Table 6. Estimates of prediction error based on cross-validation of the form quotient board foot volume equation. The statistics (min, mean, and max) are summaries across all species in each group.

| | Measured F used | | | | | | $F - \bar{F} = 0$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ERROR[a] | | | ABSOLUTE ERROR[a] | | | ERROR[a] | | | ABSOLUTE ERROR[a] | | |
| Group | min | mean | max | min | mean | max | min | mean | max | min | mean | max |
| Conifers | −1.1 | −0.1 | 1.0 | 6.6 | 9.6 | 14.4 | −0.6 | 1.0 | 3.6 | 10.3 | 13.1 | 15.2 |
| Hardwoods | 0.3 | 1.0 | 2.0 | 7.0 | 7.9 | 9.0 | −0.9 | 1.3 | 5.0 | 9.6 | 11.7 | 14.4 |

[a] See text for definitions of ERROR and ABSOLUTE ERROR.

pose the data for each species group were divided in half. Since the data were not arranged in any systematic fashion, the halving was done by choosing every other observation. Equation coefficients based on fitting to one half were used to predict for the other half. *ERROR* and *ABSOLUTE ERROR* were computed for each half and averaged across the two halves. Actual heights were used. The new equations appear to provide very good, though possibly slightly high predictions (Table 6). Ninety percent of the errors for an individual equation were generally less than 17% in absolute value when the measured form quotient was used. If form quotient is not measured ($F - \bar{F} = 0$) one can expect the same magnitudes for *ERROR* as long as the trees to which the equations are applied are near the average form or deviate equally above and below average form. *ABSOLUTE ERRORs* will, of course, be somewhat higher if form is not measured. □

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# Juvenile Performance of Exotic Larches in Central Wisconsin[1]


**Chen H. Lee and Hans G. Schabel,** *College of Natural Resources, University of Wisconsin, Stevens Point, WI 54481.*



*ABSTRACT. A permanent test plantation consisting of a single provenance of Japanese larch and six provenances of European larch was established in central Wisconsin in the spring of 1982 by hand planting 2-0 stock grown from seed originating in Europe. A randomized complete block design with seven replications was used. Altogether 294 trees (6 trees/plot × 7 plots/block × 7 replications) were installed in the test.*

*After five growing seasons in the field, plantation survival was 98%. Nineteen percent of the trees had suffered bark damage by deer, and 22% had terminals clipped by grasshoppers. The damages were not related to seed source origin, and they were of short duration.*

*The between-seedlot differences in annual shoot elongation were statistically significant in each of three consecutive growing seasons. Mean annual height growth for both exotic larches combined was 53 cm. Mean total height reached 3.73 m after seven growing seasons (two in the nursery, five in the plantation). Early growth potential of both larches was more than three times that of native red pine planted adjacent to the larch study site. Although the single Japanese larch provenance was slowest growing, sensitive to late frost, and possessed the lowest percentage of straight stems, it still outperformed red pine. European larch of Polish provenances, combining good growth with straightness characteristics, is recommended for general planting purposes on suitable sites in central Wisconsin.*



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Of the ten species in the genus *Larix*, European larch and Japanese larch have been the focus of numerous studies within and outside their natural species range. Results of an international larch provenance test involving 22 forest research institutions were reported by Schober (1976). The superior performance of these two exotic larches was impressive and well recognized in the Lake States and northeastern United States (Genys 1960, Lee 1976, Barnes 1977, Einspahr et al. 1984). On suitable sites, these exotic larches consistently outgrew native tamarack and other conifers (McComb 1955, Reed et al. 1983).

The two exotic larches tolerate a variety of site conditions (Rubner 1960). Their growth is closely related to soil drainage and soil depth needed for root development (Aird and Stone 1955). In addition, they are relatively free of serious pest problems. The wood is durable and pulps readily, and the unit volume pulp yield exceeds that of jack pine and red pine (Jeffers and Isebrands 1972, Einspahr et al. 1983).

Concerns over extensive planting of genetically uniform red pine throughout Wisconsin and increasing interest in high fiber yield trees dictate a search for suitable alternative economic species. Suitable sites and provenances of the two exotic larches need further exploration. The promising juvenile growth potential of these two exotic larches in central Wisconsin is presented.

## MATERIAL AND METHODS

Seven seedlots were received from seed orchards and forest stands differing in elevation from sea level to 400 m in Europe. Each seedlot was represented by seeds collected from one to several parent trees in fall 1979. Of the seven seedlots received, three were from Germany and the remaining four were from Poland (Table 1). They were stored at 4–5°C until sowing. One seedlot (G3) from Germany was Japanese larch; all others, European larch.

The seeds were sown in Griffith Nursery at Wisconsin Rapids, central Wisconsin in the spring of 1980. The seedlings received conventional nursery care.

The 2-0 planting stock was used to establish the permanent study plantation on April 22, 1982. It followed a randomized complete block design with 7 replications. In each block (replicate), there were seven 6-tree line plots randomly installed at a 2.1 × 3 m spacing. Altogether 294 seedlings were hand planted.

