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ECOLOGY AND SILVICULTURE OF WESTERN LARCH FORESTS
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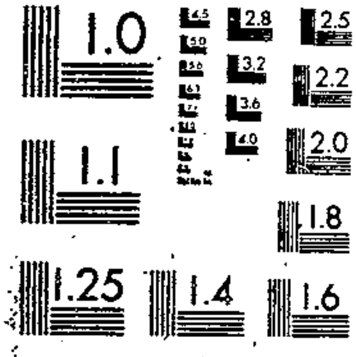

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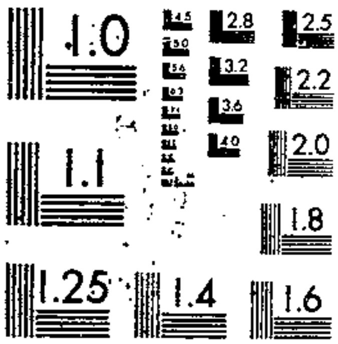

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ECOLOGY AND SILVICULTURE OF WESTERN LARCH FORESTS

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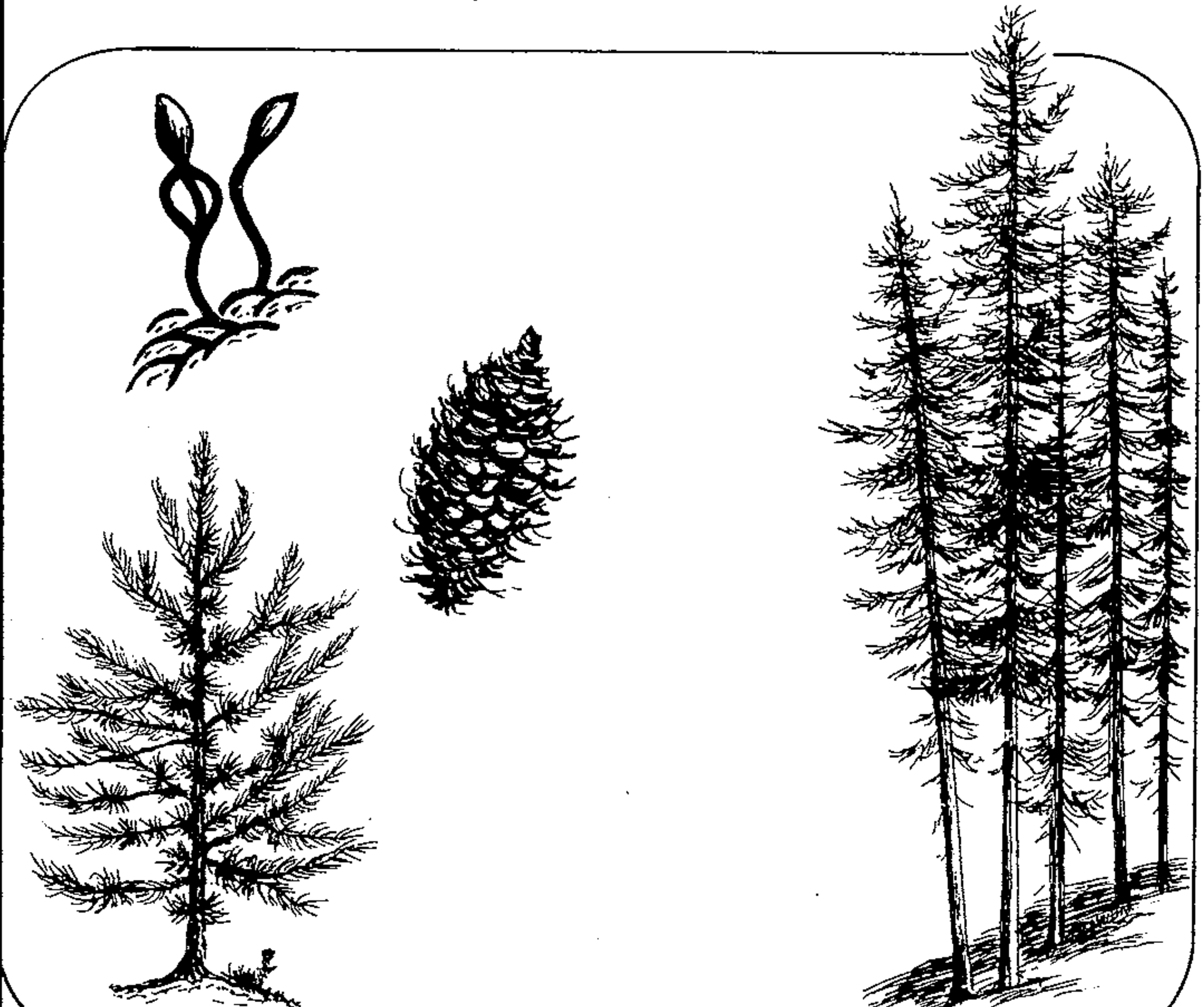

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ECOLOGY AND SILVICULTURE OF WESTERN LARCH FORESTS

by

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RESEARCH SUMMARY

Western larch forests are valued not only for the high quality wood they produce—wood used for a multiplicity of products—but also for their esthetic beauty. A wide variety of wildlife, including grizzly bear, moose, and elk, find protection and food in larch forests. Deep winter snows dramatize the watershed values.

Western larch is the largest of the North American larches. It is deciduous, and the most shade-intolerant species in the northern Rockies. Although always seral, it has a wide ecological amplitude, growing in association with most conifers native to the northern Rocky Mountains. Deficient moisture defines its lower elevational limits, while low temperatures mark the upper extreme. Larch grows best on north exposures, valley bottoms, benches, and rolling topography; southwest exposures are usually unfavorable for larch.

Dwarf mistletoe is the most serious disease-causing parasite, and larch casebearer and western spruce budworm the most serious insect pests damaging western larch. All three are widespread throughout the type and can substantially reduce growth.

Even-aged management methods, including clearcutting, shelterwood, and seed-tree cuttings, essentially mimic conditions historically created by wildfires and create conditions needed to regenerate harvested larch forests. Natural regeneration can usually be relied upon with any of these cutting methods if a mineral soil seedbed has been prepared by prescribed burning or mechanical scarification. Because larch cone crops are predictable a year in advance, seedbeds can be prepared before seed dispersal. A 1-to-1 ratio of fair or better versus poor cone crops generally precludes the necessity of artificial regeneration methods, but where natural seedfall fails, direct seeding and planting methods are good substitutes.

Characteristically, larch grows in mixed-species stands with several other conifers, gains an early height advantage over its associates, and continues to outgrow them in height for most of the life of the stand. However, the initial seedbed preparations, stocking, and insects and diseases can alter this pattern. For example, prescribed burning for seedbed preparation generally creates conditions highly suitable for early larch growth. Larch grows faster and gains a more dominant position on burned than on other types of seedbeds.

The majority of natural stands in larch forests are heavily overstocked—30,000 to 40,000 trees per acre at age 10 are not uncommon. Larch growth potential nearly always exceeds its actual growth in natural stands because larch is very sensitive to overcrowding. Diameter and height growth reductions, even of the dominant trees, are readily apparent in stands under 10 years old. This illustrates the need to thin very early in the life of the stand to take full advantage of its rapid juvenile-growth potential. Without early thinning, the highly intolerant crowns are reduced, and overall vigor declines. Maintaining good vigor also results in greater resistance to snow and wind as well as insect and disease damage.

Larch response to thinning in older stands is directly related to the degree of overstocking and associated tree vigor at the time of thinning. Moderately overstocked stands respond rapidly while heavily overstocked stands, with their smaller crown ratios and reduced vigor, respond proportionately slower. Dominant and codominant trees consistently respond most favorably to thinning and should be featured in management.

Overmature larch forests generally show negative or little net volume growth because mortality exceeds or approximates growth. Partial cuttings in old-growth forests produce only minor net growth increases, principally on species other than larch. However, immature larch forests possess substantial growth potential under management. This bulletin provides growth and yield information—stratified by site indices, physiographic site, and ecological habitat type—for predicting this potential growth.

CONTENTS

A vigorous young western larch stand developing on a clearcut
in a scenic mountain setting in western Montana.

INTRODUCTION

This bulletin summarizes and consolidates ecological and silvicultural knowledge of western larch (*Larix occidentalis* Nutt.) forests. It is based heavily on studies conducted during the last three decades in western Montana and northern Idaho—the heart of western larch country—by the USDA Forest Service Silviculture Research Unit, Missoula, Montana. Coram Experimental Forest, located in northwestern Montana near Glacier National Park, has served as the focal point for much of the larch research.

Also incorporated in the bulletin is valuable information gleaned from research and observation in the white pine type and other related timber types within the range of western larch. Most of the latter research was conducted by other research units of the Intermountain and Pacific Northwest Forest and Range Experiment Stations, the British Columbia Forest Service, and universities in Montana, Idaho, Oregon, and Washington.

Specific research to determine the detailed silvicultural practices required to reproduce and grow western larch and associated species began in 1946. For the next 15 years, research emphasized seedbed requirements, methods of cutting to enhance natural regeneration, and seed production and dispersal in natural systems. By 1960 more effort was being directed to problems of direct seeding and immature stand management. In the last 10 years interdisciplinary studies in cooperation with other Forest Service research units and the University of Montana were undertaken to study insect and disease relationships, nutritional requirements, effects of cultural treatments on water use and understory vegetation development in young stands, and effects of prescribed burning on watershed values, wildlife browse, air quality, and stand regeneration.

This bulletin presents in-depth discussions, tables, and figures describing economic, biological, and environmental values; tree regeneration and stand management opportunities; and growth and yield estimates of western larch forests. Although many questions remain, we believe this summary bulletin provides a substantial base of knowledge for western larch management.

IMPORTANCE OF WESTERN LARCH

Western larch, a deciduous conifer, holds a position of prominence in the multiple use forests of the northern Rocky Mountains. The seasonally changing hues of its delicate foliage enhance the beauty of the landscape for all who view the forest. Because larch is an aggressive pioneer species, it readily covers the scars following wildfire and logging on mountain slopes, and thus protects many of the region's watersheds. A wide variety of birds and animals find protection and food in these forests. The wood products industry relies heavily on this species to provide materials for a variety of needs.

Western larch now leads all species except Douglas-fir in annual volume cut in the northern Rockies. Its wide use arises from: (1) its desirable wood qualities, (2) dwindling supplies of other species, (3) increased timber demands (beginning during World War II), (4) diversification of product utilization by industry, and (5) increasing accessibility of large, untouched old-growth stands.

Range

Western larch is found in the Upper Columbia River Basin of southeastern British Columbia, northwestern Montana, northern Idaho, and northeastern Washington; along the east slopes of the Cascades in Washington and north-central Oregon; and in the Wallowa and Blue Mountains of northeastern Oregon and southeastern Washington (Sudworth 1908; Fowells 1965; and Knudsen and others 1968) (fig. 1). Although western larch is occasionally planted or seeded outside its natural range (Genys 1968), no significant efforts have been made to determine its adaptability to other climatic or geographic zones.

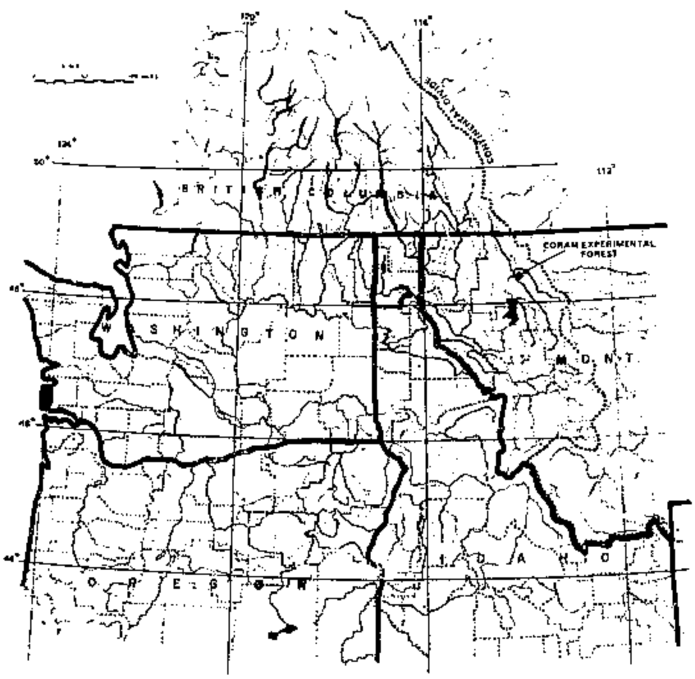

Figure 1.—The range of western larch and location of the Coram Experimental Forest (focal point of much western larch research).

Resource

According to the report "The Outlook for Timber in the United States" (USDA Forest Service 1973), western larch comprised a plurality of the stocking on 2.7 million acres of commercial forest land in 1970. This is down from acreages previously reported (USDA Forest Service 1965) because of shifts in land use. Larch also forms an important component in most of the other forest types in the northern Rocky Mountains (mountainous areas in Idaho, Montana, and northeastern Washington) west of the Continental Divide. Larch reaches its best development in western Montana and northern Idaho, where its greatest acreage of commercial forest is found (table 1). Table 1 shows that most of this land is publicly owned. About 80 percent of the cubic-foot and board-foot volume of western larch is centered in the forests of the Northern Region of the USDA Forest Service, which includes northern Idaho, Montana, western North Dakota, and western South Dakota. About 40 percent of the total volume is located in western Montana.

	Million ft³	*Million bd. ft. (Int. 1/4-inch log rule)*
Northern Rocky Mountains (Montana and Idaho)	3,955	18,835
Pacific Northwest (Washington and Oregon)	2,799	12,421
Total	6,754	31,256

TABLE 1. Area of commercial timberland,[1] by ownership, where western larch forms a plurality of the stocking, January 1, 1970[2]

Ownership	Northern Rocky Mt. (Montana and Idaho)	Pacific Northwest (Washington and Oregon)	Total
	Thousands of acres		
National Forest	1,217	473	1,690
Other public	161	112	273
Forest industry	199	36	235
Farm and misc. private	454	90	544
All ownerships	2,032	711	2,743

[1] Data may not add to totals because of truncation.
[2] From USDA Forest Service (1973).

Mature and Overmature Stands

Western larch is an important source of saw logs in the northern Rockies because about 60 percent of the area in which it is a major component is uncut (table 2). Most of this area is in western Montana. The vast majority of these virgin forests are by definition (Society of American Foresters 1971) overmature; i.e., declining in vigor, health, and soundness. Few of these stands fall in the mature definitions; i.e., fully developed, particularly in height, and with vigor sufficient for full seed production.

Harvest of larch has generally increased since the start of World War II (fig. 2), and with the volume of other species diminishing, the demand for larch will remain high. The present economies of many communities within the range of western larch depend heavily on the continued harvest of this versatile species.

TABLE 2.—Area of commercial timberland[1] for all ownerships where western larch forms a plurality of the stocking, by productivity class and stand size, January 1, 1970[2]

Productivity class (site) (ft³/acre/yr)	Sawtimber		Poletimber		Seedlings & saplings		Total		Total all States
	Mont. & Idaho	Wash. & Oreg.	Mont. & Idaho	Wash. & Oreg.	Mont. & Idaho	Wash. & Oreg.	Mont. & Idaho	Wash. & Oreg.	
	Thousand acres								
120+	524	53	199	19	108	33	832	105	937
85–120	313	79	107	58	66	59	487	196	683
50–85	396	173	158	73	46	90	600	336	936
20–50	87	37	14	10	10	27	111	74	185
Total	1,321	342	478	160	232	209	2,032	711	2,743

[1] Data may not add to totals because of truncation.
[2] From USDA Forest Service (1973).

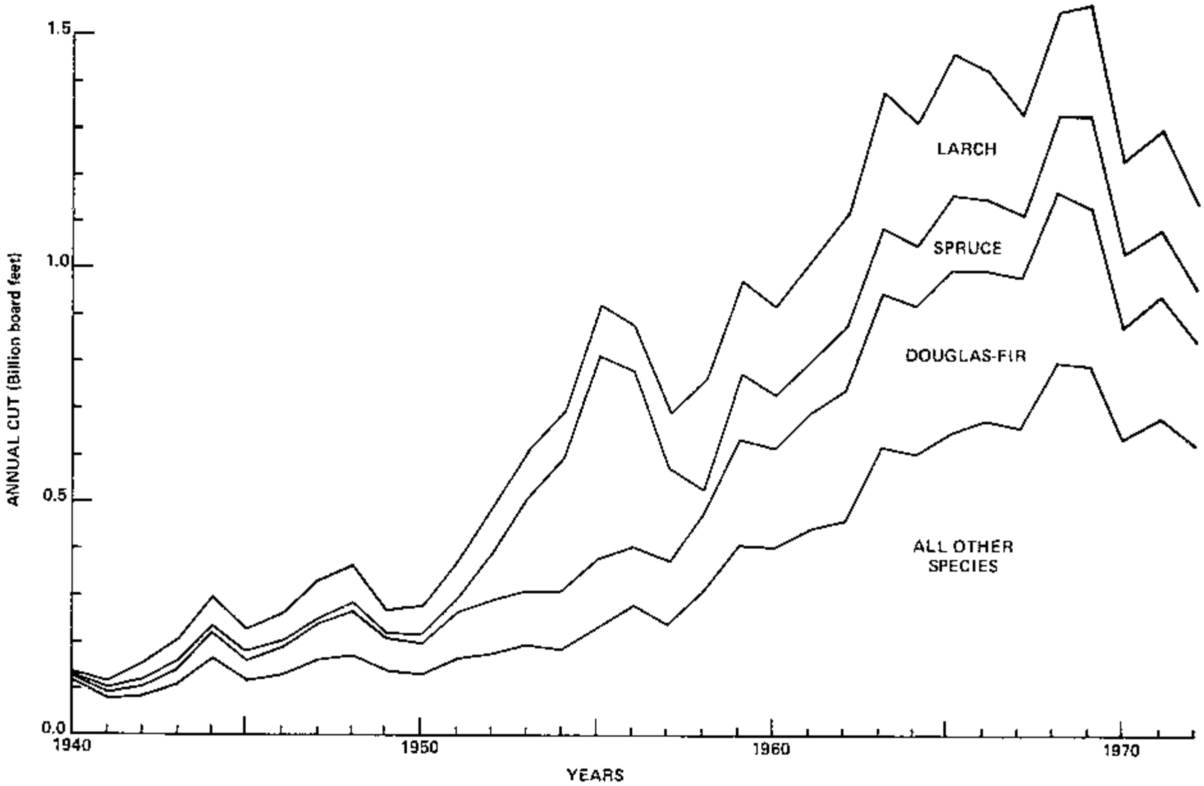

Figure 2.—Timber cut annually in the northern Rocky Mountains (Northern Region, USDA Forest Service).

Immature Stands

In 1970 nearly 40 percent of the western larch type consisted of immature stands (table 2). Most of these were established following the large burns of the first half of the century. Since wildfires occur randomly, pole and sapling stands abound in some areas but are rarely found in others. Although old growth still predominates, timber harvest and subsequent regeneration are steadily converting the type to younger age classes of better geographic distribution.

Immature larch stands can be divided into three broad categories on the basis of their origin: natural burns, early partial cuttings, or current even-aged management systems. Overly dense stands usually develop following natural burns and even-aged cutting systems; thus, overstocking is a top-priority problem in managing immature larch stands.

Nonstocked Lands

Nearly 1.5 million acres of nonstocked commercial forest land lie within the northern Rocky Mountains west of the Continental Divide (determined from tables in Wilson [1962], Hazard [1963], and Pissot and Hanson [1963]). Failure of tree regeneration after severe wildfires, and sometimes after cutting, has been responsible. Perhaps half of this nonstocked acreage has the potential for supporting good larch growth.

Products

Larch timber is used mainly for lumber (Betts 1944), particularly in construction where wood with high strength and hardness is required (Kotok 1973). It also makes fine veneer, and is used for utility poles, railroad ties, mine timber, and pulpwood (Western Pine Association 1953; Wilson 1964a, b). Larch is used interchangeably with Douglas-fir for construction lumber and plywood (Kotok 1973). The plywood industry in the northern Rockies uses considerable western larch; for example, in Montana larch supplied about half of the wood used in the manufacture of plywood in 1962 (Wilson 1964a), and about 40 percent in 1966 (Setzer and Wilson 1970).

Larch makes excellent utility poles because of its long length, exceptional form, and great strength. Wilson (1963) reported that larch made up 11 percent of all utility poles produced in the Northern

Region between 1947 and 1962. Nearly 60 percent of these were between 40 and 55 feet long, but only 18 percent of those from lodgepole pine, the top pole material in Montana, were in this range.

The best domestic source of arabinogalactan, a water-soluble natural gum (Ettling and Adams 1968), is from the wood of western larch (Nazareth and others 1961), the only conifer which contains it (Johnson and Bradner 1932). Arabinogalactan is used for offset lithography and in the food, pharmaceutical, paint, ink, and other industries. The wood contains from 4 to 23 percent arabinogalactan on a drywood basis (Austin 1954) with the highest concentrations in the lateral roots and decreasing up the tree (Mitchell and Ritter 1950, 1953). Because waste butt logs, sometimes left in the woods, are high in sugar content, they are the most desirable source of the gum (Austin 1954). However, these sugars react chemically with fresh concrete and prevent proper curing; thus, concrete forms should not be made from larch (Kotok 1973).

The oleoresin of western larch can be used to produce "Venice" turpentine and related products. The oleoresin has the consistency of honey, is light amber in color, and has an agreeable odor. It contains 16-percent volatile pinene and limonene (Mahood 1921).

TREE AND FOREST DESCRIPTION

Tree Characteristics

Western larch is the largest of the North American larches. Its straight trunk frequently grows to a height of 100 to 180 feet and attains a diameter at breast height (d.b.h.) of 3 to 4 feet in 250 to 400 years (fig. 3). At 600 to 700 years of age, the trees may reach a height of over 200 feet and a d.b.h. of 5 to 8 feet. A tree measuring over 24 feet in circumference (about 92 inches d.b.h. and 177 feet tall) was reported near the Kootenai National Forest in Montana (American Forestry Association 1973). Koch (1945) reports a stump at Seeley Lake, Montana, with 915 growth rings; the diameter measured 78 inches inside bark. Another tree in that stand measured 88 inches d.b.h. when cut. A deep, wide-spreading root system develops to support the weight of these large trees (Larsen 1916). The crown occupies half to a third of the total height of the mature tree and forms an open pyramid composed of short horizontal branches, which are thinly clad with leaves. The light-green deciduous needles are 1 to 2 inches long and borne on spur shoots in clusters of 14 to 40. New leaves form on the same spurs for several years.

Figure 3.—Old-growth larch stands with trees up to 5 feet in diameter near Seeley Lake, Montana, Lolo National Forest.

Larch is the most shade-intolerant tree in the northern Rocky Mountains (Baker 1949). Only in its early seedling stage is partial shade tolerated (Haig and others 1941).

The bark of young trees is thin, scaly, and dark or grayish-brown. The trunks of mature and overmature trees have reddish-brown bark, 3 to 6 inches thick, that is composed of rounded plates (fig. 4). These old trees have deeply furrowed bark near the base but furrowing decreases up the trunk. Higher up and on branches it is thin and scaly and more brown than red.

Little genetics work has been done with western larch. However, natural hybridization of western larch and subalpine larch (*Larix lyallii* Parl.) apparently occurs in those few areas where the two species grow together (Carlson and Blake 1969). Even where the geographic ranges of the two species overlap, elevation differences of a thousand feet or more usually separate them. Wang (1971) reports that interspecific hybrids of western larch and Japanese larch (*Larix leptolepus* Murr.) were more vigorous and taller than open-pollinated western larch progenies at the end of the first and second growing seasons.

Associated Vegetation

Western larch occurs in association with most conifers native to the northern Rockies (Daubenmire 1966, Larsen 1923). It grows with ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) on the lower, warmer, and drier sites of the Douglas-fir zone; with grand fir (*Abies grandis* [Dougl.] Lindl.), white pine (*Pinus monticola*

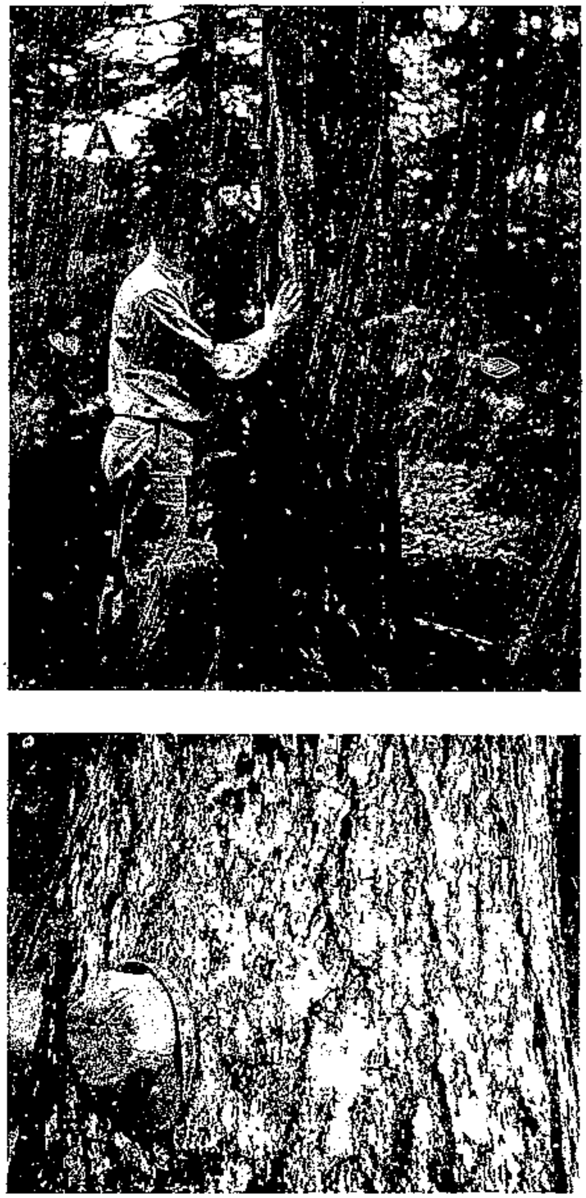

Figure 4.—Western larch bark structure is affected by age. Photo A shows the bark pattern of a 60-year-old fast-growing larch, while photo B shows the bark of a veteran that has grown over 600 years.

Dougl.), western redcedar (*Thuja plicata* Donn), and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) on moist sites in the western hemlock zone; and with Engelmann spruce (*Picea engelmannii* Parry), subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.), mountain hemlock (*Tsuga mertensiana* [Bong.] Carr.), and whitebark pine (*Pinus albicaulis* Engelm.) on the cool, moist locations in the subalpine fir zone (fig. 5).

Figure 5.—An old-growth western larch stand with the more shade-tolerant Engelmann spruce and subalpine fir in the understory at Coram Experimental Forest, Montana.

Habitat Types

Daubenmire and Daubenmire (1968) describe western larch as a seral species occurring in 13 of 21 different habitat types of eastern Washington and northern Idaho. These are:

The *Pseudotsuga menziesii* series

Pseudotsuga menziesii–Symphoricarpos albus
Pseudotsuga menziesii–Physocarpus malvaceus
Pseudotsuga menziesii–Calamagrostis rubescens

The *Tsuga heterophylla* series

Abies grandis–Pachistima myrsinites
Thuja plicata–Pachistima myrsinites
Tsuga heterophylla–Pachistima myrsinites
Thuja plicata–Oplopanax horridum

The *Abies lasiocarpa* series

Abies lasiocarpa–Menziesia ferruginea
Abies lasiocarpa–Pachistima myrsinites
Abies lasiocarpa–Xerophyllum tenax (fig. 6)
Tsuga mertensiana–Xerophyllum tenax
Tsuga mertensiana–Menziesia ferruginea
Abies lasiocarpa–Vaccinium scoparium

As a result of further investigation, Pfister and others[1] identified larch as seral in 19 of 30

[1]Pfister, Robert D., Stephen F. Arno, Richard C. Presby, and Bernard L. Kovalchik. 1972. Preliminary habitat types of western Montana, USDA Forest Service, R–1 TM and INT, 80 p.

Figure 6.—*Abies lasiocarpa-Xerophyllum tenax* habitat type, showing larch growing in association with *Xerophyllum* (the dominant undergrowth). This represents an early stage in the succession of tree and understory species.

preliminary habitat types in western Montana. Daubenmire's (1952, 1953) classification has also been used to successfully rate productivity (see "Growth and Yield" section) in northwestern Montana larch stands (Roe 1967).

Timber Types

Classified on the basis of existing forest cover, larch is found in the following forest cover types (Society of American Foresters 1954):

Type Number	*Type*
	Major Component
212	Larch–Douglas-fir
213	Grand fir–larch–Douglas-fir
214	Ponderosa pine–larch–Douglas-fir
	Minor Component
205	Mountain hemlock–subalpine fir
206	Engelmann spruce–subalpine fir
210	Interior Douglas-fir
215	Western white pine
218	Lodgepole pine
237	Interior ponderosa pine

The larch–Douglas-fir forests are found commonly in northern Washington, Idaho, Montana, and southeast British Columbia. Minor associates in the stand are lodgepole pine, grand fir, western white pine, ponderosa pine, western redcedar, and Engelmann spruce. Along the eastern limits of the type, western larch is replaced by interior Douglas-fir. *Pachistima myrsinites* (Pursh) Raf., *Vaccinium membranaceum* Dougl. ex Hook. *Menziesia ferruginea* Smith, and *Rubus parviflorus* Nutt. are usually common among the shrubs in this cover type (Society of American Foresters 1954).

The grand fir–larch–Douglas-fir combination occurs along the east slopes of the Cascade Range, the Okanogan highlands in northern Washington, and in Idaho, Montana, and the northern Blue Mountains of Oregon. Associates are usually western hemlock, western white pine, Engelmann spruce, and ponderosa pine. *Pachistima* occurs in this type as well as *Berberis nervosa* Pursh and *Physocarpus malvaceus* (Greene) Kuntze (Boe 1958).

In the mixture of ponderosa pine–larch–Douglas-fir, ponderosa pine is present in significant amounts but does not predominate. In western Montana, Idaho, eastern Oregon, and Washington, the type occupies intermediate zones between ponderosa pine and the more moist larch–Douglas-fir sites. Grand fir, western white pine, and lodgepole pine are sometimes present in minor amounts. Characteristic shrubs are *Physocarpus malvaceus* (Greene) Kuntze, *Amelanchier alnifolia* Nutt., and *Arctostaphylos uva-ursi* (L.) Spreng. (Boe 1958).

ENVIRONMENTAL FACTORS

Climate

Climatic factors generally define the distribution of western larch. Deficient moisture limits it at lower elevations and low temperature limits it at the upper extremes. It is confined to a climatic zone having cool mean annual temperatures of at least 40° to 45° F (Haig 1931) and a mean annual precipitation of more than 28 inches (Cunningham and others 1926; Kirkwood 1922; Larsen 1930). The growing season for larch varies with altitude (Daubenmire 1946) and season, but generally extends from May to August. This period has a high proportion of clear, hot days with the mean temperature ranging from 53° to 67° F. Only 17 to 30 percent of the annual moisture falls during the growing season. Heavy snowfall and low temperature are common in the winter. Wind velocities are usually low, especially during the growth period.

Precipitation

Larch stands receive from about 18 to nearly 50 inches of precipitation annually. Although precipitation increases with elevation, it varies with geographic location, ranging from approximately 28 inches in the northern portion to 32 inches in the southern portion (USDC Idaho 1964; Montana 1965; Oregon 1965; Washington 1965).

Much of the precipitation falls as snow. At 19 stations (see appendix A) within the range of larch, annual snowfall averaged 103 inches from 1910 to 1960, and ranged from 170 inches at Granite, Oregon (elevation 4,939 feet) to 49 inches at Coeur d'Alene, Idaho (2,158 feet). Haig and others (1941) report that Roland, Idaho, at the upper altitudinal extreme of these stations, received an average of 244 inches of snow. At some of these stations, snow may persist from late October through May.

Approximately 34 percent of the total precipitation falls in the winter months and 48 percent comes in spring and fall. Over half (10 percent) of the remaining precipitation comes in June, with July and August usually being very dry. Records from 29 stations (appendix A) (USDC Idaho 1964; Montana 1965; Oregon 1965; Washington 1965) show that precipitation for the growing season averages 6 inches but ranges from 4 to 9 inches. Records at Hungry Horse Dam, near the Coram Experimental Forest, show that from 1947 to 1970 precipitation varied from a high of 13 inches in 1964 to 5 inches in 1967. Extended periods of extreme drought occur frequently. Clear, sunny days with low humidity and high evaporation rates are characteristic of this region. Within the range of western larch, the sun shines 60 to 80 percent of the daylight hours during the summer months (Kincer 1928). Clear weather and the accompanying insolation hasten the depletion of soil water near the surface, and particularly on exposed slopes allow the soil temperatures to increase to the point of killing exposed succulent vegetation. Haig and others (1941) explain that these harsh conditions are somewhat balanced by low wind velocities, long retention of snow cover at many points, and moderate precipitation during May and June.

Temperature

Mean annual temperature ranges from 37° F at Mullan Pass, Idaho (elevation 5,963 feet) in the central part of the range to 52° F at Orofino, Idaho (elevation 1,027 feet) in the southern part (see appendix A). The growing season temperature records for the 29 stations listed in appendix A (USDC Idaho 1964; Montana 1965; Oregon 1965; and Washington 1965) show that the rise in monthly mean temperature is abrupt, with July the warmest month in the year. Yearly temperatures usuallv vary from subzero in the winter to around 100° F in the summer. During July and August, Larsen (1922a) found the air in an uncut stand of timber of the Priest River Experimental Forest to be 10° F warmer than in the open at night and about 10° F cooler in the hottest part of the day.

The frost-free season is short and irregular (usually from 60 to 160 days), but frosts may occur in any month.

Edaphic

Land Characteristics

Western larch characteristically occupies northerly exposures, valley bottoms, benches, and rolling topography. Southwest exposures usually are not favorable sites for larch (Boe 1958). It occurs at 2,000 to 5,500 feet in the north and up to 7,000 feet in the southern part of its range (Kirkwood 1922; Larsen 1930; Sudworth 1918).

Soil

Larch grows primarily on soils derived from glacial till or bedrock, but also in some areas on soils of loessial or volcanic ash origin. The most common parent materials are the argillites and quartzites from the extensive pre-Cambrian belt series (Alden 1953). These soils may be gravelly, sandy, or loamy in texture and occur on landforms ranging from flood plains to steep slopes.

