Ecology and Management of Larix Forests: A Look Ahead

Proceedings of an International Symposium

Whitefish, Montana, U.S.A.
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Compilers:

Wyman C. Schmidt
Kathy J. McDonald

Knowledge-Based Systems for Larix Forests
Jimmie D. Chew and Elizabeth D. Reinhardt

We have the information necessary to manage natural resources wisely, but it is often difficult to access and use. The information is often fragmented, unwieldy, and time consuming to use. Methods of sharing, distributing, and applying this knowledge are not well developed. But social demands have resulted in increasing complexity in resource management, and economic considerations demand that we look for more efficient ways to capture our knowledge and make it usable.

A combination of fundamental concepts from systems science and principles from artificial intelligence can be used to develop a broad category of decision support systems known as knowledge-based systems. For the Larix forests of the Northern Rockies, several knowledge-based systems exist in various stages of development to help make information accessible and to interpret it for application. These systems cover the range of scales from landscape analysis to individual stand prescriptions.

Landslide Analysis System
A knowledge-based system is currently being developed to provide a framework for the application of the Forest Service's Northern Region's ecosystem management effort. This system will use concepts associated with landscape structure, function, and change. Rule-based components will be used to identify structure and make inferences for function. Knowledge on ecosystem processes will be used to identify the probability of change in both structure and function. The interpretation of changes will be used to design desired landscapes. Differences between current and desired landscapes can identify where management activities are needed to achieve and maintain ecosystem functioning.

Stand Diagnosis System
Whether or not one has used a landscape-level analysis to identify large, contiguous areas of stands that need to be evaluated for treatment needs, the stand diagnosis expert system (Chew 1989) is available. This knowledge-based system is called an expert system because it captures the expertise of silviculturists in diagnosis in the silvicultural prescription process. This step compares the existing stand to a desired future condition, a target stand, and identifying possible treatment needs. Silviculturists' and other resource specialists' knowledge in identifying stand conditions that are necessary to meet specific resource objectives on specific types of sites, is captured within the target stands. Stocking level concepts in the Regional Silvicultural Practices Handbook are a fundamental part of the target stand. Limitations on harvest methods identified by Forest Plans or habitat type guidelines are used. Insect and disease information is incorporated as hazard ratings. The system captures local variables such as how suitable leaf trees are defined and how one determines the feasibility of removing overstories. The system is available for National Forests within the Northern Region.

The treatment alternatives developed by the system are not prescriptions. Additional interdisciplinary work is necessary before a choice can be made from the possible

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treatments. For the chosen treatment, the silviculturist has to develop a sequence of detailed activities that compose the prescription.

**STAND CULTURE SYSTEM**

To help prepare the detailed prescriptions, another system is being developed to use the existing research knowledge that is available for stand culture. The results of research at Miller Creek and Coram Experimental Forest on thinning and regeneration of western larch will provide the initial basis for the system. Concepts in stand dynamics will be incorporated into the system. This knowledge will be combined with many tools that are currently available at the Forest and District level such as rating guides for thinning stands. The system will provide a vehicle for technology transfer and consistency in making sure knowledge is applied at the prescription level.

**PRESCRIBED FIRE SYSTEM**

Prescribed fire is used to manipulate forest ecosystems to accomplish a variety of resource management objectives. Managers use information from a variety of sources that include results of scientific research and of their own experience. A knowledge-based system (Reinhardt and others, in press) was developed to retrieve both technical and qualitative information and interpret it for application. Site data and the manager’s objectives for treating the site with prescribed fire are user inputs to the expert system. The system develops a fire prescription: ranges of acceptable fire effects, a description of the desired fire treatment, and a range of conditions under which to burn to achieve the desired treatments and effects. The system’s performance was validated using data from research burns in a variety of forest types throughout the Interior West of the United States. It performed well within the limited geographical domain of that area.

**REFERENCES**


Reinhardt, E. D.; Wright, A. H.; Jackson, D. H. [In press]. Development and validation of a knowledge-based system to design fire prescriptions. AI Applications. 6(4).

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**Can Western Larch Plantations Survive and Grow on the East Slope of the Montana Rockies?**

Dennis M. Cole and Jack A. Schmidt

With minor local exceptions, the range of western larch (*Larix occidentalis* Nutt.) is restricted to mountainous maritime-influenced areas west of the Continental Divide in the United States and Canada. Frost effects on the flowering and seed production phases are often factors limiting natural regeneration of western larch. However, it has long been known that planted western larch can survive and grow east of the Continental Divide in Montana.

For some years, we have heard of western larch being planted on different eastside Ranger Districts in National Forests, so we made a survey of them, and of personnel of other agencies, to find out more. We were informed of 15 western larch plantings east of the Divide and were able to locate nine of them (fig. 1), each representing a different forest habitat type (table 1). Elevations of the planting sites ranged from 1,340 to 2,164 m, and ages of the plantings ranged from 11 to 25 years.

General differences in survival, development, and condition of the planted western larch could be seen between the different plantations. Because few records exist on the plantations, neither percent survival nor the origin of planting stock could be determined in most cases. However, from visual examinations, we conclude that some of the larch in each plantation will likely persist—perhaps even to maturity.

The major factor limiting fully successful establishment at all sites was frost damage to terminal leaders. This
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of abnormal meiosis. Around 16 percent of its PMC’s were degenerated, and 12.4 percent of cells formed aberrant microspores. We believe that high frequency of meiotic irregularity in Siberian larch was partly due to its earliness in meiosis.

Pollen Germination

Tamarack showed the highest germination rate (78.7 percent) while European larch was the lowest (46.5 percent). The germination tests revealed that there was little correlation between frequency of meiotic abnormality and pollen germination. For example, the pollen germination rate of Siberian larch was higher than that of Japanese larch, which had the lowest in frequency of meiotic abnormality. This result indicated that some meiotic irregularities could recover to form normal pollen, while pollens that seemed cytologically normal may have other deficiencies.

Pollination Frequency

Pollination frequencies were more than 90 percent except in tamarack, whose frequency was 75 percent. Furthermore, most of the ovules were pollinated with more than one pollen. This fact indicated that pollen quality was not the major factor reducing seed yield.

Abortion of Female Strobili

Strobili abortion soon after pollination was high in all four species. In Siberian larch, about 80 percent of strobili were aborted either by contact with pollination bags or by frost damage.

Degeneration of Female Gametophytes

Abortion of ovules before fertilization, which gave rise to flat seeds, was observed in 4 to 6.8 percent of ovules depending on the species.

Fertilization Frequency

Frequency of ovules in which fertilization had occurred ranged 75 to 90 percent depending on the cross. The cross between tamarack and European larch was the lowest, while the cross between European larch and Japanese larch was the highest. It seemed that there might be a certain degree of incompatibility between some larch species.

Embryo Degeneration

Embryo degeneration during early stages of development was common in all four species. Embryos degenerated in 20 to 40 percent of the fertilized ovules depending on the cross but were most common in the tamarack x European larch cross. The frequency of polyembryony at the early stage of embryo development influenced later stage embryo condition. It is possible that competition among embryos in a seed contributed to degeneration of embryos.

Larix Lyallii and Larix Occidentalis Within USDA Forest Service Research Natural Areas

Angela G. Evenden

The Forest Service, U.S. Department of Agriculture, participates in a federal program to develop a national network of Research Natural Areas. The major goal of this network is to preserve a representative array of all significant natural ecosystems and their inherent processes as ecological baseline areas. The Forest Service has established nearly 300 Research Natural Areas nationwide. These areas are important ecological reference sites and are used for scientific studies, education, and long-term ecological monitoring. The areas are managed to maintain natural conditions, with as little human intervention as possible. However, in some ecosystems, human activities have interrupted natural processes.

In these cases, prescribed management actions may be required to restore the processes upon which the natural communities and species depend. Habitat type and plant association classification systems are often employed to set targets for ecosystems to include within the Research Natural Areas network. Larix lyallii (alpine larch) and L. occidentalis (western larch) are represented in these areas within a variety of classified vegetation types. Larix lyallii is found at high elevations, often near treeline, in Abies lasiocarpa forest types of Idaho, Montana, and Washington. Table 1 lists the eight areas in the Northwestern United States containing L. lyallii. Larix occidentalis is a seral component of mid-elevation Pseudotsuga menziesii forest types. Old-growth and mature stands of L. occidentalis occur within 27 areas in Idaho, Montana, Oregon, and Washington (table 2). Common overstory dominants in these RNAs...
Table 1—List of Research Natural Areas (RNA) on National Forest System lands in Idaho and Montana representing subalpine forests dominated by *Larix lyallii* Parl. (alpine larch). National Forest, RNA size (hectares), elevation range (meters), and associated species are also presented.

<table>
<thead>
<tr>
<th>State and RNA</th>
<th>National Forest</th>
<th>RNA size (ha)</th>
<th>RNA elevation range (m)</th>
<th>Associated tree species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IDAHO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allan Mountain</td>
<td>Sawtooth</td>
<td>668</td>
<td>2,912 to 3,707</td>
<td>Abies lasiocarpa</td>
</tr>
<tr>
<td>Grave Peak</td>
<td>Clearwater</td>
<td>146</td>
<td>2,088 to 2,524</td>
<td>Pinus albicaulis, Abies lasiocarpa</td>
</tr>
<tr>
<td>Salmon Mountain</td>
<td>Bitterroot</td>
<td>778</td>
<td>1,939 to 2,682</td>
<td>Pinus albicaulis, Picea engelmannii, Abies lasiocarpa</td>
</tr>
<tr>
<td><strong>MONTANA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bass Creek (proposed)</td>
<td>Bitterroot</td>
<td>803</td>
<td>1,244 to 2,564</td>
<td>Pinus albicaulis</td>
</tr>
<tr>
<td>Carlton Ridge</td>
<td>Lolo</td>
<td>372</td>
<td>1,700 to 2,500</td>
<td>Pinus albicaulis (overlaps with <em>Larix occidentalis</em> at lower limits in RNA)</td>
</tr>
<tr>
<td>Dexter Basin (proposed)</td>
<td>Deerlodge</td>
<td>448</td>
<td>2,347 to 3,899</td>
<td>Abies lasiocarpa</td>
</tr>
<tr>
<td>Sapphire Divide (proposed)</td>
<td>Bitterroot</td>
<td>546</td>
<td>2,316 to 2,708</td>
<td>Pinus albicaulis, Picea engelmannii, Abies lasiocarpa</td>
</tr>
<tr>
<td>Tuchuck</td>
<td>Flathead</td>
<td>635</td>
<td>1,585 to 2,220</td>
<td>Pinus albicaulis, Abies lasiocarpa</td>
</tr>
</tbody>
</table>

Table 2—List of Research Natural Areas (RNA) on National Forest System lands in Idaho, Montana, Oregon, and Washington representing subalpine forests dominated by *Larix occidentalis* Nutt. (western larch). National Forest, RNA size (hectares), elevation range (meters), and associated species are also presented.

<table>
<thead>
<tr>
<th>State and RNA</th>
<th>National Forest</th>
<th>RNA size (ha)</th>
<th>RNA elevation range (m)</th>
<th>Associated tree species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IDAHO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquarius</td>
<td>Clearwater</td>
<td>1,579</td>
<td>488 to 1,218</td>
<td>Thuja plicata, Pinus monticola, Abies grandis, Pseudotsuga menziesii</td>
</tr>
<tr>
<td>Bear Creek</td>
<td>Payette</td>
<td>126</td>
<td>2,106 to 2,537</td>
<td>Pseudotsuga menziesii</td>
</tr>
<tr>
<td>Cuddy Mountain</td>
<td>Payette</td>
<td>425</td>
<td>1,474 to 2,754</td>
<td>Pseudotsuga menziesii</td>
</tr>
<tr>
<td>Hunt Girl Creek</td>
<td>Idaho Panhandle</td>
<td>609</td>
<td>1,200 to 1,900</td>
<td>Thuja plicata, Tsuga heterophylla, Pinus monticola, Abies grandis</td>
</tr>
<tr>
<td>Montford Creek</td>
<td>Idaho Panhandle</td>
<td>118</td>
<td>930 to 1,341</td>
<td>Pseudotsuga menziesii, Abies grandis, Pinus monticola</td>
</tr>
<tr>
<td>Upper Fishhook</td>
<td>Idaho Panhandle</td>
<td>130</td>
<td>1,823</td>
<td>Thuja plicata, Abies grandis, Pinus monticola, Pseudotsuga menziesii</td>
</tr>
<tr>
<td>Upper Shoshone Creek</td>
<td>Idaho Panhandle</td>
<td>534</td>
<td>1,090 to 1,954</td>
<td>Pseudotsuga menziesii, Pinus contorta</td>
</tr>
</tbody>
</table>

(con.)
Table 2 (Con.)

