LARCH POTENTIAL IN THE NORTH-CENTRAL STATES

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Projections indicate that there will be an increasing demand for forest products in the next few decades. By far the greatest increase will be in the demand for pulpwood. Among the many species under consideration for meeting the increased demand is larch.

Larch appears to have a potential for shorter pulpwood rotations when grown under intensive management (Schreiner, 1970). Several larch species combine good form and rapid juvenile growth with satisfactory wood density and good fiber characteristics. Larch also responds well to weed control, irrigation, and fertilization. Although the yield of pulp per unit weight is lower from larch than from spruce or pine, the yield per unit volume of wood is greater than from spruce or pine and the pulping properties are comparable to those of spruce (USDA Forest Service, 1964; Nevalainen and Hosia, 1969).

LARCH PLANTATIONS IN THE NORTH-CENTRAL STATES

Larch has generated considerable interest in the Northeast and has been planted over a wide geographic area. However, it has been largely neglected in the North Central States, except for experimental plantings comparing different larch species that have been established throughout the region. Results obtained from several of these plantings that represent a wide range of soils, growing conditions, and latitudes may help to emphasize the growth potential of larch in this region.

European Larch

Lemmien and Rudolph (1968) reported on growth of European larch (*Larix decidua* Mill.) in six plantations located in southern Michigan. The planting sites were gently sloping, varied in aspect, and had sandy-loam soils. At 32 years of age approximately half the stand volume was contained in the best 150 trees per acre. These potential crop trees had an average total height of 56 feet and D.B.H. of 8.5 inches.

Since 1958 the University of Michigan has participated in an international provenance test of European larch seed sources collected from natural stands and plantations. two test plantings were established in southern Michigan in 1960 and 1961 consisting of seedlings from 12 and 20 sources, respectively.

Survival of seedlings from all sources in these plantations at 10 years of age from seed was satisfactory to excellent. Excellent height growth was attained by trees from sources such as Schlitz, Dobris, and and from two Sudeten larch sources from Czechoslovakia. Poorest growth was exhibited by trees from high-elevation French Alp sources (Barnes, 1970). Average total height for trees from the fastest growing source (Schlitz) was 17 feet, while those from the slowest growing source averaged 9.5 feet in 10 years.

The North Central Forest Experiment Station established an unreplicated test of larch seed sources in northern Wisconsin in 1949 on an open, sodded field on an upland site with soil ranging from a fine sandy-loam to silt-loam. Average total heights of trees from the two tallest European larch sources, originating from Czechoslovakia and Poland, five years after planting, were 6.47 and 6.05 feet, respectively (Stoeckeler, 1955). At 25 years of age from seed, 14 of the largest and best-formed trees from five sources, selected for inclusion in a larch breeding program at the Institute of Forest Genetics, Rhinelander, Wisconsin, had an average total height of 53.2 feet and d.b.h. of 8.0 inches.

Results of a European larch provenance test in northeast Iowa have been reported by Gatherum (1965). Six-year survival of seedlings from three sources from the Alps and two Sudeten provenances ranged from 37 percent for a source from the Austrian Alps to 96 percent for a Sudeten source from Breslau, Poland, and height growth ranged from 4.3 feet for a source from the French Alps to 13.4 feet for the Breslau source. Individual tree height growth ranged from 1.0 foot (French Alps source) to 19.0 feet (Breslau source). Height growth was associated with altitude of seed origin, and a 1000-meter increase in altitude of seed origin resulted in a 6.4-foot decrease in height growth.

Japanese Larch

The largest testing program of larch in the North Central States is the cooperative, regional NC-99 (formerly NC-51) study of geographic variation in Japanese larch (*Larix leptolepis* [Sieb. and Zucc.] Gord.). Farnsworth, *et al.* (1972) observed the 9-to-13-year performance of trees from 7 seed sources planted at 13 locations in eight states. They also reported on the growth of trees from 22 seed sources (including the first 7 origins) planted at five locations in three states. The paper included information on survival, height growth, stem form, growth initiation, spring frost damage, and winter injury. Individual cooperators have discussed earlier performance of their respective plantings in Iowa (Kepler and Gatherum, 1964), Minnesota (Pauley, Mohn and Cromell, 1965), Nebraska (Read, 1970), and Wisconsin (Lester, 1965).