Western larch occurs primarily on two soil orders—spodosols (formerly the gray wooded) and alfisols (formerly the brown podzolic) (Nimlos 1963). The spodosols are found on the wetter forest sites and as a result are more productive for larch than the alfisols. Deep, porous soils of mountain slopes or valleys favor its best development (Larsen 1940). Excellent growing conditions for larch occur on well-developed spodosols with light-textured surface horizons over strongly textured clay horizons.[2]

The soils within the larch type are relatively cool. Mueller (1970) reports that the high-elevation Truefissure soil has mean annual and mean summer temperatures of 40° and 46° F, respectively, at 20 inches in depth. The lower elevation Tarkio and Savenac soils average 42° and 50° F mean annual and mean summer temperatures at 20 inches.

Soil productivity for larch growth is influenced most by the soil's ability to absorb and retain large amounts of water. A soil-site study in the larch type revealed that out of a large number of soil variables, only the moisture-holding capacity accounted for any significant amount of the site productivity.[3]

This relationship is illustrated below:

Soil series	*Larch site index*	*Soil moisture-holding capacity (Upper 12 inches of the soil profile)*
		(Inches)
Truefissure	68	3.0
Waits	60	1.7
Yourame	52	1.0

Variations in soil depth, physical composition, and organic content influence the amount of moisture available for tree growth. Although soil productivity occasionally may be limited by insufficient nutrients, particularly nitrogen, it appears that this is not common and that the availability of moisture far overshadows the lack of nutrients. As a result, soil variations affecting distribution of larch are more likely to be physical than chemical.

Damage

Physical

Fire

Wildfires have periodically burned large forest areas in the northern Rockies, and even today's modern detection and suppression systems have not eliminated them. Down through the ages, wildfires maintained the natural distribution of larch (fig. 7) (Daubenmire 1943, Larsen 1929), and prescribed burning is now commonly used to prepare seedbeds. Mature and overmature larch are the most fire-resistant trees in the northern Rockies, primarily because of their thick bark (Flint 1925).

Figure 7.—A 30- to 40-year-old stand of western larch that began after a fire, Flathead National Forest, Montana.

[2]Carlson, T. C. 1964. Specific gravity and site index as related to soil series. Master of Science Thesis, Univ. of Montana.

[3]Embry, R. S. 1960. A soil site study of western larch (Larix occidentalis, Nuttall) in Montana. Master of Science Thesis, Univ. of Montana.

Haig and others (1941) point out that low resin content of the bark, high and open branching habit, low flammability of the foliage, and low duff volume also contribute to the species' ability to survive fire. However, fire readily kills the thin-barked seedlings, saplings, and pole-sized trees (Cunningham and others 1926; Sudworth 1918).

Wind

Larch is moderately to highly resistant to windthrow, as its deep, wide-spreading root system provides excellent anchorage (Harlow and Harrar 1937). In a dense 75-year-old stand that had been thinned in north Idaho, high winds uprooted 28 percent of the western white pine compared with only 6 percent of the western larch (Haig and others 1941). Windthrow seldom occurs in young or open-grown stands, but in dense old-growth stands that are infected with root rot it may be a problem, particularly when opened up by logging. For example, 11 years after clearcutting in an old-growth stand on the Coram Experimental Forest, 5, 25, and 52 percent of the total number of larch died within the 1-chain peripheral strip around the square 15-, 30-, and 60-acre blocks, respectively. Windthrow and wind breakage accounted for almost 90 percent of these deaths. Similar mortality was noted along the boundaries of 3- and 5-chain-wide clearcut strips where 10-year losses averaged 12 and 16 percent.

Isolated groups of seed trees left in clearcuts are also vulnerable to windthrow. On the Coram Experimental Forest, over a third of the residual volume in 1/4- and 1/2-acre circular groups on a 125-acre clearcut was lost to windthrow within 5 years after logging.

Topography plays an important role in windthrow losses. Trees on upper slopes and ridgetops, particularly where winds are channeled through narrow canyons and saddles, are very susceptible. Five-year records of windthrow in seed-tree groups at Coram Experimental Forest show that groups on the upper slopes sustained 60 percent loss as compared with only 12 percent loss in similar groups located in a more sheltered valley bottom.

Snow and Ice

Larch is not generally susceptible to damage from snow and ice. Since it is a deciduous tree, the branches seldom accumulate excessive amounts of either snow or ice. Occasionally, however, wet snow arriving early in the fall or late in the spring catches larch with a full complement of needles, causing severe bending in sapling and pole stands (fig. 8) and broken branches in mature trees. However, stands less than about 10 years have been observed completely bent over by an early wet snow in the fall without showing any adverse effects the following year.

Temperature

Once established as a seedling, larch is well adapted to the temperature extremes common throughout its range. The most apparent temperature damage after this time is cone crop loss frequently attributed to hard frost late in the spring. Potentially good cone crops can be completely eliminated or drastically reduced. Unseasonably low temperatures can also freeze newly developed foliage, but we know of no instances where the crown did not make at least a partial recovery during the same growing season. However, severe frost damage is detrimental to the current year's growth and can still be apparent the next growing season (fig. 9).

Noxious Fumes

Young larch needles are extremely sensitive to noxious fumes from industrial plants, but the needles become less susceptible as they mature (Leaphart and Denton 1961). Because larch sheds all of its needles annually, the tree accumulates fewer harmful deposits than other conifers. Fluorine and sulfur dioxide gases both injure larch foliage, but fluorine is the more toxic of the two.

Figure 8.—Snowbend in a 14-year-old larch stand caused by a heavy, wet snow in early June 1965, Coram Experimental Forest.

Figure 9.—A severe mid-June frost damaged the upper crown of this young western larch. The photo, taken the following May, shows both the newly developing needles and the persistently damaged portions of the shoots.

Shaw[4] determined that larch needles were more susceptible to fluorine gas than those of western white, ponderosa, and lodgepole pine. Recent improvements in methods of reducing stack gases can reduce these potential hazards.

Long-term direct or indirect effects of fluorides on growth and reproduction of larch and its associated vegetation are poorly understood[5] (Carlson and Dewey 1971). They found levels of 25 p/m on foliage as much as 8 miles from the source (5 p/m is found normally and 30–35 p/m produce toxic needle effects).

[4]Shaw, C. G. 1969. Fluorine injury to ponderosa pine in the vicinity of Spokane, Washington. Mimeo. handout for field trip at 1969 A.P.S. meeting.

[5]Carlson, Clinton E. 1971. Monitoring fluoride pollution in Flathead National Forest and Glacier National Park. Insect and Disease Branch, Div. of State and Private Forestry, USDA Forest Serv., Region 1, Missoula, Montana. Mimeo Rep. 25 p.

Biological

Diseases

Larch dwarf mistletoe (*Arceuthobium laricis* [Piper] St. John) is the most serious disease-causing parasite of western larch. This organism causes spiketops and defects such as burls and brashness (fig. 10), creates conditions suitable for entry of other diseases and insects, reduces seed vitality, and sometimes kills outright (Weir 1916a; Kimmey and Graham 1960). However, its most widespread and damaging effect is decreased diameter and height growth. Slight infections can reduce growth to three-fourths and heavy infections to one-half of normal in young trees (Gill 1935). The following growth reductions can be expected in trees with different levels of infection (Pierce 1960):

Infection level	*Basal area growth reduction (Percent)*
Light	14
Medium	41
Heavy	69

Infection level was based on the amount of crown in which brooming (proliferation of branching due to dwarf mistletoe) was present. Light level was for trees with less than one-third broomed; medium was one-third to two-thirds; and heavy was over two-thirds.

Larch dwarf mistletoe infections are found throughout most of the natural range of western larch (Weir 1916a; Foster and Wallis 1969; Hawksworth and Wiens 1972). In addition, Smith (1970, 1971) has successfully inoculated larch

Figure 10.—Dwarf mistletoe-infected larch residuals over a mixed stand of reproduction, Colville National Forest.

growing in the greenhouse and in plantations with hemlock dwarf mistletoe (*Arceuthobium tsugensis* [Rosendahl] G. N. Jones). Therefore, hemlock mistletoe may occasionally infect western larch where the two tree species grow together. Surveys in three areas illustrate the seriousness of larch dwarf mistletoe: 86 percent of the larch stands in northeastern Washington are infected (Graham and Frazier 1962), from 20 to 79 percent of the stands in the lower panhandle of Idaho are infected (Graham 1960), and about 36 percent of the stands in west-central Montana are infected (Graham 1964).

Surveys also show that the largest trees in residual overstories are infected most heavily and they in turn are the source of infection for the younger larch (Graham and Frazier 1962). Infection is six to seven times heavier in sapling and pole stands with an overstory of older trees left from fires or logging than in similar stands with no overstory.

Although dwarf mistletoe infection is heaviest in older trees, no age class is immune. Infected trees as young as 4 years have been observed by Weir (1916b), and Wicker[6] has shown that 4-month-old larch can be successfully inoculated. However, infection in young trees is usually light because the trees present a small target for the dwarf mistletoe seed (Wicker and Shaw 1967). Also, snow, wind, rain, insects, and molds remove most dwarf mistletoe seeds before they infect the seedling (Wicker 1967).

Larch dwarf mistletoe is not restricted to larch; lodgepole pine, western white pine, scotch pine, subalpine fire, and Engelmann spruce may also become infected (Weir 1918; Kuijt 1954; Graham 1959; Graham and Leaphart 1961; and Hawksworth and Wiens 1972).

The rate of spread of larch dwarf mistletoe has not been determined, but a recent study shows that mistletoe seed can be ejected as far as 45 feet (Smith 1966). Thus, 20 evenly spaced, diseased trees per acre (such as a residual overstory) could infect a whole acre of understory trees with just one good crop of dwarf mistletoe seeds.

Studies are currently underway to evaluate thinning-dwarf mistletoe relationships. Quantitative data are not yet available, but preliminary observations indicate that vigor of the dwarf mistletoe is enhanced by the increased amount of available light in the thinned stands. However, even a moderate level of dwarf mistletoe infection did not prevent larch growth acceleration following thinning.

Three other important diseases are found in larch: the brown trunk rot caused by the quinine fungus, *Fomes officinalis* (Vill. ex Fr.) Fuall; red ring rot caused by *Fomes pini* (Thore) Lloyd (fig. 11); and needlecast caused by *Hypodermella laricis* Tub (Cohen 1967). A host of less common fungi also infect larch (Shearer and Mielke 1958; Leaphart 1964; Foster and Wallis 1969; Hepting 1971). Some of them, such as the shoot blight disease (*Encoeliopsis laricina* [Ettlinger] Groves) and the fungus *Phacidiopycnis pseudotsugae* (Wils.) Hahn, are potentially serious pathogens (Funk 1969; Wicker 1965). However, most have not caused significant problems to date. Although estimates of defect caused by disease and injury for some local areas have been derived (Aho 1966), total effects of most larch diseases on growth and mortality have not been evaluated (Leaphart and Denton 1961).

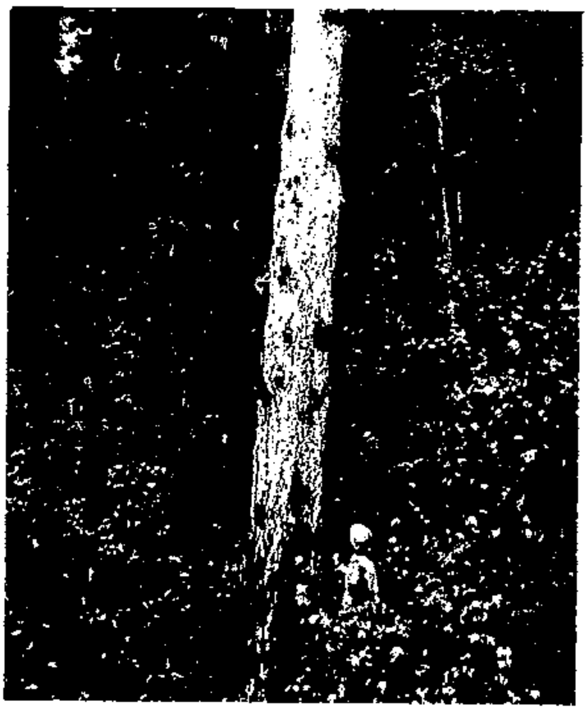

Figure 11.—Western larch infected with *Fomes pini*, Flathead National Forest.

[6]Wicker, E. J. 1965. Biology and control of dwarf mistletoe on Douglas-fir and western larch. Ph.D. Thesis, Washington State Univ.

Insects

Larch casebearer (*Coleophora laricella* Hbn.) is currently the most serious pest of western larch. This defoliator, of European origin, is found worldwide on nearly every species of larch. It was discovered in western larch forests near St. Maries, Idaho, in 1957 (Denton 1958, 1965). In the absence of natural controls, a casebearer population built up and spread very rapidly; by 1972 the insect had infested more than one-half of the western larch type (Denton 1972). Apparently the casebearer is well adapted to the northern Rockies environment, and it will no doubt eventually infest all western larch forests, even isolated stands (Denton and Tunnock 1968).

The casebearer can conceivably continue heavy defoliation until biological controls are established or until the larvae starve for lack of food. Starvation appears probable only after the trees suffer repeated defoliation to the point where foliage production is greatly curtailed. Although little tree mortality directly attributable to the casebearer was reported during the first 10 years of the epidemic, mortality is now apparent in northern Idaho larch stands. In addition, vigor loss and serious suppression of diameter growth have occurred. Studies have shown as much as 92 to 94 percent reduction in radial growth in a 4- to 5-year period (Tunnock and others 1969). Direct growth reduction will continue to occur as long as the trees are defoliated. In addition, the reduced vigor resulting from repeated defoliation also is likely to make the larch trees more susceptible to secondary insects, such as wood borers, that may finally kill many trees.

Because western larch is shade intolerant, the growth reduction caused by the casebearer can have serious long-term management implications even without mortality. Larch can maintain itself in mixed stands only as long a it holds a dominant position in the crown canopy. Repeated defoliation slows its growth and places it at a competitive disadvantage. In this way, larch loses it dominance in the stand and eventually its potential for recovery, even though the outbreak may subside later.

Industry has reported a serious reduction in the width of sapwood in defoliated larches, thereby making these trees less desirable or even unfit for utility poles. Casehardening, which prevents the penetration of preservatives into the wood, is another phenomenon reported by industry.

Direct control of the casebearer is possible with aerial sprays of dimethoate, phosphamidon, or malathion (Denton 1966; Denton and Tunnock 1968). However, direct control alone can provide only limited and local benefits, which may have little effect upon the total casebearer epidemic.

Some entomologists believe that the casebearer infestation will be contained in the long run through natural and biological controls. Weather and starvation are important natural factors that can decimate casebearer populations. Biological agents such as parasites and predators are similarly important. At least 50 species of parasites are known to attack the casebearer in Eastern States but fewer to date have been found in the West. In the Idaho area infested by casebearer in 1957, three species of native parasites were recovered 1 year later (Denton 1972). However, in 1968, 16 native parasites were recovered (Denton 1972). These 16 species parasitized 17 percent of the casebearer population in that area. Similar surveys in British Columbia recorded nine parasitic species in the 1966 to 1968 period with a corresponding maximum parasitism of 14 percent of the casebearer (Andrews and Geistlinger 1969). In a 1970 survey in Montana, northern Idaho, and northeastern Washington, Bousfield and Lood (1973) recovered 20 species of parasites of casebearer. Undoubtedly, the number of native parasite species attacking casebearer will continue to increase. Of the native parasites, *Spilochalcis albifrons* (Walsh) and *Dicladocerus* sp. are the most common (Denton 1972; Bousfield and Lood 1973).

Agathis pumila (Ratz.), a host-specific European parasite of larch casebearer, was credited with materially helping check and control casebearer in the tamarack (*Larix laricina* [DuRoi] Koch) forests of eastern United States and Canada. As a result, it was selected as the primary parasite to release in western larch forests in 1960. That year, several thousand *Agathis* adults were successfully introduced from New England into severely infested larch stands in northern Idaho. In the ensuing 10 years, records at five release sites showed substantial increases in *Agathis* parasitism at some and little at others (Denton 1972). Up to 66 percent parasitism was found at one site, 40 to 50 percent at two sites, and 2 percent or less at the others. The highest rate of parasitism prompted a tenfold decrease in casebearer numbers during the 10-year period.

The spread rate of *Agathis* from the release sites has been slow. Although after 10 years it was recovered up to 6 miles from the release point, the amount of parasitism decreased abruptly after one-half mile. This slow rate of spread has been attributed to the tremendous casebearer host populations immediately available. The spread rate should start to increase when casebearer population areas are sufficiently reduced (Denton 1972). To increase the rate of spread of *Agathis* throughout the range of casebearer, 10,000 *Agathis* adults in 1964, and 30,000 adults in 1965 were distributed in several hundred larch stands throughout the casebearer infestation. Since then, greater establishment of *Agathis* has been achieved by introducing this parasite while it is in its overwintering stage, as larvae inside the casebearer. However, because of the tremendous host populations and their wide dispersal, considerable time will likely elapse before *Agathis* becomes an effective biological control agent (Denton and Tunnock 1968).

Although most of the biological control efforts have centered around *Agathis pumila* (Ratz.), two other parasites of European origin—*Chrysocharis laricinellae* (Ratz.) and *Dicladocerus westwoodii* Westwood—were released in Idaho and Washington in 1972 (Ryan and Denton 1973); however, it is still too early to evaluate their effectiveness.

The effect of predation on larch casebearer is largely unknown, but a number of arthropods and birds have been observed feeding on it (Denton 1972). Black-capped chickadees, *Parus atricapillus* L., appear to feed heavily on casebearer larvae.

Another insect jeopardizing larch is the western spruce budworm (*Choristoneura occidentalis* Freeman), which reduces juvenile height growth and detracts from form (Fellin and Schmidt 1967; Schmidt and Fellin 1970). The usual diet of western spruce budworm larvae is the current year's foliage of many conifers. However, since 1962 budworm larvae have been found feeding not only on the foliage of larch seedlings, saplings, and poles but also severing the stems of the current-year terminal and lateral shoots (fig. 12A and B), as well as damaging cones and seeds (fig. 13) (Fellin and Shearer 1968). This is occurring wherever the distributions of larch and budworm overlap.

Of the injuries described, the most serious is severance of the current-year terminal shoots (Schmidt and Fellin 1973). Net annual height growth of trees whose terminals were severed averaged 27 percent less than that of trees whose terminals were not severed. Greater height losses might have been expected, but some growth was usually regained when one or more laterals turned up and replaced the severed terminal. Since about one-fourth to three-fourths of the tree terminals

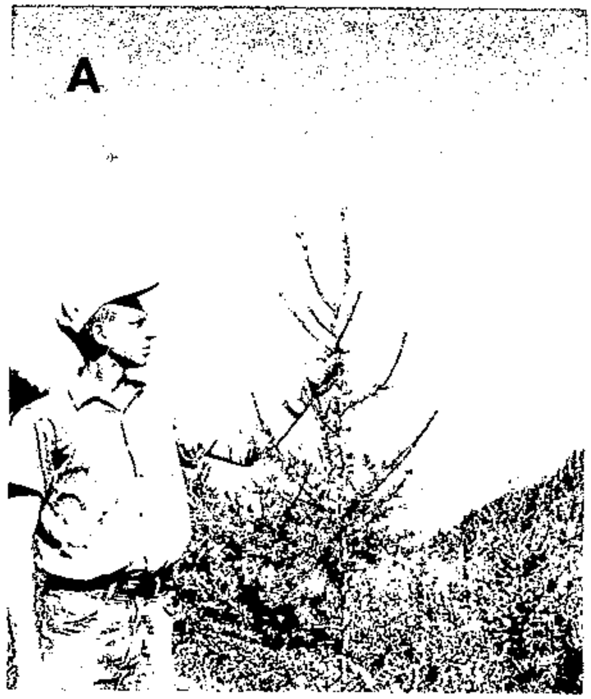

Figure 12.—*A*. Forks can develop in young western larch as a result of feeding damage by western spruce budworm. A budworm larva severed the terminal of this larch 1 month before the photo was taken. Two laterals have already assumed a near-vertical position. *B*. Development of forks in young western larch as a result of feeding damage by western spruce budworm. This larch tree demonstrates the effect of budworm severance during the previous year's growing season. Two lateral branches turned up after the terminal was severed and formed the double terminal.

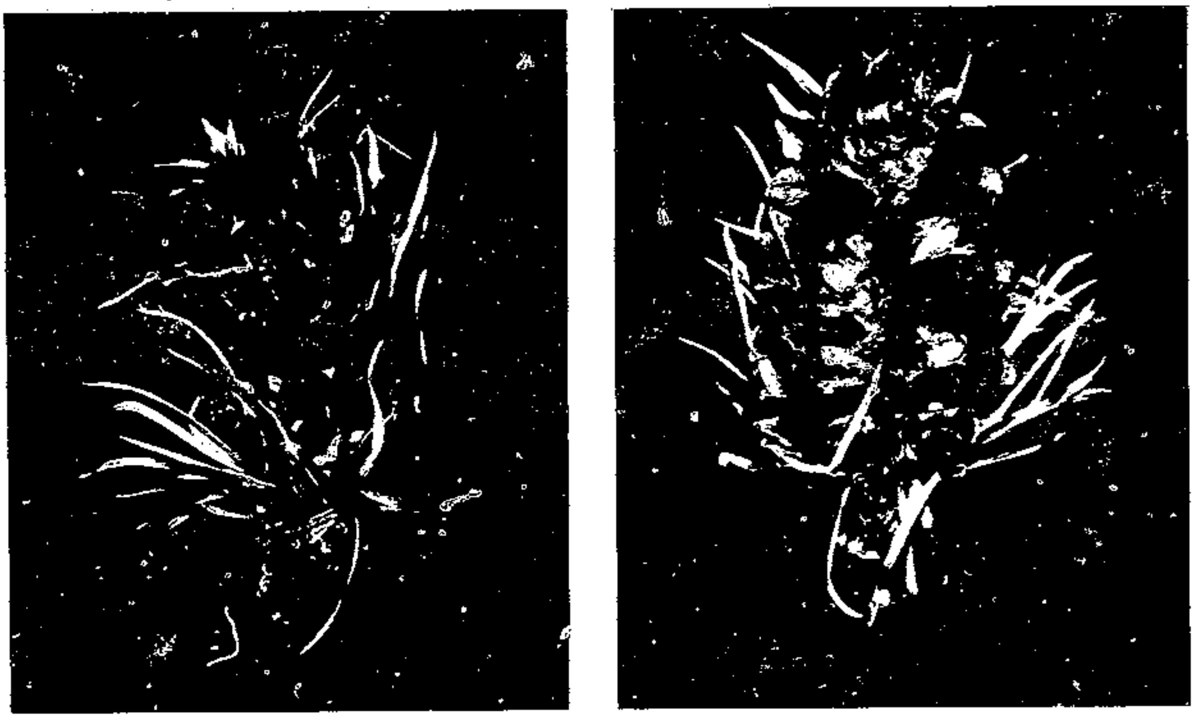

Figure 13.—Cones and seeds of western larch damaged by spruce budworm larvae.

were severed annually during a 10-year period in the area studied, the overall damage added up to a substantial loss in height growth for the stand.

Repeated severing of stems and upper laterals produces crooked boles and misshapen, bushlike trees (Fellin and Schmidt 1973a). In response to loss on the terminal, lateral branches turn up to replace the leader (fig. 12B) and a fork is formed. Although forks do not appear to persist more than about 5 years, crooked boles remain to document the previous damage.

Western larch management can be adversely influenced by sustained budworm damage of this type. If high budworm populations continue in the northern Rockies, the incidence of multiple-topped trees will increase, and trees will become less able to outgrow forks. Moreover, severance of the terminal leaders places larch at a competitive disadvantage with some of its associated species, particularly lodgepole pine, and thus reduces its potential for later recovery.

Although the incidence of budworm damage did not appear related to stand density in their study, Schmidt and Fellin (1973) feel that thinning has the potential of ameliorating the effects of budworm damage by establishing a more vigorous stand. Not only are the more vigorous trees with large-diameter shoots severed less often than those with small-diameter shoots, but the trees are better able to recuperate rapidly when budworm populations decline.

Schmidt and Fellin (1973) speculate that budworm will become more widespread in larch forests on a wider range of site qualities and ecological habitat types. They expect significant but less pronounced effects of budworm on the better sites.

Although we usually associate unseasonal frosts and low temperatures with tree damage, these factors can have a negative effect on budworm and hence a positive effect on the trees. Temperatures as low as 21° F were recorded in western Montana in mid-June 1969, a period when western budworm larvae are actively feeding. Fellin and Schmidt (1973b) found that the freeze reduced budworm populations on western larch, Douglas-fir, and ponderosa pine more than 90 percent, and subsequent budworm damage to young larch up to 70 percent the following season.

The larch sawfly (*Pristiphora erichsonii* [Hartig]) and the larch budmoth (*Zeiraphera griseana* [Hubner]) have caused heavy but sporadic damage to western larch. The western larch sawfly (*Anoplonyx laricivorus* Roh. and Midd.), the twolined sawfly (*Anoplonyx occidens* Ross), and a looper (*Semiothisa sexmaculata* [Pack.]) also damage larch occasionally.

Bark beetles are not generally a serious threat to larch. The Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.) occasionally attacks felled, injured, or weakened trees and it has been known to kill apparently healthy, mature trees (Keen 1952). Other minor pests such as the false hemlock looper (*Nepytia canosaria* [Wlkr.]), an engraver beetle (*Ips plastographus* [LeConte]), and the larch engraver (*Scolytus laricis* Blkm.) damage larch only infrequently.

Animals

Animals rarely damage larch. Small rodents are probably the greatest threat because of their seed- and seedling-eating habits (see section on factors affecting survival). Squirrels (*Tamiasciurus hudsonicus* [Bachman]) commonly cut and cache larch cones, particularly in years when a good cone crop of larch coincides with poor cone crops of its associate species. In the process of cutting the cones, squirrels occasionally clip some small branches, thereby reducing lateral growth and possibly the number of the buds that may develop into cones the next year.

Deer (*Odocoileus* sp.), elk (*Cervus canadensis* [Bailey]), and moose (*Alces alces* [Nelson]), while herded up during the winter, will browse larch to some extent. Larch is thought to be relatively unpalatable for these game species and is taken only as a last resort. In addition, much of the larch type occurs in areas of heavy snowpack not suitable for the critical winter game range.

Figure 14.—A bear girdled and killed this young larch while feeding on the inner bark.

Bears (*Ursus* sp.) occasionally girdle and kill vigorous young saplings by stripping the bark at their base (fig. 14), but this sporadic damage is not considered a significant problem.

Porcupines (*Erethizon dorsatum* [Brandt]) are common in the larch type but seldom damage western larch. This is in marked contrast to the heavy damage they cause to larch growing in the Eastern United States (Cook 1969; Fowells 1965).

STAND REGENERATION

Forest managers rely heavily on natural regeneration as a means of restocking cutover lands with western larch in the northern Rockies (Schmidt and Shearer 1973). Current overstocking of many areas denuded by wildfire or cutting attests to the relative ease with which this species becomes established when the environmental conditions are right. Early writers (Whitford 1905) called attention to abundant larch reproduction following fires and along road cuts. Cary[7] attributed the seedling abundance to the survival of larch seed trees after fires, abundant seed supply, "wide reach" of the seed, and the ability of larch seeds to germinate and of seedlings to survive on soil "entirely open to the sun." Brewster[8] pointed out that 1- to 4-year-old seedlings survived best on mineral soil in full sunlight. Larsen (1916) found that larch reproduced promptly and more uniformly on burned and bare mineral soil than on sod, litter, and raw humus.

Despite the apparent ease with which larch stands restock, failures do occur. In such situations, direct seeding or planting often is the best method of reforestation. Prior to 1963, few attempts were made to stock areas with western larch by either seeding or planting. Many early attempts at direct seeding failed because of adverse climatic conditions or severe plant competition. Wahlenberg (1925) held little hope for success anywhere except possibly on fresh burns with low rodent populations. Schopmeyer and Helmers (1947) concluded that freshly burned, northerly slopes and flats could be direct seeded successfully in the western white pine type. However, in the few instances where western larch was included with other species, the survival was generally very low. Survival of early plantings also was usually low. Higher survival in more recent years is attributed mainly to judicious selection of sites, sowing and planting on fresh, well-prepared seedbeds, and favorable first-year growing conditions.

Broadly speaking, the basic requirements for regeneration include an ample supply of seed, a favorable seedbed, and environmental conditions that favor initial seedling survival. There are many factors influencing this triumvirate that either benefit or restrict restocking. Because many of them apply equally to natural and artificial regeneration, they will be discussed later where pertinent.

Seed Production

Seed production is a major consideration in planning for natural regeneration. Because larch bears cones throughout the crown, seed production is generally proportionate to the size of the crown. For example, a study during a year of high seed production showed a range of 56 cones in a tree with 45 major branches to a high of 2,090 cones in a tree with 95 major branches. In the Coram Experimental Forest, vigorous, full-crowned, mature larch trees that averaged about 22 inches in diameter and 300 years in age produced about five times as much seed as 14-inch trees in the same stand and age class; larch trees below 12 inches in diameter and averaging 300 years in age were considered ineffective seed producers.

Planting and seedling programs also depend upon large quantities of seed sometimes 2 to 3 years in advance of the actual needs on the ground. Knowledge of seed production is important for the support of such programs.

Flowering

Larch buds commonly are borne on the end of dwarfed, short, spurlike lateral branchlets. The vegetative buds are small—usually between one-tenth and one-eighth of an inch in diameter. Flowerbuds range from one-eighth to three-sixteenths of an inch in diameter and are as long or longer than they are wide. The staminate buds are

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[7] Cary, Austin. 1911. Silvicultural study of white pine stands, Kaniksu National Forest. USDA For. Serv., unpublished report.

[8] Brewster, D. R. 1912. Characters of western larch bearing upon marketing and management problems. USDA For. Serv., unpublished report.

A

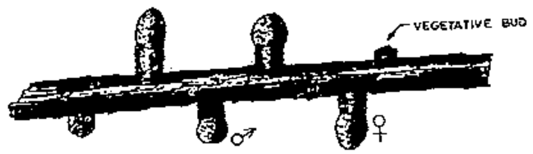


Figure 15.—*A*. Sketch showing ovulate (♀), staminate (♂), and vegetative winter buds of western larch; *B*, longitudinal section of ovulate and staminate buds.

B

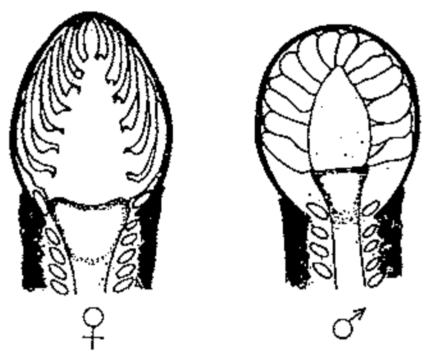


Figure 16.—An 8-year-old western larch producing cones.

usually globose or subglobose, about as long as they are wide, and ovulate buds are usually 1½ to 2 times longer than they are wide and rounded or conical on the end (fig. 15). When question arises, buds can be positively identified by cutting to expose a longitudinal section.

Separate male and female flowers develop close together on the same tree (USDA Forest Service 1948). The strobili (new conelets) appear after the tree has broken dormancy in the spring—usually about April 15 to May 15. They precede the foliage development by several days and vary from green and green-brown to a distinctive red color. The conelets grow rapidly and soon reach the size of the old cones that have persisted from previous years. The old cones are distinguishable from the conelets primarily by their dull-brown color—size distinction alone is not reliable. The new cones mature in one season and are from 1 to 1¾ inches long. They ripen in late August, and open soon afterward during dry days and shed their seeds. The cones may fall throughout the following winter or remain attached for several years. Cones may be produced on saplings as young as 8 years (fig. 16); Olson (1932) reported cones on 16-year-old trees that originated from the 1910 fires in northern Idaho.

Maturity

Seeds generally mature by mid-August, cones begin to open by late August, and seeds are mostly shed by mid-October (Boe 1958). Cone scales open and the seeds are shed usually after the cones have dried to a moisture content of 35 to 40 percent. Frequent summer rains may maintain high moisture content in the cones until a dry period occurs. All the cones on an individual tree dry out at about the same rate, but the drying rate may vary considerably among trees. In a sample of five trees, the cones on one dried enough for seed dispersal to begin by September 14, on two others by September 21, on the fourth by September 28, and on the last by October 1.

Although tests have been limited, cone specific gravity or moisture content do not appear to be reliable indicators of larch seed maturity, as they do in other species. Likewise, cone color or changes in color do not reliably indicate seed maturity. Further research is required to establish reliable measures for predicting seed maturity.

Young trees usually produce better seed than overmature trees (Shearer 1959). Six-year seed production records from 300-year-old overmature larch stands showed great annual differences in the percent of sound seed produced, but production never exceeded 42 percent in any year (table 3). Seeds sampled on five trees about 66 years of age averaged 70 percent viability and ranged between

TABLE 3.—Estimated number of western larch seeds released per acre, percent soundness, and seed crop rating in each of 6 years

Year	Estimated number released per acre	Soundness	Seed crop rating
	Thousands	*Percent*	
1952	1,173	42.4	Good
1953	98	4.9	Near failure
1954	4,548	33.2	Good
1955	163	21.5	Near failure
1956	24	10.0	Near failure
1957	262	17.1	Poor

48 and 78 percent. Griffith[9] found that viability ranged from 32 tc 80 percent among nine trees that varied from 191 to 516 years of age during a bumper seed crop, but detected no viability–age relationships.

Variability and Prediction of Seed Crops

Western larch, as well as many of its associate species, produces good and fair seed crops at irregular intervals. Several studies (Haig and others 1941; Boe 1954; Shearer 1959) point out that good crops are produced at approximately 5-year intervals, but occasionally two good seed years may occur in close succession. For example, 1952 was a "bumper" seed year followed by another in 1954 (table 3). Also, 1964 was a good seed year followed by another in 1965. Records for 22 years, covering most of the larch range in the northern Rockies, showed a 1:1 ratio between fair or better versus poor crops (Boe 1954). Detailed 6-year records of larch seed production on the Coram Experimental Forest show two good crops, two poor crops, and two near failures (Shearer 1959). In one instance, four successive cone crops were nearly complete failures. Highest seed soundness (42 percent) usually was related to years of high production, while lowest soundness (5 percent) was associated with low production.

Often it becomes necessary to coordinate seedbed preparation, seed collection, and other management activities with seed-year predictions because of the irregular time intervals between good seed years. The prospects of a seed crop can be assessed as much as a year in advance of cone maturation and seed fall (Roe 1966). At the end of the growing season (when the buds are set), it is easy to identify staminate, ovulate, and vegetative buds by their relative sizes and shapes. A detailed method of sampling the future cone crop is described in appendix B.

Collection and Extraction

Usually larch cones are gathered from squirrel caches or from trees as they are felled during logging. The cones in standing trees are difficult to collect because they are small and widely distributed in the crown. Collections should be made in years when there are heavy seed crops to obtain the highest quality seed and at the least cost per pound of cleaned seed.