<table>
<thead>
<tr>
<th>State and RNA</th>
<th>National Forest</th>
<th>RNA size (ha)</th>
<th>RNA elevation range (m)</th>
<th>Associated tree species</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONTANA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bass Creek</td>
<td>Bitterroot</td>
<td>803</td>
<td>1,244 to 2,564</td>
<td><em>Pseudotsuga menziesii</em>, <em>Abies grandis</em></td>
</tr>
<tr>
<td>Barktable Ridge</td>
<td>Lolo</td>
<td>341</td>
<td>1,646 to 1,905</td>
<td><em>Pinus ponderosa</em>, <em>Pinus monticola</em>, <em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>Big Creek</td>
<td>Kootenai</td>
<td>77</td>
<td>745 to 800</td>
<td><em>Pinus ponderosa</em>, <em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>Carlton Ridge</td>
<td>Lolo</td>
<td>372</td>
<td>1,700 to 2,500</td>
<td><em>Abies lasiocarpa</em>, <em>Picea engelmannii</em>, <em>Pinus contorta</em> (overlaps with <em>Larix lyallii</em> at upper limits in RNA)</td>
</tr>
<tr>
<td>Coram</td>
<td>Flathead</td>
<td>340</td>
<td>1,060 to 1,440</td>
<td><em>Pseudotsuga menziesii</em>, <em>Abies lasiocarpa</em></td>
</tr>
<tr>
<td>Lower Ross Creek</td>
<td>Kootenai</td>
<td>368</td>
<td>866 to 1,402</td>
<td><em>Thuja plicata</em>, <em>Pinus contorta</em></td>
</tr>
<tr>
<td>Petty Creek</td>
<td>Lolo</td>
<td>125</td>
<td>1,200 to 1,500</td>
<td><em>Pseudotsuga menziesii</em>, <em>Pinus contorta</em>, <em>Abies grandis</em></td>
</tr>
<tr>
<td>Plant Creek</td>
<td>Lolo</td>
<td>105</td>
<td>1,500</td>
<td><em>Pseudotsuga menziesii</em>, <em>Pinus contorta</em></td>
</tr>
<tr>
<td>Pyramid Creek</td>
<td>Lolo</td>
<td>210</td>
<td>1,600 to 2,460</td>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>Swan River</td>
<td>Flathead</td>
<td>276</td>
<td>942 to 1,049</td>
<td><em>Pinus contorta</em>, <em>Pinus monticola</em>, <em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>Ulm Peak</td>
<td>Kootenai</td>
<td>279</td>
<td>1,273 to 1,953</td>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>Wolf-Weigel</td>
<td>Kootenai</td>
<td>101</td>
<td>1,082 to 1,311</td>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>OREGON</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canyon Creek</td>
<td>Malheur</td>
<td>284</td>
<td>1,433 to 1,798</td>
<td><em>Pseudotsuga menziesii</em>, <em>Abies grandis</em></td>
</tr>
<tr>
<td>Indian Creek</td>
<td>Wallowa Whitman</td>
<td>396</td>
<td>1,872 to 2,125</td>
<td><em>Pseudotsuga menziesii</em>, <em>Pinus contorta</em>, <em>Abies lasiocarpa</em>, <em>Tsuga mertensiana</em></td>
</tr>
<tr>
<td>Metolius</td>
<td>Deschutes</td>
<td>581</td>
<td>850 to 1,460</td>
<td><em>Pseudotsuga menziesii</em>, <em>Pinus ponderosa</em>, <em>Arctostaphylos patula</em></td>
</tr>
<tr>
<td>Mill Creek</td>
<td>Mt. Hood</td>
<td>330</td>
<td>790 to 1,040</td>
<td><em>Abies grandis</em>, <em>Pinus ponderosa</em></td>
</tr>
<tr>
<td>Ochoco Divide</td>
<td>Ochoco</td>
<td>777</td>
<td>1,250 to 1,650</td>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>Rainbow Creek</td>
<td>Umatilla</td>
<td>170</td>
<td>1,100 to 1,440</td>
<td><em>Abies grandis</em>, <em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td>WASHINGTON</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meeks Table</td>
<td>Wenatchee</td>
<td>27</td>
<td>1,280 to 1,585</td>
<td><em>Pseudotsuga menziesii</em>, <em>Calamagrostis rubescens</em></td>
</tr>
<tr>
<td>Salmo</td>
<td>Colville</td>
<td>563</td>
<td>1,158 to 2,080</td>
<td><em>Thuja plicata</em>, <em>Tsuga heterophylla</em></td>
</tr>
</tbody>
</table>

are *Pseudotsuga menziesii*, *Abies grandis*, *Thuja plicata*, and *Pinus monticola*.

All Research Natural Areas are available to the scientific community for nonmanipulative research and ecological monitoring. Permission to utilize an area for research may be obtained through the National Forests and the Forest Service Research Stations.
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The Role of Epicormic Branches in the Life History of Western Larch

Ronald M. Lanner

Abstract—As a western larch (Larix occidentalis) tree matures, its first-order branches decline, die, and are replaced by clustered epicormics that form a replacement crown. These epicormics grow from dormant buds at first-order branch-bases, appearing at successively higher positions in the crown, eventually making up entire crowns of old trees. Crown replacement is a normal life-history trait which prolongs the life span, not an injury response. It occurs in Larix, Pseudotsuga, Abies, Picea, Tsuga, Sequoia, and Sequoiadendron.

The first-order branches of larch originate from the elongation of axillary buds formed on the leading shoot. As leader growth continues over the years, a first-order branch that was at the time of its formation the uppermost branch in the crown finds itself progressively lower in the crown and eventually becomes the lowermost live branch. After a period of decline, it may die and eventually fall from the tree. During this process of crown formation and recession, a branch's characteristics change, as well as its position in relation to other branches. It grows longer, it spreads laterally by producing one or more additional orders of branching, and it grows in diameter. Its orientation changes from an acute angle to a right angle. The stress at its junction with the bole is increased not only by the weight of new biomass but by snow-loading, rain-soaking, wind-torque, birdnest, mistletoe witchesbrooms, and epiphytic lichens. Each year's suite of foliage is farther from the source of its water and more exposed to drying winds. In the meantime its light environment is changing from unshaded to progressively more heavily shaded.

In this paper I maintain that these changes set limits on the size, and therefore the age, that a branch can attain, and they eventually lead to its death. The death of a branch, however, is not detrimental to the tree as a whole because larch is equipped with embryonic replacement branches whose release mitigates the effects of the loss. These replacements are of epicormic origin—they result from the outgrowth of dormant buds located at the base of the first-order branches. Finally, the new replacements, which eventually dominate the crown, prolong the tree's life.

This argument is based on preliminary data and observations reported here, through analogy with Douglas-fir (Pseudotsuga menziesii), and on speculation.

MATERIALS AND METHODS

Observations of standing western larch have been made at several Montana locations: Seeley Lake and vicinity, Morrell Lake Trail (Lolo National Forest), and Coram Experimental Forest. Stands at Coram were aged 45 years, 60 to 70 years, and 350 to 500 years (residual old growth) (Shearer 1992). Trees at the other locations were old growth, aged 300 to 500 years. Elevations of the observed stands ranged from 900 to 1,375 m. Associated species at Coram Experimental Forest were white spruce (Picea glauca), Douglas-fir, western white pine (Pinus monticola), and lodgepole pine (P. contorta). Associates at the Morrell Falls Trail were Engelmann spruce (P. engelmannii), subalpine fir (Abies lasiocarpa), Douglas-fir, and lodgepole pine. Trees were measured with an Abney level and diameter tape, and branches were viewed with 10 x binoculars.

RESULTS

The 45-year-old stand on the South Fork of Abbott Creek had been thinned about 30 years prior to examination. A sample of four typical trees was 20 to 25 cm diameter at breast height (d.b.h.) (23) and 20 to 23 m in height (2 = 20.9). Height to the first live branch (base of live crown) was 2 to 5 m (2 = 4.1). These trees and 16 others were examined for the presence of epicormic shoots arising from the bole and from lower first-order branch bases. About half the trees had such shoots, the longest of which were about 0.3 m in length (fig. 1). Several of these had sprouted 2 years previously and were unbranched. Some of the epicormics arose from the bole and some from branch bases. Due to the difficulty in seeing where all of them originated, however, the percentages of each category cannot be stated. None were in clusters. The first-order branches that made up the crowns were in distinct whorls and appeared evenly spaced around the circumference of the bole.

The trees in the 65 to 70-year-old stand were widely interspersed among Douglas-firs and lodgepole and western white pines. Four typical trees ranged from 38 to 46 cm d.b.h. (2 = 41.9) and from 24 to 26 m in height (2 = 24.6). Some of these sample trees were adjacent to a meadow and had live branches to within 30 cm of the ground surface. On one tree an epicormic shoot about 45 cm long had sprouted several years previously from the stub of a 7.6-cm diameter branch that had been broken off at a height of 5 m. In several instances epicormic shoots emerged singly or in groups of two or three from the bases of lower limbs that were still alive. The first-order branches

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composing the tree crowns tended to be evenly spaced around the circumference of the boles and in distinct whorls.

The old-growth western larches are along the South Fork Road at the southwest corner of the Coram Experimental Forest Natural Area. The stand consists of emergent, scattered larches with an understory of lodgepole and western white pines, white spruce, and northern black cottonwood (*Populus trichocarpa*). Six typical trees (table 1) ranged from 76 to 99 cm d.b.h. (x = 82.5) and 44 to 49 m in height (x = 46.6). Heights to base of live crown were 9 to 18 m (x = 14.1). In most of these trees' crowns, two distinctive branch types could be discerned. The lower limbs of all the trees emerged from the bole in clusters of usually two or three contorted or drooping branches. Many of these were associated with the conspicuous stubs of fallen first-order branches. The upper limbs of all but one tree appeared to be relatively straight first-order limbs emerging singly from the bole. The only tree lacking these limbs had a 9-m long dead spike-top and a crown below the spike made up entirely of clustered branches. Due to visibility problems (parallax, epiphytic lichen growth, dense branching) it was never possible to be certain of the height of the uppermost clustered branches or the lowermost single first-order limbs. In all cases, however, the clustered branches made up the major part of the crown (table 1), and in all trees except the one with a dead spike, there was a zone in midcrown in which both categories of branches occurred (fig. 2).

**DISCUSSION**

If we interpret the branching characteristics of these trees of various ages to represent a developmental continuum, an interesting pattern emerges. Apparently, the original first-order branches eventually die and are replaced by clusters of epicormics that often emerge from the bases of those first-order branches ("primaries") while the primaries still live. This process of primary branch replacement begins at the crown base and continues gradually upward. When carried to completion, the replacement process results in a crown comprised entirely of branches of epicormic origin. Thus, trees living on into old age would eventually be totally supported by replacement crowns whose components originated as epicormic branches.

An interesting physiological question is: What triggers the emergence of these epicormic branches? Epicormics are often symptoms of injury or stress that result from the release of inhibited buds in the tree bole or on major limbs. Release has been variously attributed to thinning shock (Powells 1965), pruning (Cosens 1952), or air pollutant stress ("Angsttriebe," Westman and Lesiński 1985). The mistaken notion that epicormics are rare in conifers has long persisted (Harlow and others 1979). In an earlier study on epicormic branching in Douglas-fir, Bryan and Lanner (1981) were unable to find any evidence that such branching depends on perturbations for its expression. Instead, they regarded the appearance of epicormics as "a routine event in the normal life cycle of the tree" and speculated that no exogenous triggering mechanism was required.

