The International Larch Provenance Test in Southeastern Michigan, USA

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(Received April / June 1977)

European larch (Larix decidua Miller), native in a limited range in Central Europe, has been introduced widely throughout Central Europe, England, and in the United States since about 1850 (Hunt 1932). It has been chiefly grown in the northeastern United States along with the Japanese larch (Larix *leptolepis* [Sieb. et Zucc.] Gord.) and the Dunkeld hybrid larch (L. X eurolepis = L. decidua X L. leptolepis). These larches are successful introductions due to their rapid early growth (outgrowing all native conifers in the first 25 years, Hunt 1932), good form, dense and durable wood, and pleasing aesthetic qualities.

The importance of the right provenance has been recognized for decades in Europe and has also received attention by North American foresters (McComb 1955, Cook 1955, 1974, 1975). Although little planting of larch has been conducted in the Western Great Lakes Region, S. H. Spurr, silviculturist of the University of Michigan, initiated a series of tests of European, Japanese, and hybrid larch in the 1950's. Beginning in 1958 he arranged participation in the 2nd International Larch Provenance Test, organized by R. Schober of the University of Göttingen, Göttingen, Germany. Fourteen European countries and the United States participate in this test which involves 68 provenances (Schober 1976). A review of results from 31 test plantations in West Germany was presented by Schober (1976). Twenty-four of the 68 provenances have been tested Michigan.

The objective of this paper is to report the performance of the provenances over the 19-year period 1958—1976. Seeds were sown in a nursery in the spring of 1958 and out-planted in two experirnents, one in 1960 and another in 1961. Following a description of the planting site, the methods, results, and discussion will be presented separately for each experiment.

The planting site for both tests is located in southeastern Michigan on forest property of the University, near Ann Arbor, Michigan (Lat. 42° 15' N; elev. 268 m). The soil is sandy loam of glacial outwash origin. The climate is continental, slightly modified by the Great Lakes. Mean annual precipitation is approximately 770 mm, half of which falls during the growing season. The mean annual air temperature is about 9.3° C; the mean temperature from May to September is 19° C.

Experiment I

Twelve provenances were selected: 10 of European larch, 1 of Japanes larch, and 1 of progeny of the Dunkeld hybrid larch (Table 1). The seed of the Dunkeld source was apparently collected from a Danish stand of Dunkeld hybrid larches and is a population of F, seedlings. A randomized complete-block design with two replicates was used. There were two blocks, 12 plots per block, and 72 trees per plot (6 rows of 12 trees each). Two-year-old seedlings (2—0 stock) were planted in April 1960 at a spacing of 2.4 X 2.4 meters.

The total height of each tree was measured annually from 1960 through the 1967 growing season. Diameter at breast height (DBH) was measured in the winter of 1976—77 (19 years from seed).

The survival, total height at 10 years from seed, and DBH at 19 years are presented in Table 2. Considering the relatively poor, droughty site conditions, height and diameter growth have been good, especially of Schlitz, a plantation source of unknown origin, and the two Czechoslovakian sources (40 and 39). Mühldorf (3), the lowest elevation Austrian source, and Neumünster (34), another plantation source of unknown origin, have consistently exhibited good growth. The high elevation Austrian and Italian sources have shown the poorest growth.

The growth of the Schlitz source has been the best of all sourees at every measurement. In contrast, the Czechoslovakian sources were poorest of all during the first four

Table 1. — Provenance information for 12 larch populations planted in southeastern Michigan, U.S.A.

Provenance Number	Provenance	Source Seed	Elevation m	Latitude	Longitude
2	Schonwies	Austria	1100	47° 12'	10° 40'
3	Mühldorf	Austria	900	46° 52'	13° 21'
5	Langau 59	Austria	1000—1100	47° 51'	15° 12'
7	Langau 38/41	Austria	1100	47° 49'	15° 10'
12	Sterzing/Flains	Italy	1000	46° 54'	11° 26'
15	Ahrntal/Val Aurina	Italy	1200	47° 00'	12° 00'
*28	Schlitz 65	Germany	300	50° 43'	9° 31'
*34	Neumünster	Germany	50	54° 15'	10° 10'
39	Zabréh-Dubicko	Czech.	450—550	49° 50'	16° 58'
40	Ruda nad Moravou	Czech.	480	49° 59'	16° 54'
36	Ina	Japan	1200	35° 52'	138° 5'
—	Dunkeld	Denmark, Distrikt of Boller[1])			

[1]) Progeny of the Dunkeld hybrid larch (Larix decidua x L. leptolepis).
* Seeds obtained from a plantation; original source unknownn.

Table 2. — Height, diameter, and survival values for larch sources in Experiment I, randomized complete-block design.