Survival of the original plantings varied from near complete failure to very successful. Several factors were believed to be responsible for much of the initial mortality, such as use of 2-0 stock instead of 2-1 stock generally used in Japan, poor site quality at some locations, inadequate weed control in some plantings, and leafing out of seedlings before planting.

When planted on the proper soil (loam or sandy loam), the Japanese larch grew much faster than spruces or pines planted in the same vicinity, and only European larch grew as rapidly. Growth on unsuitable sites (dry, sandy soils; frost pockets; or swamps), however, was poor (Farnsworth, *et al.,* 1972).

Significant differences were noted among origins for time of growth initiation, stem form, spring frost damage, time of leaf fall, winter cold damage, and

importance compared to the great differences in growth rates.

Growth of trees in the 7-origin test was good in several plantations. At 7 years of age from seed (5 years after planting), mean plantation total height was 8.4 feet in central Minnesota (Pauley, Mohn, and Cromell, 1965), 8.7 feet in northeast Iowa (Farnsworth, *et al.,* 1972), and 9.7 feet in eastern Nebraska (Read, 1970). The Nebraska plantation averaged 24.3 feet in total height at age 12 (Farnsworth, *et al.,* 1972).

In both the 7- and the 22-source tests there were significant seed source-plantation interactions. In the 7-source test a single origin was responsible for most of the interaction. It ranked first to third in 9 plantations in Michigan, Indiana, and Iowa and was 14 percent taller than the plantation averages, while in the Nebraska plantation it ranked last and was 17 percent shorter than the plantation average.

Tamarack

Tamarack *(Larix laricina* [Du Roil K. Koch) has not been widely planted in the North Central Region. Consequently, little was known about genetic variation in tamarack until 1961 when a cooperative NC-99 range-wide seed source study was begun by the University of Minnesota, College of Forestry.

Germination and seedling survival in nursery sowings of seed from approximately 60 seed sources were low, probably as a result of poor seed handling and nursery technique. Mean height of 2-0 stock from 16 sources grown in a Minnesota nursery ranged from 9.4 inches for an east-central Minnesota source to 23.2 inches for a Nova Scotia source, and differences among sources were significant (Pauley, 1965).

Several field plantings of seedlings from various seed sources were established in Michigan, Minnesota, and Wisconsin between 1966 and 1969. One of the plantings established in the fall of 1967 in northern Wisconsin contained trees from 24 provenances; trees from 6 provenances were planted as 2-2 stock and the remaining trees were planted as 3-0 stock. After four growing seasons in the field, survival of trees planted as 2-2 stock was considerably better than that of trees planted as 3-0 stock (92 and 78 percent, respectively). Total height growth and 1971 terminal elongation are summarized in Table 1.

Table 1. Total height and terminal elongation of 24 tamarack provenances grown in northern Wisconsin[1]

Age (years)	Total height (feet)			1971 Terminal Elongation (feet)		
	Mean	*Minimum*	*Maximum*	*Mean*	*Minimum*	*Maximum*
8	8.6	8.0	9.8	1.8	1.7	1.9
7	6.0	3.9	7.0	1.4	0.8	1.9

[1]Unpublished data on file at the Institute of Forest Genetics, Rhinelander, Wisconsin

In general, trees from Maine, northern and western Wisconsin, and east-central Minnesota sources were tallest, while those from Lower Michigan, Manitoba, and Alberta sources were shortest.

UTILIZATION OF LARCH FIBER

Although larch wood is used for pulp throughout the world, it is not highly regarded for pulp manufacture. This prejudice is due mainly to a high percentage of water soluble extractives (arabinogalactans) associated with the heartwood. These extractives interfere with the pulping reaction in acid sulphite cooks and result in high chemical consumption in the cooking and bleaching of kraft pulps (Leathart, 1969).