My observations reported here shed no new light on this question. The 45-year-old stand and the old-growth stand had been previously thinned or partially cut, so we cannot exclude the possibility that a change in stand density stimulated epicormic branching. Such an influence does,

![Figure 1](image)

**Figure 1**—Epicormic shoots arising from the base of a first-order branch on a 45-year-old western larch on the Coram Experimental Forest, MT.

**Table 1**—Crown characteristics of six 350- to 500-year-old western larches on the Coram Experimental Forest, MT

<table>
<thead>
<tr>
<th>Tree</th>
<th>Diameter at breast height (cm)</th>
<th>Total height (m)</th>
<th>To first epicormic cluster (m)</th>
<th>To highest epicormic cluster (m)</th>
<th>To first live primary branch (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>99</td>
<td>48.2</td>
<td>9.1</td>
<td>39.6</td>
<td>24.4</td>
</tr>
<tr>
<td>2</td>
<td>76</td>
<td>46.3</td>
<td>17.7</td>
<td>39.0</td>
<td>46.5</td>
</tr>
<tr>
<td>3</td>
<td>81</td>
<td>43.9</td>
<td>12.8</td>
<td>34.8</td>
<td>29.3</td>
</tr>
<tr>
<td>4</td>
<td>81</td>
<td>46.6</td>
<td>12.8</td>
<td>37.2</td>
<td>32.3</td>
</tr>
<tr>
<td>5</td>
<td>79</td>
<td>48.8</td>
<td>17.1</td>
<td>39.6</td>
<td>28.0</td>
</tr>
<tr>
<td>6</td>
<td>79</td>
<td>45.7</td>
<td>15.2</td>
<td>36.6</td>
<td>none</td>
</tr>
<tr>
<td>Mean</td>
<td>82.5</td>
<td>46.6</td>
<td>14.1</td>
<td>37.8</td>
<td>32.1</td>
</tr>
</tbody>
</table>

*Uppermost 9 m is dead.*
Epicormic branching is not necessarily induced in larch by exogenous effects but may indeed occur routinely even in the absence of such effects. For example, Nairn (1958) reported "adventitious branches" on tamarack (L. laricina) following sawfly attack, and Burns and Honkala (1990) stated that western larch responds to release by producing "sprouts from adventitious buds on the upper bole." But according to Pierce (1960), western larch produces epicormics upon self-pruning, the replacement process that is the subject of this paper.

An obvious question from the standpoint of evolutionary ecology might be: What possible advantage is there in replacing established branches with new ones? This offers fertile ground for speculation.

Big persistent limbs have several liabilities. They are heavy, especially when loaded with rain-soaked lichens, snow, birds nests, and witchesbrooms. Thus, they require for support a large woody mass with its considerable need for maintenance respiration. If they cannot create that necessary support they may break off, leaving a large wound on the trunk and broken branches.

Big limbs high in the crown act dangerously like sails in the wind, increasing susceptibility to windthrow. Limbs like those of western larch, which frequently and systemically become infected by dwarf mistletoe, can act as conduits for the parasite into the tree's bole. The longer an infected limb persists, the greater a threat it is for its parent tree. Weir (1916) called attention to the "secondary crown" of epicormics that results after infected branches, laden with brooms, are "lopped" from larch crowns by the wind. He illustrated a trunk cross section showing four "generations" of a regenerating branch base. Heaps of fallen witchesbrooms were often found at the base of infected larches.

It is thus advantageous for western larch to allow its primary limbs a limited life-span, replacing them with clusters of wiry little branches that emerge from long-dormant buds residing within the bases of the very branches they are replacing, that are economical to maintain, and that could be shed when they start to become liabilities. I have recently observed this process occurring commonly on European larch (L. decidua) in the Swiss Alps and in alpine larch (L. lyallii) in northwestern Montana.

In addition to the widespread occurrence of epicormic replacement branches in Douglas-fir (Bryan and Lanner 1981) and larch, I have also observed it in Abies, Tsuga, Picea, Sequoia, and Sequoiadendron. Thus, a genetically programmed "ontogenetic shift" in branch formation appears among several important coniferous genera. Not surprisingly, ontogenetic changes occur in these long-lived organisms. During its early years, a tree is in competition for the atmospheric volume it needs to grow into, so its growth strategy must emphasize "shoots of exploration," rapidly elongating axes that capture volume. Later, its major need is to produce less energetically demanding "shoots of exploitation" that bear masses of foliage on minor axes (Edelin 1977; Thiebaut and others 1981). A better understanding of this shift can only emerge from detailed study of old trees—a category of research that has been sorely neglected in forestry.

REFERENCES


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October 5-9, 1992

Compilers:

Wyman C. Schmidt
Kathy J. McDonald
Figure 1—Stem taper equation for Japanese larch by development in tree size as for tree 349 in the permanent sample plot GV, Giesegaard estate, in every 10 years of the period 1915 to 1965.

REFERENCES


Effect of 20 Years of Regulated Stand Densities on Bole Form of Young Western Larch

Ward W. McCaughey, Wyman C. Schmidt, and Jack A. Schmidt

Because of economic factors such as increasing mill costs and diminishing wood supplies, accurate tree volumes and dimensional characteristics are essential if our wood resources are to be fully utilized. And because utilization standards are constantly being adjusted toward use of smaller stems, a bole form or taper function equation is an important factor in tree volume calculations.

Bole form varies considerably between species within the Intermountain West (Amidon 1984; Van Hoosier and Chojnacky 1983). Volume equations for western larch (Larix occidentalis Nutt.) have been developed using a variety of bole form equations, but they did not account for spacing effects (Plank and Snellgrove 1978). In this paper, we describe a study designed to evaluate bole form differences between three spacing levels at four locations in western Montana. Girads and Absolute form quotients were used as measures of bole form.

METHODS

This study complements a larger study on spacing effects on the growth and development of western larch.
Schmidt and Seidel 1988) and was initiated to evaluate the effects of three spacings on the bole form of "young" western larch in western Montana. In 1961, four study areas were established in western Montana—two on the Coram Experimental Forest and one each on the Flathead and Lolo National Forests. Each location contained extensive overstocked stands of young, 7- to 9-year-old, western larch reproduction with minor components of Engelmann spruce (Picea engelmannii Parry ex Engelm.) and Douglas-fir (Pseudotsuga menziesii var. glauca [Beissn.] Franco). These young stands at each location were thinned in 1961 to a wide range of densities. From the 704, three initial stand densities of 704 (1740 TPA), 360 (890 TPA), and 146 (360 TPA) trees per hectare of pure western larch were selected for evaluating bole form.

After growing at these stand densities for 20 years, the study plots were thinned again in early 1982 to wider spacings at the four locations, and felled trees were sampled for this study (table 1). Ten thinned trees in each 0.04 ha plot were randomly selected for bole form measurements. Sample trees were marked at 13 locations along the bole, and outside bark diameter and bark thickness was measured and recorded (fig. 1). Outside bark diameters were measured with a diameter tape to the nearest 0.25 cm. Bark thickness was measured with a Swedish bark gauge to the nearest 0.13 cm. Total height was also measured on sample trees and recorded to the nearest 0.3 m.

Outside bark diameter and bark thickness measurements were taken on each sample tree at the following locations along the bole:

1. 1.37 m aboveground, diameter at breast height (d.b.h.)
2. 4.9 m aboveground
3. One-half total height above 1.37 m
4. Deciles of total height (base of each section)

Inside bark diameters were calculated by subtracting twice the bark thickness from the outside bark diameter value at each measurement location. Decile measurements were used to construct graphic representations of average bole forms. Bole form quotients (Girards and Absolute) were computed and evaluated for their between-spacing differences. Analysis of variance from the SAS computer statistical package was used to analyze spacing effects on tree heights, outside bark diameters, Girards (GFQ), and Absolute (AFQ) form quotient. All significance tests were computed at the $p \leq 0.05$ level. Equations used to compute GFQ and AFQ were:

$\text{Girards form quotient} = \frac{d_1}{D_1} \times 100$

$\text{Absolute form quotient} = \frac{d_2}{D_2} \times 100$

where $d_1 =$ diameter inside bark at 4.9 m
$D_1 =$ diameter outside bark at breast height

$D_2 =$ diameter inside bark at one-half total height
$D_2 =$ diameter inside bark at breast height

### RESULTS

Mean tree heights and outside bark diameters generally increased as stand density decreased from 704 to 360 to 146 trees per hectare (TPH) (table 2). Outside bark diameters at the 146 TPH stand density were always significantly larger than the 704 and the 360 TPH stand densities.
The 360 TPH stand density had significantly larger diameters than the 704 TPH stand density with the exception of Pinkham Creek, which still showed an absolute but not significant increase. Figure 2 demonstrates average bole configuration for western larch trees growing at 146, 360, and 704 TPH for all four study locations. An opposite relationship exists between high and low values for GFQ and AFQ. A high GFQ value indicates a more buttressed tree form in comparison to a lower GFQ value, while a high AFQ value indicates a less buttressed tree form in comparison to a lower AFQ value.

Results from analysis of variance for Girard's form quotient (GFQ) for the four study locations showed that Cottonwood Lakes was significantly different from Coram 1, Coram 2, and Pinkham Creek. Stand density differences using GFQ were analyzed separately for Cottonwood Lakes and pooled for the other three study locations. Girard's form quotient could not be computed for the 704 TPH stand density at Cottonwood Lakes because sample trees were less than 4.9 m tall. There was no significant difference in GFQ between the 360 (GFQ 34.6) and 146 (GFQ 31.2) TPH stand density at Cottonwood Lakes.

The GFQ of 64.8 for the 146 TPH stand density was significantly greater than the GFQ of 57.5 for the 360 and the GFQ of 50.2 for 146 TPH stand densities for the combined data set of Coram 1, Coram 2, and Pinkham Creek. There was no significant difference in the GFQ between the 360 and 146 TPH stand densities for the three combined areas.

The AFQ value for Coram 2 was significantly different from Coram 1, Cottonwood Lakes, and Pinkham Creek, which were not significantly different from each other. Density differences using AFQ were analyzed separately for Coram 2 and pooled for the other three study locations. The AFQ of 56.3 for the 146 TPH stand density was significantly lower than the AFQ of 61.3 for the 360 TPH and the AFQ of 59.7 for the 704 TPH stand densities at Coram 2. The AFQ values for the two denser spacings at Coram 2 did not differ significantly. There were no significant differences in AFQ values between the three densities for the pooled areas. However, there was an absolute increase in AFQ as stand densities changed from 704 (AFQ 56.5) to 360 (AFQ 57.5) to 146 (AFQ 58.6) TPH.

DISCUSSION AND CONCLUSIONS

These bole form data describe the dimensions of trees that could be used in thinning from below. Thinning from below is a practice commonly used in young western larch stands and best fits the biology of this highly shade-intolerant species. As a result, most trees removed in early thinnings, such as trees in this study, are potentially those that would be used for small diameter wood products.