The limited cone collection period (between seed ripening and shedding) can be extended by collecting larch cones early and permitting the seeds to ripen in the unopened, stored cones. The "after-ripening" process results in little or no reduction in seed viability. To study the effects of after-ripening on larch, cones were picked at weekly intervals from late July until seedfall in 1964. Seeds were extracted immediately from one half of the cones in each sample. The remainder of the cones were stored at 70° F and 25-percent relative humidity until October 30 when the seeds were extracted from them. Seeds that ripened in stored cones (collected from July 29 through September 14) showed a much higher viability than did those which were extracted on the day of collection (fig. 17). Viability was not increased by leaving the seeds in cones collected September 21 or 28.

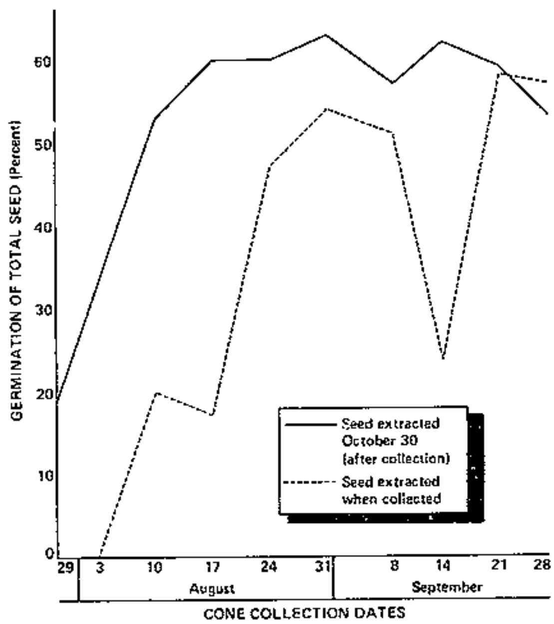


Figure 17.—Effect of extraction time and collection date on germination of western larch seed 30 days after the start of incubation.

[9]Griffith, R. D. 1972. Larch seed viability study. St. Regis Forest Products Division, J. Neils Operations, Libby, Montana, 2 p.

Storage

Larch seed may have to be stored for many years to insure an adequate supply for reforestation between good seed crops. Larch seed has been kept for 1 to 2 years at room temperature in sealed containers with an average loss in viability of about 6 percent (USDA Forest Service 1948). However, storage in sealed containers at 0° F is recommended.

Seed Testing

The viability percent of larch seed is frequently used to estimate the number of seed needed for nursery or field sowing. But without pretreatment, germination (and hence viability testing) may continue for over 4 months (Shearer and Tackle 1960). Schmidt[10] and Schmidt (1962) tried several seed treatments in an attempt to find reliable and rapid viability tests. His work showed that either soaking in water for 18 days at 33° F or soaking in U.S.P. 3 percent H_2O_2 for 12 hours in an open or a closed container plus incubation gave 98 percent germinative capacity in a total of 28 days. He recommended sand stratification, steeping, or naked stratification as treatments for larch seed prior to field sowing.

Dissemination

The small, light larch seeds are dispersed readily from trees reserved in shelterwood or seed-tree cuttings and from trees bordering clearcut strips or patches. Seeds are dispersed more uniformly throughout seed-tree and shelterwood cuttings than in clearcuttings (Boe 1953; Roe 1955; and Shearer 1959).

The quantity of seed produced in seed-tree or shelterwood cuttings is largely a function of the number of trees reserved. On similar seedbeds at Coram Experimental Forest, leaving 13 seed trees per acre resulted in 10 to 15 percent more stocked plots and two to four times as many seedlings per acre than leaving four trees per acre (fig. 18). Favorable seedbeds often become overstocked with seedlings following repeated good seed years.

Seed normally falls in excessive amounts near the edges of stand openings, and decreases rapidly toward the center. Seed reaching the center of a 60-acre clearcut block in the Coram Experimental Forest (825 feet from the margin) amounted to only about 5 percent of that which fell near the uncut margin (table 4, fig. 19). During the 6-year study period, which included two bumper seed crops, 14,000 to 44,000 sound seed per acre accumulated at the center of the clearcutting—easily enough seed to establish a well-stocked stand on favorable seedbeds.

[10]Schmidt, Wyman C. 1961. Effects of some treatments on the dormancy of western larch seed. Master's Thesis, Univ. of Montana

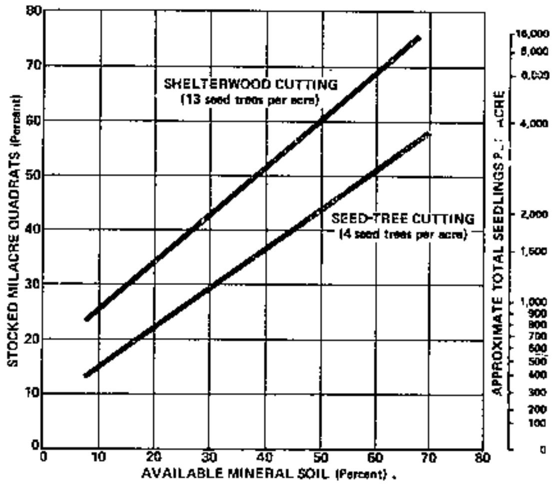


Figure 18.—Influence of cutting method and available mineral soil on establishment of first-year western larch seedlings.

The species composition of seed dispersed from mixed stands bordering openings changes in favor of the lighter-seeded species toward the center of such openings. The small, light larch and Engelmann spruce seeds reach greater distances in larger quantities than the heavier Douglas-fir and subalpine fir seeds. This is illustrated by the quantities of seed that fell at the timber edge, and at 4 and 10 chains from the seed source on the Coram clearcuts (fig. 20). The composition of first-year seedlings observed at the center of the 60-acre block corroborates the seed-dispersal pattern. Engelmann spruce experienced greater seedling

TABLE 4.—Seedfall in a 60-acre clearcut block expressed as percent of seedfall in the surrounding timber

Distance from timber edge (chains)	Direction to timber			
	Northwest	Northeast	Southeast	Southwest
	Percent			
1	81	48	25	36
2	42	20	13	14
3	23	15	21	9
4	17	9	13	12
6	6	10	4	2
8	5	5	2	2
10	1	3	7	2
12	1	2	5	1

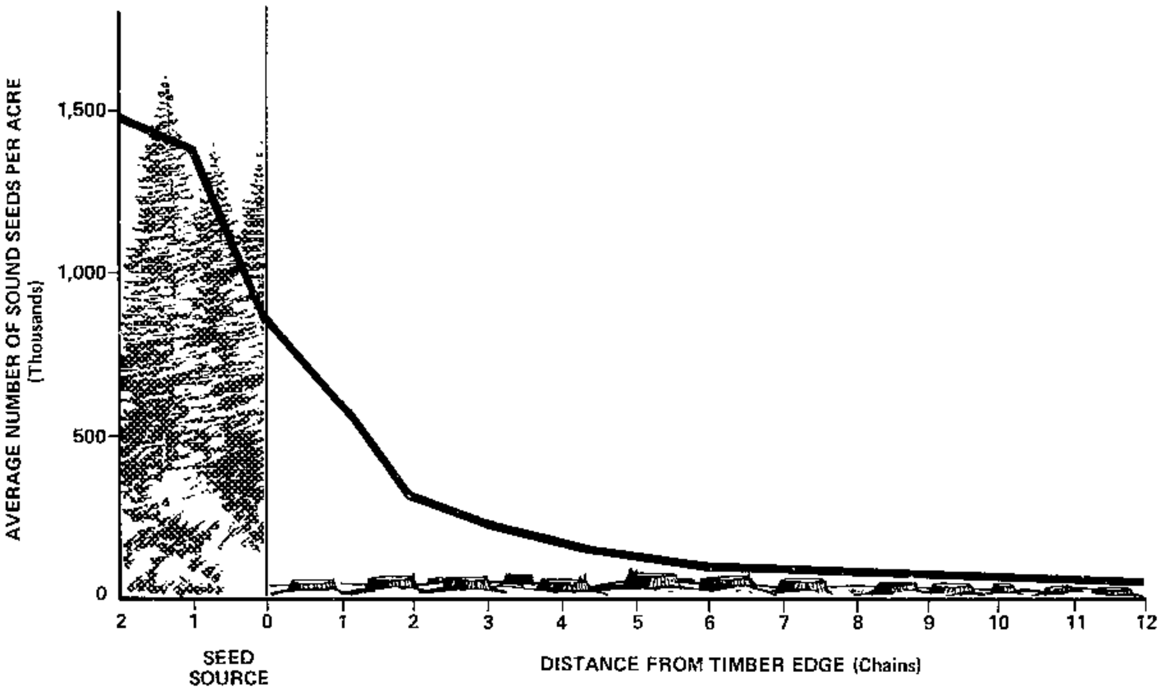


Figure 19.—Average number of sound western larch seeds dispersed per acre over three clearcut blocks from 1952 to 1957 by distance from seed source.

mortality than the other species, but its stocking still exceeded that of subalpine fir at the center despite the latter's higher seed production.

Germination

Larch seeds germinate well on all types of seedbeds and aspects, but success depends chiefly upon temperature and moisture conditions. Germination begins at or soon after snowmelt in the spring: from late April at low-elevation, exposed sites to mid-May or early June on sheltered north slopes at higher elevations. Seeds dispersed in the fall and early winter germinate the next spring and do not hold over into the second year. Larch normally germinates 1 to 2 weeks before its associates and is about 90 percent complete in 3 weeks. Larsen (1922b) determined that seeds of trees associated with larch begin germinating at temperatures between 50° and 60° F and peak at between 70° and 80° F. Larch probably begins to germinate at temperatures below 50° F, because some radicles emerge before snowmelt. This early germination allows the seedling to develop a deeper and more branched root system to penetrate the soil ahead of moisture deficiency in July and August. Although rodents and other seed-destroying agents can greatly reduce the quantity of seed available for spring germination, our studies have shown that high populations of rodents do not necessarily cause excessive larch seed loss (Shearer and Halvorson 1967).

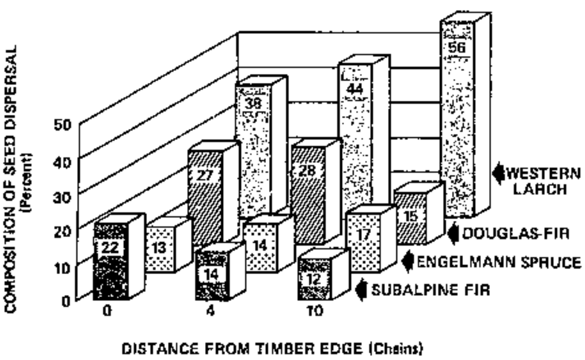


Figure 20.—Composition of seed dispersed at 0, 4, and 10 chains from timber edge.

Seedling Survival

The survival of newly emerged larch seedlings depends upon the microenvironments of the site. Western larch is a seral or pioneer species whose seedlings are well adapted to disturbed conditions, such as those found on bare mineral soil or following severe burns. Larch seedling survival is poor on the undisturbed litter, humus, or sod of the mature forest. Shaded sites and areas with heavy root competition (whether they be in mature forests or heavily stocked immature stands) will also limit seedling survival (Larsen 1916; Roe 1952, 1955).

Most western larch seedling losses occur during the first 3 years (Haig and others 1941). Usually, less than half the seedlings survive the first year. Although losses continue in succeeding years, the probability of seedling survival steadily increases. As was shown in a study of 15 areas by Haig and others (1941), only 39 percent of the larch seedlings survived the first 3 years, but nearly 85 percent of the 3-year-old seedlings survived the next 3 years. Hence, the survival probability of larch seedlings increased steadily each year after germination (using the previous year's survival as the new base).

Years since germination	*Mortality (Percent)*	*Survival probability (Percent)*
1	46	54
2	8	85
3	7	85
4	3	92
5	2	94
6	1	97
	67	

These data were derived from areas quite favorable to larch seedling survival and growth and are therefore applicable only to the better larch sites. Research is needed to develop survival probabilities for the various site conditions under which larch grows.

Factors Affecting Survival

Seedling mortality begins soon after germination, usually in late April or early May while the soil is still wet. The influence of various environmental factors exhibits a seasonal sequence (Haig 1936, Haig and others 1941; Shearer 1961). Early–season mortality, which may last until the end of June or mid-July, is usually caused by biotic agents such as fungi, rodents, birds, and insects. As soil moisture is depleted and summer begins, the influence of biotic agencies decreases and physical factors begin to take their toll.

Fungi

Studies on the Priest River and Coram Experimental forests have shown fungi to be the most destructive of the biotic agents among first-year larch seedlings (Haig 1936; Haig and others 1941; Shearer 1961). Fungi caused greater mortality in seedlings growing on duff than on exposed mineral soil surfaces in full sun or partial shade. However, under full shade, where temperature did not differ markedly between duff and mineral surfaces, the reverse was true (table 5). The results for Douglas-fir were similar to those for western larch except that neither seedbed condition was superior to the other under partial shade.

TABLE 5.—First-year seedling mortality caused by fungi (in percent of total germination)[1]

Species	Full sun		Partial shade		Full shade	
	Duff	Mineral soil	Duff	Mineral soil	Duff	Mineral soil
Western larch	96	14	70	7	30	61
Douglas-fir	97	33	37	38	19	66

[1] From Haig and others (1941).

Animals

Moderate-to-heavy rodent populations usually do little damage to larch seed or seedlings (Shearer and Halvorson 1967). However, Douglas-fir seed was selectively taken in preference to larch and spruce from fall-sown seed spots at Coram. In one instance, all seed spots sown with Douglas-fir seed were disturbed and 38 percent of the seed was found hulled. An undetermined additional amount may have been carried off the plots and not accounted for. In comparison, 40 and 13 percent of the larch and spruce seed spots were disturbed, with at least 3 and 1 percent of the seed destroyed. Spring-sown western larch and Douglas-fir seed sustained only 60 and 15 percent as much loss as fall-sown seed.

Insolation

Insolation, the most important physical agent, kills first-year seedlings by causing high soil surface temperatures (in excess of 135° F) and consequent heat girdling of seedlings. These losses usually start in late June. As expected, studies in northern Idaho (Haig and others 1941) showed that insolation-caused losses were highest under full sunlight (table 6). Also, in the 2-year study period, the number of days that reached or exceeded lethal temperatures annually averaged 44 more on duff and 16 more on burned mineral soil than on natural mineral soil.

Drought

Drought, unlike heat damage, causes heaviest seedling losses in full shade with only minor losses occurring in full sun and partial shade (Haig and others 1941) (table 6). Drought losses are usually brought about by shallow first-year root penetra-

TABLE 6.—First-year seedling mortality on mineral soil caused by physical factors, in percent of those seedlings surviving biotic losses[1]

Physical factor	Full sun			Part shade			Full shade		
	Unburned soil	Burned soil	Weighted average	Unburned soil	Burned soil	Weighted average	Unburned soil	Burned soil	Weighted average
Insolation									
Western larch	74	79	75	16	32	24	—	—	—
Douglas-fir	78	84	81	9	19	14	—	—	—
Drought									
Western larch	4	4	4	1	3	2	90	94	93
Douglas-fir	6	4	5	1	1	1	16	20	17

[1] From Haig and others (1941).

tion and drying of the upper soil. The drain on the soil moisture by the overstory and other vegetation in full shade may account for more rapid drying of the soil. Shade from noncompetitive objects such as snags, stumps, and logs can be beneficial to seedling survival.

Aspect

Aspect, although it has little effect on germination, greatly affects seedling survival through its influence on soil surface temperature and moisture. Western larch, when it occurs, usually forms only a minor component of the stand on dry south and west slopes where high temperature and low moisture kill most if not all of the first-year seedlings (Larsen 1916, 1925; Shearer 1961).

TABLE 7.—Percent of milacre quadrats stocked with new seedlings[1] *(1949—1953) by ground preparation treatment, Coram Experimental Forest*

Treatment	Percent of[2] favorable seedbed	Percent of milacre quadrats stocked		
		Western larch	Engelmann spruce	Douglas-fir
Control[3]	15	21	10	20
Understory slashed	23	27	·	17
Mechanical scarification	42	41	15	31
Prescribed broadcast burn	48	46	26	27

[1] Adjusted by analysis of covariance to mean seed crop.

[2] Includes any seedbed judged to be favorable to seedling establishment on the basis of exposed mineral soil and the removal of competing vegetation whether accomplished expressly by treatment or incidental to logging activity.

[3] The control was logged but given no special ground preparation treatment other than that incidental to logging.

Larsen pointed out that first-year larch seedlings died on west slopes during warm July and August days, notwithstanding the shade cast by Douglas-fir and ponderosa pine trees.

North, northeast, and northwest slopes generally present the most favorable conditions for western larch seedling survival (Larsen 1916, 1924; Shearer 1961). Sandy flats, when shaded, also favor larch regeneration, but full exposure to the sun creates an environment inimical to first-year seedling survival.

Site Preparation

The forest manager can increase seedling survival of all species, particularly shade-intolerant species like western larch, through site preparation. When the mineral soil surface is exposed by removing competing vegetation, more light, moisture, and nutrients are available for tree growth. However, the prescription must be applied judiciously to comply with multiple use considerations imposed on the area.

On the Coram Experimental Forest and elsewhere, studies that have included site preparation as one of the variables have demonstrated that exposed mineral soil prepared either by prescribed burning (fig. 21) or scarification (fig. 22) provides the best environment for establishment of larch regeneration and also, as shown in table 7, for other more shade-tolerant species (Roe 1955). The stocking rates agree with the estimated percentages of favorable (exposed mineral soil) seedbed in each of the treatments. The number of seedlings and the stocking achieved 1, 3, and 13 years after three types of seedbed preparation at Coram (there were bumper seed crops in 1952 and 1954) are presented in table 8. The great quantities of seed contributed to the overabundant stocking on some of the seedbeds. Although the number of seedlings per acre in 1965 where slash had been hand piled and

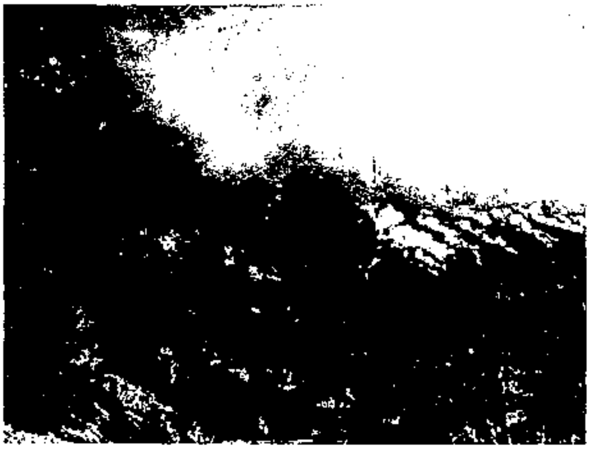


Figure 21.—Prescribed burning on a north-facing slope on the Coram Experimental Forest. To prepare a good seedbed, the slash and duff must be dry enough to burn to mineral soil.

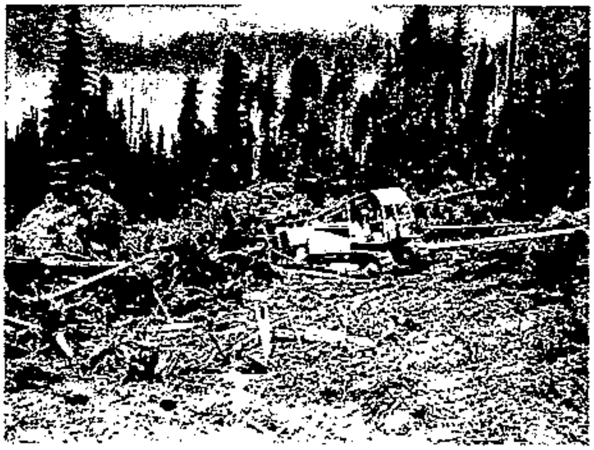


Figure 22.—Mechanical scarification using a brush blade mounted on a bulldozer, Kootenai National Forest. Logging slash and brush are pushed into piles or windrows and burned.

burned appears to be sufficient to stock the area adequately, a glance at the stocking rate shows that these seedlings occupied only slightly more than 20 percent of the area as compared with nearly 70 percent where seedbeds had been broadcast burned. Furthermore, larch dominated more than two-thirds of the stocked plots on the burned seedbed. The mechanical scarification treatment resulted in 60-percent stocking, with about two-thirds of the stocked plots dominated by western larch. Similar results have been found in other western Montana areas (Steele and Pierce 1968) and in northern Idaho (Boyd and Deitschman 1969).

According to Vogl and Ryder (1969), burning heavy accumulations of slash created by dozer piling may cause excessively high soil temperatures and alter the physical characteristics of the soils. They found that the damage to the soils may last 15 years or longer. Shearer and Hammer (1968) found that following prescribed burning root mortality was highest when soil water was lowest. Duff reduction and soil heating were also greatest at that time. In logged areas, soil water loss was lower in the surface 4 inches of soil than it was in adjacent uncut areas. Prescribed burning caused little additional water loss below the surface inch of soil.

The forester usually can choose between mechanical scarification and prescribed burning for seedbed preparation on slopes up to 35 percent. But on steeper slopes scarification becomes impractical, if not undesirable.

Boyd and Deitschman (1969) summarized some of the advantages and disadvantages of prescribed burning and mechanical scarification for site preparation in the larch-fir type. They found that prescribed burning (1) created conditions for

TABLE 8.—Number of seedlings per acre and percent of milacre plots stocked by seedbed treatment and year of measurement (Coram Experimental Forest). Western larch (W.L.); the other species are chiefly Douglas-fir, Engelmann spruce, and subalpine fir

Seedbed treatment in 1952	Species	1953 Number	1953 Stocking	1955 Number	1955 Stocking	1965 Number	1965 Stocking
		Thousands	*Percent*	*Thousands*	*Percent*	*Thousands*	*Percent*
Prescribed	W.L.	9.5	48	28.5	86	11.0	69
broadcast burn	Other	1.1	32	2.2	9	1.5	10
Mechanical	W.L.	5.5	56	25.9	74	2.9	45
scarification	Other	0.8	8	2.0	14	1.3	15
Hand–pile slash	W.L.	1.7	27	8.5	59	1.0	24
and burn piles	Other	1.4	36	2.2	23	1.4	27

desirable stocking with fewer seedlings, (2) eliminated unwanted advance growth, and (3) was usually less costly. Mechanical scarification (1) had the capability of exposing mineral soil for regeneration while preserving any desirable advance growth and (2) decreased the risk of damage to adjacent seed-producing trees and of injury to workers.

When the land manager's choice is limited to prescribed fire, he must burn when the litter and duff layers will be reduced greatly along with the slash, thus exposing the soil. Spring burning usually fails to do this because the duff layers are then normally so wet that they do not burn. When burning fails to expose mineral soil, larch will not become established and shrubs or other vegetation usually occupy the site. A second chance for burning is then remote because too little fuel remains for a good burn. On northerly slopes where larch grows best, the fuels are dry enough to burn to mineral soil on only a few days in midsummer. Consistent rain throughout the summer may prevent prescribed burning on these slopes until a drier year.

The question of how much seedbed should be prepared by mechanical means of prescribed burn often arises. It is obvious that 100-percent preparation is not only unnecessary but also costly. The following results from several studies (Roe 1955) demonstrate that as few as three seed trees per acre will adequately stock an area that has 50-percent favorable seedbed.

Percent favorable seedbed	*Number seed trees per acre*	*Percent milacre stocking*	*Number larch seedlings per acre*
50	3	42	1,500
50	4	44	2,000
50	13	60	4,000
50	15	50	2,000

Direct Seeding

Western larch is as well adapted to direct seeding as any other species in the northern Rocky Mountains. Because the seeds are small they are not as subject to rodent depredation as larger seeded species such as Douglas-fir and ponderosa pine. Other favorable factors are prompt germination, moderate first-year top growth, and relatively aggressive root growth (fig. 23).

Methods

Spot seeding is more reliable than broadcast seeding because: (1) the seeds are placed on the most favorable microsites that provide the best chances of germination, and (2) the seeds are covered with soil, maintaining higher moisture around the seeds and closer contact between seed and soil. Three studies comparing western larch, Douglas-fir, and Engelmann spruce have shown that spot seeding results in twice as many seeds germinating than does broadcast sowing (table 9). Survival also was greater for seedlings growing on seed spots because their location was selected to avoid competition from other vegetation. In contrast, seedlings from broadcast sowings are distributed randomly, some of them under heavy vegetative competition. However, even though spot seeding is more successful than broadcast seeding on the basis of seed-seedling ratios, low labor costs make broadcast seeding less costly per established seedling. This, of course, assumes an adequate seed supply.

Figure 23.—Newly germinated western larch seedling, Coram Experimental Forest.

Spring-sown seed should be coated with a rodent repellant that also acts as a fungicide and insecticide. Spring-sown larch, Douglas-fir, and Engelmann spruce seeds coated with 1-percent Endrin and 1-percent Arasan had twice the germination of uncoated seeds or seeds coated with this formulation and a latex binder (table 10).

Prompt and complete germination of spring-sown seed requires stratification (Schmidt 1962; Shearer and Halvorson 1967). Seed sown in the spring without pretreatment germinates slowly and incompletely in the first year. Some of the ungerminated seed may hold over and germinate the following spring, but the delay exposes the seed to rodents, fungi, and other seed-destroying agents for a longer time with a consequent decrease in total germination potential. Although hydrogen peroxide induces rapid germination for seed viability

TABLE 9.—Germination (percent of estimated viable seed) of spot- and broadcast-seeded western larch, Douglas-fir, and Engelmann spruce and survival of seedlings after two growing seasons

Species	Seeding	Coram—1, 1962		Coram—2, 1962		Spruce Creek, 1963	
		Germ.	Survival	Germ.	Survival	Germ.	Survival
		Percent					
Western larch	Spot	50	[1]6(12)	52	10(20)	29	8(28)
	Broadcast	25	1(2)	26	4(14)	11	2(20)
Douglas-fir	Spot	43	12(27)	43	10(24)	—	—
	Broadcast	19	3(17)	23	5(21)	—	—
Engelmann spruce	Spot	47	1(2)	48	4(8)	—	—
	Broadcast	19	[2](2)	24	1(2)	—	—

[1] Numbers in parentheses are percent of germinated seed.
[2] Less than 0.5 percent.

TABLE 10.—Germination (percent of estimated viable seed) of western larch, Douglas-fir, and Engelmann spruce by chemical coating and season of sowing

Species	Season sown	No coating	1-percent Endrin and 1-percent Arason	1-percent Endrin and 1-percent Arasan and latex
		Percent		
Western larch	Fall	29	([1])	33
	Spring	30	73	32
Douglas-fir	Fall	16	([1])	18
	Spring	40	53	38
Engelmann spruce	Fall	9	([1])	15
	Spring	44	71	43

[1] None sown in the fall because the chemicals would wash off during the overwintering period.

tests, it reduces hypocotyl development and probably decreases the ability of larch to survive under field conditions (Dhillon and Johnson 1962). Also, tests failed to show that hydrogen peroxide increased larch seed germination under field conditions. Johnson[11] demonstrated that hydrogen peroxide improved germination only when the temperature was maintained near 80° F.

[11]Johnson, Paul S. 1961. Effects of some alternating temperatures on western larch seed germination. Master's Thesis, Montana State Univ., 57 p.

Season

Germination of seed sown in the fall is comparable with that of naturally dispersed seed; however, there are some distinct differences associated with spring sowing. Spring sowing with stratified seed reduces the time seeds are exposed to seed-destroying agents such as rodents. When moisture content remains high in the upper soil layers through mid-June, spring-sown, stratified seed germinates better than fall-sown seed, as shown in two studies on the Coram Experimental Forest (table 11). However, spring seeding can fail when the soil surface moisture is depleted before germination is completed. In a study at Spruce Creek on the Coeur d'Alene National Forest (now part of the Idaho Panhandle National Forest), no moisture fell for 3 weeks following sowing and most of the larch seeds dried out before they could germinate (table 11). Another study on the Coram Experimental Forest showed that spring sowing too soon after snowmelt cut germination from stratified seed in half (Shearer and Halvorson 1967). It is not known how late in the spring stratified larch seed can be sown successfully; however, this date varies from year to year, depending on moisture and temperature conditions.

The survival of larch seedlings is also influenced by the season of sowing. For example, table 11 shows that after two growing seasons at Coram, survival of larch seedlings (based on percent of germinated seed) was more than 2½ times greater from seed sown in the fall of 1961 than from seed sown in the spring of 1962. The reversal of this trend at Spruce Creek resulted because the few spring-sown seeds that did germinate were on very

TABLE 11.—Germination (percent of estimated viable seed) of fall- and spring-sown western larch, Douglas-fir, and Engelmann spruce seed and survival of seedlings after two growing seasons

Species	Season sown	Coram—1, 1962		Coram—2, 1962		Spruce Creek, 1963	
		Germ.	Survival	Germ.	Survival	Germ.	Survival
				Percent			
Western larch	Fall	19	[1]4(21)	31	10(32)	38	10(26)
	Spring	30	2(8)	45	5(12)	2	1(35)
Douglas-fir	Fall	15	4(25)	17	4(24)	—	—
	Spring	47	11(23)	44	10(22)	—	—
Engelmann spruce	Fall	16	[2] (2)	12	1(6)	—	—
	Spring	50	1(2)	53	3(6)	—	—

[1] Numbers in parentheses are percent of germinated seed.

[2] Less than 0.5 percent.

moist microsites. Survival of Douglas-fir and Engelmann spruce seedlings at Coram was greater from spring-sown than fall-sown seed. Overwintering seed losses were high for Douglas-fir because of rodent depredation and for Engelmann spruce probably because of loss in seed viability due to fungi.

These results suggest that fall direct seeding of larch will be most successful, but that spring sowing of stratified Douglas-fir and Engelmann spruce seed will increase the establishment of these species. If seed of western larch is to be sown in combination with seed of Douglas-fir and/or Engelmann spruce, spring sowing is most desirable to reduce overall seed losses.

Aspect

Germination usually succeeds equally well on all aspects, although the peak may be reached a week later on north than on south and west slopes (Shearer 1967; Shearer and Halvorson 1967). However, because of poor seedling survival on south- and west-facing slopes, direct seeding should not be attempted on these aspects. Germination is often better on the middle and lower slopes than on the upper slopes and ridgetops.

Planting

Stock

From 1900 to 1930, several age classes of larch seedlings were grown and outplanted on nonstocked land in western Montana and northern Idaho. Most of this stock was produced either at Savenac Nursery or Priest River Experiment Station (now Priest River Experimental Forest). Wahlenberg (1926) described the practices used in production of western larch at these locations. Seedling development was usually too slow for production of 1–0[12] stock large enough to outplant because of the short growing seasons at these cool mountain nurseries. During the second year, the seedlings often grew too large to handle easily. The 2–0 stock had a tendency to become topheavy and spindly with deep taproots and poorly developed laterals. The 1–1 seedlings had better formed tops and roots but were still larger than optimum for field planting. No specific age class recommendations were made on the basis of early planting.

Currently, 1–0 larch planting stock is produced almost exclusively in nurseries with longer growing seasons than those previously mentioned. This age class requires less lead time to grow stock for specific areas and is less costly to produce than 1–1 or 2–0 stock. High-quality 1–0 seedlings have 4- to 8-inch tops and well-developed, fibrous roots at least 8 inches long. These seedlings grow rapidly when outplanted (fig. 24). Without adequate nursery controls, however, some seedlings grow nearly 2 feet tall during the first growing season in the nursery (fig. 25), and develop long taproots with few laterals. These undesirable tendencies can be controlled best by regulating density, restricting water supply, and pruning tops and roots.

No information is available on the effect of handling larch nursery stock. At present, there is no reason to suspect any serious problems if trees are lifted before needle growth begins and are given reasonable care during lifting, sorting, storing, moving, and planting.

[12] Age of nursery stock; the first figure indicates years in the seedbed and the second figure years in the transplant bed.

Figure 24—First-year growth of a western larch seedling planted as 1-0 stock on the Coram Experimental Forest.

Figure 25.—1–0 western larch nursery stock grown at the Montana State Forest Tree Nursery. Some seedlings are nearly 2 feet tall.

Methods

Machine planting is preferable to hand planting where conditions allow, because trees are planted more uniformly, early growth is greater, and cost is usually less. In the spring of 1964, several thousand 1–0 larch seedlings were machine planted and hand planted by mattock[11] on the Coram Experimental Forest. Survival after two growing seasons was 88 and 74 percent for machine and hand planting, respectively. Vigor was significantly higher among machine-planted seedlings, as shown below:

	Vigor after two seasons (in percent)			
	Good	*Fair*	*Poor*	*Dead*
Machine planting	67	16	5	12
Mattock planting	40	27	7	26

Competition from shrubs and grasses caused most of the deaths and contributed to the decline in vigor of some seedlings. Survival and vigor were generally high because of the favorable summer moisture during the first two growing seasons.

In another location on the Coram Experimental Forest, 5-year height growth was significantly greater among machine-planted and hole-planted seedlings than among mattock-planted seedlings.

Experience with larch planting to date is not sufficient to make spacing recommendations. However, it is generally felt that planting which results in 300 surviving trees per acre will eliminate the need for precommercial thinning and will provide enough trees to utilize the site by the time they reach merchantable sizes.

Western larch should not be planted in pure stands because of the risk of losing an entire plantation to insects or disease. The larch casebearer is an example of an insect that now threatens every stand of larch. Mixed stands can lose the majority of one species and the other species can still provide a sizable cut at maturity. Because larch grows in association with many other species, the selection of species to interplant should be based on site limitations. On drier sites, larch grows with Douglas-fir, lodgepole pine, and sometimes ponderosa pine. On mesic sites, Engelmann spruce, Douglas-fir, lodgepole pine, western white pine, and grand fir are most frequently associated with larch. On very moist sites it grows with western redcedar and western hemlock. Engelmann spruce and Douglas-fir probably are the two most common associates that should be interplanted with larch.

Block–by–block, row–by–row, or tree–by–tree mixtures may be planted in reforestation projects if the soil and vegetation are uniform. Where the site

[11]Hand-planting methods reported here include "mattock," where trees are placed in slits in the soil made by mattocks, and "hole," where trees are placed in holes made either by shovels or power augers.

quality or cover conditions are variable, or the topography is not uniform, it is advisable to plant each species or species combination on the most appropriate site.

Season

Early comparisons indicated that spring planting was more favorable than fall planting (Schopmeyer 1940). However, it now appears that both fall and spring planting can be successful, depending on climatic conditions and site location.

Fall planting, where it can be implemented, permits the larch seedlings to express their characteristic early growth initiation in the spring when soil water content is highest. On heavy soils or on low-lying lands subject to heavy frost heaving, planting normally should be deferred until the spring when the danger of low temperatures has passed. Fall planting succeeded in recent tests when seedlings with well-developed root systems were planted after fall rains had thoroughly wet the soil but before snow covered the ground. Sinclair and Boyd (1973) recommend waiting until October 15 to lift and plant larch nursery stock; however, this may not leave enough time before snow or frozen soil make planting difficult. Shearer (1970) points out that seedbeds prepared by prescribed burning within a year after cutting have high soil water content compared with soils in adjacent uncut stands. He suggests that sufficient soil water remains following burning to promote high survival of seedlings planted in September or October without waiting for heavy fall rains.