The distribution of extractives in larch is related to heartwood formation, and heartwood percentage is associated with age and slow growth. However, because the wood of younger trees consists largely of sapwood, its extractive content is lower, and it pulps more readily (Uprichard, 1963).

The juvenile wood of conifers is becoming more acceptable as a raw material as the demand for fiber increases. Juvenile fiber shows promise, not only as the exclusive source for certain products but also as a supplement to hardwood fiber and for mixed conifer furnishes (Zobel and Kellison, 1972). Compared with older wood, juvenile wood has a lower specific gravity, thinner-walled fibers, a lower cellulose content, and a higher incidence of compression wood (Zobel, Kellison, and Kirk, 1971), resulting in lower yields, lower strength values, and higher chemical consumption.

The lower pulp yields associated with high incidence of compression wood in young larch result from the breakdown of the cell wall and slow delignification during sulphite pulping (Philipp, Jacopian, and Casperson, 1970). This breakdown does not occur, however, during sulfate pulping (Dadswell, Wardrop, and Watson, 1958).

Current evaluations suggest that young larch wood is suitable for certain kraft products. The kraft process will undoubtedly be most important in the future due to pulping diversity and various pollution considerations. Currently there are many kraft mills in the North Central States, and the number is increasing.

Much research has demonstrated the suitability of larch fiber as a raw material. The evidence strongly suggests that larch should be used more in the future. For example, Cook (1947) observed that European larch pulped by the sulphate process was suitable for paper making. The kraft yield was only slightly less than spruce and was comparable to spruce in strength properties. Cook also believed that yields could be increased by adjusting the cooking schedules to fit the specific requirements of larch. We expect that, with the new continuous pulping processes, mills will have little difficulty in handling this problem. For example, Zaitseva, Fedorishcheva, Antonovskii, and Nikitin (1958) have shown that larch pulp yields can be increased by increasing the sulphidity in the kraft process without detracting from other pulping properties.

Nevalainen and Hosia (1969) and Hakkila, Nikki, and Palenius (1972) also concluded that larch was suitable for sulphate pulps and was comparable to spruce and pine. They found that larch pulps closely resemble southern pine kraft pulps and would be suitable for paper and boards requiring superior tear properties. Furthermore, they found that larch pulps compare favorably in other properties.

Packman (1966) also found that (although young Japanese larch wood has lower specific gravity, tracheid length, extractive content, and a higher lignin content than mature larch wood) it compares favorably in physical pulp properties with other species. Older wood, however, requires more bleaching for the desired brightness.

Further improvement in the pulping characteristics of young material can be made through selection and breeding. Breeding for improved specific gravity has been successful in southern pines (Zobel and Kellison, 1972), although the surface has only been scratched in improving wood quality, of other species such as larch. Rapid growth rate in Parch should definitely have top priority in a tree-improvement program. Some larch maintain a high specific gravity during rapid growth due to dense springwood (Pearson and Fielding, 1961). Certainly specific gravity and extractive content are important wood characteristics related to the pulping properties of young larch and should have high priority for tree improvement. Tracheid length is also a promising characteristic to be considered for tree improvement (Zobel and Kellison, 1972).

RECOMMENDATIONS

The growth data presented here suggest that the juvenile growth rate of larch planted on the best larch sites will equal or exceed that of jack pine or red pine planted on the best pine sites, and the yield of kraft pulp will exceed that of jack pine or red pine on a per cord basis.

Because larch has not been planted in the North Central States (except for experimental purposes), not enough plantation-grown larch pulpwood is available for commercial-scale pulping studies designed to compare actual yields from larch with yields from plantation-grown pine. We, therefore, recommend that small commercial-scale larch plantations be established in the North Central States.

Moreover, based upon the information presented here, we feel that site, spacing, rotation, and management recommendations can be made for the planting and genetic improvement of larch in the region.