Only trees removed by thinning were sampled for this study, and as with any thinning, they generally were the slowest growing trees. In spite of that, relative differences in bole form between stand densities are evident as shown by differences in visual appearance of bole form (fig. 3), mean height and outside bark diameter measures (table 2), and in Girard and Absolute form quotients. Trees growing under a low stand density of 146 TPH, compared to

---

### Table 2—Mean total height and outside bark diameter at breast height (d.b.h.) of western larch grown under three spacing levels at four locations in western Montana

<table>
<thead>
<tr>
<th>Area</th>
<th>Spacing level</th>
<th>Trees per ha</th>
<th>Total height (m)</th>
<th>Outside bark d.b.h. (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coram 1</td>
<td>704</td>
<td>A</td>
<td>7.5</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>B</td>
<td>9.2</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>146</td>
<td>C</td>
<td>12.6</td>
<td>C</td>
</tr>
<tr>
<td>Coram 2</td>
<td>704</td>
<td>A</td>
<td>8.7</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>B</td>
<td>9.4</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>146</td>
<td>C</td>
<td>10.8</td>
<td>C</td>
</tr>
<tr>
<td>Cottonwood Lakes</td>
<td>704</td>
<td>A</td>
<td>4.1</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>B</td>
<td>6.6</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>146</td>
<td>C</td>
<td>6.6</td>
<td>C</td>
</tr>
<tr>
<td>Pinkham Creek</td>
<td>704</td>
<td>A</td>
<td>9.2</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>B</td>
<td>9.0</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>146</td>
<td>C</td>
<td>11.4</td>
<td>B</td>
</tr>
<tr>
<td>All areas combined</td>
<td>704</td>
<td>A</td>
<td>7.4</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>B</td>
<td>8.6</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>146</td>
<td>C</td>
<td>10.3</td>
<td>C</td>
</tr>
</tbody>
</table>

1. Different letters within a column, by individual area, denote significant differences at the p ≤ 0.05 level.

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**Figure 2**—Visual representation of bole configuration for western larch trees growing at 146, 360, and 704 trees per hectare. All four study locations have been pooled and averaged.

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higher densities, are significantly taller, have larger outside bark diameters, and have GFQ and APQ values consistently larger or smaller, respectively.

The visual representation of bole form for the 146 TPH stand density indicate that trees appear to be blocky with more taper than trees growing under the 360 or 704 TPH stand densities. This is due to less competition from other trees, more growing space, and greater crown retention by this highly shade-intolerant species. Crown development was not a part of this supplemental study but will be evaluated in the main study on spacing effects on the growth and development of western larch.

It appears that spacing affects bole form of "young" western larch, and these differences should be considered when evaluating stands, from initial and subsequent intermediate thinnings, for potential wood products such as posts and poles. Further study of crop trees is needed to evaluate bole form differences over a variety of age, site, and stand densities and for development of volume equations specific to spacing levels. By using the full complement of trees in the stand, volume equations describing growth and bole form should be developed.

REFERENCES


Growth of 19 Larch Provenances in Croatia

Steve Orlic and Marijan Ocvirek

Research of European larch provenances in Forest Research Institute, Jastrebarsko, was started in 1965 (Dokus 1975). Seed samples were obtained from Czechoslovakia, Poland, Germany, and Croatia. The quantity of seed or plants was limited. Field trials were established on pilot plots in three ecologically characteristic regions of continental Croatia. Because of the limited quantity of plants, larch was planted with Weymouth pine in inter-rows. In addition to the 18 European larch provenances, the trial included one provenance of Japanese larch from southern Korea.

The aim of the researchers was to determine the European larch variability, to define the provenance that would be best for this environment, and to see what increment could be expected from this economically interesting conifer species. It is known that European larch has a wide area of natural distribution in Europe, both horizontally and vertically, and diverse edaphic and climatic conditions.

Pintaric (1966) established international larch provenance trials on Igman in Bosnia in 1961. The research included 11 provenances of European and one provenance of Japanese larch. The trials were established in the region of sessile-flowered oak, in a common hornbeam community, and a montane beech forest. During the first 5 years the best was Krnov provenance from Czechoslovakia. Pintaric (1966) points out big differences between trees of the same provenance. These differences are sometimes bigger than the ones between the provenances themselves.

MATERIALS AND METHODS

The research program included 18 European larch provenances—13 provenances from Czechoslovakia, one from Poland, two from Bavaria, Germany, and two from Croatia—and 1 Japanese larch provenance from southern Korea. The 19 provenances were:

- Bruntal, Razova, Czechoslovakia
- Albrehtice, Czechoslovakia
- Sabinov, Brezovacka, Czechoslovakia
- Liptovsky, Mikula, Czechoslovakia
- Nizbor, Drevic, Czechoslovakia
- Jeromerice, Czechoslovakia
- Ruda, Raskov, Czechoslovakia
- Rajec, Czechoslovakia
- Pozorice, Czechoslovakia
- Jihlava, Hencov, Czechoslovakia
- Bliyzyn, Svinia gora, Poland
- Durdevac, Croatia
- Vujnovic brdo, Gospic, Croatia
- Tanap, Visoka Tatri, Czechoslovakia
- Baden-Württemberg, Germany
- Litovel, Usov, Czechoslovakia
- Ruda on Moravi, Czechoslovakia
- Amorbach, Kirchell, Germany
- Yongwol-kun, Southern Korea

Steve Orlic and Marijan Ocvirek are with the Forest Research Institute, Jastrebarsko, Croatia.
Ecology and Management of Larix Forests: A Look Ahead

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Wyman C. Schmidt
Kathy J. McDonald
Old-Growth Western Larch Forests: Management Implications for Cavity-Nesting Birds

B. Riley McClelland

Abstract—This paper discusses the role western larch plays in the habitat requirements for cavity-nesting birds. The pileated woodpecker's importance as a "pathfinder" species, the importance of old-growth western larch, and the need for management strategies that feature optimal ecological values are emphasized.

Characteristics of nest trees and surrounding habitats were documented for more than 300 cavity nests used by 28 bird species in northwestern Montana between 1975 and 1991. Study areas included the Coram Experimental Forest and Glacier National Park. Forests of western larch (Larix occidentalis) and Douglas-fir (Pseudotsuga menziesii) were studied most intensively.

There were more nests in western larch and fewer in Douglas-fir than expected, based on availability. Forest stands characterized as old growth (with trees large and old relative to species and site, large snags and logs, and a high incidence of broken tops and heartwood decay) supported the highest density and diversity of cavity nesters.

A "PATHFINDER" SPECIES AND ITS NESTS

The study focused on the pileated woodpecker (Dryocopus pileatus), a "pathfinder" species that creates nesting, roosting, and feeding opportunities for many birds and small mammals incapable of excavating in the dense wood of western larch. Fifty-three pileated woodpecker nests were in western larch; only one was in Douglas-fir. Mean diameter at breast height of larch nest trees was 80 cm; 72 percent were snags.

Nearly all larch nest trees had visible evidence of heartwood decay: conks (primarily Phomitopsis officinalis) or white pocket rot in the wood chips from the cavity excavation. Because undecayed larch wood is dense and difficult to excavate, woodpeckers selected trees with heartwood decay. Such trees usually were more than 200 years old. Western larch may have been preferred because the sapwood is slow to decay, leaving a cylinder of relatively firm and protective sapwood surrounding a core of decaying heartwood. In Douglas-fir snags, the sapwood and heartwood decay nearly concurrently as the snag ages.

Considering its pathfinder role and need for large decaying trees, the pileated woodpecker is appropriately identified as a sensitive species, dependent on the old-growth component in western larch forests. However, the pileated woodpecker is not a meaningful management indicator for a diverse range of old-growth forests; the pileated woodpecker does not nest in all tree species (e.g., Engelmann spruce or subalpine fir) and it rarely nests in high elevation forests. Additionally, attributes of old growth are site specific. Use of a single bird species as an indicator for a complex and diverse array of old growth is illogical.

BIOLOGICAL DIVERSITY

Where retention of biological diversity is important in western larch forests, old growth is an essential component. This will require subordinating maximum timber production on selected low elevation, productive sites and planning on a landscape scale—not simply one cutting proposal at a time. Heartrot, for example, may decrease timber production, but it is an indispensable process in cavity-nesting habitat. So called salvage and sanitation sales can destroy cavity-nesting habitat even while leaving substantial volume on site.

Rather than focusing on minimum habitat standards for cavity nesters (e.g., nest tree size and density of snags) management strategies should emphasize optimum ecological values (Conner 1979).

Historically, extensive stands of old-growth western larch were shaped by lightning, wildfire, insects, disease, and decay. However, in recent decades the extent of old-growth larch forests in northwestern Montana has been diminished primarily by logging. In the future, regardless of how eloquently "New Forestry" and biodiversity jargon dominate forest planning rhetoric, the terms will be cantards unless a biologically objective perception of diversity is applied. The roles of all native flora and fauna including insects, decay organisms, snags, old growth, and pathfinders need to be recognized and incorporated into long-term management strategies for western larch forests.

REFERENCE

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Compilers:

Wyman C. Schmidt
Kathy J. McDonald
Ectomycorrhizal Relationships in Western Larch Ecosystems

Deborah Page-Dumroese
Alan Harvey
Martin Jurgensen
Russell Graham

Abstract—Ectomycorrhizae depend on soil organic materials for successful colonization and activity in larch ecosystems of the Intermountain West, U.S.A. Western larch (Larix occidentalis Nutt.) and three other conifer species were evaluated to assess the role of site disturbances and organic horizons on root growth and ectomycorrhizal activity. All species use organic horizons and principal growth substrates. Use of mineral horizons varies by species. Soil types with the greatest organic matter supported the greatest fungal and root growth.

Ectomycorrhizal fungi predominate in temperate forests of the Intermountain West (Molina and Amaranthus 1991). Conifers in western larch (Larix occidentalis Nutt.) ecosystems form an obligate, usually mutually beneficial, relationship with ectomycorrhizae. Ectomycorrhizal fungi, in general, may allow trees to successfully compete with grasses and herbs for resources (Bowen 1980), and their hyphae can connect plants of different species to facilitate the transfer of carbon and nutrients (Bjorkman 1960; Harvey and others 1979). In return, the fungi receive simple sugar energy sources from host plant roots (Bjorkman 1962; Marx and others 1977). Ectomycorrhizal associations depend on environment, particularly soil fertility (Bjorkman 1962) and organic matter content (Harvey and others 1978), and play a critical role in soil development and plant nutrition. Ectomycorrhizal tip formation is dependent on rhizosphere conditions such as moisture content, pH, temperature (Slankis 1974), and the content and type of organic matter (Bjorkman 1970; Harvey and others 1979). Harvey and others (1976, 1978, 1987) and Harvey (1982) have demonstrated that humus and brown cubical decayed wood are major substrates for ectomycorrhizal root-tip growth. Organic horizons also have a direct effect on tree root development (Coutts and Philipson 1977; Page-Dumroese and others 1989). Organic soil horizons, such as humus, decaying wood, and charcoal, are positively correlated with root growth because of their high moisture contents, high gas exchange, and low bulk densities.

Reforestation success depends on seedlings using site resources quickly. On relatively fertile sites, competition for nutrients, space, and water is keen. On droughty, nutrient-depleted, or stressful sites, only a brief period exists for favorable growth and, if a seedling fails to establish during that time, survival is unlikely (Amaranthus and Perry 1987, 1989). Ectomycorrhizal root structures help provide greater drought resistance than nonectomycorrhizal roots (Parke and others 1983). Microbial populations shift in response to the loss of organic matter, nutrients, and decaying root systems (Kozlowski and Ahlgren 1974; Perry and Rose 1983). On harsh sites, these alterations may jeopardize reforestation (Pilz and Perry 1984), because without a living host, ectomycorrhizal fungi do not persist long (Amaranthus and Perry 1987; Hacskaylo 1973). Total elimination of ectomycorrhizal roots was reported 1 year after clearcutting a high-elevation site in western Montana (Harvey and others 1980).

The effect of ectomycorrhizae on seedlings is not consistent (Kropp and Langlois 1990). Ectomycorrhizae are generally thought to be crucial for acceptable growth and survival (Perry and others 1987), and failure of afforestation efforts in absence of ectomycorrhizal inoculum (Meyer 1973) demonstrates their importance. However, Harvey and others (1991) point out that the "cost" of maintaining an active complement of these fungi may be high. Seedling growth responses vary according to soil chemical and physical characteristics as well as the fungal inoculum present (Danielson 1988; Marx and Cordell 1998).

This paper discusses comparative root growth and ectomycorrhizal colonization on four conifer species common to western larch ecosystems of the Intermountain West, U.S.A.

METHODS

Two studies of western larch ecosystems in the Northern Rocky Mountains have been conducted to assess the potential role of disturbance types and organic horizons on root growth and ectomycorrhizal formation and distribution. This entailed (1) evaluation of natural conifer regeneration associated with undisturbed and harvested forests, and (2) the development of planted conifer regeneration associated with four postharvest site preparation treatments.