The test plantation is located on a moraine with a 6 to 20% slope facing north to northwest near the northwest corner of NE1/4 NE1/4, Section 22, T24N, R9E, about 3 km southeast of the Village of Polonia, Portage County, central Wisconsin. The site was an old alfalfa field until the establishment of the test plantation. The soil is a coarse loamy mesic type of Typic Hapludalf of the Wyocena series. During the first growing season in the field in June 1982, the seedlings were watered once due to a long dry spell and received two mechanical weedings. One more weeding was administered during the 1983 growing season.

Annual height increment (annual shoot elongation) was assessed, and the test plantation was monitored weekly for pest evidence for 3 consecutive years from 1984 to 1986. After 5 growing seasons in the field, total height was measured to the nearest 2.5 cm. Other data recorded were mortality and stem straightness.

Plot means were used as items in an analysis of variance to test the significance of between-seedlot differences in growth traits where the degrees of freedom were 6, 6, and 36 for seedlot (provenance), blocks, and error term, respectively. In order to correlate between the growth characteristics obtained in different growing seasons (Table 2), simple correlation analyses were employed using seedlot means as items with 5 degrees of freedom.

**Table 1. Origin of German (G) and Polish (P) provenances of Japanese* and European larch.**

| Code | Source | Latitude (N°) | Longitude (E°) | Elevation (m) |
|---|---|---|---|---|
| G 1 | Gahrenberg seedorchard | .......... *Unknown* | .......... | 400 |
| G 2 | Harbker | 52.10 | 11.00 | 300 |
| G 3* | NW Deutsches Tiefland | .......... *Unknown* | .......... | 300 |
| P 2 | Skarzysko | 51.10 | 20.45 | 280 |
| P 3 | Lezajsk-Dabrowki | 50.88 | 22.15 | 220 |
| P 4 | Stary Sacz | 49.32 | 20.37 | 400 |
| P 5 | Bobolice | 54.00 | 16.35 | 150 |

* Japanese larch of unknown provenance introduced to Germany from Japan.

**Table 2. Growth characteristics among seven larch seedlots in central Wisconsin.**

| Seedlot no. | Mean annual shoot growth 1984 | 1985 | 1986 | Total height 1986 | Straight stem 1986 |
|---|---|---|---|---|---|
| | ........ | (cm) | ........ | ........ | (%) |
| G 1 | 70.3 | 64.5 | 150.6 | 383.7 | 29 |
| G 2 | 69.3 | 58.7 | 140.5 | 360.6 | 26 |
| G 3 | 52.3 | 51.3 | 107.6 | 321.0 | 12 |
| P 2 | 67.7 | 63.5 | 146.6 | 381.0 | 40 |
| P 3 | 63.2 | 69.5 | 155.5 | 392.0 | 36 |
| P 4 | 64.7 | 56.8 | 144.8 | 381.3 | 17 |
| P 5 | 68.8 | 66.7 | 150.3 | 393.2 | 19 |
| Plantation mean | 65.2 | 61.6 | 142.3 | 373.2 | 26 |
| F values | 2.780* | 4.113** | 3.281* | 2.408 | — |

* Significant at the 5% level.
** Significant at the 1% level.

## RESULTS AND DISCUSSION

The young seedlings were healthy, showing no signs of any pest problems while in the nursery beds. They appeared uniform in growth, and no height data were taken.

Field survival was excellent when assessed at the end of the fifth growing season in 1986. Of the total 294 trees planted, only 6 had died (2% mortality). Three of the six Japanese larch (G3) were dead due to clipping by rabbit and girdling by meadow vole. When planted further north of the species natural range in Hokkaido, northern Japan, Japanese larch was observed to be more sensitive to late frost than the European larch nearby (Yanagisawa 1958). Although not quantified, frost damaged all seedlots in our study plantation with a higher frequency in Japanese larch. The central Wisconsin study supports the Japanese observation.

The between-seedlot differences in annual shoot elongation were statistically significant at either 1 or 5% level for 3 consecutive years from 1984 to 1986 (Table 2). In fall 1986, mean height was 3.73 m for all seedlots combined. These two exotic larches have averaged 53 cm per growing season. This growth rate exceeded that of the 7-year old European larch planted at Laona, Wisconsin (Einspahr et al. 1984), by 15 cm. A Lower Michigan study also confirmed the superior growth potential of exotic larches (Reed et al. 1983). Growth attained in that study by the 12-year-old European larch was comparable to that realized by the best 16- to 18-year-old tamarack on nearby similar sites. In our study, the 1986 growing season was particularly favorable. The seven exotic larch seedlots averaged 142 cm in growth in a single growing season. This figure was more than twice the average amount of growth (65 and 62 cm) attained in each of the 2 previous years.

Would fast-growing seedlots continue to maintain their superior performance? Seedlot means in annual shoot elongation obtained in each of three growing seasons were used to run simple correlation analyses. The 1984 vs. 85, 1984 vs. 86 and 1985 vs. 86 correlation coefficients in annual shoot elongation were 0.619 (nonsignificant), 0.826 (significant at 5%), and 0.872 (significant at 5%), respectively. In general, fast-growing seedlots remained fast growing in our test plantation.