Spring planting must be completed as early as possible to assure that root systems will be established before the upper soil dries in the summer. Sinclair and Boyd (1973) report that survival decreased continuously the longer planting was delayed in the spring, particularly on dry sites.

Vegetative buds of western larch seedlings open readily in the spring—well before those of any other conifers native to the northern Rocky Mountains. Nursery stock must be lifted as soon as snow melts from the nursery beds and must be stored in a cooler at about 32° to 34° F to prevent the initiation of needle growth. Seedlings that break dormancy at the nursery and are subsequently outplanted show decreased survival. This varies from practically no effect in trees where the buds are just breaking to almost complete mortality in trees that are lifted when the needles are nearly fully extended. The new needles of the latter wilt and die.

Sites

Evidence that larch once occupied a site (such as logs, stumps, or remnants of a former larch stand) is the best basis for judging whether it will grow if successfully seeded or planted. On areas where such evidence is absent, the decision of whether to use larch must be based on the vegetationally defined habitat type. For example, larch is a highly productive major seral species within the *Pachistima* union. On these sites, larch grows well and is one of several alternatives for reforestation. On areas where larch is a minor seral component, i.e., in the *Menziesia*, *Xerophyllum*, *Physocarpus*, or *Calamagrostis* unions, it may be favored with one or more other species but does not have as high a growth rate as within the *Pachistima* union.

Survival of planted larch is generally best on stony or gravelly soils and poorest on heavy soils found in swales or on flats. In a recent successful planting on the Coram Experimental Forest, survival was highest where planting was difficult because of the stoniness of the soil. This is corroborated by a survey of natural seedling establishment on cutover areas in the Kootenays of British Columbia (Glew and Cinar 1964), where twice as many larch seedlings were found growing on glacial tills than on colluviums. Larch development is best in full sunlight and where there is abundant soil moisture. Seedbeds free from competing vegetation optimize these factors.

Many areas burned over in the past are now brush covered and need seedbed preparation before they can be regenerated. Cuttings that fail to reforest within a few years usually require additional treatment to decrease the competition until regeneration becomes established. Prescribed burning or mechanical scarification are the most frequently used methods to prepare seedbeds. When fire is used for site preparation in brush fields, the vegetation may first need to be killed by spraying with chemicals. The dry, dead vegetation may carry a fire hot enough to create a satisfactory seedbed. However, Ryker (1966) found that chemically killed brush on south- and west-facing slopes did not burn any better than green brush on the same aspects. On north-facing slopes, burning failed because of high fuel moisture contents.

Furrowing in the fall with a heavy disk drawn by a crawler tractor exposed about 30-percent mineral soil on an old understocked cutting on the Coram Experimental Forest (fig. 26). Machine planting in these furrows the next spring was successful but insufficient time has passed to evaluate the effects of

Figure 26.—Furrow prepared with a disk drawn by a crawler tractor to facilitate machine planting of western larch seedlings on the Coram Experimental Forest.

this method on tree growth. On adjacent areas too steep for equipment to operate, scalping followed by hand planting was not as successful because competing vegetation was not as thoroughly eliminated.

Plantations are subject to attack by the same destructive agents as natural seedlings. Total losses in the first growing season after outplanting are usually less than 10 percent if weather and soil moisture conditions are favorable.

Cutting Methods

Early Partial Cuttings

Partial cutting was commonly practiced in western larch forests prior to the 1950's. Objectives were to remove merchantable volume and reserve trees for future cuts (Koch and Cunningham 1927). Usually only 1,000 to 2,000 bd. ft. per acre were reserved in stands that originally contained 10,000 to 40,000 bd. ft. Volume tables for cutover stands (USDA Forest Service 1937) included only stands with reserve volumes of 5,500 feet or less.

These partial cuttings tended to convert larch forests to other species not only because larch was shade intolerant, but because larch was preferred and most heavily cut (Polk and Boe 1951). Most old-growth larch stands contained many undersized and cull trees of other species such as Douglas-fir, lodgepole pine, and subalpine fir. These trees were costly to remove and so they were left in the residual stands. They may have been somewhat younger than the trees cut, but nevertheless they were too old to respond well to release and to provide good growing stock. These practices assisted in bringing about a substantial change in the species composition of the stands left after early cuts.

Signs of decadence and ultimate breakdown of the overmature, seral larch trees signify an accelerated rate of forest succession. The tolerant understory then develops more rapidly because of its release and occupies the site more fully as the overstory is reduced by natural causes or logging.

Opening mature and overmature larch stands through partial cutting results in a deterioration of their vigor, as illustrated in table 12. These data were obtained from the Blue Mountain studies, Kootenai National Forest, in a stand selected for shelterwood cuttings because it possessed many vigorous trees. But following cutting, the reduction in tree vigor became evident even to casual observers. Many of the trees that had well-shaped, full crowns prior to logging developed spike tops and thin crowns in relatively few years. A heavy stocking of understory trees was present, and this competition probably contributed to the slow growth and deterioration of residual larch trees. This apparent effect of understory trees on residual overstory trees was verified in a Coram Experimental Forest study (Roe 1956), where 300-year-old residual larch trees grew substantially faster in diameter when the understory was removed than when the understory was not removed while logging.

Even-Aged Cutting Methods

Beginning in the mid-1940's, foresters began to favor even-aged management of western larch. They found that when the objective was to grow larch at maximum growth rates, it was necessary to cut overmature stands heavily. Establishment of young trees of acceptable species by two-cut shelterwood, seed tree, or clearcutting methods resulted in higher growth increments in the long run than the practices discussed under partial cuttings. A number of factors brought about the change:

- Larch is very intolerant and cannot live long in the shade of its associates. Unless larch occupies a dominant position in the stand, its growth will decrease and it may be nearly eliminated by more tolerant species.
- Stands mature at 120 to 150 years on average sites (LeBarron 1948). After maturity is reached, declining growth and increasing natural mortality do not justify holding

TABLE 12.—Changes in vigor of tree overstory following three types of cutting[1]

	Cutting method								
				Shelterwood					
	Seed tree			Economic selection			Vigor selection		
Vigor class	1948	1953	1958	1948	1953	1958	1948	1953	1958
	Percent								
Good	67	10	5	28	0	0	53	31	22
Fair	33	47	80	50	39	53	37	48	59
Poor	0	43	15	22	61	47	10	21	19

[1] See appendix C for detailed description of types of cutting.

reserve stands for additional increment. (fig. 27).

- Larch regeneration requirements are met best in open residual stands or clearcuttings when a good seed supply and a favorable seedbed are provided.
- Even-aged management provides the best silvicultural control of mistletoe.
- Heavy cutting or clearcutting reduces the cost of logging by spreading the fixed costs over a greater volume removed (Roe and Squillace 1953).

Harvest cutting, in addition to removing biologically or financially mature timber, involves the regeneration of a new stand. The removal of timber must create conditions that fit the requirements of natural or artificial regeneration by providing a favorable habitat for subsequent growth of seedlings and young stands (Boyd 1969; Roe 1952; Schmidt 1969). If western larch is to be an important component of the new stand, the requirements for its successful regeneration play a paramount role in planning the cuttings and other work following logging.

Figure 27.—Heavy natural mortality in an overmature western larch stand. Note the absence of larch in the subalpine fir-dominated understory.

The desirable silvicultural objectives in western larch stands are to:

- Obtain natural larch reproduction within 5 years.
- Maintain a relatively high proportion of western larch in the reproduction of sites for which it is best suited.
- Take advantage of characteristically rapid juvenile growth through early stocking control.
- Control diseases, especially dwarf mistletoe and heart rot.
- Optimize watershed, recreation, and wildlife habitat values.

Several cutting methods are available to regenerate even-aged stands of larch and associated species. Beginning in 1949, these cutting methods were tested on the Coram Experimental Forest and some were replicated on the Kootenai National Forest. These studies evaluated seed production and dispersal, seedling establishment and growth, logging costs, and residual stand growth. Appendix C summarizes the methods.

Clearcutting

Clearcuts may assume a variety of shapes and sizes depending upon the management objectives and such factors as effective seeding distance, topography, esthetics, hydrology, and harvest costs. The effective seeding distance is the distance to which adequate quantities of seed may be dispersed to provide acceptable minimum stocking rates under existing seedbed conditions. This distance differs by seedbed conditions and quantity of seed produced and dispersed. Effective seeding distance, therefore, imposes an upper limit on the size

TABLE 13.—Number of trees per acre and percent of milacre plots[1] stocked on clearcuts by seedbed type[2] and distance from seed source, Coram Experimental Forest

Seedbed	Distance from timber edge	Western larch						Other species					
		1953		1957		1961-1962		1953		1957		1961-1962	
		M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing
	Chains												
Mineral	0–1	24.9	100	33.8	95	19.3	95	4.3	86	14.1	89	15.2	95
	2–4	5.5	88	9.2	97	9.5	85	.8	29	1.6	62	2.4	65
	6–8	3.0	71	6.8	71	3.3	81	1.3	43	1.2	52	2.5	52
	10–12	2.9	60	2.3	60	3.3	60	1.0	60	.8	60	1.0	80
Burned	0–1	5.2	77	5.7	69	3.5	69	.2	15	4.0	62	3.8	54
	2–4	3.3	69	5.2	78	5.2	78	.2	20	2.0	56	2.0	57
	6–8	2.0	64	3.7	76	3.7	78	.1	9	.5	28	1.8	57
	10–12	1.0	61	1.7	50	1.0	39	.1	6	.6	39	1.2	56
Forest floor	0–1	.1	7	.6	13	.1	13	.1	20	.2	20	.2	20
	2–4	.1	10	.2	18	.1	10	.1	2	.3	16	.3	19
	6–8	.0	3	.0	3	.1	7	.0	3	.1	3	.1	10
	10–12	.0	0	.0	0	.0	0	.0	0	.0	0	.0	0

[1] At least 70 percent of each quadrat consisted of one seedbed type.
[2] Seedbeds were prepared in 1952 and heavy seed crops occurred in 1952 and 1954.

TABLE 14.—Number of trees per acre and percent of milacre plots stocked on strip cuttings by seedbed condition, Coram Experimental Forest[1]

Seedbed condition	Western larch						Other species					
	1954		1958		1963		1954		1958		1963	
	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing	M trees per acre	Percent stock-ing
Uncut strip—forest floor	0.1	3	0.0	0	0.0	0	0.8	33	0.6	23	0.6	26
Cut strip—forest floor	.6	22	.7	20	.3	14	.8	37	1.4	41	1.5	43
Cut strip—scarified	.5	22	16.7	75	9.8	72	.5	25	16.5	92	16.3	89
Cut strip—burned	.0	0	20.1	87	14.1	87	.1	7	12.3	87	16.6	100

[1] Seedbeds were prepared in 1953 and a heavy seed crop occurred in 1954.

of the cutting if no supplementary seeding is planned. Results from harvest cutting tests on the Coram Experimental Forest (tables 13 and 14) illustrate the relationship very well. The tests included clearcuts of several sizes of blocks and strips surrounded by a well-stocked, uncut, overmature western larch stand containing trees of fair to poor vigor. The regeneration period included one or two very good seed years—1952 and 1954 in the clearcuts, and 1954 in the strips. Western larch stocking was higher close to the seed source than at 10 to 12 chains.

Stocking on natural forest floor (poor seedbed), although it followed the same diminishing trend with increasing distance from the seed source (tables 13 and 14), did not reach an acceptable level on any of the clearcuttings despite an abundant supply of seed.[14] In contrast, the mineral soil and burned seedbeds were heavily overstocked near the cutting boundary and well stocked by the end of the regeneration period at 6 to 12 chains from the seed source. The strip cuttings were overstocked on favorable seedbeds by the end of the regeneration

[14] Shearer, Raymond C. 1959. Seed dispersal and seedling establishment on clearcut blocks in the larch—Douglas-fir type in northwestern Montana. Master's Thesis, Utah State Univ., 72 p.

period (table 14). Of all the cuttings, a 60-acre clearcut (approximately 12 chains to the center) showed the best stocking because the overstocked portion did not occupy the total area. But even in this clearcut only 26 percent of the area was not overstocked. It must be remembered, however, that the seedbeds on these areas received above average seedfall either once or twice while they were in good condition. Overstocking may not have been as great had the seed crops been more normal or had the good seed years occurred later when the seedbeds were less receptive.

The shape and size of clearcuttings should be strongly influenced and sometimes limited by uniformity in topography, but dwarf mistletoe protection and effective seeding distance also must be considered. Topography affects the meteorological conditions in a cutting, and thus the ease with which prescribed fire can be controlled. A cutting that contains more than one exposure may be difficult to burn for seedbed preparation and slash disposal. For instance, when a south slope will burn well, the north slope may be difficult to burn, and when the north slope is ready to burn well, the south slope may be too dry to burn safely.

Larch stands containing heavy infections of dwarf mistletoe are best treated by clearcutting (Kimmey and Graham 1960). They recommend that cutting boundaries avoid heavy infection centers and follow disease-free corridors or cleared rights-of-way where possible. From the standpoint of reducing mistletoe infection in future stands, square or rounded blocks are preferable to narrow strips or openings with deep, undulating borders; infected trees should not be left. Slashing or otherwise eliminating diseased unmerchantable residuals (including advance reproduction) within the cutting and sanitation cutting in the bordering stand will also decrease the likelihood of infection in the new stand (Kimmey and Graham 1960).

Lateral movement of dwarf mistletoe is slow from infected trees surrounding clearcuts into young, even-aged reproduction. If we assume an average rate of spread of one-half foot per year, trees within 60 feet of the cutting margin are accessible to infection within a rotation period of 120 years.

Early removal of dwarf mistletoe-infected larch trees growing adjacent to new reproduction will diminish the probability of dwarf mistletoe spread. Seedlings less than 10 years of age are small targets and are unlikely to be hit by an ejected dwarf mistletoe seed (Wicker 1967). Wicker and Shaw (1967) found that the probability of a seedling 42 inches or less in height being hit by a dwarf mistletoe seed is less than 2 in 1,000. But as the young trees increase in size they provide better targets and the probability of direct hits and subsequent infection increases. Thus infected trees should be removed as soon as possible after the seedlings are established.

However, biological and physical phenomena are not the only factors that influence clearcutting practices. Social values such as esthetics are assuming increasing importance as more and more people turn to our forests for rest, relaxation, and revitalization. Because clearcutting can significantly alter the appearance of the forest, public objections are not uncommon, particularly when clearcuts are not blended into the landscape. As a result, esthetics can impose significant constraints on what may be biologically and economically desirable sizes and shapes of clearcuts. Principles of landscape architecture can be used to blend clearcuts into the landscape by modifying boundaries through feathering, following natural topographic and vegetative features, and adjusting sizes to fit the particular area conditions—not only to prevent reduction in forest esthetic values, but in many cases to actually enhance the appearance.

Prescribed burning costs are lowest when the cutover areas possess the minimum perimeter in relation to the area. The following tabulation shows the relationship between perimeter and area for 60-acre cuttings of three different shapes. The narrow cutting requires more than 2½ times as much fireline construction as the square cutting of the same area. Cost of seedbed preparation methods for clearcuts not requiring burning or firelines is unaffected by shape.

Dimensions of 60-acre cut (Chains)	*Perimeter (Chains)*	*Perimeter per included area (Chains/acre)*	*Ratio to minimum perimeter*
24.5 by 24.5	98	1.63	1.00
12.0 by 50.0	124	2.06	1.26
5.0 by 120.0	250	4.17	2.56

Seed-Tree Cutting

The seed-tree method is in essence a clearcut but with selected seed trees withheld from cutting (fig. 28). Therefore, the method provides the same conditions as the clearcut except that seed dispersal is more uniform over the seedbed and species composition can be regulated. The seed source may be

Figure 28.—Seed-tree cutting followed by dozer scarification, Lolo National Forest. Note heavy cone production on reserved trees.

Figure 29.—Group seed-tree cutting, Coram Experimental Forest. Groups of seed trees, one-fourth and one-half acre, were reserved.

reserved within the cutting either as scattered trees (fig. 28) or as groups (fig. 29). Seed dispersal distance does not impose size limitations upon seed-tree cuttings, because the seed trees are distributed over the cutting.

The seed-tree method provides the opportunity for regulating species and genetic composition of the new stand. However, the interaction of other factors, such as seedbed, with the seed-tree method has been demonstrated in both Coram and Blue Mountain tests (table 15). Wherever mineral soil seedbed is prepared and a seed source is present, larch tends to dominate its associate species. For example, larch dominated 52 percent of the milacres on the scarification treatment at Coram after 13 years, while other species dominated only 16 percent of the plots. The same trend applies to the prescribed burn treatment at Coram and to both treatments at Blue Mountain. However, the reverse trend prevailed on the hand-pile slash treatments because some species, particularly Douglas-fir and subalpine fir, were better adapted than larch for establishment and survival on the predominantly undisturbed natural forest floor seedbed.

As few as three western larch seed trees per acre can supply the required amounts of seed to reproduce larch stands during years of abundant

TABLE 15.—Reproduction in seed-tree cuttings by number of years since slash disposal and seedbed treatment at two locations

Slash disposal and seedbed treatment	Seedlings per acre (thousands)						Stocked milacre plots (percent)					
	Western larch			All seedlings			Western larch			All seedlings		
	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr
CORAM EXPERIMENTAL FOREST PLOTS												
Hand pile slash[2]	0.6	4.6	1.7	3.0	7.9	4.5	24	55	28	62	86	79
Scarification[3]	2.2	13.4	3.1	2.8	15.3	4.5	55	75	52	60	85	68
Prescribed burn	1.6	5.1	2.3	3.7	8.0	3.4	46	76	41	73	95	63
BLUE MOUNTAIN PLOTS												
Hand-pile slash[2]	.3	6.8	—	.5	28.7	—	15	37	—	54	94	—
Scarification[3]	4.6	12.6	—	7.3	40.6	—	62	53	—	75	94	—
Prescribed burn	1.8	20.9	—	2.3	31.8	—	45	58	—	55	77	—

[1] Collected only at Coram.
[2] These small piles were burned later.
[3] A bulldozer with a brush blade scarified the seedbed and piled the slash; the slash piles were burned later.

seed production. Dominant, full-crowned, overmature trees of fair to good vigor and 18 inches d.b.h. or larger were selected in the seed-tree tests at Coram and Blue Mountain. All seedbed treatments were successful, and even with few seed trees per acre the number of seedlings on the Blue Mountain cutting was excessive. About a thousand 5- to 10-year-old seedlings distributed on half the milacres would be more than sufficient to stock the area. These cuttings also were subjected to the above-normal seed years of 1952 and 1954.

By leaving seed trees as the seed source and the understory stands to provide partial shade for new seedlings, St. Regis Paper Co. foresters have consistently regenerated south- and west-facing slopes with 100 to 500 larch seedlings per acre.[15] Bare soil exposed by skid trails and other logging activities provides enough seedbed for this regeneration.

Seed-tree cuttings are not recommended in stands heavily infected by dwarf mistletoe. It is extremely difficult to select disease-free trees by observation from the ground, and infected seed trees serve as scattered sources of infection for the new seedlings. All seed trees should be removed as soon as possible after seedling establishment to (1) enhance seedling development and (2) remove infected overstory trees that may serve as sources of dwarf mistletoe infection for the young seedlings.

Figure 30.—A fine larch stand growing adjacent to Hungry Horse Reservoir—an area of increasing recreational importance; Flathead National Forest.

Shelterwood Cutting

The shelterwood method furnishes a heavy seed source and considerable shade. On exposed sites it offers the greatest protection for new seedlings. Esthetic considerations may also preclude heavy cuttings or clearcuttings (fig. 30). In such situations, shelterwood cutting may disturb the scenery the least and still provide for adequate regeneration. Thus it can be useful adjacent to campgrounds, lakes, and other areas of heavy recreation use. The residual stand density of shelterwoods can be adjusted to fit the biological and esthetic requirements for a particular management situation.

Shelterwood cuttings often reserve a heavy stand that provides merchantable cuts after the initial removal. The two-cut shelterwood, comprised of the initial cut for regeneration and a removal cut later, is generally most appropriate for regenerating larch and other intolerant species. Although overmature stands have little potential for growth response, younger stands may accelerate their growth after the initial removal. However, the overwood cannot be held long without a detrimental effect on the growth of larch reproduction underneath.

Two kinds of shelterwood cuttings were tested in overmature stands on the Coram Experimental forest and at Blue Mountain on the Kootenai National Forest:[16] (1) Vigor selection.—About half of the volume was reserved by favoring the most vigorous larch trees in the stand. (2) Economic selection.—About three quarters of the larch trees 18 inches d.b.h. and larger were removed. More detailed description of these tests is given in appendix C.

Reproduction that resulted under the shelterwood cuttings can be characterized as heavily overstocked (tables 16 and 17). The abundant seed dissemination in 1952 and 1954 coupled with the large number of seed trees per acre resulted in an overabundance of surviving seedlings and much greater stocking than would be expected during most seed years.

[15]Personal communication with R. Griffith, St. Regis Paper Co., Libby, Montana.

[16]Growth of the shelterwood (residual stands) is discussed in the "Growth and Yield" section.

TABLE 16.—Reproduction in vigor-selection shelterwood cuttings by number of years since slash disposal and seedbed treatment at two locations

Slash disposal and seedbed treatment	Seedlings per acre (thousands)						Stocked milacre plots (percent)					
	Western larch			All seedlings			Western larch			All seedlings		
	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr
CORAM EXPERIMENTAL FOREST PLOTS												
Hand-pile slash[2]	4.1	19.9	0.9	5.0	21.6	1.8	29	75	36	61	79	43
Scarification[3]	12.2	59.9	4.5	13.5	62.3	5.8	65	85	50	71	88	59
Prescribed burn	6.4	54.1	19.7	7.3	56.4	21.6	26	95	82	77	97	85
BLUE MOUNTAIN PLOTS												
Hand-pile slash[2]	1.1	8.1	—	2.6	38.5	—	27	41	—	69	97	—
Scarification[3]	9.5	31.5	—	11.7	60.9	—	69	66	—	77	98	—
Prescribed burn	10.6	40.2	—	12.5	49.9	—	78	91	—	90	97	—

[1] Collected only at Coram.
[2] These small piles were burned later.
[3] A bulldozer with a brush blade scarified the seedbed and piled the slash; the slash piles were burned later.

The vigor of the larch seed source strongly affects the abundance of larch reproduction. On all seedbeds the "vigor selection" method produced significantly larger quantities of seedlings than did the "economic selection." Thus the "vigor" shelterwood may produce the best stocking during poorer seed years.

The combination of a shelterwood seed source and scarification (dozer-pile and burn) or prescribed burn slash disposal provides good control of species composition in the new stand. In the Coram and Blue Mountain studies, western larch generally dominated the reproduction both in terms of seedlings per acre and the percent of milacre plots stocked (tables 16 and 17). In the one exception (hand-piled slash), undisturbed forest floor predominated the seedbed, which favored other species such as subalpine fir and Douglas-fir. In any event, the reproduction was still a desirable mixture of species.

With increasing utilization of both live and dead material (including whole-tree logging), slash

TABLE 17.—Reproduction in economic-selection shelterwood cuttings by number of years since slash disposal and seedbed treatment at two locations

Slash disposal and seedbed treatment	Seedlings per acre (thousands)						Stocked milacre plots (percent)					
	Western larch			All seedlings			Western larch			All seedlings		
	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr[1]	1 yr	3 yr	13 yr
CORAM EXPERIMENTAL FOREST PLOTS												
Hand-pile slash[2]	0.4	1.1	0.1	1.4	2.7	.6	29	43	5	67	81	24
Scarification[3]	2.2	4.4	1.2	2.8	6.2	2.4	53	69	38	64	88	56
Prescribed burn	20.4	26.2	11.1	21.0	27.7	12.7	91	91	78	96	91	87
BLUE MOUNTAIN PLOTS												
Hand-pile slash[2]	.5	1.7	—	1.1	6.6	—	23	27	—	41	77	—
Scarification[3]	5.7	17.4	—	6.0	30.9	—	70	64	—	79	86	—
Prescribed burn	6.2	27.5	—	6.9	32.7	—	85	77	—	86	90	—

[1] Collected only at Coram.
[2] These small piles were burned later.
[3] A bulldozer with a brush blade scarified the seedbed and piled the slash; the slash piles were burned later.

volumes previously left in the woods after logging will continue to decrease. With lighter fuels, fires under the shelterwood should become easier to regulate. We feel that light fires will usually prepare adequate seedbed for regeneration where the shelterwood provides a heavy well-distributed seed source. As a result, the need for bulldozer scarification will likely decrease.

The shelterwood method provides the least opportunity for control of dwarf mistletoe and it should not be used in heavily infected stands. In lightly infected stands, use of the shelterwood requires removal of the overwood immediately after reproduction is established. Strict observance of this requirement is needed to avoid dwarf mistletoe infection in the new stand.

Early removal within 10 to 15 years of the shelterwood following establishment of the reproduction should be planned for two reasons: first, because larch requires 30 percent or more of full sunlight for rapid growth, a heavy shelterwood will suppress early growth of the seedlings. Larch seedlings that do not hold a dominant position in a mixed stand will be greatly suppressed or eliminated. Second, overmature residual stands begin to deteriorate in vigor following partial cutting, and although the most vigorous trees are reserved, growth is not great. Moreover, the shelterwood is subject to windthrow, and high mortality may result.

Comparison of Cutting Methods

Each method discussed has some advantages over the others. Before selecting a cutting method, its advantages and disadvantages should be weighed against the management objectives, the requirements of the site, and the silvical requirements of the trees. As an aid to such analyses, the desirability of the cutting methods has been ranked for a number of important factors that must be considered when harvesting and regenerating mature and overmature larch stands (table 18). We recognize that these ratings are subjective and in some cases oversimplified. However, the table provides a means of quickly comparing the various cutting methods; managers can develop alternatives in the decision process that fit their individual needs (Shearer 1971). Single-tree selection cutting is also included in the comparisons. Although it is not a recommended timber practice in larch stands, there may be instances in which it will be prescribed for objectives other than timber production. "No cutting" has been included also under "multiple use considerations' because this may be a viable alternative in areas of high recreation or water production value. Once the decision has been made to use a particular method, special studies may be needed to further evaluate the position taken. The table is not all inclusive, and may have to be modified or enlarged as additional information becomes available.

TABLE 18.—Factors to consider in selecting alternative cutting methods[1]

Factors	Desirability (Least) 1	2	3	4	(Most) 5
TIMBER HARVEST					
1. Utilization of old-growth timber	SS	SW	GS	ST	CC
2. Logging ease	SS	SW	GS	ST	CC
3. Protection and maintenance of stand vigor	SS	SW	ST	GS	CC
4. Resistance to windthrow of residual trees	ST	SW	SS	CC	GS
EASE OF SEEDBED PREPARATION AND SLASH DISPOSAL					
	SS	SW	GS	ST	CC
SEED DISPERSAL					
1. Amount and distribution	CC	—	GS	ST	SS, SW
2. Control of species composition	CC	GS	ST	—	SW, SS
DEVELOPMENT OF NEW STAND					
1. Seedling establishment on:					
Hot, dry sites	CC	SS	ST, GS	—	SW
Cool, moist sites	—	SS	—	ST,CC	SW, GS
2. Juvenile development	SS	SW	GS	ST	CC
3. Distribution:					
Tolerant species	—	CC	—	ST, GS	SS, SW
Intolerant species	SS	CC	—	ST, GS	SW
4. Overstocking potential	CC	ST	SS	GS	SW
MULTIPLE USE CONSIDERATIONS[2]					
1. Esthetic attraction	CC	ST	SW	GS	SS, NC
2. Forage, livestock: quantity and use	NC	SS	GS	SW	CC, ST
3. Forage, big game:					
Quantity	NC	SS	SW	GS	CC,ST
Use	NC	SS	CC, ST	SW	GS
4. Timber production	NC	SS	GS	SW	CC, ST
5. Water production:					
Yield	NC	SS	—	GS,SW	CC, ST
Quality	—	—	CC, ST	GS, SW	NC, SS
6. Soil protection	CC	ST	SW, GS	SS	NC

[1] Legend for alternative cutting methods:
NC = No cutting
CC = Clearcutting
ST = Scattered seed-tree cutting
SW = Shelterwood cutting
GS = Group-selection cutting (groups 1 acre or less)
SS = Single-tree-selection cutting

[2] For a fuller discussion of multiple use considerations see Shearer (1971).

STAND MANAGEMENT

Composition

Various mixtures of five or six associated tree species commonly are found in the several habitat types that support larch. Ecological factors such as seed crop frequency, season and intensity of fires, climate, plant succession, and soil type bring about these varied species combinations. Different methods of cutting and the subsequent seedbed treatments or lack thereof also contribute to the diversity of species combinations.

Historically, overstocked, even-aged stands containing a high proportion of seral species such as larch and lodgepole pine arose following extensive wildfires. These stands usually display the greatest homogeneity (though a wide variety of species is often present) and are most desirable for current management. On the other hand, stands that resulted from early partial cuttings are generally less desirable for subsequent management. Because these cuttings usually followed immediate economic rather than silvicultural objectives, many of the residual stands depart considerably from natural stands in age, composition, and quality. They usually contain large proportions of shade-tolerant species, and the unmerchantable understory trees left after logging often comprise the bulk of today's growing stock (fig. 31). Occasionally, where enough high-quality trees remain, weeding can improve the stand. Other stands may have so few trees with good growth potential that clearcutting and starting over with seeding or planting may be the best silvicultural alternative.

Harvest cutting methods and seedbed preparation techniques commonly practiced since about 1950 aim toward even-aged management and create highly satisfactory conditions for larch establishment and development. Thrifty young forests similar to those created in natural stands by wildfires are developing on these cuttings throughout the range of larch (fig. 32). They are comprised largely of larch but also include both the tolerant and intolerant associated species (Boyd and Deitschman 1969; Schmidt 1969). Individual stands may differ considerably because of variable habitat types, seed sources, seed years, environmental conditions, and seedbed preparations.

Stocking

The majority of young natural larch stands are heavily overstocked. Stocking rates often reach 30,000 to 40,000 stems per acre (fig. 33), and conse-

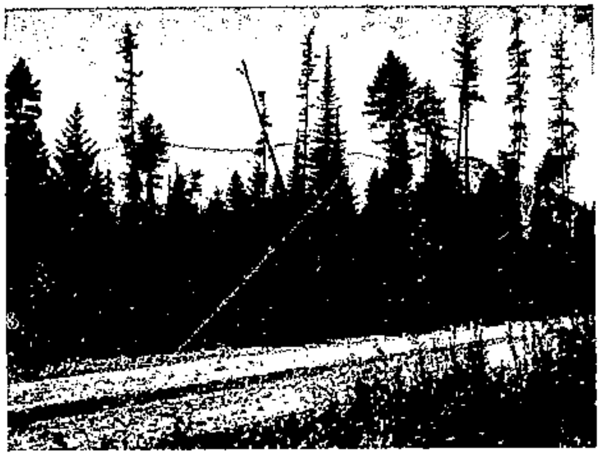


Figure 31.—Uneven-aged stand that developed under a partial cutting. Larch is only a minor component of this new stand, while it predominated in the former stand.

Figure 32.—A rapidly growing 10-year-old larch stand (foreground) developing on a clearcut in the Coram Experimental Forest.

Figure 33.—A 9-year-old larch stand stocked with 23,000 trees per acre—far too many for optimum growth and development; Coram Experimental Forest.

quently, growth rates of individual trees suffer. Study of a typical 9-year-old stand on the Coram Experimental Forest showed that already the young trees were significantly affected by overstocking (Schmidt 1966). At stand densities of 5,000 trees per acre, dominant larch grew twice as fast in diameter, a third faster in height, and maintained longer, fuller crowns than they did at stand densities of 35,000 stems per acre (fig. 34).

The number of stems per acre decreases drastically as the stands grow older, but nonetheless, too many trees survive to allow adequate growing space (fig. 35). Stand records on the Coram Experimental Forest show that from ages 3 to 13 the number of larch stems decreased from 13,400 to 3,100 on scarified seedbeds and from 5,100 to 2,300 on burned seedbeds. Other stands established following fires on the Lolo National Forest show that from ages 30 to 57 years the number of stems was reduced by about one-half (Roe and Schmidt 1965). Trees per acre decreased from 7,500 to 3,050 on one plot and from 3,020 to 1,660 on another as a result of intense intertree competition. Although cause of mortality was not recorded in this study, suppression appeared to be the major factor.

Figure 35.—An overstocked 35-year-old larch stand with a heavy spruce understory, Flathead National Forest.

Many of the trees growing in heavily overstocked stands become spindly in form and show reduced vigor (fig. 36). Such trees are especially vulnerable to damage from the weight of heavy snow accumulations. A study of young white pine stands where larch was a major constituent showed that snow damage caused about half of the larch losses, suppression about a third, and mechanical injuries, insects, disease, windthrow, and unknown factors caused the remainder (Haig and others 1941).

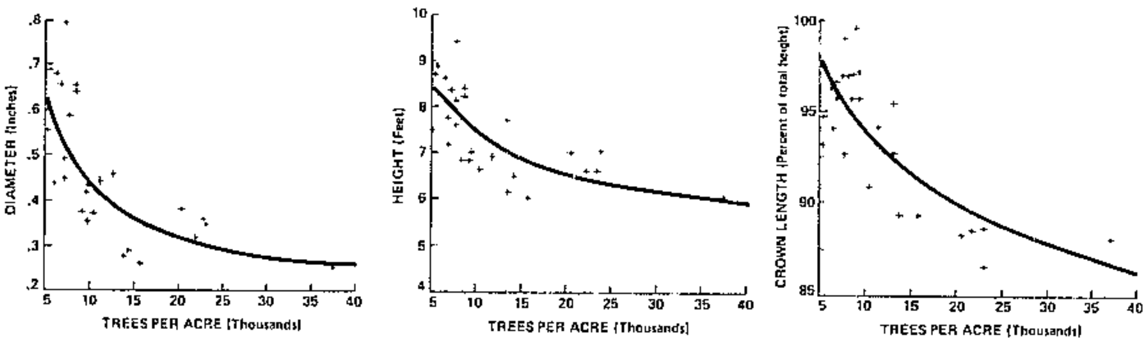


Figure 34.—Effects of stand density on 9-year-old larch.

Figure 36.—A 57-year-old larch stand where heavy overstocking has severely restricted both diameter and height growth, Lolo National Forest.