The Natural Regeneration Study

This study was conducted on 11 different sites (fig. 1). Six sites were in northwestern Montana, three within the
boundaries of the Coram Experimental Forest, one within the Lubrecht Experimental Forest, and two on the Miller Creek Watershed. The other five sites were within the Priest River Experimental Forest in northern Idaho. For further information on site location and characteristics see Harvey and others (1976). Site treatments included undisturbed forests, clearcuts with broadcast burns, and underburned partial cuts. Tree species examined were western larch, Douglas-fir (*Pseudotsuga menziesii* var. *glauc* [Beissn.] Franco), western white pine (*Pinus monticola* Doug. ex D.Don), and Engelmann spruce (*Picea engelmannii* Parry).

Samples consisted of 10- by 30-cm soil cores (Jurgensen and others 1977) taken randomly, five from around each plot center, 10 plot centers total, scattered evenly over 1 ha of uniform conditions on each study site. Samples were taken during late spring and early summer over several years (1978 to 1982) to obtain maximum seasonal ectomycorrhizal activity for each site (Harvey and others 1978). Roots were separated from soil cores and active ectomycorrhizal tips counted with the aid of a dissecting microscope (10-50x). Each active tip was counted, even though in many cases it was part of a complex structure. From the core, total root length was also measured.

Analysis of variance was used for testing the effects of site, soil component, ectomycorrhizae, and root length. If significant differences were found, Duncan's multiple range test was used to evaluate significance of differences between means.

### The Planted Regeneration Study

This study was conducted on two sites at different elevations within the Priest River Experimental Forest. For more information about site characteristics and soil chemical and physical properties from this study see Page-Dumroese and others (1986, 1989). A randomized complete block experiment was established at each site. Both sites were mechanically prepared in the summer of 1982 by concentrating the forest floor and mineral soil from the top 10 cm of a 1.5-m wide area and forming mounds. Treatments on these sites consisted of (1) mounded soil beds with competing vegetation left in place, (2) mounded soil beds with competing vegetation removed manually in year 1, (3) a scalped area where the top 10 cm of organic matter and mineral topsoil were removed, and (4) an area essentially undisturbed after harvesting. At the low-elevation site, there were four treatments with four replications in one large block. A higher elevation, mid-slope site consisted of four treatments with three replications.

In May 1983, the treatments were planted with locally adapted, 1+0 container-grown Douglas-fir, western white pine, and western larch on a 1-by 1-m spacing.

Fifty-five Douglas-fir and western white pine and five western larch seedlings were excavated from each treatment replication four times during the growing season for 2 consecutive years (1983 and 1984). Ectomycorrhizal root tips were counted on the entire seedling root system using a dissecting microscope. Seedling rooting depth and longest lateral roots were also measured.

An analysis of variance was conducted on the data, utilizing a randomized complete block design. The treatment means were separated using Duncan's multiple range test.

### RESULTS AND DISCUSSION

#### Natural Regeneration Study

Species morphology and soil moisture were factors expected to influence ectomycorrhizal colonization of seedling roots, especially for natural regeneration (Harvey and others 1980). Generally, those habitat types with the largest amounts of soil organic matter (from Harvey and others 1987) supported the greatest numbers of ectomycorrhizae (table 1). In general, soil organic matter depth increased as precipitation and elevation increased.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Western white pine</th>
<th>Engelmann spruce</th>
<th>Western larch</th>
<th>Douglas-fir</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSME/PHMA</td>
<td>40a</td>
<td>—</td>
<td>—</td>
<td>10b</td>
</tr>
<tr>
<td>PSME/VAGL</td>
<td>—</td>
<td>—</td>
<td>93a</td>
<td>54a</td>
</tr>
<tr>
<td>ABLA/CLUN</td>
<td>2a</td>
<td>14b</td>
<td>14b</td>
<td>—</td>
</tr>
<tr>
<td>ABLA/XETE</td>
<td>17a</td>
<td>272a</td>
<td>14b</td>
<td>20b</td>
</tr>
<tr>
<td>THPL/PAMY</td>
<td>88a</td>
<td>27b</td>
<td>27b</td>
<td>23b</td>
</tr>
<tr>
<td>TSHE/CLUN</td>
<td>—</td>
<td>39b</td>
<td>13b</td>
<td>55a</td>
</tr>
</tbody>
</table>

1*PSME/PHMA* = *Pseudotsuga menziesii*/Physocarpus malvaceus
2*PSME/VAGL* = *Pseudotsuga menziesii*/Vaccinium globulare
3*ABL:CLUN* = *Abies lasiocarpa*/Clintonia uniflora
4*ABLA/XETE* = *Abies lasiocarpa*/Xerophyllum tenax
5*THPL/PAMY* = *Thuja plicata*/Pachistima myrsinites
6*TSHE/CLUN* = *Tsuga heterophylla*/Clintonia uniflora

*Different letters indicate significant differences (*P* ≤ 0.05) across habitat types.*
Harvey and others (1980) noted that the quantity of ectomycorrhizal root tips in random soil samples directly reflect relative ecosystem productivity. In addition, each seedling species produced abundant ectomycorrhizae in specific habitat types. For example, Engelmann spruce seedlings produced the greatest number of ectomycorrhizae in the ABLA/CLUN habitat type, larch produced the most in the PSME/VAGL habitat type and western white pine was most prolific in the TSHE/CLUN habitat type. Douglas-fir appeared more of a generalist, producing about the same numbers of ectomycorrhizae in all habitat types.

Site treatments altered both location of seedling ectomycorrhizae and greatest root length (tables 2 and 3). In undisturbed conditions, neither Engelmann spruce nor western larch had longest roots or ectomycorrhizae in mineral or humus horizons. After a clearcut and burn, all four species had lateral roots and ectomycorrhizae in the mineral soil and decayed wood horizons. On the burned sites, lower pH values may have made the mineral soil more suitable for ectomycorrhizal activity.

In clearcut and burned sites, Douglas-fir used mostly decaying wood for ectomycorrhizal development. Western white pine and larch, conversely, formed most of their

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil horizon</th>
<th>Western white pine</th>
<th>Engelmann spruce</th>
<th>Western larch</th>
<th>Douglas-fir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undisturbed</td>
<td>Mineral</td>
<td>43a</td>
<td>—</td>
<td>—</td>
<td>36a</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>19b</td>
</tr>
<tr>
<td></td>
<td>Decayed wood</td>
<td>23a</td>
<td>15a</td>
<td>13a</td>
<td>14b</td>
</tr>
<tr>
<td>Clearcut and burn</td>
<td>Mineral</td>
<td>88a</td>
<td>39a</td>
<td>16a</td>
<td>19a</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td>—</td>
<td>75a</td>
<td>—</td>
<td>6a</td>
</tr>
<tr>
<td></td>
<td>Decayed wood</td>
<td>66a</td>
<td>39a</td>
<td>10a</td>
<td>41a</td>
</tr>
<tr>
<td>Partial cut and underburn</td>
<td>Mineral</td>
<td>—</td>
<td>—</td>
<td>98a</td>
<td>30a</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td>—</td>
<td>—</td>
<td>18a</td>
<td>64a</td>
</tr>
<tr>
<td></td>
<td>Decayed wood</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>30a</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences ($P \leq 0.05$) across soil horizons within treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil horizon</th>
<th>Western white pine</th>
<th>Engelmann spruce</th>
<th>Western larch</th>
<th>Douglas-fir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undisturbed</td>
<td>Mineral</td>
<td>17.0a</td>
<td>—</td>
<td>—</td>
<td>11.7a</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>12.8a</td>
</tr>
<tr>
<td></td>
<td>Decayed wood</td>
<td>14.5a</td>
<td>24.0a</td>
<td>18.4a</td>
<td>14.6a</td>
</tr>
<tr>
<td>Clearcut and burn</td>
<td>Mineral</td>
<td>17.7a</td>
<td>16.2ab</td>
<td>14.1a</td>
<td>14.8a</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td>—</td>
<td>11.0b</td>
<td>—</td>
<td>11.5a</td>
</tr>
<tr>
<td></td>
<td>Decayed wood</td>
<td>19.1a</td>
<td>25.5a</td>
<td>19.5a</td>
<td>12.2a</td>
</tr>
<tr>
<td>Partial cut and underburn</td>
<td>Mineral</td>
<td>—</td>
<td>—</td>
<td>12.5a</td>
<td>13.5a</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td>—</td>
<td>—</td>
<td>13.3a</td>
<td>11.1a</td>
</tr>
<tr>
<td></td>
<td>Decayed wood</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.0a</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences ($P \leq 0.05$) across soil horizons within treatment.
Table 4—Root length in random soil cores as affected by soil horizon. Values are averages across habitat types and treatment ($n = 243$)

<table>
<thead>
<tr>
<th>Soil horizon</th>
<th>Western white pine</th>
<th>Engelmann spruce</th>
<th>Western larch</th>
<th>Douglas-fir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>17.7a</td>
<td>16.3a</td>
<td>13.3b</td>
<td>12.7b</td>
</tr>
<tr>
<td>Humus</td>
<td>—</td>
<td>—</td>
<td>25.0a</td>
<td>—</td>
</tr>
<tr>
<td>Decayed wood</td>
<td>17.8a</td>
<td>13.7a</td>
<td>18.9ab</td>
<td>14.8a</td>
</tr>
<tr>
<td>Charcoal</td>
<td>—</td>
<td>11.0a</td>
<td>13.3b</td>
<td>11.2c</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences ($P \leq 0.05$) across soil horizons.

Ectomycorrhizae in mineral soil. This may have been because postharvest organic horizons depths were relatively shallow (Harvey and others 1978). A partial cut with underburning seemed to be more detrimental to organic horizons, as evidenced by high ectomycorrhizal development in mineral horizons. The large volume, general distribution, and high moisture content of decayed wood throughout the soil profile probably contributed to its ability to retain and support ectomycorrhizal activity when compared to other soil components. Irrespective of site treatment, organic horizons, and in particular decayed wood, were the locations of greatest root length (table 4). When humus horizons were present, western larch was notably adept in exploiting them.

No specific attempts were made to identify particular ectomycorrhizal fungi associated with these seedlings. However, Harvey and others (1976) noted that fruiting structures of *Russula brevipes* Pk. and the distinctive morphology of *Cenococcum graniforme* (Sow.) Ferd. et Winge were often associated with Douglas-fir seedlings during sampling. Douglas-fir is also host to *Rhizopogon vinicolor* Smith, *Laccaria laccata* (Scop. ex Fr.) Berk and Br., and *Hebeloma crustuliniforme* (Bull ex St. Am.) Quel. (Perry and others 1987). Estimates indicate that Douglas-fir may form ectomycorrhizae with over 1,500 fungal species over its entire range (Trappe and Strand 1969). Far fewer fungi are estimated to form ectomycorrhizae with western larch. Some that have been noted include: *Suillus caepipes* (Opat.) Smith et Thiers, *Suillus grevellii* (Kl.) Singer, *Cenococcum graniforme, Laccaria laccata,* and *Pisolithus tinctorious* (Pers.) Coker and Couch (Amaranthus 1992; Chakravarty and Chatarpaul 1990; Harvey and others 1976).

**Planted Regeneration Study**

Western larch seedlings planted in raised planting beds formed fewer ectomycorrhizae than seedlings growing in scalped treatments (fig. 2a). Seedlings growing in treatments considered stressful (such as mounding with no competition control or scalping) formed most of their...
ectomycorrhizae in the mineral horizons. Seedlings in the mound with weed control and the no-site-preparation treatment formed most of their ectomycorrhizae in organic soil horizons. These latter two treatments also had the greatest height growth (see Graham and others, this proceedings). There were few differences in western larch root length among these treatments (fig. 2b).