Source No.	Origin	Total Height 1961[1] m (ft)	rank	1967[2] m (ft)	rank	rank	Diameter 1977[3] cm (in)	Significance[4]	Survival 1977 %
*28	D	0.72 (2.4)	1	6.1 (20.0)	1	1	12.8 (5.0)		97
40	CS	0.48 (1.6)	11	5.4 (17.6)	3	2	12.5 (4.9)		92
39	CS	0.46 (1.5)	12	5.4 (17.6)	2	3	12.3 (4.8)		95
3	A	0.56 (1.8)	4	5.0 (16.4)	5	4	12.3 (4.8)		90
*34	D	0.56 (1.8)	4	5.2 (17.1)	4	5	11.9 (4.7)		92
36	J	0.51 (1.7)	8	4.3 (14.1)	10	6	11.8 (4.6)		70
Dunkeld		0.71 (2.3)	2	4.7 (15.4)	7	7	11.7 (4.6)		88
12	I	0.50 (1.5)	10	4.3 (14.2)	9	8	11.5 (4.5)		90
2	A	0.51 (1.7)	8	4.2 (13.9)	11	9	11.4 (4.5)		74
15	I	0.55 (1.8)	6	4.5 (14.8)	8	10	11.1 (4.4)		94
5	A	0.61 (2.0)	3	4.9 (16.0)	6	11	11.0 (4.3)		93
7	A	0.54 (1.8)	7	4.0 (13.3)	12	12	10.2 (4.0)		79

[1]) Age: 4 years from seed.
[2]) Age: 10 years from seed.
[3]) Age: 19 years from seed.
[4]) Sources not connected by the line are significantly different at $P < .05$.
* Seeds obtained from a plantation; original source unknown.

years of the test. However, they responded rapidly thereafter and are today among the fastest growing sources. The rank correlation of total height for all sources from 1959—1965 was low ($R = 0.33$); the rank correlation of 1967 height and 1976 diameter was high ($r = 0.81$).

The excellent performance of the plantation soureces is probably due to (1) inbreeding release (less inbreeding in these sources than in trees grown from seed collected from natural stands which have had the opportunity to become inbred over generations), and (2) natural and artificial selection (by thinning) pressures in the plantations where seeds were collected for this test. The equally fine growth of the Czechoslovakian sources is probably due to a greater correspondence of macroclimate (more contentinental) compared with that of sources from Austria, Italy, and Japan.

Survival has been good to excellent for all sources. Survival probably would have been excellent for all sources had not a frost pocket occurred in a portion of one replicate of sources 2, 7, 36, and Dunkeld.

Marked differences in crown form were found between the high elevation, alpine sources of Austria and Italy (small and narrow) and the Japanese larch and Dunkeld source (wide-spreading). The Czechoslovakian and the plantation sources were intermediate. Damage from a severe ice storm of March 1976 was closely related to crown form and growth rate. The Japanese larch (36) was the most heavily damaged; 31% of its stems were either broken off, bent over, or had broken branches. Fast growing sources 28, 39, and 40 exhibited 11%, 12%, and 10% damaged stems, respectively. In contrast, negligible damage occurred in the smaller, narrower crowns of the high elevation Austrian and Italian sources. These six sources (2, 3, 5, 7, 12, and 15) exhibited an average of only 1.8%.

Experiment II

A test of 20 porvenances was initiated in the spring of 1961 *(Table 3)*. Using a completely randomized design, eight, three-year-old seedlings (2—1 stock) were planted at a 1.8 × 1.8 m spacing in each of four blocks. Four trees of each source in each block were thinned in 1969. Total height of each tree was measured in 1963, 1964, and 1965. DBH was measured in the winter of 1976—77. The results of these measurements are presented in *Table 4.*

As in the first experiment, plantation sources (28, 30, and 34) and two sources from Czechoslovakia (the most continental areas represented in this test) grew best. Sources from the Maritime Alps grew very slowly although their survival was high. Major differences in climate between origin and planting site probably explain their extremely slow growth compared to the more continental Czechoslovakian sources. European larch sources of Austria and Italy, with three exceptions (18, 19, and 3) were significantly slower growing ($P < .05$) than the Czechslovakian and plantation sources. The Japanese larch was undistinguished in growth and suffered more ice damage than the other sources. A close relationship was found between the performance in height at 10 years from seed and DBH 19 years from seed ($r = 0.93$).

Diameter relationship to latitude and elevation

A correlation analysis of 19-year DBH and latitude for the larch provenances of Experiment I whose origin was known showed a omderately low relationship ($r = 0.47$). The relationship of DBH with elevation was relatively strong ($r = 0.80$). Because growth of North Temperate Zone species, when grown in new environments, is closely related to the climatic environment of their native habitats (primarily length of growing season and photoperiod) (Spurr and Barnes 1973), adjusting latitude for elevation has often shown a closer correlation with growth than unadjusted latitude (Wiersma 1963). Using the adjustment factor of 1 degree of latitude equals 100 meters in elevation, the correlation of latitude adjusted for elevation and DBH was strong ($r = -0.91$).