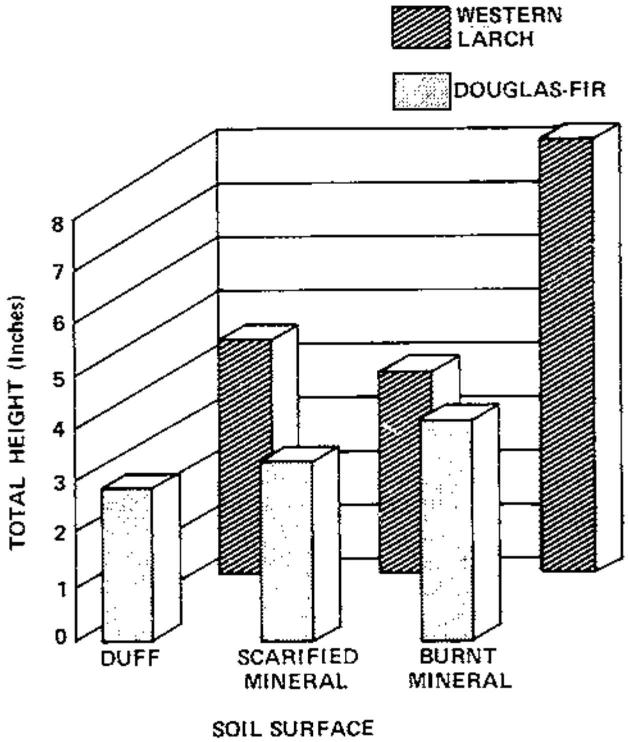


Figure 37.—Total height of 2-year-old larch and Douglas-fir seedlings on three types of soil surface.

In many instances overstocking has been serious enough to nearly preclude the possibility of producing merchantable timber products, at least within a reasonable rotation period. In terms of products we now harvest from these forests, the growth loss attributable to overstocking in immature stands may equal or exceed losses caused by factors such as fire, insects, and disease.

Factors Affecting Development

Characteristically, larch outgrows most of its associates in height for about the first 90 years. This rapid growth is probably an expression of genetic selection that enables larch, a highly shade-intolerant species, to survive the competition in mixed stands. These differences are apparent even at an early age and can vary by the type of seedbed on which the stands developed. Haig and others (1941) showed that 2-year-old larch seedlings on a burned seedbed on the Priest River Experimental Forest grew approximately twice as tall as those on natural bare mineral or duff-covered soil nearby (fig. 37). Microchemical tests after burning revealed an increased supply of several important mineral nutrients within the upper 3 inches of soil, including manganese, magnesium, nitrogen, phosphorus, and calcium. The total carbon content was reduced slightly. At the end of the second season the larch grown on burned soil had an average green top weight almost three times that of those grown on natural mineral surfaces.

The early growth advantage of larch seedlings on burned seedbeds persists for at least 17 years, as shown in a test of larches growing on areas with different seedbed preparation treatments. As demonstrated in the following tabulation (average height in feet), 12-year-old trees had grown approximately a third faster on burned areas than they had on mechanically scarified areas or on those with no seedbed treatment. Between ages 12 and 17, these growth differences diminished, but the trees still held a more dominant position in the canopy on the burned seedbed. The growth advantage on the burned areas was probably a result of reduced vegetative competition, more available nutrients, and more light.

Seedbed preparation	*Stand age*	
	12	*17*
Broadcast burn	8.3	12.9
Mechanical scarification	5.9	11.0
None	6.0	10.3

Some of these growth responses may be explained by differences in soil moisture, because infiltration of water into the soil differs with the kind of seedbed preparation treatment (fig. 38). A test of infiltration on the Coram Experimental Forest showed that water passed into the soil only half as fast on mechanically scarified seedbed as on un-

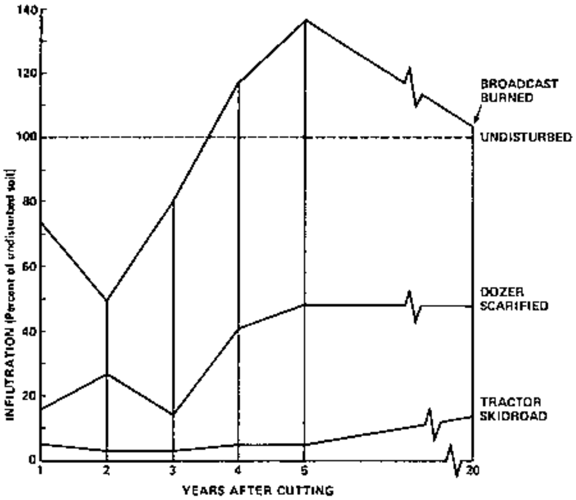


Figure 38.—Infiltration on three treated soil surfaces as a percentage of infiltration on undisturbed soil.

disturbed forest floor or on broadcast burned seedbed (Tackle 1962). Consequently, the dozer-scarified seedbed has the potential for more surface runoff, with correspondingly less soil moisture available for tree growth, than the burned seedbed. These differences in infiltration can persist at least 20 years.

Reduction of vegetation during seedbed preparation enhances the growth of larch seedlings that become established (Schmidt 1969). On mineral soil seedbeds, where most of the competing vegetation has been destroyed, larch grows twice as fast as it does on heavily vegetated forest floor for at least the first 15 years (fig. 39). Where it has had this early growth advantage, larch dominates the stand by outgrowing its associates. In contrast, Douglas-fir both dominates and outgrows larch on undisturbed forest floor.

Young stands also demonstrate pronounced growth differences by species and vigor classes (Schmidt 1969). Larch and lodgepole pine grew more than twice as fast as Douglas-fir and subalpine fir, and more than three times as fast as spruce, between ages 10 to 15 on the Coram Experimental Forest (fig. 40). Larch and lodgepole in unmanaged stands up to 38 years old grew three to four times as fast in height as western white pine, and over four times as fast as western hemlock and

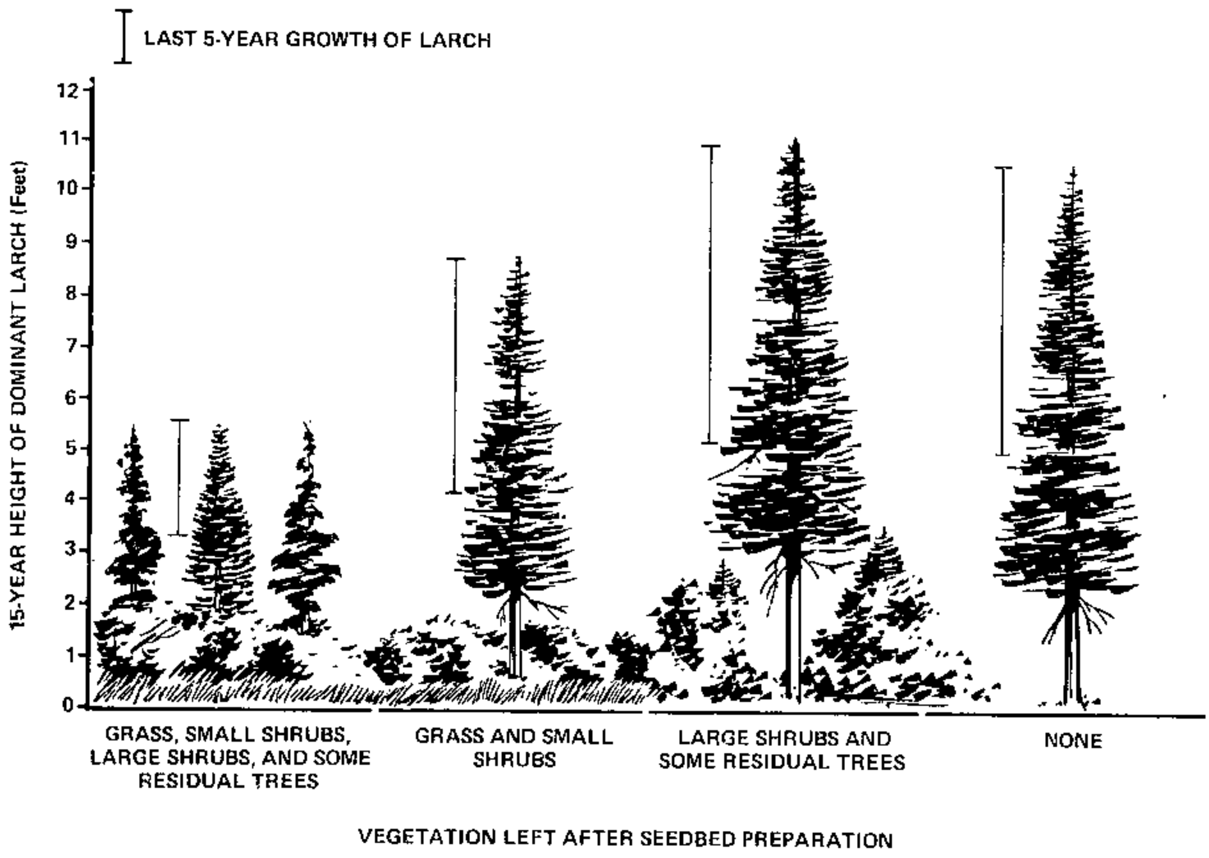


Figure 39.—Effects of vegetative competition on larch height growth.

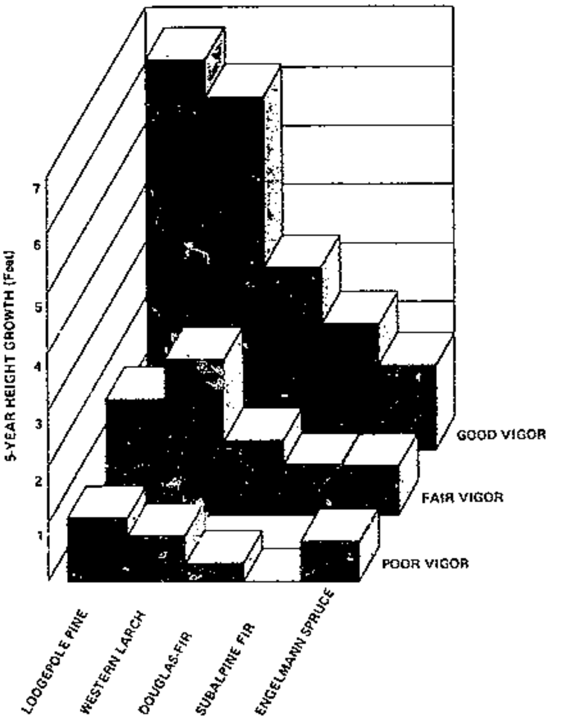


Figure 40.—Height-growth comparisons of larch and its associated species for three vigor classes.

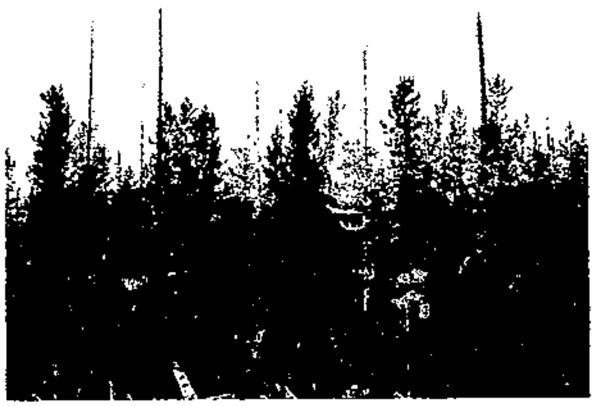


Figure 41.—Larch is growing more rapidly and overtopping lodgepole pine in this 45-year-old stand, Flathead National Forest.

western redcedar in northern Idaho (Wellner 1940, 1946, Deitschman and Pfister 1973). In thinned stands, larch and white pine grew at about the same rate, even though larch was discriminated against in the original thinning. Larch grows rapidly in height and moderately in diameter until ages 75 to 100 years. Annual height growth may average about 1.5 feet between ages 10 and 20 (Brewster 1918). Annual growth of 30 inches is not uncommon on medium and better sites (Cunningham and others 1926). Larch and lodgepole continue to outstrip their associates in height growth for about the first 50 years, after which the differences between all associates become less pronounced, particularly on the better sites (Deitschman and Green 1965; Boyd 1959) (fig. 41).

Mosher (1965) compared 10-year diameter growth rates of larch, lodgepole pine, and Douglas-fir trees growing in an unmanaged stand on a medium site in northeastern Washington. From ages 65 to 75 larch grew at an average rate of 1.3 inches, as opposed to 0.8 inch for each of its associates. Also, mortality from natural causes took a heavier toll of both lodgepole pine and fir than it did of larch. Mortality was evenly distributed throughout the size classes of lodgepole pine, but it was restricted to the smaller size classes of larch and fir.

Cultural Treatments

The primary objective of most stand improvement work is to grow bigger and better trees at a faster rate (fig. 42). Economic evaluations indicate that combinations of thinning and pruning substantially increase the yield value of larch stands and provide a favorable rate of return on the investment (Wikstrom and Wellner 1961; Hutchison and Roe 1962). Assuming a 140-year rotation with a precommercial thinning at 20–40 years and pruning at 40–50 years, the average stumpage yield value on a good site may be increased from about $400 per acre in untreated stands up to over $900 for thinned stands and nearly $1,700 for stands that have been both thinned and pruned.

Although larch fertilization studies are presently underway (Behan 1968a), and preliminary data show a positive diameter growth response in young larch stands (Behan and Chord 1970),[17] it is still too early to determine if larch will respond enough to economically justify fertilization. Nutrient requirements of larch are still undetermined, but Behan (1968b) induced and described visual symptoms of nutrient deficiencies in larch needles. Analyses of wood quality from seedlings raised under different nutrient levels (in greenhouse conditions) indicate that physical and mechanical wood properties may be unsatisfactorily altered if an imbalance in available nutrients occurs (Murphy and others 1969). However, we anticipate no unsatisfactory effects of fertilization on wood proper-

[17]Chord, William E. 1971. The effect of fertilization on *Larix occidentalis* in western Montana. Master's Thesis, Univ. of Montana. 59 p.

Figure 42.—Cross-section of western larch showing 7 years of improved growth after thinning, Kootenai National Forest.

ties of larch growing under forest conditions because gross nutrient imbalances have not been found.

Silviculturists usually enjoy a wide latitude in selecting the final composition and cultural treatments of the stands. Where stands have originated as a result of wildfire or even-aged silvicultural systems, species composition is usually diverse enough to provide managers with a variety of management alternatives (Boyd and Deitschman 1969; Schmidt 1969). Stands that develop under partial cuttings are less diverse in species composition and generally provide fewer management options. Selection of species to favor in management should be based on knowledge of the productivity of the ecological habitat for all the available species. The productivity of larch in different habitat types is fairly well established, as indicated in the "Growth and Yield" section, but corresponding data for associated species are not yet available. Because larch is highly productive in all habitat types having the *Pachistima* union, it should usually be one of the featured species in cultural treatments in these types. Larch may also be favored by cultural work in the *Abies-Menziesia*, *Abies-Xerophyllum*, and *Pseudotsuga-Physocarpus* habitat types, where it is a minor seral species. However, monoculture is not recommended in any of the habitat types where larch occurs, and is rarely necessary because of the variety of species found in most stands.

Foresters are always faced with the problem of objectively evaluating the condition of young larch stands. Is the stand in need of immediate cultural treatment? Is the stand in such poor condition that it would respond very little to treatment? Which stands should have the highest priority? A technique involving the use of potential growth rates simplifies the evaluation of present stand conditions (Roe and Benson 1966). The technique is intended primarily as a convenient management tool that can be used with simple field measurements. Larch trees and stands growing on nearly all conceivable combinations of site quality and ecological habitat type can be evaluated. The method and the potential diameter and growth curves are given in appendix E. These curves were derived from data collected in larch pole stands over a variety of site, ecological habitat, and physiographic conditions throughout the northern Rockies. The data were based on larch growing in lightly stocked, but not open-grown, natural stands.

Thinning

The objective of thinning is normally to maintain or improve tree growth, but other important forest uses may also benefit and in some cases may be the primary impetus. For instance, thinning can enhance the value of a stand for big game habitat. Larch thickets are frequently dense enough to reduce the browse production of understory shrubs to low levels. Thinning releases the suppressed shrubs by increasing the amounts of light and soil moisture available to them, allowing greater browse production (fig. 43). Thinning may also in-

Figure 43.—Big game browse production increased dramatically in only 2 years after this larch and spruce stand was thinned. Flathead National Forest.

crease the accessibility of an area to big game, particularly in young stands where the trees are not large enough to cause heavy slash accumulations. In thick, older stands thinning may produce slash deep enough to restrict animal movement, thus negating the value of increased browse production. This illustrates the desirability of early thinning.

Recreation values can also be enhanced by proper stand improvement measures. Potential recreation sites may be so densely stocked as to preclude any satisfactory camp or picnic area development without thinning. Also, scenic vistas along roadsides and turnouts may be dramatically improved by thinning the crown canopies enough to provide the visitor a distant view.

Thinning can also increase water yields from an area by reducing the amount of transpiring surface. Precipitation averages about 30 inches throughout the range of larch, and even small increases in water yields can have a significant effect for all downstream water users.

Figure 44.—This 14-year-old larch tree grows in a stand thinned at age 9 to 360 trees per acre. It has maintained continuous rapid height and diameter growth and a full vigorous crown. Coram Experimental Forest.

Seedlings and Saplings

Young seedling and sapling stands offer the greatest opportunity for larch cultural work. These are the most dynamic periods in the life of larch stands and the ones that can be most easily molded to fit management objectives. As described in the "Stocking" section, growth losses start in heavily overstocked stands less than 10 years old. Every year of delay in treatment reduces the total growth potential for individual trees. For example, potential growth estimates indicate dominant larch trees on good sites can average nearly 12 inches d.b.h. in 50 years and 20 inches in 100 years if given sufficient growing space from the time of establishment. However, similar trees in unmanaged normal stands will average only about 7.5 inches d.b.h. in 50 years and 13 inches in 100 years. Individual tree growth once lost can never be regained. It should be emphasized, however, that *total* wood yields will not likely be increased by thinning except in stands that would otherwise stagnate—rather, thinning concentrates the yield on fewer but larger utilizable trees.

The advantages of early silvicultural treatment in larch stands are:

1. Early thinning allows growth to accrue on trees with the greatest potential rather than accumulating on numerous stems, most of which would never be harvested. Only through early stocking regulation can the full growth potential of individual larch trees be realized.

2. Early thinning permits uniform radial growth within a tree by maintaining the normally rapid juvenile growth (fig. 44).

3. Early thinning encourages good crown development and prevents the serious crown reduction often experienced in heavily overstocked stands. Larch crowns are highly intolerant throughout their life and once reduced, long periods of release are required to increase the ratio of the crown length to total height.

4. Good vigor can be maintained where trees are given adequate room to grow. This generally results in greater resistance to most damaging agents, such as wind, snow, disease, and insects.

5. Large amounts of slash do not accumulate in stands thinned at an early age. The small thinned trees decompose rapidly on the forest floor, an important fire management side benefit.

6. Early cleaning promotes fast growth of trees selected to provide the desired species composition.

Care should be taken not to miss small seedlings while thinning. The more tolerant associated species such as Douglas-fir, subalpine fir, spruce, hemlock, and cedar usually grow slower than larch and sometimes do not exceed 6 inches in height at age 10 in dense stands. If missed while thinning, seedlings of this size may develop rapidly after their release and overstock the stand again.

For example, a thinning study in the western white pine type (Deitschman and Pfister 1973) demonstrated that very small seedlings of western larch, western hemlock, and western redcedar missed in the original thinning of an 8-year-old stand made a strong comeback after the taller trees were removed. In less than 30 years, these small larch dominated much of the stand, at the expense of the favored western white pine, and the hemlock and cedar formed a dense understory.

Branch turnups can be a problem in young larch stands (fig. 45). If the tree is cut off above a live branch, the surviving branch or branches may turn up and reform the tree. In some cases these develop rapidly because of the established root system; in others they show little growth. The impact or extent of this condition is presently undetermined. Open-grown trees with live branches near the base all present potential branch turnup problems, while those growing in dense thickets usually have dead branches at the base and can be cut off below the lowest live branch with little fear of later branch turnups.

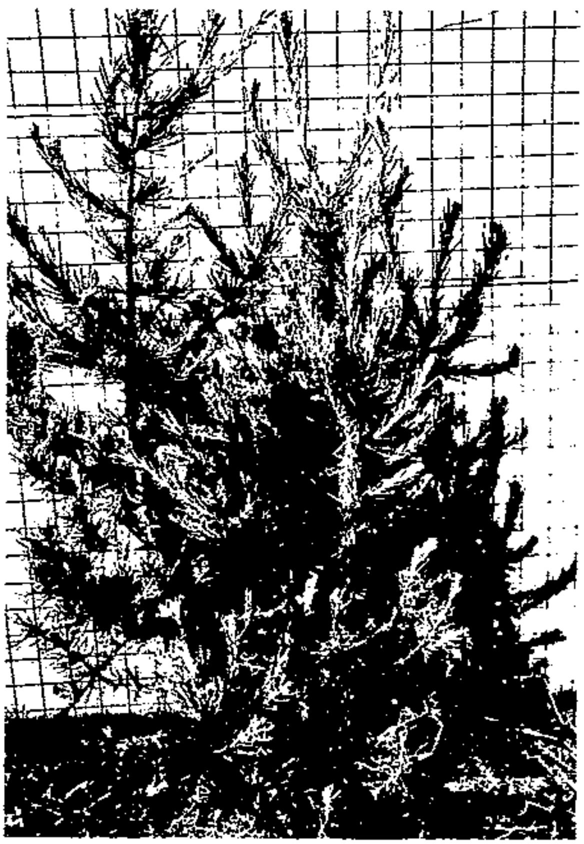


Figure 45.—Branch turnup 3 years after the tree was originally cut, Coram Experimental Forest. Note the original stump and the multiple leader growth.

TABLE 19.—Relation of actual to potential crop-tree diameter growth on a medium site during the age period 50 to 60

Comparison of growth by treatment (inches)	10-year growth	Percent of site potential
Potential growth	1.8	100
Actual growth		
Heavy thinning	1.4	78
Moderate thinning	1.2	67
Unthinned	1.0	56

Poles

Larch response to thinning is directly related to individual tree vigor at the time of thinning. Since young larch are normally more vigorous, they respond more rapidly and significantly to thinning than older trees. Results of a limited commercial thinning in larch were reported as early as 1912.[16] In this study, a 160-year-old stand (which by present standards was well beyond rotation age) was thinned by removing all trees between 12 and 17 inches d.b.h. for tie bolts. All trees larger and smaller were reserved. Although the trees were old, the reserve trees responded by increasing diameter growth. Trees with broken tops did not respond.

Larch crop trees in a 50-year-old larch stand in Montana responded promptly and significantly after thinning by increasing average diameter growth (Roe and Schmidt 1965). Thinning promoted individual tree growth close to the potential growth for the site and age. Diameter growth in the heaviest thinning reached 78 percent of the site potential in the first 10 years—22 percent closer to the potential goal than in the unthinned plots (table 19). Basal area and cubic-foot volume growth relationships closely paralleled those of diameter growth. Crop trees on thinned plots averaged 35 percent greater basal area growth than those on the unthinned plot for the first 10 years after thinning.

A similar response was apparent in a 30-year-old stand in Montana that was thinned from below to a spacing of approximately 7 by 7 feet. However, the thinning was too light—the average diameter increase reached only 57 percent of the potential for that site. Nevertheless, this growth rate substantially exceeded that of the heavily overstocked unthinned stand, which grew at only 37 percent of the potential rate.

[16]Larsen, J. A. 1912. Applicability of thinning for ties in stands of western larch and Douglas-fir, Blackfeet National Forest, USDA Forest Serv., unpublished report, 11 p.

A stocking level study on a high-quality site (S.I. 80 at base age 50) in eastern Oregon showed that 33-year-old larch responded to thinning by sharply increasing diameter growth (Seidel 1971). As expected, the greatest diameter growth response was in the most heavily thinned stands, averaging 0.36 inch per year on the low-density and 0.11 inch on the high-density plots. The lowest density (96 trees per acre) plots produced about 64 ft³ per acre annually while the highest density (745 trees per acre) plots produced about 133 ft³. Even though volume and basal area growth on the highest density plots about doubled those on the lowest, the growth was distributed on nearly eight times as many trees.

The 5- and 10-year results from a crop-tree thinning of western larch in British Columbia support the use of heavy thinning if diameter growth is the primary objective (Illingworth 1964; Thompson 1969). Four levels of thinning were tested—removal of trees within a radius of 16, 12, 8, and 0 (control) feet of the crop trees. Diameter increment of trees ranging from 1 inch to 6 inches d.b.h. responded in direct relation to amount of release from adjoining trees.

Thus, it is apparent that thinning accelerates individual tree diameter growth and enables larch to reach merchantable sizes earlier. However, it must also be pointed out that concentrating the growth on too few trees results in less than total potential volume yield. Thus, the decision to thin, or how to thin, is usually contingent upon the desired end products from the stand.

Larch height growth responds to thinning only in the heavily overstocked stands. Trees in a 30-year-old thinned stand that had been heavily overstocked added 48 percent more height than did similar trees in adjacent unthinned areas (Roe and Schmidt 1965). But, thinning did not affect height growth of trees in a 50-year-old Montana stand that was only moderately overstocked before thinning (Roe and Schmidt 1965), or the 33-year-old Oregon stand (Seidel 1971) and the pole-sized stand in British Columbia (Illingworth 1964; Thompson 1969) mentioned earlier.

Thinning also benefits larch crop trees by increasing their average specific gravity (Lowery and Schmidt 1967). Thus, thinned pole-sized trees were not only larger than their unthinned counterparts, as reported by Roe and Schmidt (1965), but they also had a bonus of superior density and strength properties. Specific gravity of crop trees thinned at age 50 increased with age for the next 15 years whether thinned or not, but specific gravity in the

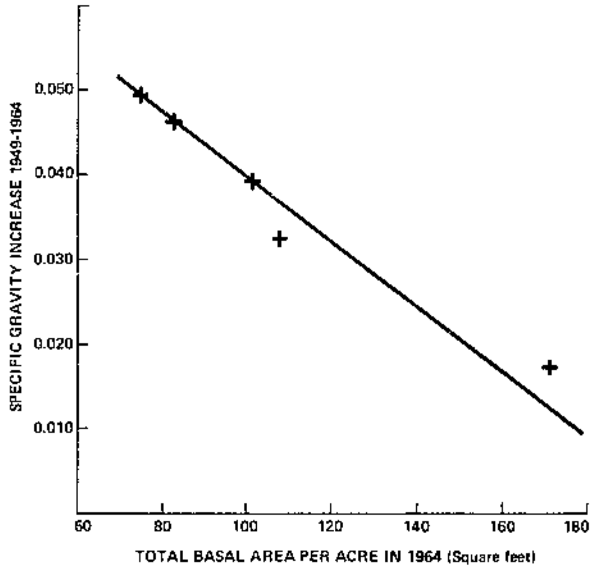


Figure 46.—The effect of total stand basal area on average 15-year change in specific gravity of western larch crop trees.

thinned plots increased in the range of 0.03 to 0.05 while those in the unthinned plot increased only 0.02. Specific gravity increased most on areas with the least total basal area (fig. 46).

Growth response is strongly related to stand structure and stocking prior to thinning (Roe and Schmidt 1965). Moderately overstocked stands respond rapidly after thinning (fig. 47), while heavily overstocked stands respond slowly. For example, an analysis of 10-year growth after thinning in a 50-year-old stand disclosed that growth response was related to the stand basal area prior to thinning (fig. 48). Stands with the least basal area before thinning grew the most in diameter. This again illustrates the advantage of thinning early before serious competition for moisture, nutrients, and light has reduced the trees' vigor, crown length, and ability to respond.

Selection of crop trees is highly important; dominant and codominant trees consistently show the greatest response to thinning and should be selected for crop trees. Uniform spacing is also important, but secondary to crop tree selection.

Methods

Circular powersaws are well-suited for thinning young larch stands where stem diameters are 3 inches or less (fig. 49). Trees larger than this, particularly in pole-sized stands, require chainsaws or some combination of circular saws and chainsaws. Hand thinning with pruning clippers or shears, or

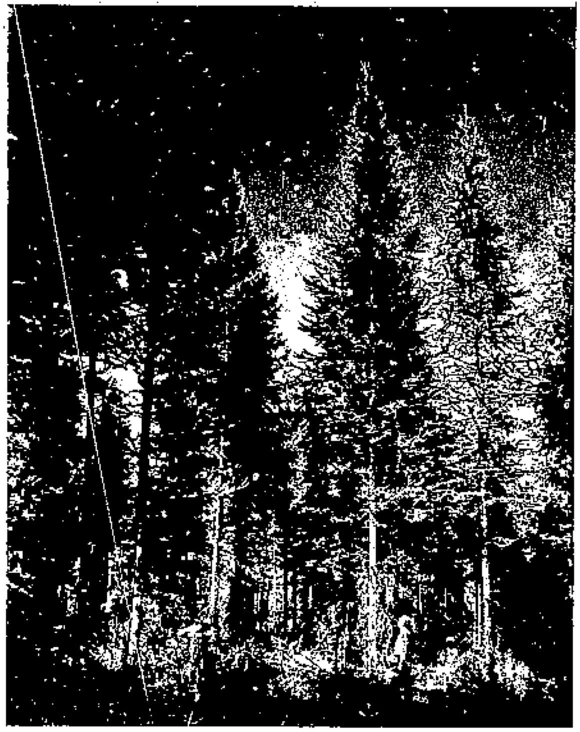


Figure 47.—This 35-year-old larch stand was only moderately overstocked before thinning and had maintained good crown ratios. After thinning, the trees responded rapidly by accelerating diameter growth. Kootenai National Forest.

merely pulling out all the excess trees when they are still very small, may also be used for thinning young larch stands that are not too badly overstocked. However, hand methods generally are costly and impractical for most thinnings.

Silvicides sprayed on the basal portion of the stems or on the foliage in spring and early summer kill larch trees readily. This is particularly true of foliar applications of selective herbicides such as 2,4,5-T, Tordon, and 2,4-D. Northern Rocky Mountain conifers are ranked in descending order of susceptibility to killing by silvicides as follows:

1. Western larch and western hemlock.
2. Subalpine fir, grand fir, lodgepole pine, and western white pine.
3. Douglas-fir and western redcedar.
4. Engelmann spruce.

Chemical injections have been used successfully in pole-sized stands that are not too heavily overstocked, but some of the environmental problems associated with herbicides discourage or prohibit their use until the side effects are better understood.

Bulldozer strip thinning has been tried in pole stands to reduce the thinning cost (fig. 50); this

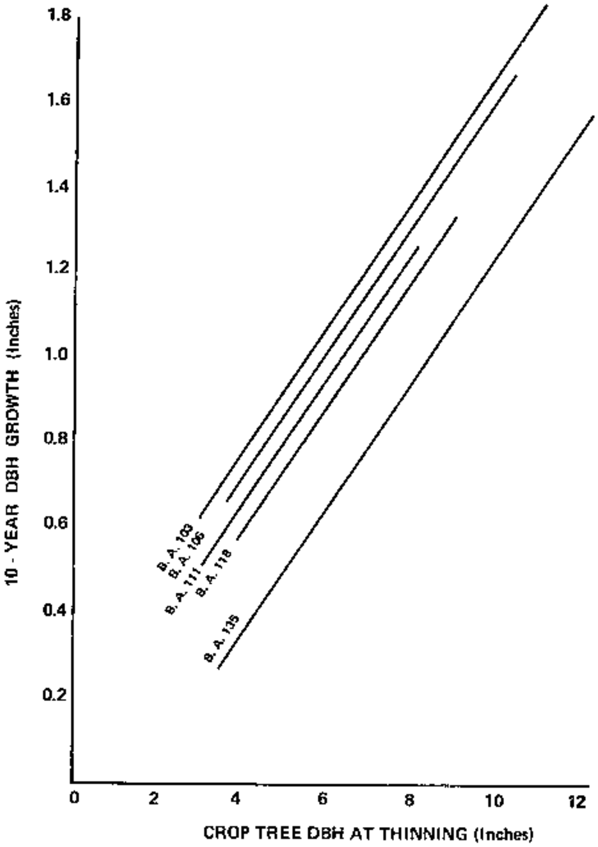


Figure 48.—Relation of 10-year d.b.h. growth of western larch crop trees to d.b.h. and basal area prior to thinning.

Figure 49.—Thinning 9-year-old larch with a circular powersaw, Flathead National Forest.

Figure 50.—*A*. Strip thinning in a 30- to 40-year-old western larch and lodgepole pine stand with a roller-chopper towed by a bulldozer, Flathead National Forest; *B*, an aerial view of strip thinning; *C*, a strip thinning 1 year after treatment demonstrating the response of understory shrubs to increased light and moisture in the strips.

method may have merit in stands where normal thinning practices are not economically feasible. However, St. Regis Paper Company foresters[19] report little release of the trees in the "leave" strips without additional work. After leaving 4- to 6-foot strips, they thinned the strips with powersaws at a cost of about half that for total thinning by powersaws. However, because the stems pushed down into the residual strips were often under tension, they had a whipping action when sawed and were hazardous for the saw operators.

Pruning

Although western larch is one of the best self-pruners in overstocked stands, natural pruning is undependable in thinned or lightly stocked stands. Open-grown larch often retain their branches over the entire bole. Stands thinned early in life and natural lightly stocked stands will require pruning to produce knot-free wood.

Limited pruning tests on 50-year-old larch trees have shown rapid healing of pruning wounds, but epicormic branches were produced along the upper portions of the pruned section. In heavy thinning, 54 percent of the boles formed epicormic branches in the upper half of the pruned section, while in the medium thinning, only 25 percent of the trees produced epicormic branches and these were confined to the upper quarter of the pruned section. Because epicormic branches develop slowly and shade out soon after crown closure, they are probably of little consequence in knot formation.

[19] Op. cit., footnote 15.

GROWTH AND YIELD

Overmature Stands

Large areas of uncut, overmature larch show no net volume growth because volume lost in mortality approximates growth. Plots in overmature stands on the Coram Experimental Forest disclosed net losses in 10 years of 3, 4, and 6 percent in basal area, cubic-foot volume, and board-foot volume, respectively.

Although partial cuttings in overmature stands presumably reduce mortality and accelerate diameter growth, growth response in these stands is usually disappointingly low (see "Early Cuttings" section). This low growth rate is affected both by old age and by competition from two sources: first, individual trees of the overstory compete with each other for light and soil moisture, and second, the succeeding understory also competes with the overstory (Roe 1956). This may contribute to the stagheaded condition of many old larch trees.