Western white pine and Douglas-fir seedlings exhibited similar trends in ectomycorrhizal colonization in these treatments (figs. 3a and 4a). Seedlings in mounded, mounded with competition control, and scalped treatments had more ectomycorrhizal tips in organic than mineral soil. However, the no-site-preparation treatment showed an opposite trend; more ectomycorrhizal tips in mineral soil. This may be because the soil had intact soil horizons after harvesting and only a shallow surface organic horizon. After three growing seasons, both species growing in the mound-competition control treatment had the greatest biomass and height (Page-Dumroese and others, in press).

Western white pine seedlings produced the longest laterals in organic soils for every treatment (figs. 3b and 4b). Douglas-fir used the organic soil horizons more when competition or compaction created unfavorable growing conditions elsewhere.

Western white pine seedlings produced the longest laterals in organic soils for every treatment (figs. 3b and 4b). Douglas-fir used the organic soil horizons more when competition or compaction created unfavorable growing conditions elsewhere.

In this study, organic horizons were important for all three of these western conifers. Harvey and others (1991) noted that both Douglas-fir and western white pine responded similarly in these treatments. There was significantly more ectomycorrhizal colonization in the scalped treatment than in the other three treatments. Despite high numbers of ectomycorrhizal short roots on these seedlings, growth was not improved after 3 years (Harvey and others 1991; Page-Dumroese and others, in press). Seedlings growing in more fertile environments tend to have fewer ectomycorrhizae than those growing in harsher conditions (Brainard and Perry 1987; Page-Dumroese and others 1990). Under fertile conditions, ectomycorrhizae may represent a carbohydrate cost to seedlings deficient in factors unimproved by colonization (Reid 1979) or perhaps unavailable in low organic matter soils (Harvey and others 1991).

CONCLUSIONS

Ectomycorrhizae play an important role in maintaining healthy forest ecosystems in the Intermountain West. In most habitat types they are dependent on organic horizons for successful colonization. Western larch is well known for its ability to thrive in areas devoid of organic matter. However, it and most other western conifers benefit from intact organic horizons. The critical nature of ectomycorrhizae and organic matter in these ecosystems present many opportunities for land managers.
With careful management these soils can be protected or even improved. Recognizing the importance of organic horizons and ectomycorrhizal colonization for seedling establishment and growth provides the basis for restoration of damaged soils.

REFERENCES


Harvey, A. E. 1982. The importance of residual organic

debris in site preparation and amelioration for reforesta-
tion. In: Site preparation and fuels management on steep


Ecology and Management of Larix Forests: A Look Ahead

Proceedings of an International Symposium

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October 5-9, 1992

Compilers:

Wyman C. Schmidt
Kathy J. McDonald
Circling the globe at 60° N latitude, one is seldom out of sight of Larix on the extended landmasses of Eurasia and North America. Larch forests essentially encircle the Northern Hemisphere, stretching from eastern Siberia westward across Eurasia (but presently absent in Scandinavia), resuming in eastern North America and westward across the United States and Canada to Alaska, where except for the Bering Sea, they essentially reach our starting point back in Siberia (fig. 1). But along that approximate 20,000-km (12,000-mile) path, larch splits into 10 species and numerous varieties and hybrids. These 10 species occupy a wide variety of ecological conditions and zones ranging from lowland boreal to upper montane to upper subalpine conditions and extend south to 25° latitude at high elevations and north to 75° latitude in the boreal lowlands.

Larches have been in the same general area for a long time. Larch fossils recovered from sediments laid down in the Oligocene to the Holocene eras have been described in North America, Europe, and Asia. More species of larch have already gone extinct than the 10 presently surviving species. Fossil larch have been found in northern Canada, Poland, Russia, Japan, and Alaska, U.S.A. Lepage and Basinger (1991) list many of the fossil species described in the world literature and describe in detail excellent fossil remains of Larix albo borealis found in the Canadian Arctic.

All 10 larches are in the genus Larix, a deciduous needleleaf gymnosperm in the family Pinaceae. Although similar in appearance, shade tolerance, and deciduous character, larch species do differ substantially in growth, ability to establish on different substrates, and ability to compete successfully with associated species. Larch’s deciduous characteristic clearly distinguishes the genus from evergreen conifers with which it is almost always associated.

Larches are the exception in the characteristically evergreen world of the northern boreal and mountain subalpine forests of the northern hemisphere. They possess morphological and physiological characteristics that distinguish them from their evergreen or deciduous counterparts and likely provide them with unique establishment and survival advantages. But they do well in spite of their differences, especially in adding the diversity that is advantageous to associated flora and fauna. Aesthetically, Larix species have no real match in the evergreen world of temperate forest conifers. Their light green hues in the spring and summer, the gold in the fall, and the absence of foliage in the winter are but a part of the charm that this unique genus adds to its environs.

The 10 most commonly recognized larch species and their general distribution are listed in table 1. In addition to these 10 species there are a large number of subspecies and hybrids where natural ranges of species overlap. Larch taxonomy has had little attention internationally. The last real definitive examination was over 60 years ago by Ostenfeld and Larsen (1930). This is reflected in the lack of total agreement in the international literature about what constitutes a Larix species or a subspecies. It is the age-old taxonomy discussion between the “splitters and the lumpers.” Splitting the species into subspecies often makes biological sense at the local or regional level, but in the larger context it makes generalizations difficult. For the purposes of this introduction, generalization to 10 species is in order, but for papers within this proceedings, breakdowns into subspecies and hybrids are described that certainly prove helpful in relating to individual research activities around the world. To more readily illustrate the magnitude of and differences in Larix species distribution, I have divided the northern temperate zone into four geographic areas: North America, Europe, Northern Asia, and Southern Asia (figs. 2, 3, 4, 5). Larix distributions shown here are only approximate and are based on adaptations made from maps and narratives from several sources. Most of the descriptions in the literature are in at least partial, but usually not total, agreement. Good definitive information on exact ranges of the species is just not available in some cases.

Species boundaries in North America are relatively well defined with practically no overlap between L. laricina, L. occidentalis, and L. lyallii (fig. 2). Although L. occidentalis and L. lyallii occur in much the same geographic area, they are usually elevationally separated by 300 to 500 m. Exceptions to this are noted in this proceedings.

Larix laricina forests are by far the most extensive of the three species in North America, stretching from the east to the west of Canada and into Alaska, U.S.A. Its largely boreal habitat contrasts sharply with that of the upper montane/subalpine habitat of L. occidentalis.

Only one species of Larix occurs naturally in Europe. Larix decidua most commonly occurs in the subalpine habitat of the Alps, but it also occurs in other areas of central Europe (fig. 3). Different subspecies and varieties are commonly recognized there and are described in this proceedings. Larix sibirica (often referred to as Larix sibirica) and L. gmelinii dominate the Siberian forest landscape in Northern Asia, with L. russica to the west and L. gmelinii to the east (fig. 4). Their major boundary is contiguous in a generally north-south direction for thousands of kilometers,
Figure 1—Natural range of the genus Larix throughout the World (adapted from Krüssman 1985).

Table 1—The 10 commonly recognized species of larch with their general location and ecological situation.

<table>
<thead>
<tr>
<th>Latin name</th>
<th>Common name</th>
<th>General location</th>
<th>Ecological zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larix occidentalis</td>
<td>Western larch</td>
<td>Rocky and Cascade Mountains of U.S. and Canada</td>
<td>Upper montane to lower subalpine</td>
</tr>
<tr>
<td>Larix lyallii</td>
<td>Alpine larch</td>
<td>Rocky and Cascade Mountains of U.S. and Canada</td>
<td>Upper subalpine to timberline ecotone</td>
</tr>
<tr>
<td>Larix laricina</td>
<td>Tamarack</td>
<td>Northeastern and Lake States and Alaska in U.S. and a wide belt completely across Canada</td>
<td>Mainly boreal</td>
</tr>
<tr>
<td>Larix russica</td>
<td>Siberian larch</td>
<td>A wide belt in northern Russia and in Mongolia</td>
<td>Boreal to northern timberline</td>
</tr>
<tr>
<td>Larix gmelinii</td>
<td>Asian larch</td>
<td>Eurasia east of the Siberian larch range</td>
<td>Subalpine to northern timberline</td>
</tr>
<tr>
<td>(includes L. dahurica,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>olgensis, cajanderi,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>other subspecies)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larix mastersiana</td>
<td>Masters larch</td>
<td>Mountain areas in south China</td>
<td>Upper montane to lower subalpine</td>
</tr>
<tr>
<td>Larix griffithiana</td>
<td>Sikkim larch</td>
<td>Himalayas in Nepal, Bhutan, Tibet and south China</td>
<td>High subalpine</td>
</tr>
<tr>
<td>Larix potaninii</td>
<td>Chinese larch</td>
<td>Western China</td>
<td>High subalpine</td>
</tr>
<tr>
<td>Larix leptolepis</td>
<td>Japanese larch</td>
<td>Honshu, Japan</td>
<td>Subalpine</td>
</tr>
<tr>
<td>Larix decidua</td>
<td>European larch</td>
<td>Alps area in France, Switzerland, Austria, Italy, Yugoslavia, Germany with scattered areas in Romania, Czechoslovakia, and Poland</td>
<td>Subalpine</td>
</tr>
</tbody>
</table>
and where their boundaries overlap \( L. \times \text{czechanowski} \) (=\( L. \text{russica} \times L. \text{gmelinii} \)) is often recognized. Within the wide range of \( L. \text{gmelinii} \) there are numerous regionally recognized subspecies or varieties such as \( L. \text{cajanderi} \) in north-eastern Siberia, \( L. \text{olgensis} \) on the east coast of Russia and down into Korea, \( L. \text{principis-rupprechtii} \) in northeast China, and \( L. \text{kurilensis} \) and \( L. \text{kamtschatica} \) on Sakhalin Island and Kamchatka. These are described in other papers within the proceedings.

Southern Asia accounts for a wide variety of Larix species, ranging from the montane conditions of \( L. \text{mastersiana} \) in southwestern China to the high elevation forests of \( L. \text{griffithiana} \) in Nepal, Bhutan, and Tibet, and \( L. \text{potaninii} \) in southwestern China to the island environment of \( L. \text{leptolepis} \) on Honshu in Japan (fig. 5). \( L. \text{mastersiana} \) and \( L. \text{leptolepis} \) are unique, along with \( L. \text{lyallii} \) in North America, in having limited, but important, ranges.

To the casual observer most Larix species look essentially the same, but their cone and needle characteristics and particularly their ecological niches separate them. Some of these characteristics are illustrated in figure 6.

For at least 200 years people have carried seed from one continent to the other in hopes of finding the perfect Larix species for their area. As a result, plantations of introduced Larix can be observed at many locations in the world, particularly in Europe and eastern North America (Krüssman 1985). Genetics research, particularly with hybridization objectives, has been extensive. Some hybrids exhibit superior growth and survival characteristics, and some of that information is presented in this proceedings.

The value of Larix forests for wood products, animal habitats, water production, aesthetics, and other resources is impressive, but the values vary tremendously by species and ecological zones. These forests harbor a wide complement of fauna ranging from the moose to the mouse, the bear to the shrew, and the eagle to the hummingbird, not to mention the vast array of micro flora and fauna, as yet only generally comprehended. Many of these values and ecological principles of this truly international genus are described in this proceedings.
Figure 3—Natural range of Larix species in Europe (adapted from Ostenfeld 1930; Gower and Richards 1990; Holtmeier, this proceedings).

Figure 4—Natural range of Larix species in Northern Asia (adapted from Ostenfeld and Larsen 1930; Gower and Richards 1990; Milyutin and Vishnevetskaia, this proceedings). The area shown as *ruscica/gmelinii* is often referred to as *L. x czekanowski*, and the area in northeast China shown as *L. gmelinii* is often referred to as *L. principis-rupprechtii*. 

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**Larix gmelinii**

**Larix russica**

**Larix leptolepis**

**ruscica/gmelinii**
Larix gmellnii
Larix leptolepis
Larix potaninii
Larix mastersiana
Larix griffithiana

Figure 5—Natural range of Larix species in Southern Asia (adapted from Ostenfeld and Larsen 1930; Gower and Richards 1990; Wang, this proceedings). The area shown as russical gmellini is often referred to as L. x czekanowski, and the area in northeast China shown as L. gmellni is often referred to as L. principis-ruprechtii.