In Experiment II the correlation of DBH and elevation was again moderately strong ($r = 0.84$). However, only a slight improvement was found between the correlation of DBH with unadjusted latitude ($r = 0.70$) and adjusted latitude ($r = -0.75$). Even the unadjusted latitude correlation is moderately high because latitude and elevation are sys-

tematically related; the slow growing, highest elevation provenances (38, 26, 22, 23) are those of the lowest latitudes and the fast growing, lower elevation provenances (39, 40, 3) are those of the relatively high latitudes. Thus, the climatic differences among the provenances, especially macroclimate and elevation, are closely associated with provenance performance.

For Experiment II, in which European larch provenances (Plantation sources exluded) extend over the greatest elevational range (480 m to 1900 m), an increase in elevation

Table 3. — Provenance information for 20 larch populations planted in southeastern Michigan, U.S.A.

Provenance Number	Provenance	Seed Source	Elevation m	Latitude	Longitude
3	Mühldorf	Austria	900	46° 52'	13° 21'
5	Langau 59	Austria	1000—1100	47° 51'	15° 12'
7	Langau 38/41	Austria	1100	47° 49'	15° 10'
8	Semmering	Austria	1200	47° 38'	15° 46'
16	Cavalese	Italy	1200	46° 19'	11° 27'
18	Tenna	Italy	600	46° 4'	11° 19'
19	Pergine/Selvot	Italy	1300—1400	46° 6'	11° 23'
20	Cavedine	Italy	600—700	45° 59'	11° 4'
21	Pragelato	Italy	1900	45° 1'	6° 56'
22	Embrun/Ristola	France	1600	44° 47'	6° 57'
23	Embrun/Aiguilles	France	1560	44° 47'	6° 54'
24	Briancon/Montgenevre	France	1200	44° 56'	6° 43'
26	Briancon/de Villard	France	1400	44° 52'	6° 39'
*28	Schlitz 65	Germany	300	50° 43'	9° 31'
*30	Dobříš	CSSR	500	49° 47'	14° 11'
*34	Neumünster	Germany	50	54° 15'	10° 10'
36	Ina	Japan	1200	35° 52'	138° 5'
38	Valdeblore	France	1700—1800	44° 14'	7° 11'
39	Zabréh-Dubicko	CSSR	450—550	49° 50'	16° 58'
40	Ruda nad Moravou	CSSR	480	49° 59'	16° 54'

* Seeds obtained from a plantation; original source unknown.

Table 4. — Height, diameter, and survival values for larch sources in Experiment II, completely randomized design.

Source No.	Origin	Total Height 1967[1]) m (ft)	rank	Diameter 1977[2]) rank	cm (in)	Significance[3])	Survival 1967[4]) %
*30	CS	5.37 (17.6)	2	1	14.1 (5.5)		94
*28	D	5.18 (17.1)	3	2	13.9 (5.5)		94
39	CS	5.43 (17.8)	1	3	13.9 (5.5)		94
40	CS	5.12 (16.8)	5	4	13.2 (5.2)		91
3	A	5.15 (16.9)	4	5	13.2 (5.2)		91
18	I	4.45 (14.6)	11	6	13.1 (5.2)		100
*34	D	4.91 (16.1)	6	7	13.0 (5.1)		91
19	I	4.45 (14.6)	12	8	12.8 (5.0)		91
8	A	4.51 (14.8)	10	9	11.7 (4.6)		97
16	I	4.66 (15.3)	7	10	11.6 (4.6)		91
20	I	4.57 (15.0)	9	11	11.5 (4.5)		91
36	J	4.63 (15.2)	8	12	11.2 (4.4)		75
24	F	4.21 (13.8)	15	13	10.5 (4.1)		91
5	A	4.30 (14.1)	13	14	10.5 (4.1)		72
7	A	4.21 (13.8)	14	15	9.6 (3.8)		94
23	F	3.75 (12.3)	18	16	8.8 (3.5)		91
22	F	3.63 (11.9)	19	17	8.2 (3.2)		94
26	F	3.81 (12.5)	17	18	7.6 (3.0)		78
21	I	3.87 (21.7)	16	19	7.4 (2.9)		94
38	F	2.90 (9.5)	20	20	6.5 (2.6)		91

[1]) Age: 10 years from seed.
[2]) Age: 19 years from seed.
[3]) Sources not connected by line are significantly different at $P < .05$.
[4]) Before thinning.
* Seeds outained from a plantation; original source unknown.