There were red pine trees planted immediately next to the larch study site in 1980, 2 years earlier than the two exotic larches. Although this red pine plantation was not intended for testing purposes, 15 red pine trees were randomly selected in fall 1986 for mesurement of current year shoot elongation to be compared with the exotic larches. Mean growth was only 45 cm (ranging from 24 to 61 cm), about a third of that achieved by the two exotic larches during the same growing season.

Although the study does not provide information on the magnitude and pattern of genetic variation in central Wisconsin, the sole Japanese larch seedlot (G3) was slowest growing, about 15% slower than the plantation mean. At that rate, it still outgrew native red pine by 14 to 16% during the years of normal weather (1984 and 1985). In 1986 (a year with favorable growth conditions characterized by long and well-distributed rain), it outperformed red pine by as much as 140% (108 vs. 45 cm in current year shoot growth). This exotic larch is genetically variable in spite of its relatively narrow species range in central Japan. At age 12 from seed (or 10 plantation age), there were significant differences in height growth (ranging from 540 to 714 cm) among 22 Japanese seedlots when tested in southwestern Lower Michigan (Lee 1976).

Japanese larch is extensively planted in Hokkaido, Japan, north of its natural range. Height, diameter, and volume growth were comparable to those of European larch at age 10 in that environment (Yanagisawa 1958). In central Wisconsin, the single Japanese larch seedlot grew 28 to 38% slower than the average growth of six European larch seedlots in current year shoot elongation in three successive growing seasons from 1984 to 1986. The severe continental climate in central Wisconsin may have played a role in the phenotypic expression of the species.

The geographic variation of European larch was systematic in eight characteristics studied by Genys (1960). Seed sources from Poland, Sudetenland, and Slovakia grew significantly faster than those from other regions.

Mean current year shoot elongation of two German European larch seedlots was 5.7% faster than that of the four Polish counterparts in 1984; however, the trend was reversed in the following two growing seasons: the Polish trees grew 4.1 and 2.6% faster than the German trees in 1985 and 1986, respectively. Although the superiority of Polish trees over German trees diminished from 1985 to 1986, the central Wisconsin findings were in general agreement with the Genys study.

Schober (1976) observed that growth vigor and stem straightness in most European larch provenances did not always correlate positively. Our larch data supported his observation. A rank correlation was conducted ranking height growth and stem straightness for the six European larch seedlots (Table 2). The rank correlation coefficient was 0.286 with 4 degrees of freedom and was not statistically significant.

Certain animals were responsible for causing varied degrees of damage leading to temporary setbacks in growth. Nineteen percent of all plantation trees showed slight to moderate whitetail deer (buck) damage to their lower trunks. The damage was prevalent along the edge and corners of the plantation. As a result, many trees lost their terminal leaders (through whipping) and temporarily produced multiple stems. In addition, about 22% of the trees showed recent nonseed source related damage to their terminals by grasshoppers. The location of the test plantation in a former alfalfa field may have accounted for the damage. The damage by grasshoppers and deer amounted to temporary setbacks, and the trees generally showed excellent recovery.

Larch sawfly larvae were first discovered in the test plantation in 1985, 3 years after planting. On June 22, 1986, a careful search revealed eight colonies of this insect on four European larch seedlots (G2, P3, P4, P5). No effort was made to track the source of this insect; however, the closest stands of native tamarack known to harbor endemic populations of this insect are located about 0.75 km to the northeast of the exotic larch study site. Several pentatomid bugs were observed preying on some of the larvae. No pathological problems were observed in our exotic larch test plantation.

The westernmost part of the study plantation (i.e., the 7th replicate) is in a low area. Every year trees suffered heavily from late frost and all provenances grew 40 to 70% slower than the average of the remaining replicates (reps 1 throug 6). Exclusion of the 7th replicate data from an analysis of variance did not have any adverse effect on the ranking of individual provenance performance. However, it is wise to avoid any low area for inclusion in the future establishment of exotic larch plantations.

## CONCLUSION AND APPLICATION

All provenances tested in our study can be recommended for general planting purposes, as they showed excellent survival and juvenile growth on a Wyocena site in central Wisconsin, outgrowing native red pine on the comparable site. For fiber production, Polish European larch seedlots P5 and P3 are very promising (ranked first and second for growth, respectively), whereas European larch seedlots from Poland (P2 and P3) appeared promising for lumber production purposes (ranked first and second in percent straightness respectively). Mixed plantings would allow for removal of poorly formed trees during thinnings and would broaden the genetic base. Where insects and diseases such as pine needle rust, Scleroderris canker, or spruce budworm are of concern, exotic larches may be considered as a pine substitute. Frost pockets and dry sites should not be planted with exotic larches. They should also be tested in various mixes with hardwoods where diversification is desirable, or in environments with air pollution problems. □

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