REFERENCES
Figure 6—This series of photos depicts some of the characteristics of the world’s Larix species.

*Larix occidentalis*

*L. occidentalis* in a fall landscape scene in western Montana, U.S.A.

A 300-year old stand of *L. occidentalis* on Coram Experimental Forest, Montana, U.S.A. Large trees are about 40 m tall and nearly 1 m in diameter.

A 15-year old *L. occidentalis* in the spacing study on Coram Experimental Forest, Montana, U.S.A.

An ovulate cone of *L. occidentalis* in the early spring.
**Larix iyallii**

A late September view of *L. iyallii*, Carlton Ridge, Bitterroot Mountains, Montana, U.S.A.

Ovulate cones and emerging foliage of *L. iyallii* in early spring.

A robust stand of *L. iyallii*, Carlton Ridge, Bitterroot Mountains, Montana, U.S.A.

A planted *L. iyallii* seedling.
A stand of *L. laricina* during the October needle fall period on a lowland in Alberta, Canada.

*Larix laricina* provenance trial in Alberta, Canada.
Larix russica

A mixed species forest of larch, birch, and pine in the fall season near Lake Baikal in Russia.

A mature forest in the steppe area of Mongolia.
Larix *gmelinii*

A vigorous young forest of *L. gmelinii* in Korea.

A landscape showing an extensive forest of *L. gmelinii* in Korea.

A tall scene in an intermediate-age stand of the subspecies *L. cajanderi*, Yakutia, Russia.
A young vigorous stand of *L. gmelinii* in northeast China.

A stand of *L. gmelinii* adjoining an agricultural area in northeast China.

Establishing weather instruments in a forest of the subspecies *L. olgensis* in northeast China.

A plantation of *L. gmelinii*, subspecies *olgensis* in northeast China.
Larix mastersiana

A lace-like crown showing the drooping characteristic in a southwest China forest.

A branchlet and cone of *L. mastersiana* in southwest China.

Larix potaninii

Mature cones of *L. potaninii* in southwest China.
Larix leptolepis

A vigorous intermediate age stand in Japan.

Larix decidua

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A thinned intermediate age stand with a heavy understory in Japan.

Intermediate age *L. decidua* in a mixed-species stand of spruce and pine near St. Moritz, Switzerland.
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Wyman C. Schmidt
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Vegetation Responses to Silviculture and Woody Residue Treatments in a Western Larch Forest

Wyman C. Schmidt
Carl E. Fiedler
Ward W. McCaughey

Editor’s Note: This is an abstract of a paper that will be published separately from this proceedings. Inquiries regarding the study and data may be made through the authors at the addresses listed at the bottom of this column.

Western larch forests commonly have luxurious understory vegetation that protects the site and provides significant habitat for various wildlife species. Knowing how various forest management practices affect the response of shrub, forb, and grass components of the understory was one of the subjects of a multidiscipline study in a larch-Douglas-fir forest. This report describes 10-year response to the harvest cutting treatments: (1) clearcut, (2) shelterwood, and (3) group selection and residues disposal treatments. The third group included: (1) moderate level of woody residues followed by broadcast burning, (2) heavy amount of residues followed by broadcast burning, (3) intense removal of all residues, and (4) understory tree protected with moderate removal of woody residues.

Residues treatments were superimposed on the three harvest cutting treatments, resulting in 12 combinations. There were two replications. Also included for comparison were identical understory vegetation measurements in adjacent virgin natural forests.

Understory vegetation responded substantially in the first 10 years following treatments. The initial harvest cutting and residues treatments reduced volumes of live shrubs to as little as 3 percent of the preharvest volumes on the clearcut and burned treatments. The average for all treatments 2 years after treatment, however, was about 20 percent of preharvest level. Ten years after treatment, shrub volumes averaged 50 to 70 percent of preharvest levels with shrubs on the group selections and clearcuts responding the most and those in the shelterwoods the least. Residues treatments, particularly prescribed fire and protected understory tree treatments, also affected understory response.

The two burning treatments reduced shrub volume the most, and the treatment that attempted to protect the understory trees resulted in the least reduction in shrub volume. Herb cover and volume generally increased to greater than preharvest levels during the first 4 years after treatments. After that these values generally declined. At about 10 years they had declined to near preharvest levels. Ten years after treatment the number of different species found on the study plots exceeded that in the original mature forest. All of the increases were in the herb component of the understory vegetation.

Understory vegetation in larch-Douglas-fir forests is responsive to various combinations of harvest cutting and residues removal treatments. Vegetation responses are rapid for the first 2 to 4 years. This is followed by a gradual approach toward the levels found in mature forests. Long-term multidisciplinary studies such as this help define the trajectory of the gradual changes in understory and the relationship to other forest values and ecological processes.
Ecology and Management of Larix Forests: A Look Ahead

Proceedings of an International Symposium

Whitefish, Montana, U.S.A.
October 5-9, 1992

Compilers:
Wyman C. Schmidt
Kathy J. McDonald
Western Larch Growth and Perturbations in Stands Regulated for 30 Years

Wyman C. Schmidt
Ward W. McCaughey
Jack A. Schmidt

Western larch is one of the most rapidly growing conifers in mountain forests of the Western United States and Canada. Overstocking is a common problem that can substantially reduce the potential growth of larch. It is one of the most significant problems in managing naturally regenerated forests. Thinning offers great silvicultural opportunities in young larch forests.

We established a long-term, permanent plot study in 1961 to determine the effects of different levels of regulated stand densities on individual tree and stand growth. Also examined was the relationship of these different stand densities to perturbations such as insect, animal, snow, and other types of damage to the trees. We now have 30 years of these measurements and observations.

Diameter growth of the shade-intolerant larch was very responsive to stand density, with the greatest individual tree growth in the least dense stands. Height growth was also related to stand density with the larch growing fastest in the less dense stands. However, height response on the different densities was far less pronounced than diameter.

Three major problems occurred during the 30 years. About 5 years after the 9-year-old stand was thinned a major storm of heavy wet snow in June flattened the young forest. Although crooks in the bole of the trees are still apparent in some trees 25 years later, overall the young forest had practically no mortality from the extreme snow bend and recovered remarkably well. Western spruce budworm can sever the terminal and upper lateral stems of larch. For several years we experienced relatively severe damage to form quality and some reduction in height growth due to budworm damage before budworm populations collapsed. Black bear can be a significant management problem in some areas, and this study helped identify the type and extent of damage and its relationship to stand density. Bear feed on the inner bark of larch in the spring and often kill the tree by completely girdling it. Bear damage was most severe where trees were largest and most vigorous in stands with the fewest trees.

These results help define appropriate management strategies in young western larch forests.

Editor's Note: This is an abstract of a paper that will be published separately from this proceedings. Inquiries regarding the study and data may be made through the authors at the addresses listed at the bottom of this column.


At the time of the study, Wyman C. Schmidt (retired) was Project Leader and Research Silviculturist, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, located at the Forestry Sciences Laboratory, Montana State University, Bozeman, MT 59717-9278, U.S.A. Ward W. McCaughey is Research Forester, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Forestry Sciences Laboratory, Montana State University, Bozeman, MT 59717-0278, U.S.A. Jack A. Schmidt is Forester, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Forestry Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807, U.S.A.
Ecology and Management of Larix Forests: A Look Ahead

Proceedings of an International Symposium

Whitefish, Montana, U.S.A.
October 5-9, 1992

Compilers:

Wyman C. Schmidt
Kathy J. McDonald
Natural Regeneration After Harvest and Residue Treatment in a Western Larch Forest of Northwestern Montana, U.S.A.

Raymond C. Shearer
Jack A. Schmidt

Historically, major disturbance, usually wildfire, preceded regeneration of western larch (Larix occidentalis) in the forests of the Northern Rocky Mountains. Observation and research show that establishment of western larch and other conifers is enhanced by coupling timber harvest with site preparation that exposes some mineral soil. But regeneration probability decreases, especially for shade-intolerant species such as western larch, when there is little disturbance. This research tracked establishment of natural regeneration as influenced by harvest cutting method and forest residue reduction treatments, including light prescribed fire, on the Coram Experimental Forest located in northwestern Montana, U.S.A.

In 1974, on an east-facing slope, a forest comprised mostly of overstory Inland Douglas-fir (Pseudotsuga menziesii) and western larch was harvested using three methods of harvest cutting: a shelterwood, a clearcut, and a set of eight small group selection cuttings, within each of two elevational zones. The lower units lay between 1,195 and 1,390 m and the upper units between 1,341 and 1,615 m. Each shelterwood, clearcut, and set of group selections received four levels of timber and residue utilization. Moist fuels on about half of each area were prescribed burned in September 1975.

The interaction of poor site preparation, low cone production, and high seed mortality initially limited natural regeneration. At the outset of this study in 1974, a serious western spruce budworm (Choristoneura occidentalis) outbreak was ongoing in the study area. Budworm larvae killed most potential seed cones of subalpine fir (Abies lasiocarpa), Inland Douglas-fir, and Engelmann spruce (Picea engelmannii) that year, but larch and western hemlock (Tsuga heterophylla) disseminated considerable seed. The budworm population collapsed in 1975, and cone production quickly resumed for Douglas-fir and more slowly for Engelmann spruce and subalpine fir.

Natural regeneration began in 1975; western larch regenerated mostly on soil exposed during yarding of logs, and western hemlock on moist sites, especially near the bottom of the lower elevation units. By 1979, an average of 1,435 seedlings per ha were counted on all units: 808 larch, 571 Douglas-fir, 10 subalpine fir, 15 spruce, 21 hemlock, 5 western redcedar (Thuya plicata), and 5 lodgepole pine (Pinus contorta). Although the average number of seedlings exploded to 16,494 per ha in 1992, the average number of larch decreased to 649 seedlings. Quick recovery of shrubs and herbs virtually stopped establishment of new larch by the early 1980's.

In contrast, Douglas-fir regenerated prolifically during the 1980's and averaged 15,120 seedlings per ha in 1992. The number of subalpine fir and Engelmann spruce seedlings continued to increase slowly within all units: 268 subalpine fir per ha and to 175 spruce per ha in 1992. Also, western hemlock and western redcedar increased in numbers to 160 and 36 seedlings per ha in 1992 mostly on the warmer, moister areas of the lower elevation units. Lodgepole and western white pine (Pinus monticola) were occasionally represented.

Composition of natural regeneration in 1979 was, in percentage: western larch 59, Douglas-fir 38, and all other species 3. Percentage stocking of 0.0004 ha plots was 16 for western larch, 11 for Douglas-fir, and less than 1 for other species. In 1992, 18 years after treatment, percentage natural regeneration was composed mostly of Douglas-fir at 92, western larch 4, and all other species 4. Percentage stocking was 60 for Douglas-fir, 15 for larch, 6 each for spruce and subalpine fir, 4 for western hemlock, 2 for western white pine, and 1 each for western redcedar and lodgepole pine.

Without subsequent disturbance, the new forest will be dominated by Douglas-fir both in the overstory and understory. Occasional groups or individual western larch will also occur in the overstory, mostly where soil was exposed during logging or where prescribed fire decreased the duff layer. Subalpine fir and Engelmann spruce will slowly increase in the understory throughout the units. Western hemlock and western redcedar will be limited to the warmer, moist areas on the lower elevation units. Occasional lodgepole pine will mature as an overstory tree and may provide a temporary seed source following a future disturbance, especially fire. Because of its greater shade tolerance, the few western white pine will continue in this stand in the overstory and understory unless killed by the white pine blister rust (Cronartium ribicola).
Appendix B: International Larix Arboretum, Coram Experimental Forest Headquarters, Hungry Horse, Montana, U.S.A.

Raymond C. Shearer
Jack A. Schmidt
Wyman C. Schmidt

The Larix Symposium provided the impetus to establish an arboretum that features all Larix species of the world (figs. 1 and 2). This International Larix Arboretum, established on a 0.5 ha (1.2 acre) site next to the headquarters of the Coram Experimental Forest and near the Hungry Horse Ranger Station, was dedicated October 7, 1992, with a tree-planting ceremony that had international participation by attendees from North America, Europe, and Asia, and by teachers and students from the nearby Hungry Horse elementary school (figs. 3 and 4). This symbol of global cooperation will not only provide a visual demonstration of larch internationale, but it is designed to provide opportunities for species comparisons and genetics research.