Diameter

Diameter growth of overmature larch trees is slow. Following partial cutting, residual overmature larch respond with a moderate diameter increase on a percentage basis, but their absolute growth is still slow. Even though the diameter growth rate of residual western larch trees at Coram the first 5 years after harvesting was 67 percent higher than during the 5 years before the harvest cutting, growth was still very slow (Roe 1956). Conversely, the more tolerant Douglas–fir grew faster than larch both before and after the partial cuttings. It increased its growth rate only 42 percent after logging but still made wider rings than western larch after the partial cuttings. Removal of most of the understory trees on part of the plots 5 years after logging caused an additional 36-percent increase in growth rate of larch during the next 5-year period. The growth rate of larch on the uncut control plots increased only 2 percent during the same period. Douglas-fir growth rate did not increase as a result of understory removal. Because this species is heavier crowned and more tolerant, it is better able to grow under competition than larch; thus, the added effect of understory removal was not a significant factor. The growth rate of the residual larch trees, even after logging and understory removal, did not result in a large diameter increment.

Volume

Despite relatively large volumes of overmature trees left on some cutover areas, low board-foot increment usually results. This was demonstrated by a 39-year-old partial cutting in a western larch stand originally containing 29,000 bd.ft. per acre. Only slight differences in net annual volume increment were apparent in reserve stands ranging from 1,200 to 11,000 bd.ft. per acre (table 20) (Roe 1948b). Larch made up 52 percent of the original stand volume and 58 percent of the reserve volume in trees 10 inches d.b.h. and larger. Seventy-four percent of the increment in the most lightly stocked stand occurred as ingrowth, principally on species other than western larch, compared with only 30 percent in the most heavily stocked stand. The low net increment rate of 100 bd.ft. per year, produced by the 11,000 bd.ft. residual stands, represents a small return on the heavy volume investment in growing stock. However, by comparison, uncut overmature stands generally show no net growth, because growth and mortality are essentially equal.

Additional studies conducted at the Coram Experimental Forest and Blue Mountain on the Kootenai National Forest support these results (tables 21 and 22). Three types of cuttings were studied: (1) shelterwood (vigor selection), in which about 50 percent of the volume composed of well-shaped, vigorous trees was reserved; (2) shelterwood (economic selection), in which the larger, financially mature trees were removed leaving the less vigorous codominant and intermediate trees; and (3) seed-tree cutting, in which four to five dominant, vigorous, well-distributed trees per acre plus the nonmerchantable intermediates were left.

TABLE 20.—Relationship of mean annual board-foot growth per acre to residual stand volume, 39 years after cutting

Species	Residual board—foot stand volume (per acre)							
	1,200		4,000		5,300		11,000	
	Residual	Ingrowth	Residual	Ingrowth	Residual	Ingrowth	Residual	Ingrowth
Western larch and lodgepole pine	2	17	26	12	33	7	50	0
Douglas-fir, subalpine fir, Engelmann spruce, and ponderosa pine	21	47	31	37	35	25	20	30
All species	23	64	57	49	68	32	70	30

TABLE 21.—Growth of residual stands per acre by regeneration cutting method (Blue Mountain)

Residual stand	Shelterwood						Seed tree		
	Vigor selection			Economic selection					
	Trees	Basal area	Volume	Trees	Basal area	Volume	Trees	Basal area	Volume
	Number	*Ft²*	*Bd.ft.*	*Number*	*Ft²*	*Bd.ft.*	*Number*	*Ft²*	*Bd.ft.*
1948	66	93	18,773	41	40	6,935	35	32	5,366
1953	72	96	19,028	32	31	4,746	48	36	5,410
1958	81	104	19,806	38	35	4,917	55	41	5,696
Net 10-year growth	—	11	1,033	—	−5	−2,018	—	9	330
Periodic annual growth	—	—	103	—	—	−202	—	—	33

TABLE 22.—Growth of residual stands per acre by regeneration cutting method (Coram Experimental Forest[1])

Residual stand	Shelterwood						Seed tree		
	Vigor selection			Economic selection					
	Trees	Basal area	Volume	Trees	Basal area	Volume	Trees	Basal area	Volume
	Number	*Ft²*	*Bd.ft.*	*Number*	*Ft²*	*Bd.ft.*	*Number*	*Ft²*	*Bd.ft.*
1950	44	63	10,860	29	38	5,845	22	25	3,892
1955	40	62	11,095	26	38	5,879	18	22	3,487
Net 5-year growth	—	−1	235	—	0	34	—	−3	−405
Periodic annual growth	—	—	47	—	—	7	—	—	−81

[1] Heavy winds in December 1955 leveled 40 to 50 percent of the trees in this study, after which the shelterwoods were logged. Hence only 5-year growth records are available.

The shelterwood (vigor selection) produced the greatest net board-foot increment. However, the heavy residual of about 18.8 M bd.ft. in this cutting at Blue Mountain only reached a 10-year periodic annual increment of 103 bd.ft. per acre, or about 0.6 percent annual return on the reserve volume. The 5-year periodic annual increment showed annual returns of 0.4 and 0.3 percent at Coram and Blue Mountain, respectively. The shelterwood (economic selection) and seed-tree cuttings at both locations showed lower or even negative annual returns.

Such poor growth does not justify leaving residual trees for increment alone; however, these trees may be justified as a seed source, for shade on exposed sites, or for esthetic reasons. When a shelterwood or seed-tree cutting is planned for natural regeneration, the trees most resistant to

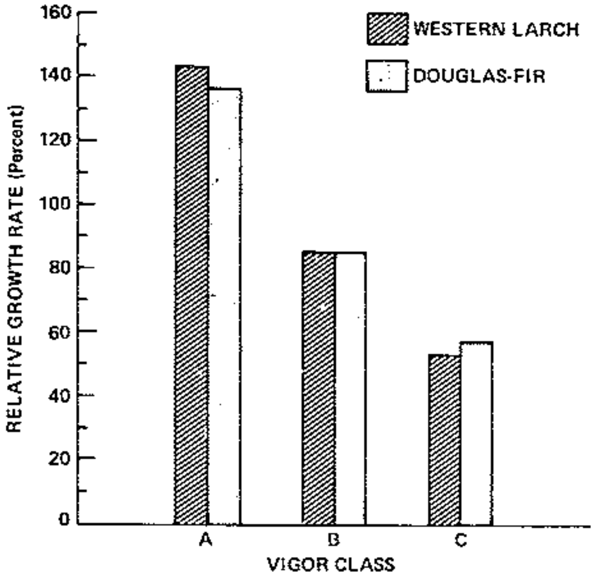


Figure 51.—Relationship of tree vigor to relative growth rates of western larch and Douglas-fir trees in cutover stands, western Montana. Relative growth rate = $\frac{\text{Average growth rate for vigor class}}{\text{Average growth rate of all sample trees}}$. These growth rates are based on board-foot increments of 416 western larch and 269 Douglas-fir trees. Relative growth rates of individual trees and of trees in uncut stands will differ from these.

windthrow and other damaging agents should be reserved to minimize the loss of merchantable volume during the regeneration period.

Vigor

Tree vigor is reflected in the growth rate of individual trees, and stand growth reflects the collective vigor of the trees (fig. 51). A vigor classification, based on seven external tree characteristics (see appendix D), aids in judging the ability of larch and Douglas-fir to respond to release (Roe 1948a). Trees of high vigor in heavily cut stands with low residual volume respond best in terms of accelerated diameter growth (Roe 1950, 1951). Residual trees of low vigor increase their diameter growth slightly in stands of less than 3,000 bd.ft., but continue to decline in growth rate in stands having heavier reserve volumes. Diameter increments of 1 inch or more per decade are usually attained only within high-vigor larch trees in residual stands of 1,000 bd.ft. or less.

Immature Stands

Larch stands and individual trees attain their greatest growth rates in the early years, tapering off as competition reduces available light, moisture, and nutrients. Cultural practices can improve and prolong growth of individual trees if done before crown lengths have been reduced and tree vigor has declined significantly.

Height

Height growth of dominant and codominant western larch trees is rapid early in the life of the stand. Site index or height-over-age curves for western larch (fig. 52 and table 23) show that dominant and codominant trees grow about 16 feet between age 20 and 30 on average sites (site index 50–60). Later on, between age 80 and 90, the dominant and codominant trees grow at only about one-third the former rate. Another comparison shows that the dominant and codominant trees on average sites attain about 78 percent of their 200-year height in the first 100 years.

Height growth of larch exceeds that of most of its associated species during the first 90 years (table 24). Lodgepole pine grows slightly faster than larch in the early years, but falls behind by age 60. Western white pine, however, surpasses larch in total height by age 90 (Deitschman and Green 1965).

Ecological habitat strongly influences site productivity and height growth of western larch

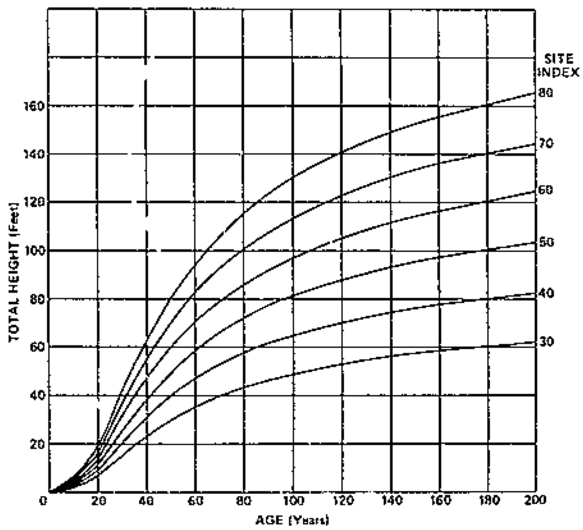


Figure 52.—Site index curves (base age 50) for western larch. (Based on reevaluation of Cummings' [1937a] basic data.

TABLE 23.—Total height (in feet) of average dominant and codominant western larch (base age 50)[1]

Age (years)	Site index 30	40	50	60	70	80
20	7	9	12	14	17	19
30	15	22	26	32	37	42
40	24	31	38	47	55	63
50	30	40	50	60	70	80
60	35	47	59	70	83	94
70	40	53	66	79	93	106
80	43	57	72	86	100	115
90	46	61	77	92	107	123
100	48	65	81	97	113	130
110	51	68	85	101	118	136
120	53	70	88	105	123	140
130	54	72	90	108	127	144
140	56	74	93	111	130	149
150	57	76	95	114	133	152
160	58	78	97	116	136	155
170	59	79	99	118	138	157
180	60	80	100	120	140	160
190	61	81	102	122	142	163
200	62	82	103	124	144	165

[1] This table was derived from the following equation:

$$\text{Log H} = \text{Log S.I.} - 20.902\left(\frac{1}{A} - \frac{1}{50}\right)$$ based upon 142 plots; $R^2 = 0.97$, S.E. = 1.08 feet.

(Roe 1967). Based on Daubenmire's (1952) classification of ecological habitats and height/age curves from Cummings' (1937a) data, the mean site indexes for ecological habitat types are as follows:

Ecological habitat type	*Mean site index*	*Confidence interval p = 0.99*
Abies lasiocarpa–Xerophyllum tenax	49.1	±2.08
Abies lasiocarpa–Pachistima myrsinites	58.2	±2.56
Tsuga heterophylla–Pachistima myrsinites / *Thuja plicata–Pachistima myrsinites* / *Abies grandis–Pachistima myrsinites*	66.3	±1.35
Pseudotsuga menziesii–Physocarpus malvaceus	62.2	±4.46
Pseudotsuga menziesii–Calamagrostis rubescens	54.6	±1.50

Larch grows most rapidly in height on the deep, moist soils of the valley bottoms, but also grows well on mid-to-lower north and east slopes, lower south slopes, and benches (fig. 53). Average site indexes for five physiographic site classes measured in western Montana, northern Idaho, and eastern Washington range from a high of 62 feet in 50 years in the valley bottoms to a low of 44 feet on the upper south and west slopes.

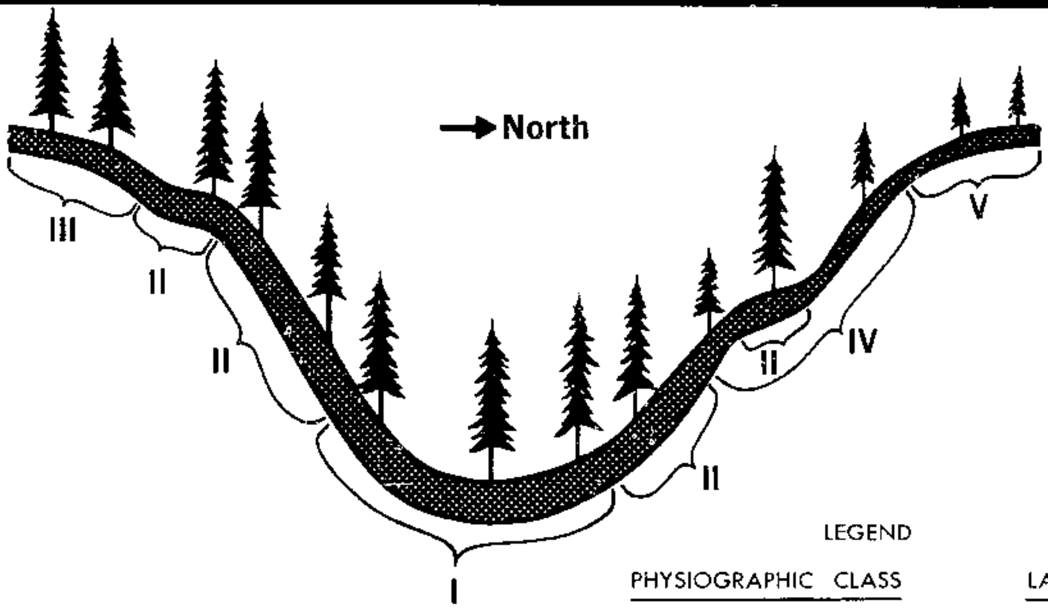
A growth curve developed for western larch growing on Waits soils[20] had essentially the same

TABLE 24.—Height of western larch and five of its associated species at three selected stand ages on land for which the white pine site index equals 60 feet at 50 years[1]

Species	Stand age (Years) 30	60	90
	Feet		
Western white pine	30	73	109
Western larch	38	77	105
Lodgepole pine	40	75	104
Douglas-fir	30	69	95
Grand fir	32	71	100
Western hemlock	28	67	100

[1] From Deitschman and Green (1965).

[20] Pearcy, Robert W. 1963. A soil-site study of western larch (*Larix occidentalis*, Nutt.) on a Waits stony loam soil. Master's Thesis, Univ. of Montana, 50 p.



LEGEND

PHYSIOGRAPHIC CLASS	LARCH SITE INDEX
I — VALLEYS BOTTOMS AND LOWER SLOPES	62 ± 2.7
II — MID—NORTH AND MID—EAST SLOPES, LOWER SOUTH AND WEST SLOPES, AND BENCHES	59 ± 1.6
III — UPPER NORTH AND EAST SLOPES	57 ± 6.2
IV — MID—SOUTH AND MID—WEST SLOPES	53 ± 4.4
V — UPPER SOUTH AND WEST SLOPES	44 ± 15.1

Figure 53.—Physiographic site classes for western larch.

slope as the average curve for larch on all soils and sites, but was considerably lower. No larch growth curves have been developed for other soil series to our knowledge.

Diameter

Western larch possesses the potential for rapid diameter growth, but overstocking, insect attacks, and dwarf mistletoe infection in natural stands often preclude full realization of this potential.

Diameter growth is also influenced by site quality, tree vigor, and tree age (tables 25 and 26). Some of these factors may be modified or controlled by management, as has been previously discussed. Converting old-growth stands to young stands and managing on shorter rotations takes advantage of the greater growth potential of younger trees.

Age and Site Index

Diameter increment normally decreases with advancing age, but this decrease is less pronounced on the better sites (table 25). Rapid growth in the first decade is typical of larch trees in stands that are not overstocked. Growth rates from 10 to 20 years of age differ only slightly from site index 40 to site index 80. But from 90 to 100 years of age trees on site index 40 land grow slightly less than half as fast as those on site index 80 land. The greater growth rates on the better sites result in substantially larger trees at harvest age (table 27). On site index 80 lands, 140-year-old trees may be 10 inches larger than those on site index 40 lands.

Vigor

The physiological condition of the tree, as indicated by external vigor characteristics (appendix D), influences the rate of diameter increment. A study of dominant and codominant larch crop trees throughout the northern Rockies showed the following growth increments when classified by vigor and adjusted for variation due to crown length and age:

Vigor	*10-year diameter increment (inches)*
Good	1.28
Medium	.91
Poor	.71

TABLE 25.—Ten-year diameter increment and growth rings per inch for average dominant western larch crop trees by site index

Decade (years)	Site index 40 Increment	40 Rings per inch	50 Increment	50 Rings per inch	60 Increment	60 Rings per inch	70 Increment	70 Rings per inch	80 Increment	80 Rings per inch
	Inches	*Number*	*Inches*	*Number*	*Inches*	*Number*	*Inches*	*Number*	*Inches*	*Number*
10–20	[1]2.5	8.0	2.6	7.8	2.7	7.6	2.9	6.8	3.0	6.6
50–60	0.9	22.2	1.1	18.2	1.3	15.4	1.5	13.4	1.7	11.8
90–100	.7	28.6	0.9	22.2	1.1	18.2	1.3	15.4	1.5	13.4
130–140	.6	33.4	.8	27.0	1.0	20.0	1.2	16.6	1.4	14.2

[1] Based on the following equation with additional allowance for changes in bark thickness:

$$10\text{-year d.b.h. growth (i.b.)} = 35.8398 \frac{1}{\text{age}} + 0.01572\ \text{S.I.} - 0.36494;\ R^2 = 0.88;\ n = 337;\ \text{S.E.} = 0.68\ \text{inch.}$$

TABLE 26.—Diameter growth of western larch crop trees by age and tree vigor on average sites (S.I. 50–60)

Decade (years)	Vigor class: Good Ten-year d.b.h. increment	Good Rings per inch	Medium Ten-year d.b.h. increment	Medium Rings per inch	Poor Ten-year d.b.h. increment	Poor Rings per inch
	Inches	*Number*	*Inches*	*Number*	*Inches*	*Number*
10–20	2.75	7.2	2.33	8.6	2.10	9.6
50–60	1.50	13.4	1.08	18.6	.86	23.2
90–100	1.25	16.0	.83	24.0	.60	33.4
130–140	1.14	17.6	.73	24.6	.50	40.0

TABLE 27.—Average d.b.h.[1] (in inches) of western larch crop trees by age and site index

Age (years)	Site index 40	50	60	70	80
20	3.0	3.2	3.5	4.0	4.4
30	4.6	5.0	5.5	6.3	6.8
40	6.0	6.5	7.2	8.1	8.9
50	7.1	7.9	8.7	9.7	10.8
60	8.0	9.0	10.0	11.3	12.5
70	8.9	10.0	11.3	12.7	14.1
80	9.7	11.1	12.5	14.1	15.5
90	10.5	12.0	13.6	15.3	17.0
100	11.2	12.9	14.6	16.6	18.5
110	11.9	13.7	15.7	17.8	19.9
120	12.5	14.6	16.7	19.0	21.3
130	13.1	15.4	17.6	20.1	22.5
140	13.7	16.1	18.6	21.3	23.9

[1] Based on accumulative 10-year periodic growth derived from the following equation with allowance for average bark thickness:

$$10\text{-year d.b.h. growth} = 35.8398 \frac{1}{\text{age}} + 0.01572\ \text{S.I.} - 0.36444;\ R^2 = 0.88,\ \text{S.E.} = 0.68\ \text{inch.}$$

The effect of vigor is much more pronounced in older trees; only a slight difference in increment occurs between good and poor vigor classes in 10- to 20-year-old trees, but increment in the good vigor class is nearly twice that of the poor vigor class between 50 and 60 years of age.

Ecological Habitat Type and Stand Density

Diameter increment of individual crop trees differs by habitat type and stand density. In the most productive habitat types, larch crop trees reach larger diameters than those in the less productive types under comparable stand densities (table 28). Larch stand densities are shown as a ratio between actual plot basal area and normal basal area (see following Basal Area section for normal or fully stocked stand values). For example, 140-year-old trees in stands of 60-percent normality range from a low of 15.1 inches d.b.h. in the least productive habitat (*Abies lasiocarpa-Xerophyllum tenax*) to a high of 20.3 inches in the most productive habitat (*Tsuga heterophylla-Pachistima myrsinites*)—a difference of 5.2 inches in the average dominant larch crop trees.

Stand density affects diameter increment of crop trees as much as site quality, or habitat type. For example, at age 140 the greatest spread in average diameter of crop trees in normal stands was 4.2 inches (*Thuja plicata–Pachistima myrsinites* and *Tsuga heterophylla–Pachistima myrsinites* habitat types vs. *Abies lasiocarpa–Xerophyllum tenax* habitat type); the difference in average diameter of

TABLE 28.—Average d.b.h. (in inches) attained by larch crop trees by habitat type and stand stocking

Age (years)	Normality[1]		
	0.6	1.0	1.4
	ABIES LASIOCARPA–PACHISTIMA MYRSINITES		
20	2.7	2.6	2.4
60	9.2	8.4	7.5
100	13.8	12.3	10.8
140	17.8	15.7	13.4
	ABIES GRANDIS–PACHISTIMA MYRSINITES		
20	2.9	2.7	2.5
60	9.5	8.6	7.7
100	14.3	12.7	11.1
140	18.5	16.1	13.8
	THUJA PLICATA–PACHISTIMA MYRSINITES AND TSUGA HETEROPHYLLA–PACHISTIMA MYRSINITES		
20	3.3	3.1	2.9
60	10.6	9.6	8.7
100	15.9	14.2	12.4
140	20.3	17.8	15.2
	ABIES LASIOCARPA–XEROPHYLLUM TENAX		
20	2.4	2.3	2.2
60	7.7	7.2	6.6
100	11.6	10.6	9.6
140	15.1	13.6	12.2
	PSEUDOTSUGA MENZIESII–CALAMAGROSTIS RUBESCENS[2]		
20	2.7	2.5	2.[illegible]
60	8.6	7.9	7.1
100	13.0	11.7	10.4
140	16.8	14.9	13.0

[1] Normality = the ratio between actual and normal basal area.
[2] Includes *Pseudotsuga menziesii—Physocarpus malvaceus.*

crop trees in stands stocked at 1.4 normality vs. stands stocked at 0.6 normality was 5.1 inches in the *Thuja plicata–Pachistima myrsinites* and *Tsuga heterophylla–Pachistima myrsinites* habitat types.

Basal Area

Stand basal area in larch forests rises rapidly up to about age 40, decelerates, then nearly levels off after age 100 (table 29). This basal area table developed from normal yield data (Cummings 1937a) shows that up to age 100 the basal area of site index 70 stands increases at an average rate of 2.67 ft^2 per year. In contrast, the basal area increase from age 100 to 200 years is only 0.37 ft^2 per year. This illustrates that as basal area stocking approaches the site potential, basal area increment drops off rapidly. Because of better tree distribution, chiefly due to mortality of the suppressed trees, the stands more closely approach the site potential with the passage of time. The effects of close stand density regulation over long periods of time in larch stands are not presently known.

Volume

Currently a substantial portion of the western larch harvest goes into lumber and timber products measured in board feet. However, every year more of the production is being channeled into uses where the board-foot unit is not applicable. In fact, the need for a cubic-foot measure of larch many years ago prompted the derivation of a cubic-foot alignment chart (Cummings 1937b). Products not measured in terms of cubic-foot volume require conversion factors. For example, cubic measure can be converted to cords or weight measures that may be more useful in chip production, and it can also be converted to board-foot equivalent.

Tables 33, 34, and 35 in appendix F show cubic-volume yields of western larch stands for 0.6-, 4.6-, and 7.6-inch minimum diameters. Normal board-foot yields for western larch stands are shown in table 36 for trees 7.6 inches d.b.h. and larger. Brickell (1970b) used these data to derive the relationship of site index to yield capability in mean annual cubic-foot increment per acre.

TABLE 29.—Basal area (in square feet per acre) of trees 0.6 inch and more in d.b.h. for normal or fully stocked stands[1,2]

Age (years)	Site index					
	30	40	50	60	70	80
20	68	74	81	88	96	105
30	105	114	124	135	147	160
40	129	141	154	167	182	198
50	147	160	174	190	207	225
60	160	174	190	207	225	245
70	170	185	202	220	240	261
80	178	194	211	230	251	273
90	185	201	219	238	260	283
100	190	207	225	245	267	291
110	194	212	231	251	274	298
120	198	216	235	256	279	304
130	202	219	239	260	284	309
140	204	222	242	264	288	313
150	206	225	245	267	291	317
160	209	228	248	270	294	320
170	211	230	250	273	297	323
180	213	232	252	275	299	326
190	214	234	254	277	302	329
200	216	235	256	279	304	331

[1] This table has been developed from the following equation:

Log. basal area = 2.27827 − 11.10347 $\frac{1}{\text{age}}$ + 0.00371 site index; standard error of estimate = 1.27 ft^2, n = 134.

[2] Values within the block lines fall within the range of the basic data.

Yield, stand, and volume tables, published by Haig (1932), for the western white pine type of northern Idaho included larch as a stand component. A local yield table, from limited data collected on the Kootenai National Forest, was published by Terry (1910).

Transmission Poles

Western larch is used for transmission poles, especially in long lengths. Its excellent form (fig. 54) and great strength make it a highly desirable pole species (Drow 1952).

Sapwood Depth

The shallow depth of sapwood (Lassen and Okkonen 1969) in western larch makes it difficult to obtain penetration of preservatives to a sufficient depth in some trees to meet industry specifications. Heartwood is many times harder to penetrate with preservatives than sapwood, thus poles must possess sapwood that is as deep or deeper than the desired depth of preservative treatment. Ordinarily, the industry requires no less than a ½-inch preservative ring in treated poles. Therefore, the finished peeled pole must be surrounded by at least a ½-inch layer of sapwood. To obtain this layer of sapwood, some companies specify a minimum ¾-inch sapwood depth in trees cut for utility poles. Then after peeling, even with some loss, a half-inch layer of sapwood will remain.

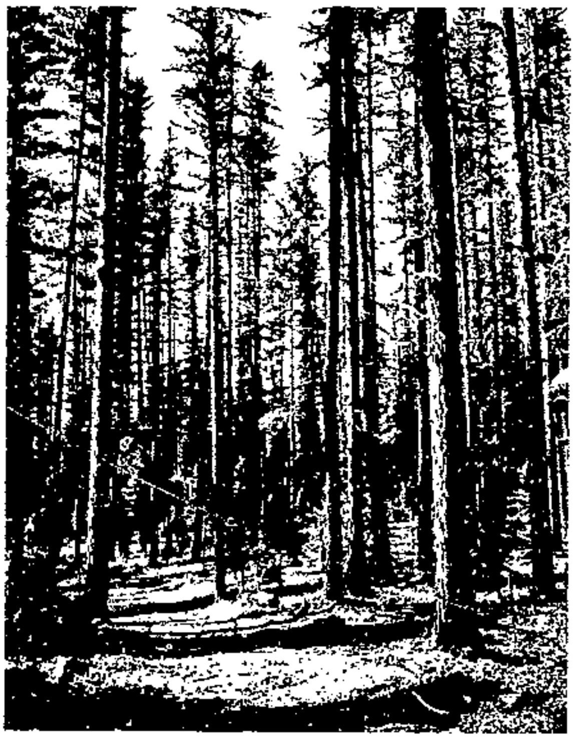


Figure 54.—The excellent form and availability of long poles make larch a highly desirable pole species.

Sapwood depth is related to growth rate or tree vigor; thus, trees growing at average or better rates normally possess enough sapwood to qualify them for transmission poles. Factors that slow down tree growth, such as overstocking, diseases, and insects, reduce the depth of the sapwood ring sufficiently to prevent effective preservative treatment. Conversely, cultural measures that improve tree growth enhance the trees' value for transmission poles. Tables and a technique for predicting the depth of sapwood in larch trees are presented in appendix G.

Spirality

Spiral grain commonly occurs in western larch, as well as in other species, and affects pole stability after installation. Studies of larch spirality (Lowery 1966; Wellner and Lowery 1967; Lowery and Erickson 1967) have pointed out several important factors:

1. Nearly all larch trees (96 percent) exhibit some spirality pattern, but fewer than 10 percent are spiraled enough to cause poles to be degraded.
2. Spiral grain is a major cause of pole twisting.
3. Poles twist in the same direction as spirality.
4. Left-spiral grain is more severe, occurs two to three times as frequently, and causes more severe pole twisting than right-spiral grain.
5. Right-spiraled poles usually contain left-spiral grain inside the pole that counterbalances the tendency toward right-hand twist, but left-spiraled poles contain no such counterbalancing force.
6. Poles with straight or right-spiral grain are stronger than those with left-spiral grain.
7. Long-crowned, rapid-growing trees in open stands tend to have grain that spirals more severely and frequently to the left than trees in closed stands.
8. The position of a tree on the slope has no apparent effect on direction or severity of spiral grain.

Pole Class

Transmission pole classes developed by the American National Standards Institute, Inc. (1972) are based upon minimum acceptable circumferences at the top and at 6 feet from the butt. The latter minimum circumference varies with the length of the pole (poles are usually measured in 5-foot classes). Although 15 pole classes are recognized, the commercial poles fall mainly in the first

12 classes. The pole classes are designed chiefly to define poles of sufficient strength for specific use requirements, and therefore they define pole quality. The dimensions of larch poles by class are presented in appendix I.

Pole lengths available from average dominant and codominant trees vary according to tree diameter, stand age, and site index. Possible pole lengths as influenced by these factors are shown in appendix J. On site index 60, an 80-year-old stand will yield poles ranging from 40 to 60 feet depending upon the tree diameter. An 18-inch tree in this situation will yield a 55-foot pole if it does not have disqualifying crook, sweep, or spiral grain.

Although pole length is related to site quality, there appears to be no significant relationship between pole class and site index. Data from a larch pole study indicated that the oest timber sites did not have a higher proportion of class 1 larch poles than the poorer sites. However, the true relationships here may be clouded to some extent because the pole trees sampled on the poorer sites were slightly older than those sampled on the better sites.

Pole class changes significantly with age and reflects the change in form as the tree grows older. The proportion of pole classes represented in four age groupings is illustrated in figure 55.

A significantly greater proportion of the higher pole classes (1 through 4) occurs in certain ecological habitat types. Western larch trees found in the *Abies grandis–Pachistima myrsinites, Tsuga heterophylla–Pachistima myrsinites*, and *Pseudotsuga menziesii–Physocarpus malvaceus* types provide by far the largest proportion of the better pole classes (1 through 4). Furthermore, trees found in these three habitat types also show the largest proportion of class 1 poles, ranging from a low of 6.5 percent to a high of 12 percent.

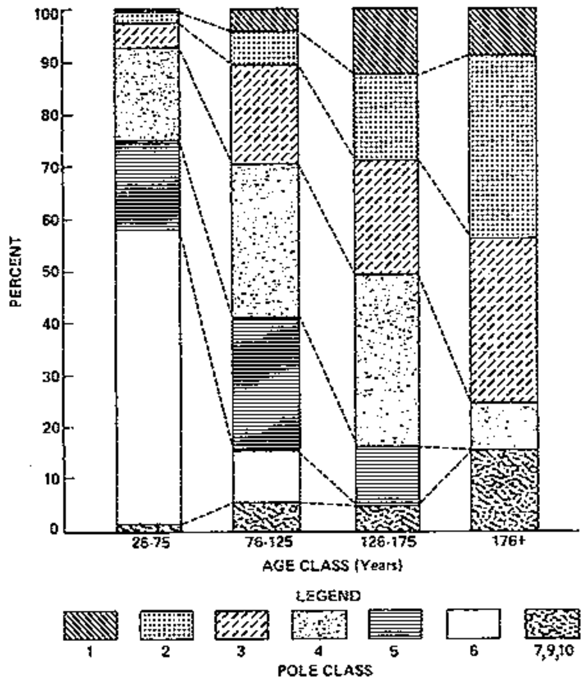


Figure 55.—Distribution of western larch poles by class within four tree age groupings. (See appendix I for description of pole classes.)

FUTURE RESEARCH

Silvicultural research in western larch forests prior to the mid-1960's was directed primarily at growing trees for commercial timber production. This was the natural outgrowth of the demands placed upon the forests for timber at that time. However, increasing public demands upon our forests for a variety of uses and a growing concern for the environment are changing the priorities of land management. The resulting interaction of uses, and specifically the effects of timber management on other forest uses, presents a whole new mix of problems for the silviculturist. Although past silvicultural research has provided much silvical and ecological information about larch forests, present and future research must develop a much broader base of knowledge and take a more holistic approach toward forest management problems. Multidisciplinary studies started about 10 years ago are now beginning to provide information on how silvicultural practices can achieve not only timber production but also meet the other multiple use demands that compete for a shrinking land base. The direction of future research must constantly be reassessed to insure the development of the knowledge needed to manage larch forests for all current and future uses.

