewhat higher mortality. On the Piedmont Plateau, the survival rates were inversely correlated to the degree of spring frost injury (r = -.54) as determined in the North Central States (Farnsworth et al., 1971).

Heights

Five years after planting, heights of different geographic strains of Japanese larch in the Allegheny Mountains ranged from 5.3 to 12.6 feet. Nine years after planting they ranged from 13.3 to 24.1 feet (Table 2). On the Piedmont Plateau, the same strains grew still more rapidly, and nine years after planting ranged from 19.9 to 28.3 feet. Compared to other conifers planted in Maryland, these growth rates of Japanese larch were outstanding.

Table 2.--Data on Japanese larch (*L. leptolepis*) from 16 different provenances studied in Maryland's Allegheny Mountains (MTS) and Piedmont Plateau (PDM)

Provenance		Survival at 8 years		Height at 12 years		Diameter at 12 years		Stem Quality[1]		Branches attacked by larch sawfly[2]	
No.	Location	MTS	PDM	MTS	PDM	MTS	PDM	MTS	PDM		
		Percent		Feet		Inches		Grades		Number	Percent
	Region A										
1.	Mt. Fuji	31	83	13.3	22.2	1.3	3.0	8	9	--	--
2.	Mt. Fuji	--	8	--	--	--	--	--	--	--	--
	Region B										
4.	Mt. Azisa	88	58	20.8	26.6	2.6	4.3	10	14	4.6	6.6
	Region C										
5.	Toyosato	81	25	23.4	28.1	3.1	5.3	8	--	4.1	5.2
7.	Tateshinayama	100	67	22.0	26.7	2.8	5.4	12	13	8.4	8.9
8.	Kitayama	56	92	19.9	25.3	2.7	4.2	8	9	8.3	8.0
9.	Nishidake	--	25	--	25.9	--	4.2	--	--	--	--
	Region E										
13.	Okunikko	100	75	20.5	21.1	2.9	3.3	11	11	1.8	2.2
14.	Okunikko	94	100	22.8	26.3	3.3	4.2	10	8	4.4	5.0
15.	Yashubara	94	58	24.1	24.4	3.4	3.9	12	15	4.8	5.5
	Region F										
16.	Kumashiroyama	88	--	19.4	--	2.7	--	8	--	4.0	5.4
	Region G										
17.	Mizunoto	--	33	--	28.3	--	5.2	--	14	--	--
18.	Nagakurayama	--	25	--	22.1	--	4.4	--	--	--	--
	Region I										
22.	Takasegawa	81	25	16.0	20.6	1.7	3.1	8	--	9.0	10.6
24.	Shikanose	81	42	19.1	22.9	2.4	3.6	8	7	13.3	18.8
25.	Akanagi	94	58	18.7	19.9	2.4	3.1	7	10	13.1	16.4
The least sign difference at 0.05 level		38	33	5.1	6.3	1.5	1.8	4	4	7.1	9.5

[1] Stem quality grades ranged from: 4 = very poor; to 20 = outstanding, scored at age of 12 years.

[2] Larch sawfly (*Pristiflora erichsonii*) attack of 7-ft. to 14-ft. tall trees, studied at age of 9 years.

Table 3.--Correlation among some characters in Japanese larches of different origin studied in Maryland's Allegheny Mountains (MTS) and Piedmont Plateau (PDM).[1]