Figure 1—Logo for the International Larix Arboretum at Coram Experimental Forest.
Figure 2—An overview of the International Larix Arboretum, Coram Experimental Forest, May 1993. Note the shade cards used to increase seedling survival.

Figure 3—Attending the dedication of the International Larix Arboretum at Coram Experimental Forest, Montana, are (from left to right): Klara Vishnevetskaia, from Moscow, Russia (currently a graduate student at Toronto); Dr. Leonid I. Milyutin, from the Institute of Forests and Wood, Siberian Branch of Russian Academy of Science, Krasnoyarsk, Russia; and, Prof. Dr. Friedrich-Karl Holtmeier, Westfälische Wilhelms-Universität, Munster, Germany.

Figure 4—During dedication ceremonies of the International Larix Arboretum, Mrs. Sung-Cheon Hong, from Daegu, South Korea, helped plant a tree with Intermountain Station Forester Jack Schmidt, right, and a student from Hungry Horse, Montana, Elementary School.
The arboretum is divided into three equal-sized blocks, about 21.3 m x 70 m (70 ft x 230 ft). Within each block, *Larix* seedlings are randomly planted every 1 m (5 ft) in rows 3 m (10 ft) apart. The design calls for 12 trees of each species, subspecies, and hybrids in each of the three blocks for a total of nearly 600 trees. The species, subspecies, and hybrids that are (or will be) planted are:

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species name</th>
<th>Comments</th>
<th>Date planted</th>
</tr>
</thead>
<tbody>
<tr>
<td>European larch</td>
<td><em>L. decidua</em></td>
<td></td>
<td>Sept. 2, 1992</td>
</tr>
<tr>
<td>Asian larch</td>
<td><em>L. gmelinii</em></td>
<td>Includes <em>dahurica</em></td>
<td>Sept. 3, 1992</td>
</tr>
<tr>
<td>Sikkim larch</td>
<td><em>L. griffithiana</em></td>
<td>Not planted</td>
<td></td>
</tr>
<tr>
<td>Tamarack</td>
<td><em>L. laricina</em></td>
<td></td>
<td>Sept. 2 and 8, 1992</td>
</tr>
<tr>
<td>Japanese larch</td>
<td><em>L. leptolepis</em></td>
<td>Formerly <em>kaempferi</em></td>
<td>Sept. 3, 1992</td>
</tr>
<tr>
<td>Alpine larch</td>
<td><em>L. lyallii</em></td>
<td></td>
<td>Sept. 17, 1992</td>
</tr>
<tr>
<td>Masters larch</td>
<td><em>L. mastersiana</em></td>
<td></td>
<td>Sept. 15, 1993</td>
</tr>
<tr>
<td>Western larch</td>
<td><em>L. occidentalis</em></td>
<td></td>
<td>Sept. 17, 1992</td>
</tr>
<tr>
<td>Chinese larch</td>
<td><em>L. potaninii</em></td>
<td></td>
<td>Sept. 16, 1993</td>
</tr>
<tr>
<td>Siberian larch</td>
<td><em>L. russica</em></td>
<td>Formerly <em>siberica</em></td>
<td>Sept. 3 and 8, 1992</td>
</tr>
</tbody>
</table>

### Larix subspecies

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species name</th>
<th>Comments</th>
<th>Date planted</th>
</tr>
</thead>
</table>

### Larix hybrids

<table>
<thead>
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<th>Common name</th>
<th>Species name</th>
<th>Comments</th>
<th>Date planted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunkeld larch</td>
<td><em>L. x euralepis</em></td>
<td><em>L. decidua</em> [pollen] &amp; <em>L. leptolepis</em></td>
<td>Sept. 3 and 8, 1992</td>
</tr>
<tr>
<td>Bitterroot larch</td>
<td><em>L. x occilial</em></td>
<td><em>L. occidentalis</em> [pollen] &amp; <em>L. lyallii</em></td>
<td>Sept. 17, 1992</td>
</tr>
<tr>
<td>Bitterroot larch</td>
<td><em>L. x Ivalocci</em></td>
<td><em>L. lyallii</em> [pollen] &amp; <em>L. occidentalis</em></td>
<td>Sept. 18, 1992</td>
</tr>
</tbody>
</table>

Source information for *Larix* species, subspecies, and hybrids in the International Larix Arboretum, Hungry Horse, Montana:

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species name</th>
<th>Provenance</th>
<th>North latitude</th>
<th>East/West longitude</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European larch</td>
<td><em>L. decidua</em></td>
<td>Heilongjiang</td>
<td>55 49</td>
<td>12 23E</td>
<td></td>
</tr>
<tr>
<td>Asian larch</td>
<td><em>L. gmelinii</em></td>
<td>Heilongjiang</td>
<td>47 00</td>
<td>127 00E</td>
<td></td>
</tr>
<tr>
<td>Sikkim larch</td>
<td><em>L. griffithiana</em></td>
<td>Heilongjiang</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tamarack</td>
<td><em>L. laricina</em></td>
<td>Murray Twpsh</td>
<td>44 12</td>
<td>77 44W</td>
<td>120</td>
</tr>
<tr>
<td>Japanese larch</td>
<td><em>L. leptolepis</em> (formerly <em>kaempferi</em>)</td>
<td>Murray Twpsh</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Alpine larch</td>
<td><em>L. lyallii</em></td>
<td>Murray Twpsh</td>
<td>46 42</td>
<td>114 11W</td>
<td>2,800</td>
</tr>
<tr>
<td>Masters larch</td>
<td><em>L. mastersiana</em></td>
<td>Murray Twpsh</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Western larch</td>
<td><em>L. occidentalis</em></td>
<td>Murray Twpsh</td>
<td>46 56</td>
<td>113 42W</td>
<td>1,200</td>
</tr>
<tr>
<td>Chinese larch</td>
<td><em>L. potaninii</em></td>
<td>Murray Twpsh</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Siberian larch</td>
<td><em>L. russica</em> (formerly <em>siberica</em>)</td>
<td>Krasnoyarsk</td>
<td>46 00</td>
<td>77 25E</td>
<td>130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species name</th>
<th>Provenance</th>
<th>North latitude</th>
<th>East/West longitude</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polish larch</td>
<td><em>L. decidua</em>, ssp. <em>polonica</em></td>
<td>Murray Twpsh</td>
<td>46 00</td>
<td>77 25E</td>
<td>130</td>
</tr>
<tr>
<td>Sudetic larch</td>
<td><em>L. decidua</em>, ssp. <em>sudetica</em></td>
<td>Murray Twpsh</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Olga Bay larch</td>
<td><em>L. gmelinii</em>, ssp. <em>Jilin olgensis</em></td>
<td>Murray Twpsh</td>
<td>43 00</td>
<td>126 00E</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species name</th>
<th>Provenance</th>
<th>North latitude</th>
<th>East/West longitude</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunkeld larch</td>
<td><em>L. x euralepis</em> (L. <em>decidua</em> [pollen] &amp; L. <em>leptolepis</em>)</td>
<td>Murray Twpsh</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bitterroot larch</td>
<td><em>L. x occilial</em> (L. <em>occidentalis</em> [pollen] &amp; L. <em>lyallii</em>)</td>
<td>Murray Twpsh</td>
<td>46 42</td>
<td>114 11W</td>
<td>2,800</td>
</tr>
<tr>
<td>Bitterroot larch</td>
<td><em>L. x Ivalocci</em> (L. <em>lyallii</em> [pollen] &amp; L. <em>occidentalis</em>)</td>
<td>Murray Twpsh</td>
<td>46 56</td>
<td>113 42W</td>
<td>1,200</td>
</tr>
</tbody>
</table>
A seedling of most of the larch species were planted along the north edge of the arboretum at its dedication. Those who planted these trees were:

<table>
<thead>
<tr>
<th>Larix species</th>
<th>Planter's name(s)</th>
<th>City and country</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Larix leptolepis</em></td>
<td>Fukio Takei</td>
<td>Naganoken, Japan</td>
<td>Nagano Prefectural Forestry Research Center</td>
</tr>
<tr>
<td>Japanese larch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix gmelinii</em></td>
<td>Yeh-chu Wang</td>
<td>Harbin, Peoples Republic of China</td>
<td>Ecological Research Group, Northeast Forestry University</td>
</tr>
<tr>
<td>Asian larch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix russica</em></td>
<td>Prof. Leonid I. Milyutin</td>
<td>Krasnoyarsk, Russia</td>
<td>V.N. Sukachev Institute of Forest, Siberian Branch, Russian Acad. of Science</td>
</tr>
<tr>
<td>Siberian larch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix decidua</em></td>
<td>Friedrich-Karl Holtmeier</td>
<td>Munster, Germany</td>
<td>Landscape Ecology, Westfalische-Wilhelms-Universitat</td>
</tr>
<tr>
<td>European larch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix occidentalis</em></td>
<td>Katrine Berg</td>
<td>Hungry Horse, Montana, U.S.A.</td>
<td>Student, Hungry Horse Elementary School</td>
</tr>
<tr>
<td>Western larch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix lyallii</em></td>
<td>Jack A. Schmidt</td>
<td>Missoula, Montana U.S.A.</td>
<td>Intermountain Research Station, FSL, Missoula, Montana, U.S.A.</td>
</tr>
<tr>
<td>Alpine larch</td>
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<td></td>
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</tr>
<tr>
<td><em>Larix laricina</em></td>
<td>Joseph Fisher</td>
<td>Hungry Horse, Montana, U.S.A.</td>
<td>Student, Hungry Horse Elementary School</td>
</tr>
<tr>
<td>Eastern larch or tamarack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix occidentalis</em></td>
<td>Clinton E. Carlson</td>
<td>Florence, Montana U.S.A.</td>
<td>Intermountain Research Station, FSL, Missoula, Montana, U.S.A.</td>
</tr>
<tr>
<td>x <em>lyallii</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western x Alpine hybrid; WL pollen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix eurolepis</em></td>
<td>Claudette Berg-Rink</td>
<td>Hungry Horse, Montana, U.S.A.</td>
<td>Student, Hungry Horse Elementary School</td>
</tr>
<tr>
<td>European x Japan hybrid; EL pollen</td>
<td>Hans G. Schabel</td>
<td>Stephens Point, WI</td>
<td>University of Wisconsin</td>
</tr>
<tr>
<td><em>Larix lyallii</em></td>
<td>Bob Muth</td>
<td>Hungry Horse, Montana, U.S.A.</td>
<td>Sixth Grade Teacher, Hungry Horse Elementary School</td>
</tr>
<tr>
<td>x <em>occidentalis</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpine x Western hybrid; AL pollen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Larix gmelinii</em></td>
<td>Gabe Buzzell</td>
<td>Hungry Horse, Montana, U.S.A.</td>
<td>Student, Hungry Horse Elementary School</td>
</tr>
<tr>
<td>spp. olgensis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olga Bay larch</td>
<td>Mrs. Sung-cheon Hong</td>
<td>Daegu, Republic of South Korea</td>
<td>Kyungpook National University</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: On September 17, 1993, Susan Colt planted *Larix mastersiana* and Jack A. Schmidt planted *L. potaninii* in the International Larix Arboretum.

A paved road, a sidewalk, and a 1.5 m (5 ft) wide strip planted with native shrubs form a border around the International Larix Arboretum. Shrubs planted in this strip are mostly snowberry (*Symphoricarpos albus*), red-osier dogwood (*Cornus stolonifera*), rose (*Rosa woodsii*), and chokecherry (*Prunus virginiana*), all from the Glacier National Park Native Plant Nursery. The arboretum is enclosed by a 2.4 m (8 ft) high chain link fence that protects the young larch from damage by large herbivores (deer, elk, moose) or by people driving vehicles or snowmobiles across the area.
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