Site requirements.—One of the most important site requirements for larch is the soil. Growth is most closely associated with soil drainage class and depth of soil. Larch should be planted on deep, moist, well drained sandy-loam to silt-loam soils (Hunt, 1932; Aird and Stone, 1955). Because larches, especially Japanese larch, are susceptible to late spring frost damage, they should be planted where there is good air drainage; frost pockets should be avoided (Cook, 1969; Heit, 1972). Larches are also shade-intolerant and should be planted in full sunlight (Cook, 1969).

Spacing.—Improved, uniform-sized material (grown under shorter rotations and closer spacings than are currently being recommended for conifer management) are necessary to obtain increased yields of fiber per acre (Larson and Gordon, 1969). This will require some modification of the current concept of spacing for large-tree forestry. Smaller trees grown at close spacings are now more acceptable for pulpwood (Zobel and Kellison, 1972).

A spacing study with European larch conducted in Germany substantiates the above ideas (Bonnemann, Huss, and Warth, 1971). Measurements after 17 and 22 years were taken on planted trees spaced at 1 x 1, 2 x 2, and 3 x 3 meters. Mortality in the 1 x 1-meter plots had exceeded 50 percent and was just becoming noticeable in the 2 x 2-meter plots after 22 years. Height growth was not affected by spacing at 17 years, but by age 22 it increased with increased spacing. Also (as spacing increased), basal area, volume production, and number of straight stems decreased while diameters of branches and incidence of canker increased. Natural beech (a potential competitor) present at time of planting died under the dense plots but survived in the widely spaced plots. We, therefore, believe that larch can be planted successfully at 6' x 6' spacings, or possibly less, with improved material.

Rotation age.—Based upon the above recommendations, a pulpwood rotation age of 20 to 25 years for larch is feasible. Exact rotation age will depend not only upon the species but also on cultural treatment and growth rate. Schreiner (1970) has recommended larch for fiber production at rotations of 6 to 16 years.

Management.—To increase fiber production per acre, more intensive management practices, such as control of competing vegetation, irrigation, and fertilization, should be utilized. Irrigation may be particularly important for larches; because they, and especially Japanese larch, are sensitive to long midsummer droughts (Heit, 1972). Young Japanese larch responds well to fertilizer applied in conjunction with irrigation.

TREE IMPROVEMENT

Selection

Studies conducted in both Europe and North America have consistently shown that Japanese larch grows faster than European larch (Aird and Stone, 1955), but it is more susceptible to both early and late frost damage (Genys, 1960). The risk of frost damage to Japanese larch would be high if the species were planted in areas such as the northern portions of the Lake States where the frost-free period is short. We believe that Japanese larch should be planted in the North Central States where a longer frost-free period would be advantageous, and that European larch and tamarack should be planted in areas where the frost-free period is short.

Seed source selection

European Larch.—Seed sources of European larch have not been adequately tested in the North Central States. Until more detailed information is available, we recommend that seed from a Sudeten source from Breslau, Poland, be used; because trees from this and nearby sources in the Sudeten Mts. in Czechoslovakia have done well in the northeast (Genys, 1960) and in early tests in the North Central States.

Japanese Larch.—Results of the NC-99 Regional Japanese Larch Seed Source Study show that seed originating from Mts. Fuji, Yatsuga, and Nantai generally produced the fastest growing trees in the North Central States. Additional gains may be obtained by collecting seed from specific stands on these mountains (Farnsworth, *et al.,* 1972).

Seeds have been rather difficult to obtain from specific stands in Japan on a regular basis. We, therfore, recommend establishment of grafted seed orchards, using scions from only the most desirable trees from frost hardy seed sources. The seed source x plantation interactions found in the NC-99 study suggest that more than one seed orchard will be required to supply the needs for the North Central area.