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APPENDIXES

APPENDIX A: WEATHER RECORDS FROM SELECTED WEATHER STATIONS WITHIN THE RANGE OF WESTERN LARCH, THROUGH 1960[1]

			Precipitation								Temperature									
	Weather		Mean	Growing season					Percent	Snowfall	Yearly mean			Yearly absolute		Growing season mean				
State	station	Elev.	annual	May	June	July	Aug.	Total	of annual		Max.	Min.	Mean	Max.	Min.	May	June	July	Aug.	Ave.
		Feet	*Inches*								*Degrees F*									
Idaho	Avery	2,492	32.5	2.4	2.3	1.0	1.0	6.7	20.5	64.4	88.0	20.0	47.4	108	-25	54.4	60.5	67.8	66.2	62.2
	Bonners Ferry	1,812	23.1	1.5	1.7	0.9	0.9	5.0	21.7	74.6	83.8	16.5	45.6	104	-29	54.4	60.1	66.5	64.5	61.4
	Coeur d'Alene	2,158	26.1	1.9	1.7	.7	.7	4.9	18.9	49.2	85.3	20.7	47.8	108	-34	55.4	61.3	69.8	67.8	63.4
	Elk City	3,975	29.8	3.0	3.3	1.2	1.5	9.0	30.2	–	83.0	11.1	–	101	-43	48.4	54.6	61.2	58.7	55.7
	Kooskia	1,261	24.7	3.0	2.5	.9	.8	7.2	29.0	–	92.1	20.9	50.9	116	-30	57.8	64.3	71.9	69.9	66.0
	McCall	5,025	26.8	2.1	1.9	.5	.7	5.2	19.5	130.8	81.1	7.6	39.9	104	-35	46.9	54.1	62.7	60.2	56.0
	Orofino	1,027	25.9	2.3	2.2	.7	.6	5.8	22.3	–	93.4	22.2	51.9	118	-24	58.7	65.2	73.1	71.1	67.0
	Pierce	3,185	41.3	3.3	3.0	1.0	.9	8.2	19.8	114.3	85.0	14.1	43.6	107	-44	51.8	57.9	65.0	62.5	59.3
	Priest River	3,175	32.5	2.1	2.3	.9	1.0	6.4	19.6	88.2	83.4	16.4	44.1	102	-35	51.8	57.9	64.3	62.5	59.1
	St. Maries	2,770	28.7	2.0	1.8	.8	.8	5.4	18.8	–	85.6	20.9	47.5	106	-26	54.5	60.8	66.8	65.1	61.8
	Sandpoint	2,100	32.7	2.0	2.1	.7	1.0	5.8	17.7	75.1	82.8	18.9	45.4	104	-35	53.3	59.2	65.3	63.6	60.4
	Wallace	2,770	42.1	2.6	2.5	1.1	1.1	7.3	17.4	82.6	83.9	19.7	44.7	107	-24	52.7	59.4	65.9	64.1	60.5
Montana	Big Fork	3,060	21.9	2.5	3.2	1.3	1.3	8.2	37.5	–	81.7	19.9	46.1	100	-20	53.5	59.1	67.5	65.9	61.5
	Haugan	3,150	31.3	1.7	2.1	.7	.8	5.4	17.1	121.5	84.7	11.3	42.6	104	-49	50.5	57.1	62.9	60.9	57.8
	Heron	2,240	34.3	2.2	2.3	.9	1.0	6.4	18.7	87.4	84.3	16.6	43.9	105	-39	52.1	57.9	64.3	62.4	59.2
	Hungry Horse	3,160	31.1	2.5	2.9	1.6	2.0	9.1	29.1	108.7	80.7	11.5	42.2	102	-40	51.1	57.6	65.0	63.1	59.2
	Libby	3,600	26.8	1.5	2.2	1.1	1.3	6.0	22.6	131.8	80.2	11.6	40.5	100	-44	48.5	54.3	61.4	59.2	55.8
	Polebridge	3,690	23.1	1.6	2.2	1.2	1.3	6.3	27.3	122.4	81.2	6.3	39.2	101	-48	48.8	54.6	61.2	58.8	55.8
	Seeley Lake	4,030	21.1	2.0	2.4	1.1	.9	6.5	30.6	120.3	82.5	4.8	40.8	101	-53	49.3	55.1	62.5	60.5	56.8
	Thompson Falls	2,435	20.8	1.8	2.0	.8	.8	5.4	25.8	–	87.6	17.5	45.3	109	-36	55.3	61.3	69.2	67.6	63.4
	Trout Creek	2,485	30.0	1.9	1.9	.9	.8	5.5	18.3	–	85.7	14.1	43.7	107	-40	51.5	57.8	64.4	62.8	59.1
	West Glacier	3,154	28.1	2.4	3.0	1.3	1.3	8.0	28.4	128.6	82.3	13.5	42.1	101	-42	51.1	57.0	64.0	62.0	58.5
Oregon	Austin	2,114	19.0	1.5	1.5	.6	.6	4.1	21.3	–	84.1	7.6	41.3	108	-52	48.1	54.6	61.8	59.4	56.0
	Granite	4,939	22.9	1.7	1.7	.6	.5	4.5	19.8	169.9	77.7	10.1	39.1	96	-28	45.0	51.3	58.5	56.7	52.9
	Meacham	4,050	33.9	2.7	2.1	.5	.6	6.0	17.7	156.1	77.7	19.2	43.5	103	-15	48.3	54.0	63.7	61.9	57.0
Washington	Deer Park	2,114	22.0	1.6	1.4	.5	.8	4.2	19.2	–	85.6	15.7	45.2	107	-42	53.3	59.4	65.9	63.8	60.6
	Metaline Falls	2,107	28.7	2.3	3.0	1.4	1.3	8.0	27.9	80.5	84.2	16.9	45.4	104	-28	54.3	59.7	66.5	64.7	61.3
	Newport	2,135	27.2	2.0	1.9	.6	.8	5.3	19.5	–	85.7	16.8	44.9	107	-41	53.1	59.0	65.4	63.1	60.2
	Northport	1,345	19.5	1.6	2.0	.9	.9	5.4	27.9	55.6	88.5	17.2	48.0	110	-27	56.8	62.8	69.0	66.4	63.8
	Average		27.9	2.1	2.2	0.9	1.0	6.2	22.9	103.3	84.2	15.2	44.4	105	-35	52.1	58.2	65.3	63.3	59.7

[1]Compiled from U.S. Dep. Commerce Climatic Summary of the United States, Supplement for 1951 through 1960.

APPENDIX B: METHODS OF SAMPLING CONES FOR LARCH SEED CROP FORECASTING

The potential of a western larch seed crop can be estimated as much as a year in advance by sampling ovulate buds. When buds are set at the end of the growing season, staminate, ovulate, and vegetative buds are fully differentiated and recognizable. A sample of the number of ovulate buds during the fall and winter provides a practical basis for estimating the next year's potential seed crop. Seed crop potential may also be evaluated in early spring by counting the new strobili or conelets with the aid of binoculars.

For descriptions of ovulate buds and conelets, see the "Flowering" section in the main text.

Sampling

Ovulate buds.—Ovulate buds are sampled by randomly collecting a minimum of 4 and up to 12 major branches from dominant or codominant trees growing in forest stands—not open-grown. A major branch is defined as one that originates at a node and extends to the exterior surface of the crown. Sample branches should be collected in the upper two-thirds of the crown and the number of ovulate buds on each branch should be counted. Branches may be obtained by (1) climbing the trees, (2) examining trees felled in logging, or (3) shooting them off with a rifle.

Conelets.—The sampling procedure is much the same as that for counting buds. The observer, using 6X or 7X binoculars, randomly selects a minimum of four major branches. He scans each one and counts the strobili, avoiding persistent cones from the previous years. Because size is not reliable in distinguishing between new conelets and old cones, the observer should move about until the light reflects the color of the conelet (conelets range from light green to purple in color). After the foliage grows out, the presence of the strobili is obscured.

Classifying Prospective Cone Production

To determine relative production, the counts of ovulate buds or strobili per major branch must be related to some standard. For western larch, 10 strobili per branch are used as the lower limit for a good seed crop, and three strobili per branch as the lower limit for a medium crop. The probability of making a wrong decision based upon the following sequential sampling plan is set at 10 percent. Values are established for sampling both *individual trees* and stands.

Individual Trees

To use the sequential sampling plan, estimate seed production for individual trees as follows: Record the branch counts (ovulate buds or strobili) as they are collected in column 2 of the tally form illustrated in table 30. Adjust for anticipated loss by reducing the count by one-half and accumulate in column 3 (Σ 1/2X) as shown. For each entry compare the cumulative total in column 3 with the critical values on either side of columns 4 or 5.

After each comparison decide whether the crop can now be classified or whether sampling should be continued. If the cumulative total exceeds the column 4A value on that line, stop sampling and rate the crop in prospect as good; if the total falls below column 4B and above column 5A values, stop sampling and rate the prospective crop as medium; finally, if the cumulative total falls below column 5B values, cease sampling and rate the prospective crop as poor. If none of the above conditions are met, continue to sample by counting another branch sample and adding it to the tally. If no decision has been reached after 12 sample counts, stop sampling and classify the prospective crop in the nearest category approached by the cumulative count.

The hypothetical example of the potential cone crop on the tally sheet in table 30 was rated as poor after the counts from seven branches were tallied. The total of 17.5, attained after the seventh branch count, fell below the critical value of 18 in line 7 of column 5B. In some instances a decision may be made after only one or two branches have been sampled, but a minimum sample of four branches per tree selected, one from each quarter of the tree crown length being sampled, is recommended.

TABLE 30.—A tally form for sequential sampling of prospective seed crops in western larch trees (see text for instructions)

(1) Branch number	(2) Branch tally (x)	(3) Σ1/2X		(4A) Good	(4B) Medium		(5A) Medium	(5B) Poor
1	**8**	**4**		20				
2	**4**	**6**		29				
3	**8**	**10**		38				2
4	**7**	**13.5**		47	25		26	6
5	**0**	**13.5**		56	34		30	10
6	**2**	**14.5**		65	43		34	14
7	**6**	**17.5**		74	52		38	18
8				83	67		42	22
9				92	70		46	26
10				101	79		50	30
11				110	88		54	34
12				119	97		58	38

Stands

Using the same procedure, one can also estimate the seed crop from a stand. The estimated *average* number of buds or cones per branch on each tree classified in the stand is entered in column 2 and accumulated in column 3 of the form shown in table 31. The limits in columns 4A and 4B and 5A and 5B of this form apply to the *means* of sample trees. The stand classification—good, medium, or poor—is determined in the same manner as for individual trees. The hypothetical example shown in table 31 indicates that the prospective seed crop should be rated as *good.*

TABLE 31.—A tally form for sequential sampling of prospective seed crops in western larch stands

(1) Tree number	(2) Tree tally (x)	(3) ΣX		(4A) Good	(4B) Medium		(5A) Medium	(5B) Poor
1	**7**	**7**		12	6		6	2
2	**8**	**15**		21	15		11	6
3	**10**	**25**		30	24		14	10
4	**8**	**33**		39	33		18	14
5	**43**	**76**		48	42		22	18
6				57	51		26	22
7				66	60		30	26
8				75	69		34	30
9				84	78		38	34
10				93	87		42	38
11				102	96		46	42
12				111	105		50	44

APPENDIX C:
SUMMARY OF REPRODUCTION CUTTING METHOD STUDIES (1) CORAM EXPERIMENTAL FOREST AND (2) BLUE MOUNTAIN, KOOTENAI NATIONAL FOREST

	Clearcut		Seed tree		Two-cut shelterwood	
	Blocks	Strips	Scattered	Groups	Vigor selection	Economic selection
I Location	1. Coram	1. Coram	1. Coram 2. Blue Mountain	1. Coram	1. Coram 2. Blue Mountain	1. Coram 2. Blue Mountain
II Area of cutting (acres)	1. 15, 30, 60	1. 91 (8 strips from 8 to 40 chains long)	1. 40 2. 58	1. 125	1. 56 2. 48	1. 41 2. 33
III Year of logging	1. 1951-1952	1. 1953	1. 1950-1951 2. 1949	1. 1955-1956	1. 1950-1951 2. 1949	1. 1950-1951 2. 1949
IV Seed source type and basal area per acre (sq. ft.)	1. Timber surrounding patches BA-248	1. 3-5 chain wide strips of uncut timber bordering 3-5 chain wide cut strips. BA-138	1. 22 WL, DF & others (10" +) BA-25 2. 7 WL (12" +) BA-21	1. 1/2 and 1/4 acre groups left intact. BA in groups–142; BA ave. for total area–2.8	1. 44 WL, DF & others (10" +) BA-63 2. 23 WL (12" +) BA-76	1. 29 WL, DF & other (10" +) BA-38 2. 10 WL (12" +) BA-26
V Good seed years (first 5 years after seedbed preparation)	1. 1952 1954	1. 1954	1. 1952 1954 2. 1952 1954	1. All crops poor	1. 1952 1954 2. 1952 1954	1. 1952 1954 2. 1952 1954
VI Seedbed preparation and slash disposal (type and year accomplished)	1.a. Broadcast burn b. Scarify and burn slash piles. (1952)	1.a. Scarify and burn slash piles. (1953)	1.a. Scarify and burn slash piles. b. Hand pile slash and burn piles. c. Lop and scatter slash. d. Broadcast burn. (1951-1952). 2.a. Scarify and burn slash piles. b. Hand pile slash and burn piles. c. Broadcast burn. (1950-1951)	1.a. Scarify and burn slash piles. (1956) b. Broadcast burn. (1958)	1. Same as scattered seed tree. (1951-1952) 2. Same as scattered seed tree. (1950-1951)	1. Same as scattered seed tree. (1951-1952) 2. Same as scattered seed tree. (1950-1951)
VII Physiographic site classes[1]	1. II and III	1. II and III	1. II 2. II	1. I and II and III	1. II 2. II	1. I 2. II
VIII Habitat type	1. *Abies lasiocarpa-Pachistima myrsinites*	1. *Abies lasiocarpa-Pachistima myrsinites*	1. *Abies lasiocarpa-Pachistima myrsinites* 2. *Abies lasiocarpa-Menziesia ferruginea*	1. *Abies lasiocarpa-Pachistima myrsinites*	1. *Abies lasiocarpa-Pachistima myrsinites* 2. *Abies lasiocarpa-Menziesia ferruginea*	1. *Abies lasiocarpa-Pachistima myrsinites* 2. *Abies lasiocarpa-Menziesia ferruginea*

[1]See "Growth and Yield" section for description of physiographic site classes.

APPENDIX D:
CLASSIFYING THE VIGOR OF WESTERN LARCH AND DOUGLAS-FIR

Character	VIGOR CLASS		
	A (Good vigor)	B (Fair vigor)	C (Poor vigor)
1. Position of crown	Usually dominant or codominant, occasionally intermediate.	Ordinarily codominant and intermediate, rarely dominant.	Usually intermediate or suppressed, occasionally codominant and rarely dominant.
2. Length of crown	Crown length 40 percent or more of the total height. Unusually wide crown may be shorter, but not less than 30 percent.	Crown length usually from 20 to 40 percent of total height. In narrow crowns greater length may be allowed.	Crown length usually will not exceed 20 percent of total height. In extremely narrow crowns greater length may be allowed, but not to exceed 50 percent.
3. Width of crown	Crown width average or wider.	Crown usually average width. May be narrow and long or wide and short.	Crown usually narrow or occasionally of average width.
4. Shape of crown	Tip usually pointed or round, never flat or spike topped.	Tip usually round, occasionally pointed, and rarely flat topped.	Tip usually flat or spike-topped, rarely round.
5. Branching and foliage	Dead branches in the crown rare, branches and foliage moderately dense or better. Branches in upper half of crown usually strongly upturned and no drooping branches.	Occasional dead twigs present, usually no dead branches in the crown. Branches and foliage of moderate density. Occasionally large crowns of extremely open density. Usually the upper branches either upturned or horizontal, with drooping branches in the lower half of crown.	Dead twigs and branches showing through the crown. Often branches drooping to the tip. In western larch[1] branches short and stout throughout the length of the crown.
6. Bark	*Western larch.*—Bark is usually dark in color and ridged or only slightly scaly with deep fissures between scales. Bark appears rough.	*Western larch.*—Bark is usually dark around base of tree, becoming scaly above. Plates not well-defined, but bark appears relatively smooth.	*Western larch*[2]—Bark usually light in color with well-defined, large, smooth bark plates and very shallow fissures between plates. Bark appears very smooth.
	Douglas-fir.—Bark usually has broad, corky ridges at the base, with light-brown new bark prominently exposed in the fissures, becoming uniformly and finely ridged and dark above. The upper quarter or more of the bole usually has smooth or slightly checked light grey bark.	*Douglas-fir.*—Bark has corky ridges at the base of the tree becoming uniformly and finely ridged above. New light-brown bark not as prominent as in A vigor and usually extending only part way up the butt log. Dark, rough bark extends at least three-quarters or more up the full length of the bole.	*Douglas-fir.*—Bark rarely has the light-brown new bark exposed in the fissures. Dark bark usually extends to the tip. Frequently the entire bole has dark, finely ridged bark.
7. Disease	No mistletoe infection.	Rarely trees with light mistletoe infection.	Trees with visible indications of moderate to heavy mistletoe infection.

[1]Frequently in western larch, short, stout branches near the tip give it the appearance of being pointed. This should not be confused with a pointed growing tip, which usually has numerous thin branches and is normally obtusely pointed.

[2]Trees with this type of bark are overmature and usually growing slowly. They should be dropped one class below that in which they would otherwise classify. Thus, if a tree qualifies for A vigor, but possesses the light, smooth bark with well-defined plates and shallow fissures, it should be dropped to the B vigor class.

APPENDIX E: EVALUATING GROWTH PERFORMANCE OF WESTERN LARCH

Method

This comparison technique contrasts relative total diameter of crop trees at the present with the relative diameter growth of the last decade to illustrate the past condition and present trends of growth in the stand. The method, developed primarily from western larch data, may be used to (1) determine the relative growth performance of trees and stands, (2) confirm the need for thinning and set priorities among stands, and (3) determine the impact of insects, disease, and overstocking on growth. Two criteria are used to evaluate the growth of individual trees or stands:

1. *Relative total diameter* is determined by comparing actual diameter with potential diameter; it shows how fast the tree or stand has grown from seed to its present age.

2. *Relative periodic growth rate* is determined by comparing the last 10-year growth with the potential 10-year growth; it shows the present performance of the tree or stand.

For both sets of curves—*total* diameter and *periodic* growth—the upper curve labeled 1.0 is the potential growth for that particular combination of site and habitat type (fig. 56). Thus, the 0.8, 0.6, and 0.4 curves are 80, 60, and 40 percent of the potential *total* diameter or *periodic* growth.

Comparing total diameter with periodic growth rate demonstrates the growth trend. For example, figure 56 shows the potential growth curves for larch growing on an *Abies lasiocarpa–Pachistima myrsinites* habitat type with a site index of 70. An evaluation of two trees, A and B, whose growth values are plotted, demonstrates their respective growth trends. Tree A achieved 0.9 of its potential total diameter for its age, site index, and habitat combination. However, during the last 10 years the tree grew at only 0.4 of its potential periodic rate. From this we would conclude that only recently has overstocking or some other factor suppressed growth. Silvicultural treatment will be needed to return this tree's growth to its previous rate. Tree B achieved only 50 percent of its potential total diameter during its 50-year existence. However, during the last decade its growth equaled its potential periodic rate. This demonstrates that tree B was badly suppressed by overstocking or some other factor during early life, but was released and is now growing rapidly. At this time the tree probably does not need any silvicultural treatment.

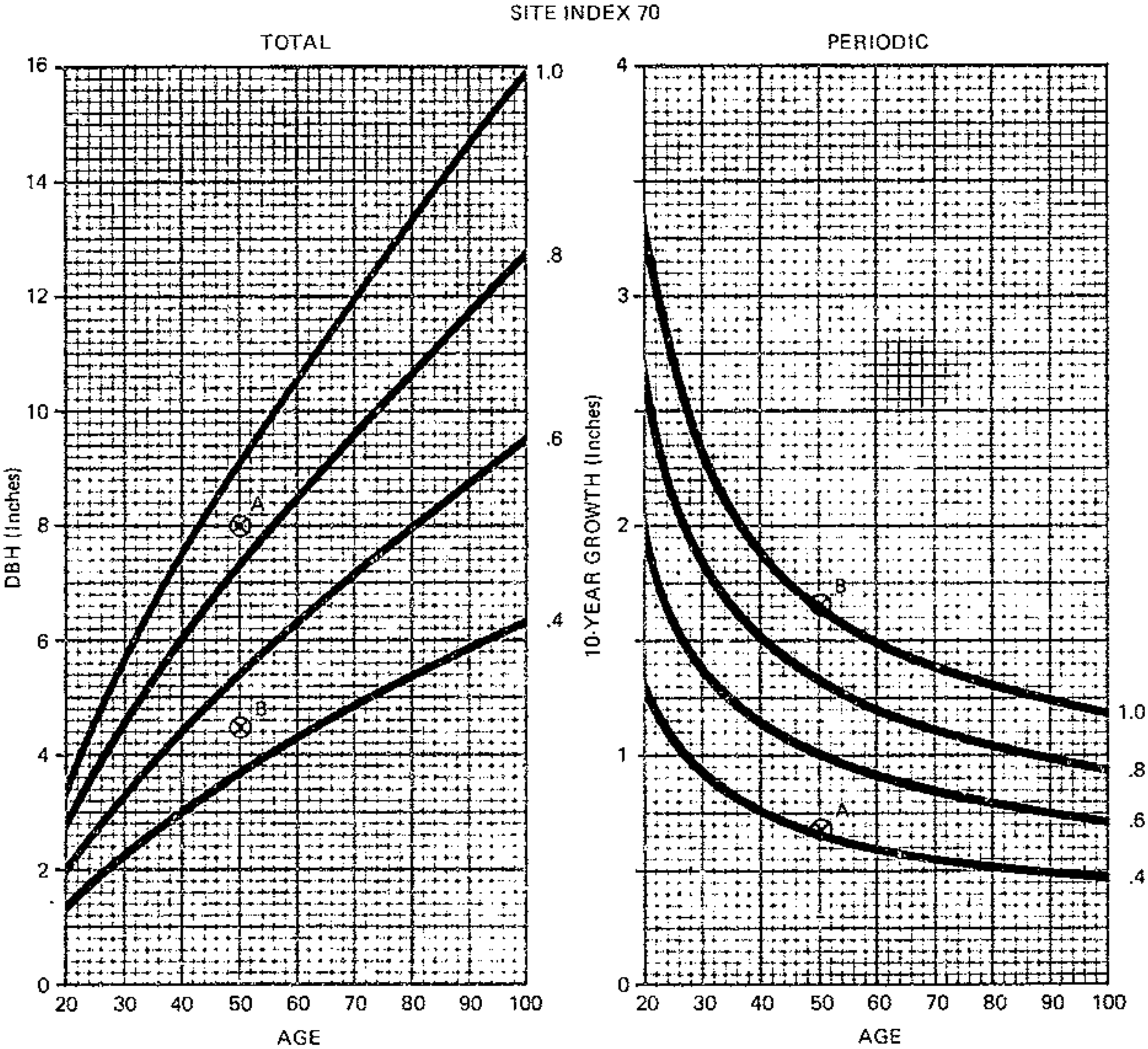
Stands may be evaluated with the same methods used for individual trees. To do this, one simply measures the present diameter and last 10-year diameter growth of 25 trees or more in the stand and categorizes the trees as shown in the following illustration of two hypothetical stands (table 32).

TABLE 32.—Growth performance of two hypothetical larch stands

Potential class	Stand C: TOTAL diameter potential	Stand C: PERIODIC growth potential	Stand D: TOTAL diameter potential	Stand D: PERIODIC growth potential
	Percent of trees in the sample			
> 0.80	70	60	70	0
0.60–0.79	30	40	30	20
0.40–0.59	0	0	0	40
< .40	0	0	0	40

Figure 56

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Pachistima myrsinites
Habitat Type



In the example of stand C, all of the trees reached diameters exceeding 0.6 of their potential total diameter and 70 percent exceeded 0.8 of their potential. The last decade's growth shows a similar pattern. All trees exceeded 0.6 of their potential periodic rate and 60 percent exceeded 0.8 of the potential periodic rate. As opposed to this, in stand D the diameter reached the same level as in stand C, but the last decade's growth declined rapidly—only 20 percent of all the trees exceeded 0.6 of their potential periodic rate. Thus, it is apparent that stand C grew at a reasonable rate throughout, while stand D grew satisfactorily at first, then declined markedly during the last 10 years. It is obvious that stand D more urgently needs silvicultural treatment to release it from the growth suppressing factor than does stand C.

Since the manager is primarily concerned with the condition and trend of the crop trees in a stand, this technique should be applied only to those trees that will be featured in management. Including trees that would not be considered in management would skew the distribution into lower potential classes and give a distorted view.

Larch trees and stands growing on nearly all conceivable combinations of site quality and ecological habitat type can be evaluated in this manner. Potential total and periodic diameter growth curves for other site and habitat type combinations follow in figures 57 to 61.

Figure 57A

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Xerophyllum tenax
Habitat Type

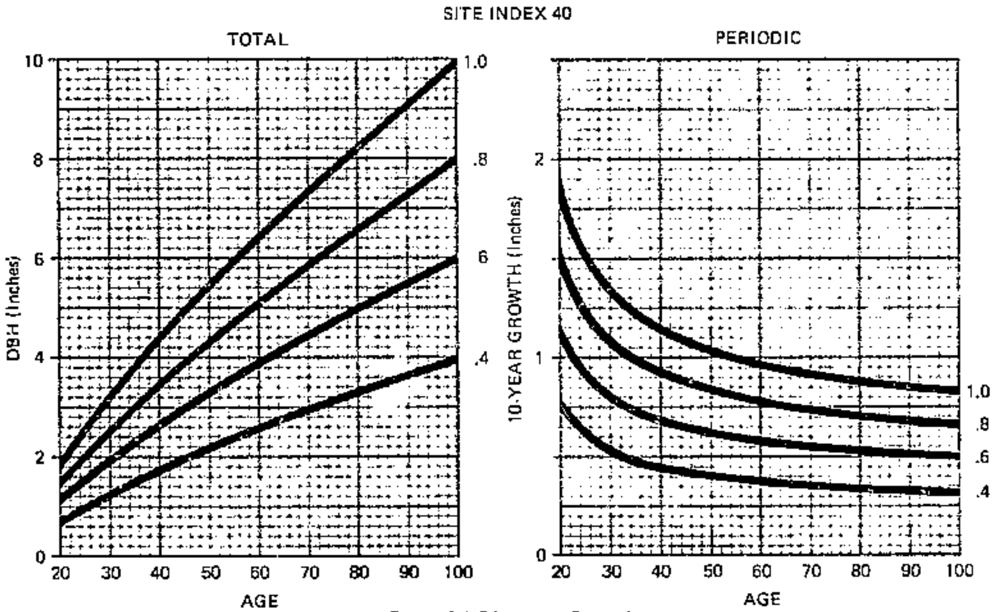


Figure 57B

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Xerophyllum tenax
Habitat Type

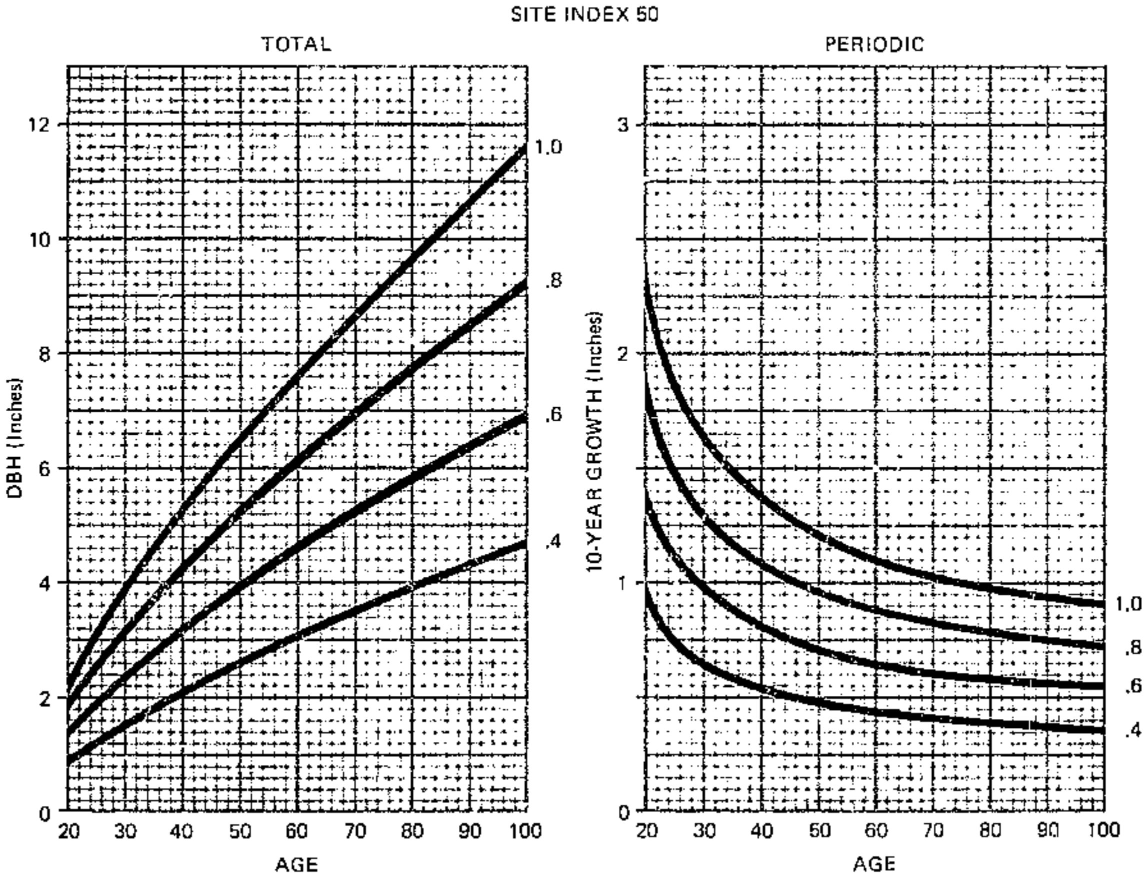


Figure 57C

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Xerophyllum tenax
Habitat Type

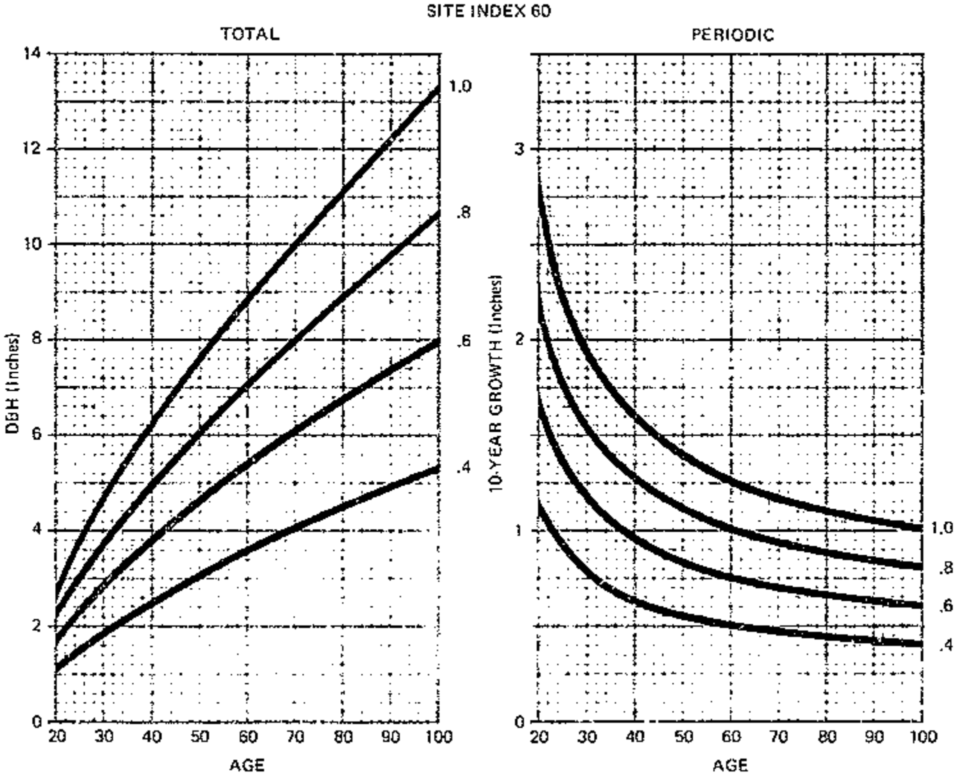


Figure 57D

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Xerophyllum tenax
Habitat Type

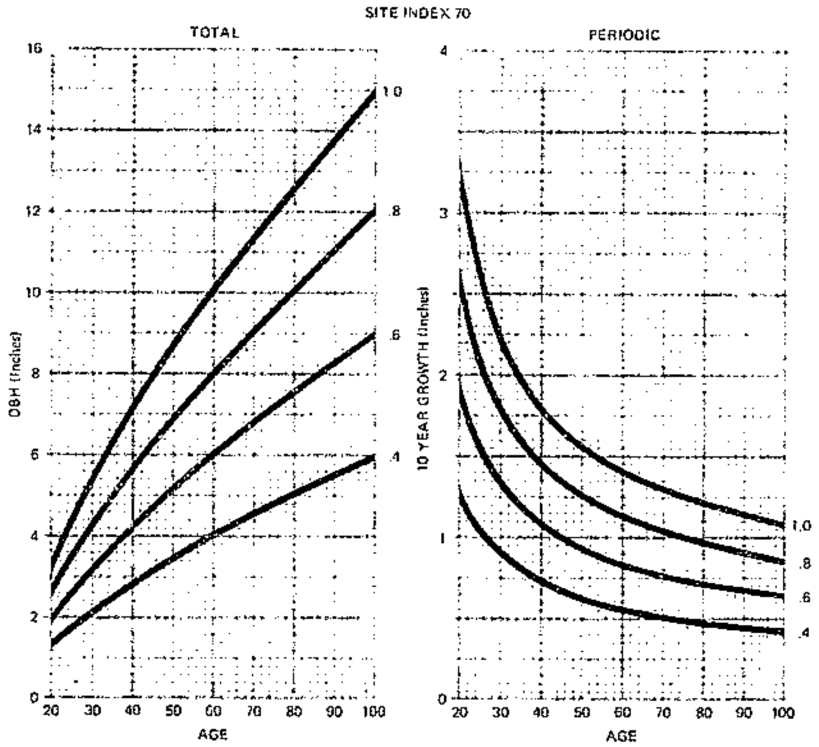


Figure 58A

Potential Diameter Growth
of Western Larch on the
Pseudotsuga menziesii-Physocarpus malvaceus and Calamagrostis rubescens
Habitat Types

SITE INDEX 40

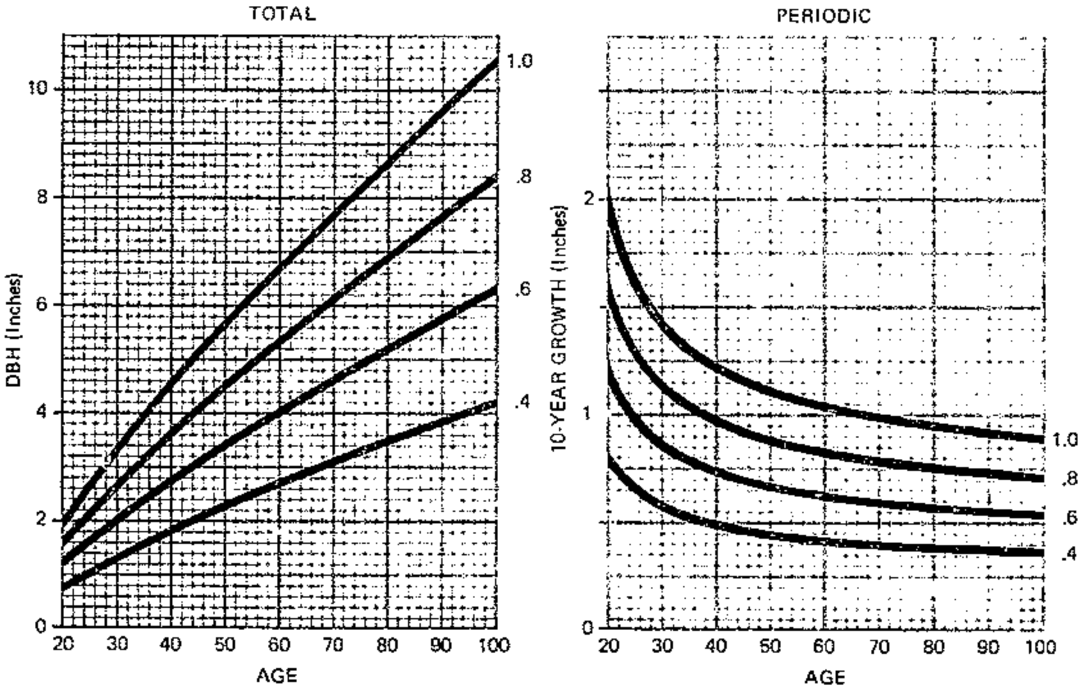


Figure 58B

Potential Diameter Growth
of Western Larch on the
Pseudotsuga menziesii-Physocarpus malvaceus and Calamagrostis rubescens
Habitat Types