of 200 m brings an approximate decrease in DBH of 2,5 cm. In Experiment I, where the provenances from the Maritime Alps were not included, and thus the altitudinal differences among provenances are much less (480 m to 1200 m), an increase of about 400 m is necessary to effect a DBH decrease of 2,5 cm. Elevation per se, however. should not be singled out as the major factor controlling growth; the macroclimate probably plays a significant role. The fastest growing provenances (excluding plantation sources) are the Czechoslovakian provenances (Sudeten larch) whose continental climate more closely resembles that in southeastern Michigann than the macroclimate of the Maritime Alps where the provenances of slowest growth originate. Thus, it is not enough to know the latitude and elevation of the provenance when selecting proper seed origin; the macroclimate characteristics of the provenance origins should be known as well.

No major differences in stem form were observed among provenances in either test.

A review of larch potential in the north-central states was given by JEFFERS and ISEBRANDS (1974). The good to excellent performance of various provenances of European larch in southeasternn Michigan on a dry, sandy site adds credence to their conclusion that larch has considerable potential for culture on relatively short rotations where pulpwood and poles are the major products. Variation within our provenances is substantial, such that selection from the best provenances followed either by clonal propagation or by breeding could bring about additional gains in fiber production.

Insect Attak

Differences among sources to a severe infestation of the larch casebearer *(Coleophora laricella* HUBNER) and to the occurrence of the larch wooly aphid *(Chermes strobilobius* KALT.) were determined for both tests (RUSH 1972). Sources 5, 18, and 38 were the most susceptible to casebearer attack, whereas the Japanese larch (36) and the Dunkeld source were relatively resistant. The fast growing plantation sources 28 and 30 were also more resistant than most of the other sources. All sources showed incidence of wooly aphid infestation (sources 38, 15, and 34 had the highest incidence) except the Japanese larch and the Dunkeld source, which were virtually unattacked.

Summary

A provenance test of European larch (22 provenances), Japanese larch (1 provenance), and F_2 seedling progeny of the Dunkeld hybrid larch (1 source) was initiated in Southeastern Michigan, near Ann Arbor (Lat. 42° N; 268 m elev.). Seeds were sown in 1958 and two plantations established, one each in 1960 and 1961, on a relatively poor, droughty site of sandy loam soil. In Experiment I, trees from 12 sources were planted in a randomized-complete-block design. In Experiment II, trees of 20 sources were planted in a completely randomized design. In both tests, trees from plantation sources (Schlitz, Dobříš, Neumünster) of unknown origin exhibited the best height and diameter growth in 19 years from seed. Inbreeding release and natural and artificial selection pressures probably accounted for the good growth. Czechoslovakian sources also exhibited very good growth. This was probably due to a closer correspondence of the macroclimate of their origin to the continental climate of Michigan compared with that of the other sources. High elevation sources of Austria, Italy, and especially the Maritime Alps of France exhibited the poorest growth. The single source of Japanese larch was the most severely damaged by ice, but it proved most resistant to infestation by the larch casebearer *(Coleophora laricella* HUBNER) and the larch wooly aphid *(Chermes strobilobius* KALT.).

Key words: provenance, seed source, inbreeding, racial variation.

Zusammenfassung

Bei Ann Arbor im Südosten des Staates Michigan (42° 15' N; 268 m NN) werden Provenienzversuche mit 22 Herkünften der Eur. Lärche, einer Herkunft der Jap. Lärche und einer generativen Nachkommenschaft der „Dunkeld"-Bastardlärchen durchgeführt. Die Samen wurden 1958 ausgesät. 1960 wurde eine Versuchsfläche mit 12 Herkünften, 1961 eine Fläche mit 20 Herkünften angelegt. Der Standort ist in beiden Fällen ein relativ nährstoffarmer und trockener sandiger Lehm. Im Lebensalter 18 weisen auf beiden Versuchsflächen die Herkünfte aus gepflanzten Beständen unbekannten Urprungs (Schlitz, Dobris, Neumünster) die besten Höhen und Durchmesserleistungen auf; geringere Inzucht sowie natürliche und künstliche Selektion dürften die Ursachen sein. Ein sehr gutes Wachstum zeigen auch die tschechoslowakischen Herkünfte — vermutlich weil das Klima des Ursprungslandes dem kontinentalen Klima von Michigan am ähnlichsten ist. Herkünfte aus hochgelegenen Standorten in Österreich, Italien und vor allem in den französischen Westalpen wachsen am schlechtesten. Die einzige Herkunft der Jap. Lärche, die durch einen Hagelsturm am stärksten geschädigt wurde, erwies sich dagegen am resistentesten gegen die Miniermotte *(Coleophora laricella* HBN.) und die Woll-Laus *(Chermes strobilobius* KALT.).

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