Japanese larch is apparently less susceptible to attack by the larch casebearer than European larch. Since about 1968, larch plantations established by the University of Michigan have suffered a moderate to serious infestation of the larch casebearer. Rust' (1972) found that Japanese larch was significantly less attacked than European larch sources.

Tamarack.—Until more data are available from the Regional NC-99 study, we recommend that seed be collected from fast-growing trees in better-than-average natural stands located near potential planting sites.

Physiological and biological selection

Shorter rotations make it possible to utilize basic information on physiological and biological parameters in a tree-improvement program (Larson, 1972). Most existing tree-improvement programs have emphasized height and diameter growth in selection and breeding. These parameters may indeed be excellent choices. We feel, however, that more physiological and biological parameters should be coupled with height and diameter.

Photosynthetic efficiency has been shown to be a useful parameter in agronomic improvement (Moss and Musgrave, 1971). Provenances that exhibit higher rates of photosynthesis and are more efficient in production of wood may be valuable in tree-improvement programs. In addition, selecting or breeding for superior plant architecture can increase plant productivity (Loomis and Williams, 1969). For example, plants with acute branch angles are more efficient at intercepting light and may be more productive. The branch habit in larch is variable and could be a basis for selection. Leaf display and leaf area are also important parameters related to wood production and should be considered.

Utilization of the growing season by a plant is also an important biological consideration. Trees that have their inherent growth pattern matched to the growing season of an area are usually more efficient in wood production. Sweet and Wareing (1968) and Wareing (1970) have shown that Japanese larch grows throughout the summer season and into autumn, thus giving it a distinct advantage over *Pinus* species.

Extractive content, as discussed previously, is an important factor in larch utilization. Larch with a low extractive content is more desirable. Hillis (1971) suggested that the extractive content can be controlled by inducing a delay in formation of heartwood or by selecting parent trees with delayed heartwood formation. This should certainly be considered in a Larch tree improvement program.

Hybridization

Probably the greatest genetic improvement in larch will occur through hybridization.

Intraspecific hybridization

Crossing of outstanding provenances or individuals within provenances of European larch and tamarack may result in considerable genetic gain. In a test recently initiated in Germany, first-season growth of progenies from selected clones of European larch from numerous areas of natural distribution have shown greater height growth than interspecific European X Japanese hybrids)

No data are available on intraspecific hybridization in tamarack. The species has a wide natural distribution, and growth of trees included in the NC-99 plantings seems to indicate much genetic variation in the species. Therefore, careful selection an breeding of tamarack may result in substantial genetic improvement.

Interspecific hybridization

Several known interspecific larch hybrids exhibit exceptional growth. The best known hybrid is a cross between Japanese and European larch that outgrows both parents on good sites in England (Leathart, 1969). Additional fast-growing larch hybrids include crosses

[1] Personal communication with W. Langner, West Germany.

between Japanese and Siberian larch, Siberian and European larch (MacGillivray, 1969), and tamarack and Japanese larch (MacGillivray, 1969; Lester, 1970). Some of these hybrids also combine other desirable characteristics of the parent species. For example, the tamarack-Japanese larch cross combines the rapid growth of Japanese larch and the adaptability of tamarack to shorter growing seasons.

Testing of the Japanese-European larch hybrid is one of our highest priorities, particularly in the Lake States area.

CONCLUSIONS

We believe that larch is a good potential candidate for shorter pulpwood rotations grown under intensive management in the North Central States and recommend that larch planting programs be started now. The initial plantings can be established on the basis of available data, and only the seed sources recommended here should be used. Some additional testing of seed sources will be required in those areas in the North Central States where inadequate tests or no tests have been conducted. Such testing may yield new and even better provenances, providing additional material for future breeding.

Simultaneously, applied breeding programs will lead to even greater improvement. Individual tree selection, made on the basis of outstanding height and diameter growth coupled with physiological and biological criteria from the most promising, best-adapted seed sources, can be utilized in the development of seed orchards.

Probably the greatest improvement in larch will occur through hybridization of the best individuals from the best seed sources, both within and between species.

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