Variables Y_2 (data from Maryland and from other plantations)[1]	Variables Y_1 (data from Maryland)									
	Survival		Height		Diameter		Stem qual.		Branches attacked by larch sawfly	
	MTS	PDM	MTS	PDM	MTS	PDM	MTS	PDM	No.	Percent
Survival, MTS	1									
Survival, PDM	.	1								
Height (12 years), MTS	.67*	.	1							
Height (12 years), PDM	.	.	.66*	1						
Diameter (12 years), MTS	.66*	.	.97**	.	1					
Diameter (12 years), PDM	.	.	.70*	.87**	.	1				
Stem quality grade, MTS	.	.	.58*	.	.	.	1			
Stem quality grade, PDM	.	.	.	.	.	.	.71*	1		
Larch sawfly on No. branches	.	.	.	.	.	.	.	.	1	
Larch sawfly on percent branches	.	.	.	.	.	.	.	.	.97**	1
Height (3 years), New York	.	.	.	.65*	.	.	.	.	.	.
Height (6 years), Germany	.	.	.	.59*	.59*	.	.	.	-.60*	-.72*
Height rank, Northern Germany	.	.	.69*	.	.75**	.	.	.	.	-.62*
Height rank, Southern Germany	.	.	.	.53*	.	.	.	.	.	.
Height (3 years), Michigan	.	.	.	.	.	.	.63*	.	.	.
Height (8 years), Illinois (Sinn)	.	.	.	.	.62*	.	.	.	.	.
Height (8 years), Illinois (4-H)	.	.59*	.	.	.	.	.76**	.	.	.
Diameter (9 years), Germany	.	.	.64**	.69**	.69*	.77**	.	.	-.62*	-.67*
Advance in budset, Germany	.78**	.	.60*	.	.70*	.	.	.	.	.
Trees with flowers, NCS	-.71*	.	.	.	.	.	.	.	.	.
Spring frost damage, NCS	.	-.54*	.	.	.	.	.	.	.	.
E. longitude of seed source	.	.	.	.	.	.	.67*	.	-.82**	-.82**

[1] The data from Maryland were subjected to correlation analysis with data from New York (Stairs, 1965), data from Germany (Hattemer, 1968 and 1969; Maschning, 1968), and data from North Central States (NCS) (Farnsworth *et al.*, 1971).

* = Significant at 0.05 level.

** = Significant at 0.01 level.

In both plantations, the heights among some populations were very significantly different. In the Alleghenies, the most rapidly growing trees (Prov. 15) came from Region E, Yashubara State Forest, Tochigi Prefecture (Fig. 1). The second most rapidly growing strain (Prov. 5) came from Region C. Seven other populations grew nearly as rapidly, while one population from Region A (Fuji Mountain) and one from Region I (Omachi County) grew distinctly slower.

In the Piedmont plantation, the most rapidly growing populations were Prov. 17 from Region G and Prov. 5 from Region C. They grew two to three feet per year, and nine years after planting they averaged over 28 feet. Nine other populations grew nearly as rapidly. The heights of the geographic strains planted in the Piedmont Plateau were positively correlated with the heights of the same populations planted in the Alleghenies (r = .66). The coefficient of determination (r^2 = .44), however, was low.

Correlation analysis also revealed that the heights of different strains in Maryland were not significantly related to the provenance data (latitude, longitude, altitude, temperature, and precipitation). Also, heights in Maryland showed no significant correlation with either seed weights or growth rates in North Central plantations (Farnsworth et al., 1971). Time of growth initiation and time of leaf fall also were not associated with the growth rates.

However, the heights of different strains in the Alleghenies were significantly correlated with the rank of heights in northern Germany (r = .69), the mean 9-year diameters in Germany (r = .64), and the advance in budset in Germany (r = .60). The heights of different populations planted on the Piedmont Plateau were significantly correlated with the rank of heights in southern Germany (r = .53); the 3-year heights in Syracuse, New York, (r = .65); the mean 6-year heights in Germany (r = .59); and the 9-year diameters in Germany (r = .69).

Diameters

Diameters among some populations of Japanese larch were distinctly different (Table 2). In the Alleghenies, they ranged from 1.3 to 3.4 inches, and in the Piedmont plantation, from 3.0 to 5.4 inches. In both plantations, the diameters were very significantly correlated with the heights (r = .97 and r = .87). Consequently, the relationships between the diameters and other characters studied were very similar to those reported for heights. Diameters in Maryland and the overall 9-year diameters in Germany were significantly correlated (r = .69 and r = .77).

Stem Quality

Stem quality of individual trees varied from poor (having two or more large crooks) to excellent (straight, no basal sweep, no crooks, no forks). Analysis of variance indicated that stem quality significantly differed among some geographic populations (Table 2).

In the Alleghenies, trees with the best stem qualities were in populations from Region E (Tochigi Prefecture). Also, Prov. 7 from Region C had a high grade of stem quality. In the Piedmont plantation, particularly outstanding were Prov. 15, Prov. 4, and Prov. 17, all from different northern and central regions. Considering both plantations, the stem quality of strains from Regions A. (Fuji Mountain) and I (western Nagano Prefecture) was relatively poor. Populations 15 and 7, which had an outstanding stem form, also showed good growth rates.

The grades of stem quality in the Piedmont plantation were significantly correlated with the grades in the Alleghenies (r = .71). Also, the number of crooks per tree reported from Michigan and the stem quality grades for six similar populations in Maryland's Allegheny plantation were, as expected, inversely correlated (r = -.52, not significant because of low degrees of freedom).

In the Alleghenies, the stem quality grades were correlated with longitude (r = .67), indicating that eastern populations had somewhat better stem quality than those from the west.

Susceptibility to Larch Sawfly

A study in 1968 showed that different geographic populations of Japanese larch had suffered somewhat different degrees of attack by larch sawfly (Harman and Genys, 1970). When all sizes of trees were under consideration, trees of Prov. 5 were the least attacked.

In this report, the comparisons of attack by larch sawfly were based on trees that were more or less equal in size (height range from 7 to 14 feet). Consequently, the suppressed small trees and the large "wolf" trees were excluded. Among these trees, in different populations, the average number of branches attacked ranged from 2 to 19 and the average percent of branches attacked ranged from 2 to 19. Both these values were strongly correlated (r = .97), and both were inversely correlated with the eastern longitude of the provenance (r = .82). This correlation and analysis of variance indicated that strains of Japanese larch from western parts of Honshu were more subject to attack by larch sawfly than strains from the east. Most heavily attacked were populations from Region I (Shikanose and Akanagi). The trees least attacked (Prov. 13) originated from a low elevation (1,360 m) in Okunikko State Forest, Nikko City, Mount Nantai (Region E).

The degree of attack by larch sawfly (percent of trees attacked) among five populations of Japanese larch planted in Michigan and the percent of attacked branches of similar populations in Maryland showed no relationship (r = -.43; 3 degrees of freedom). Among the same populations, a more meaningful relationship (r = .70; 3 degrees of freedom) occurred between the grades of attack by larch case bearer (*Coleophora laricella* (Hbn.)) in Michigan, and the percent of branches attacked by larch sawfly in Maryland (Farnsworth et al., 1971).

DISCUSSION

Japanese larch of different seed sources planted in Maryland varied in survival, growth rates, stem quality, and susceptibility to larch sawfly. On the basis of present data, no evidence was established that these traits may have been related to either latitude, altitude, temperature, or precipitation in the location of their origin. However, the analysis showed that differences in susceptibility to larch sawfly were inversely correlated with the eastern longitude--eastern populations were less susceptible. Also, longitudinal differences were evident in stem quality--eastern populations were better.

Heights of different populations planted in the Maryland mountains were correlated with the rank of heights in <u>northern</u> Germany while heights on the Piedmont Plateau were correlated with the rank of heights in <u>southern</u> Germany. Apparently, some similar populations were more adapted to colder regions, while others grew better in warmer regions.

In selection of particular strains for planting in Maryland, all four factors--survival, growth rate, stem quality, and resistance to sawfly---are important. Populations from Region I (Mount Komaga in western Nagano Prefecture) had no characters of particular value; they grew at a low to moderate rate, had a below-average stem quality, and were highly susceptible to larch sawfly. Trees from Region A (Fuji Mountain) showed a relatively poor survival, and on the basis of present data, cannot be recommended for Maryland.

Depending on the emphasis on particular characters, selection of seed sources for planting may be most promising in Regions C, E, and B (Yatsuga, Nantai, and Azusa Mountains). For rapid growth and good stem form in western Maryland, the most promising is Prov. 15 (Yashubara State Forest, elevation 1700 meters). Most promising for these two traits in central Maryland are Prov. 17 (Mizunoto State Forest, elevation 1900 meters) and Prov. 7 (Taleshinayama State Forest, elevation 1600 meters). Populations from these three provenances (15, 17, and 7) have also shown above-average growth rates in the North Central States and in Germany. Among them Prov. 15 was outstanding, with above-average heights of 21 percent in western Maryland, 8 percent in the North Central States, and 6 percent in Germany. Prov. 13 (Okunikko State Forest, elevation 1360 meters) may offer some possibilities in breeding for resistance to larch sawfly. Trees from this location grew at a moderate rate and had a good stem form.

In general, growth data from Maryland were more distinctly related to data from Germany than to data from the North Central United States. In particular, results in Maryland and in Germany were in close agreement in indicating some inferior characters among populations from Region I (Mount Komaga).

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