SITE INDEX 50

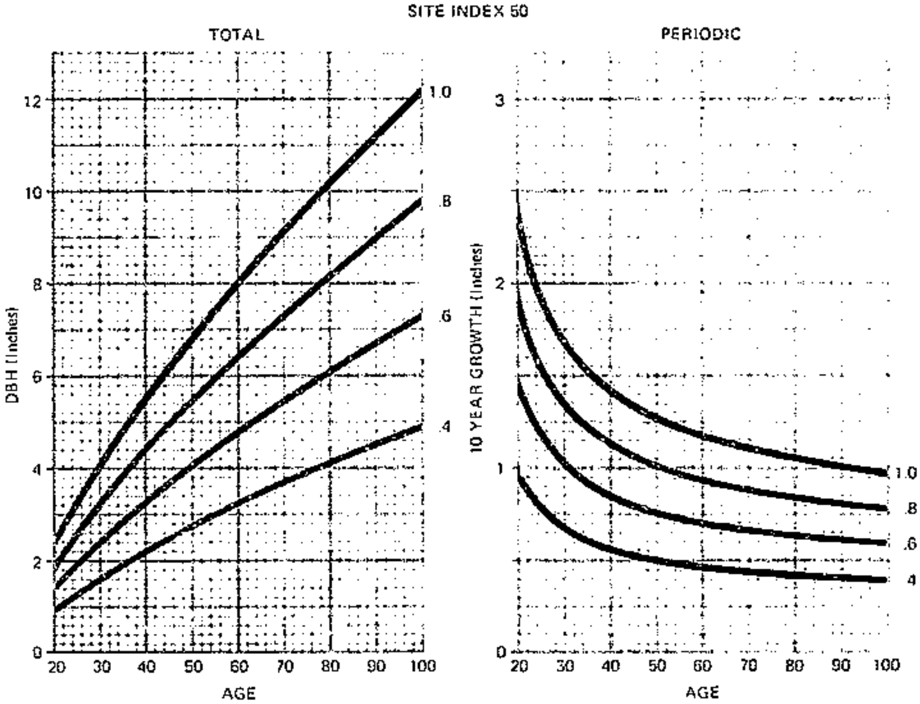


Figure 58C

Potential Diameter Growth
of Western Larch on the
Pseudotsuga menziesii-Physocarpus malvaceus and *Calamagrostis rubescens*
Habitat Types

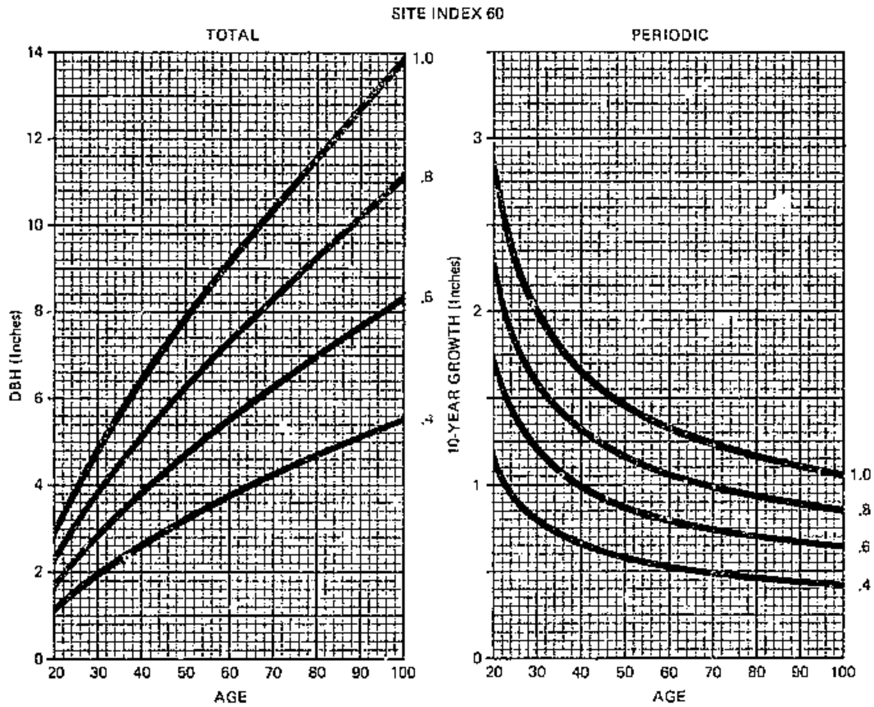


Figure 58D

Potential Diameter Growth
of Western Larch on the
Pseudotsuga menziesii-Physocarpus malvaceus and *Calamagrostis rubescens*
Habitat Types

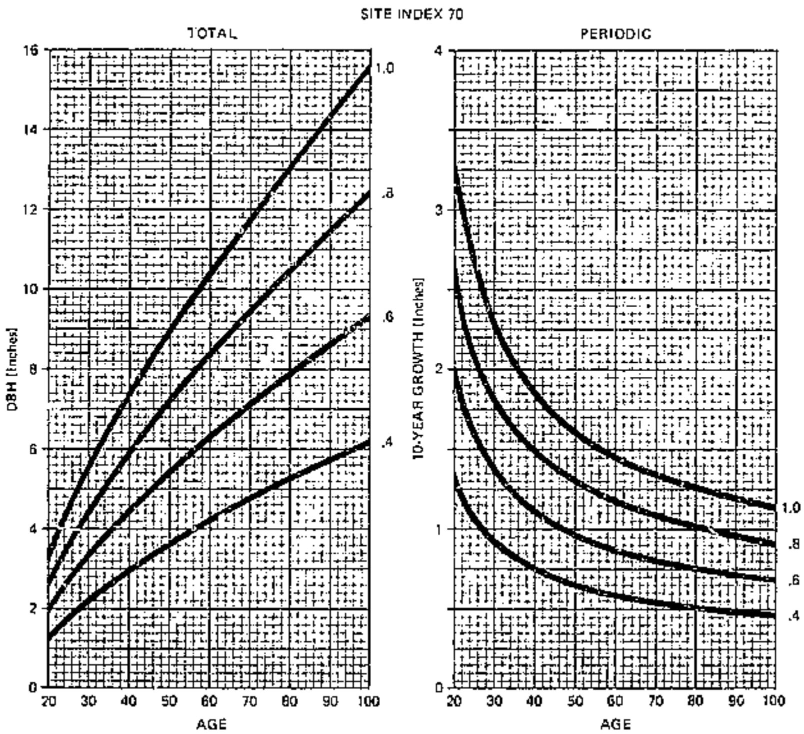


Figure 59A

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Pachistima myrsinites
Habitat Type

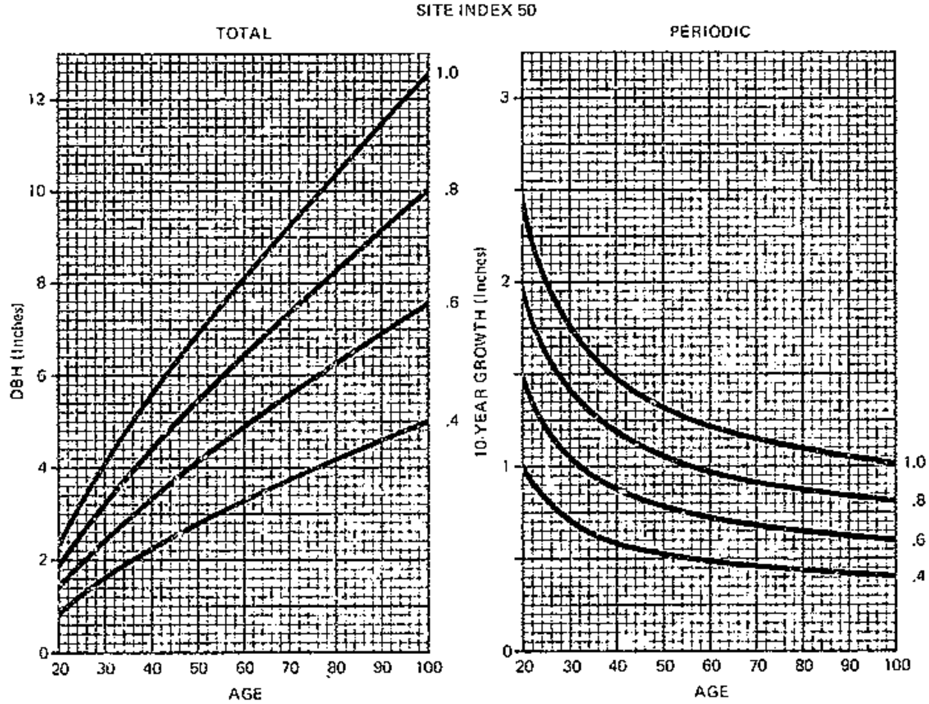


Figure 59B

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Pachistima myrsinites
Habitat Type

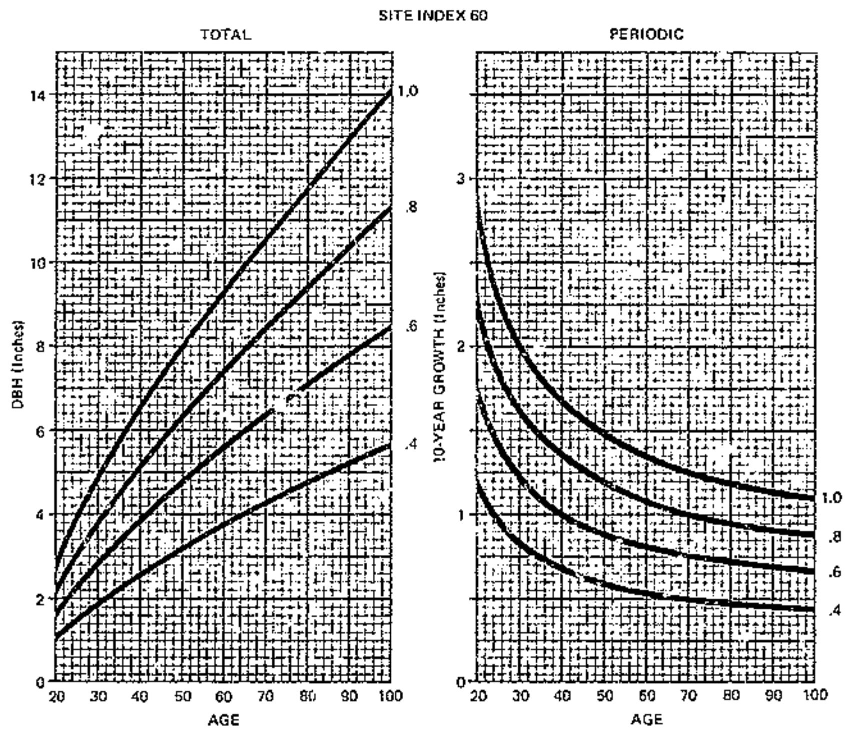


Figure 59C

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Pachistima myrsinites
Habitat Type

SITE INDEX 70

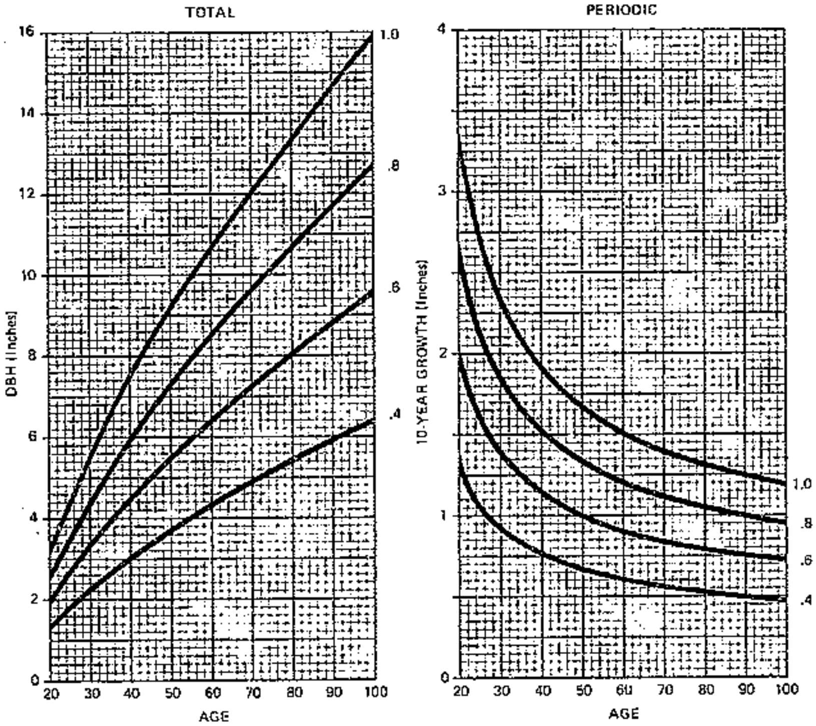


Figure 59D

Potential Diameter Growth
of Western Larch on the
Abies lasiocarpa-Pachistima myrsinites
Habitat Type

SITE INDEX 80

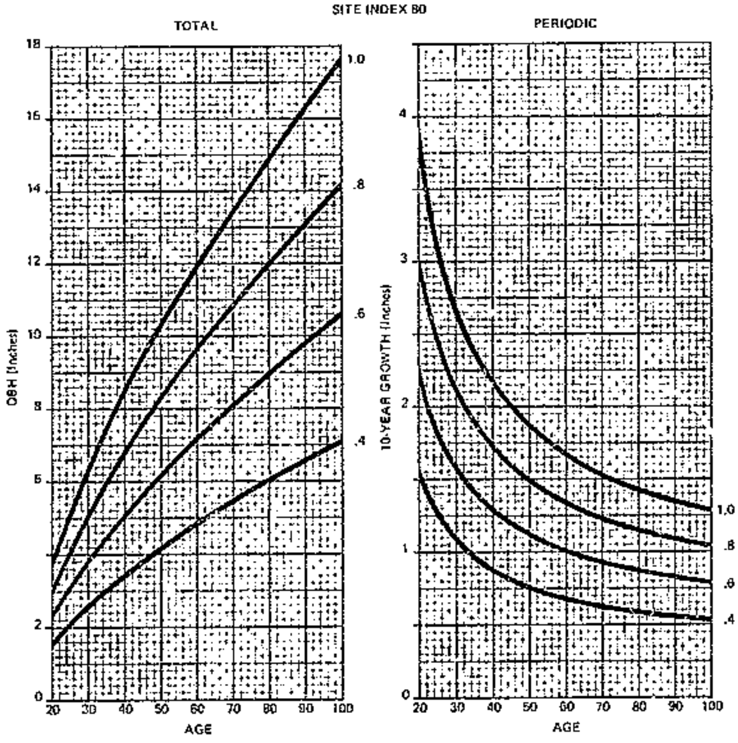


Figure 59E Potential Diameter Growth of Western Larch on the *Abies lasiocarpa-Pachistima myrsinites* Habitat Type

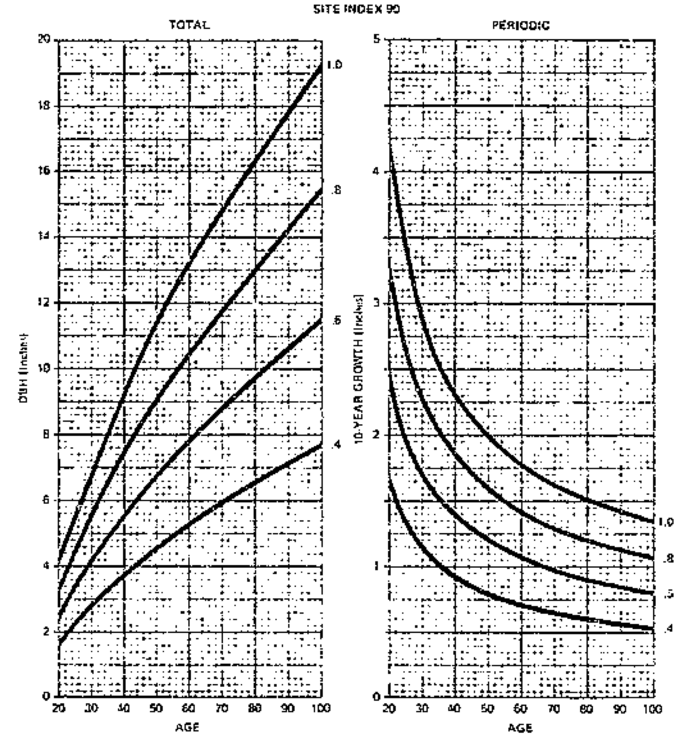


Figure 60A Potential Diameter Growth of Western Larch on the *Abies grandis-Pachistima myrsinites* Habitat Type

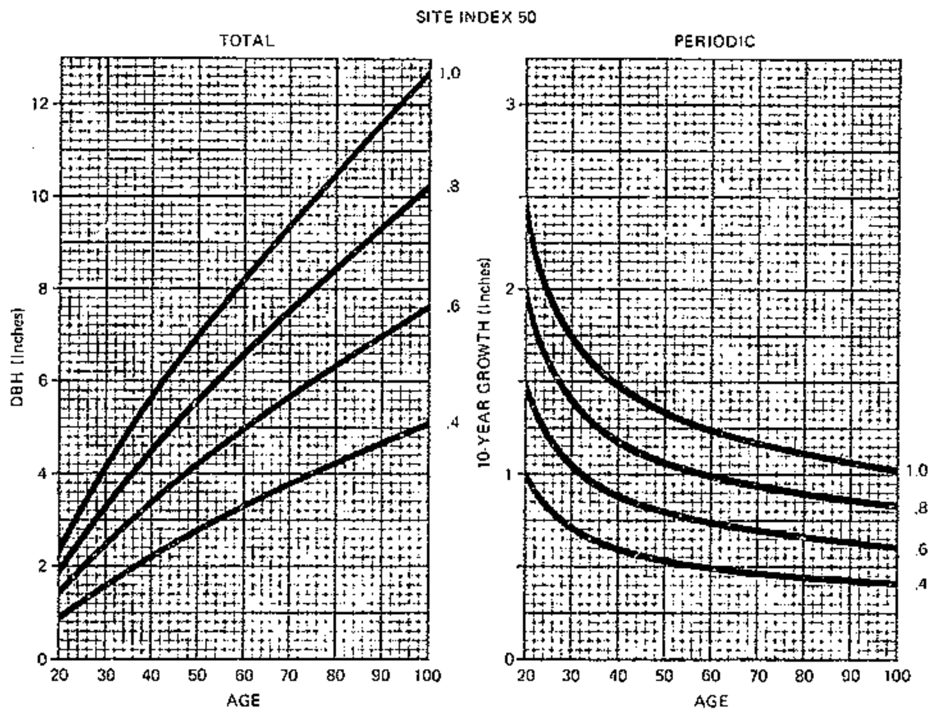


Figure 60B

Potential Diameter Growth
of Western Larch on the
Abies grandis-Pachistima myrsinites
Habitat Type

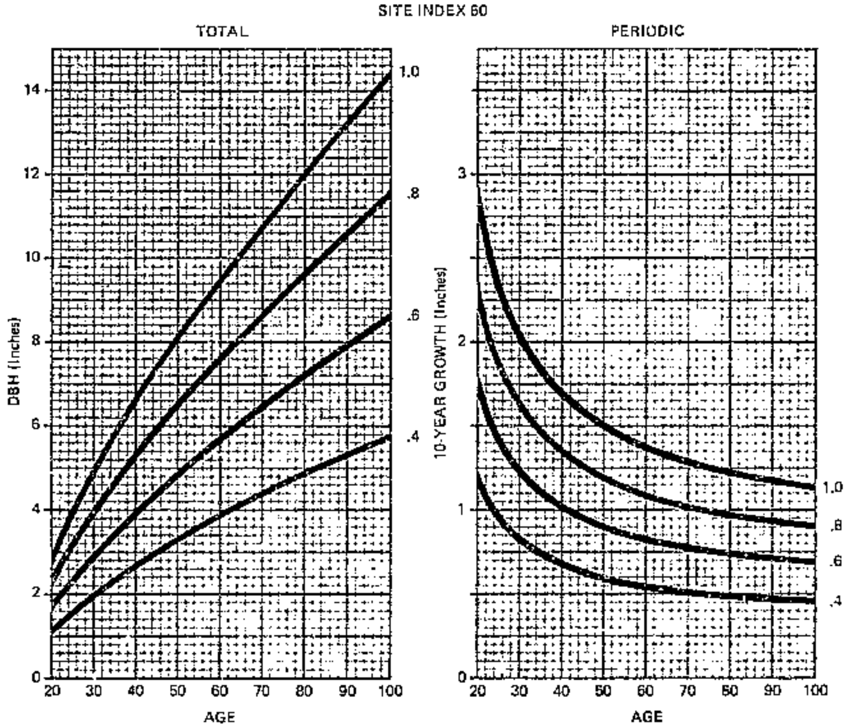


Figure 60C

Potential Diameter Growth
of Western Larch on the
Abies grandis-Pachistima myrsinites
Habitat Type

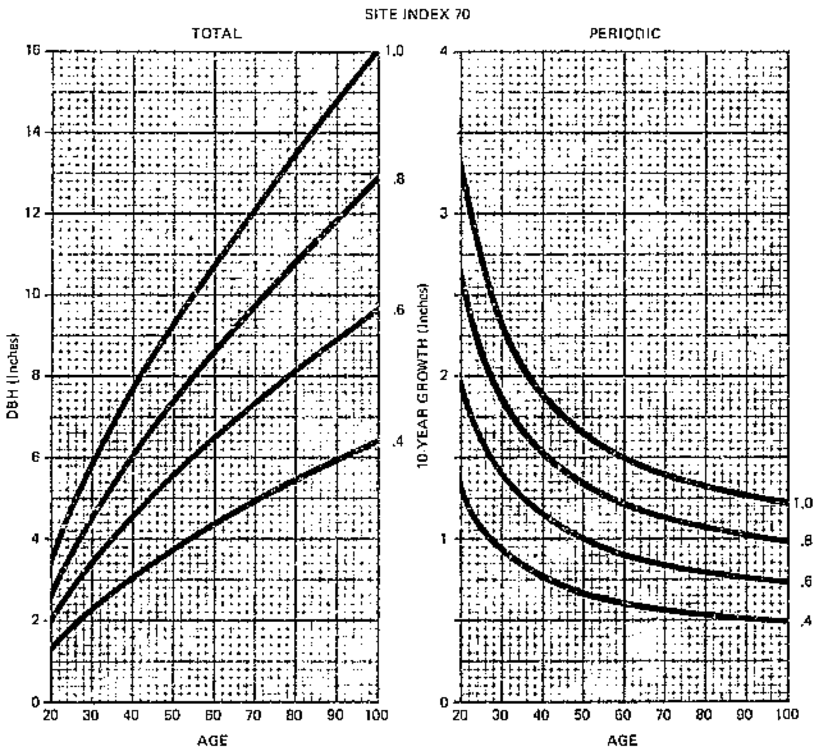


Figure 60D

Potential Diameter Growth
of Western Larch on the
Abies grandis-Pachistima myrsinites
Habitat Type

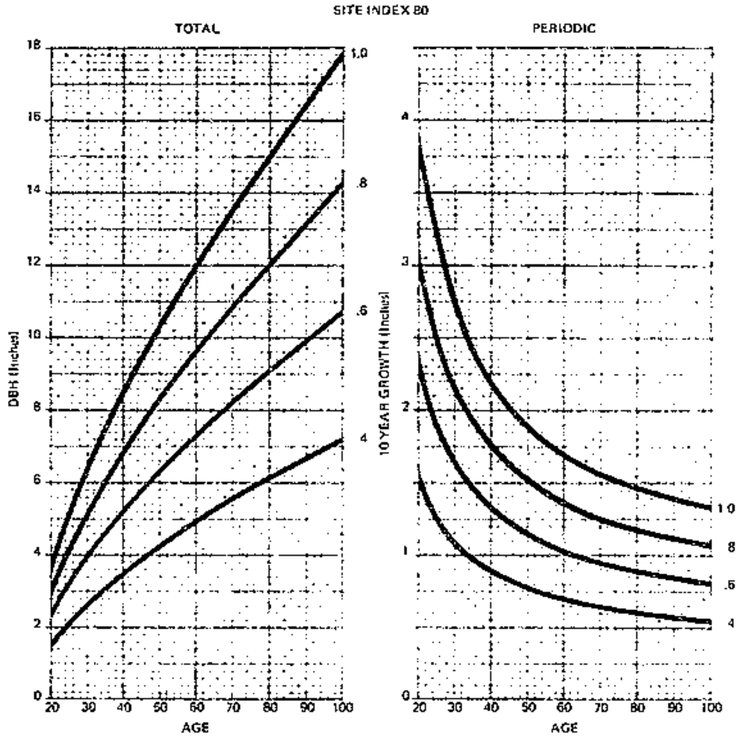


Figure 60E

Potential Diameter Growth
of Western Larch on the
Abies grandis-Pachistima myrsinites
Habitat Type

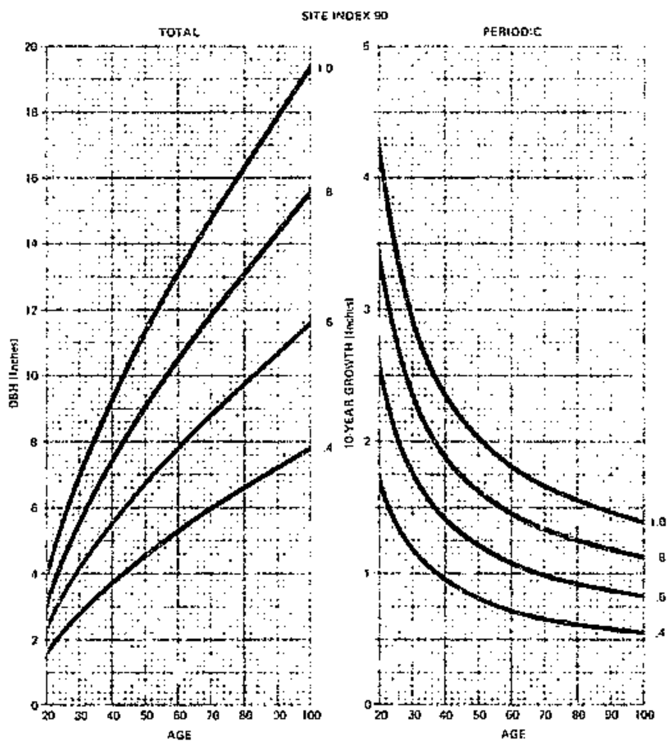


Figure 61A

Potential Diameter Growth
of Western Larch on the
Tsuga heterophylla-Pachistima myrsinites
and Thuja plicata-Pachistima myrsinites
Habitat Types

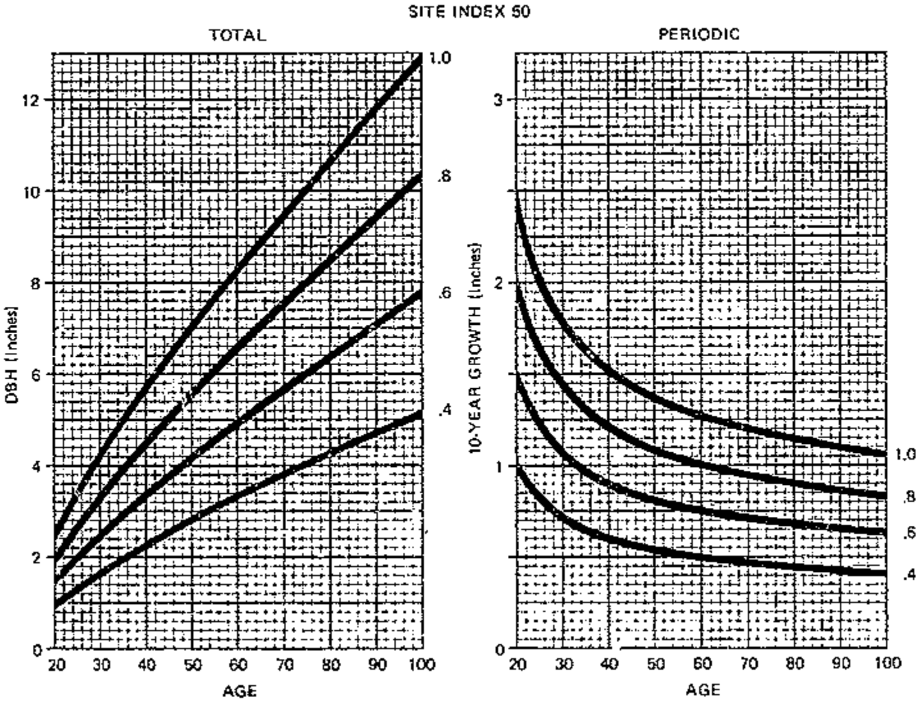


Figure 61B

Potential Diameter Growth
of Western Larch on the
Tsuga heterophylla-Pachistima myrsinites
and Thuja plicata Pachistima myrsinites
Habitat Types

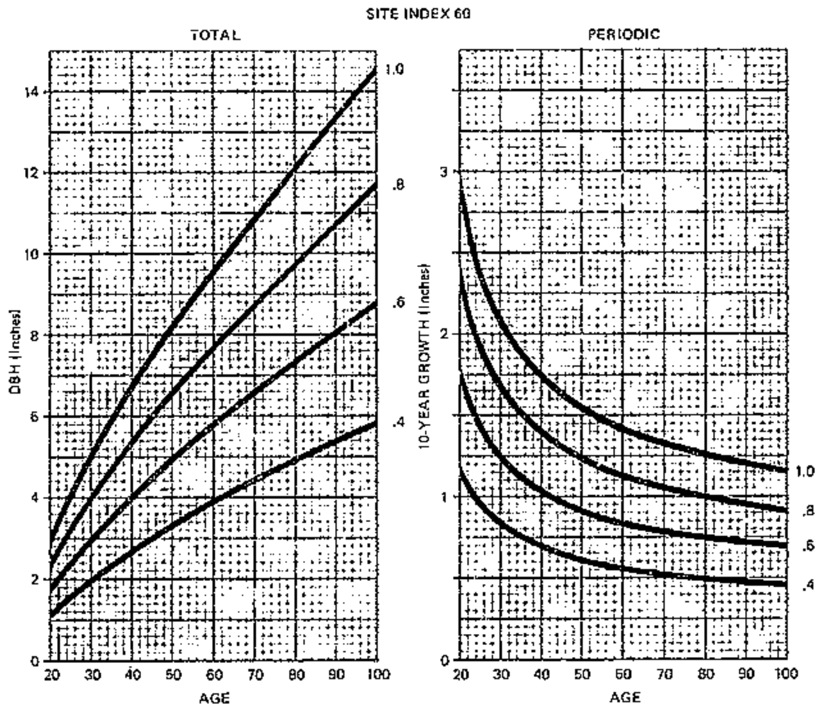


Figure 61C

Potential Diameter Growth
of Western Larch on the
Tsuga heterophylla-Pachistima myrsinites
and Thuja plicata-Pachistima myrsinites
Habitat Types

SITE INDEX 70

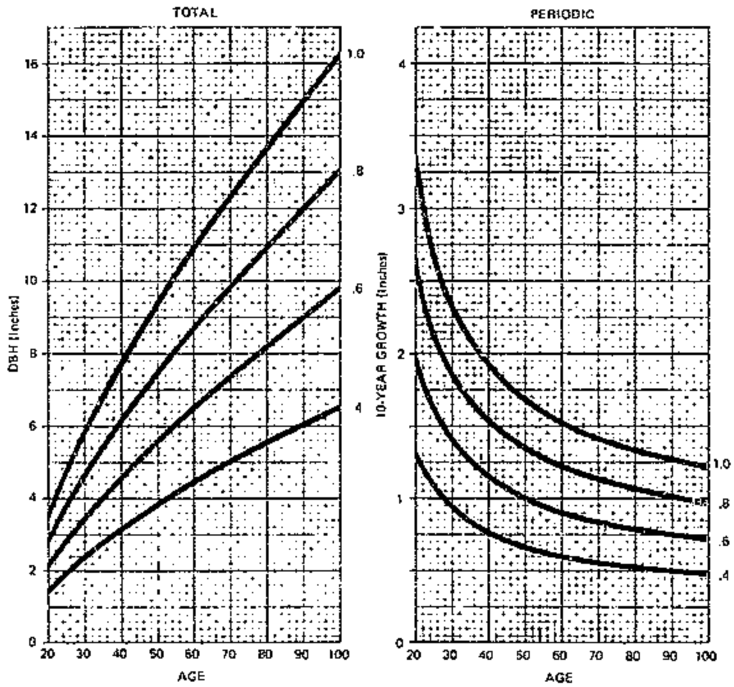


Figure 61D

Potential Diameter Growth
of Western Larch on the
Tsuga heterophylla-Pachistima myrsinites
and Thuja plicata-Pachistima myrsinites
Habitat Types

SITE INDEX 80

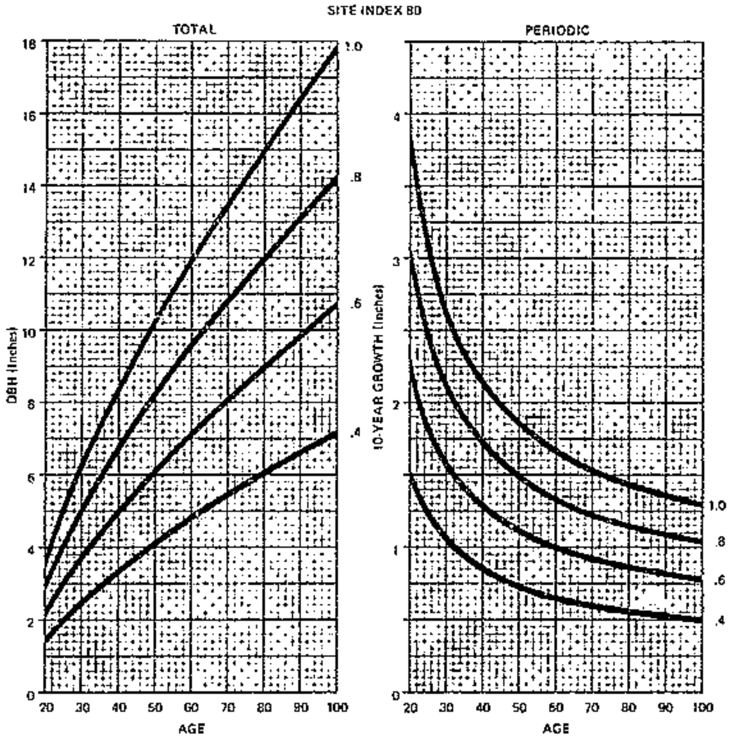
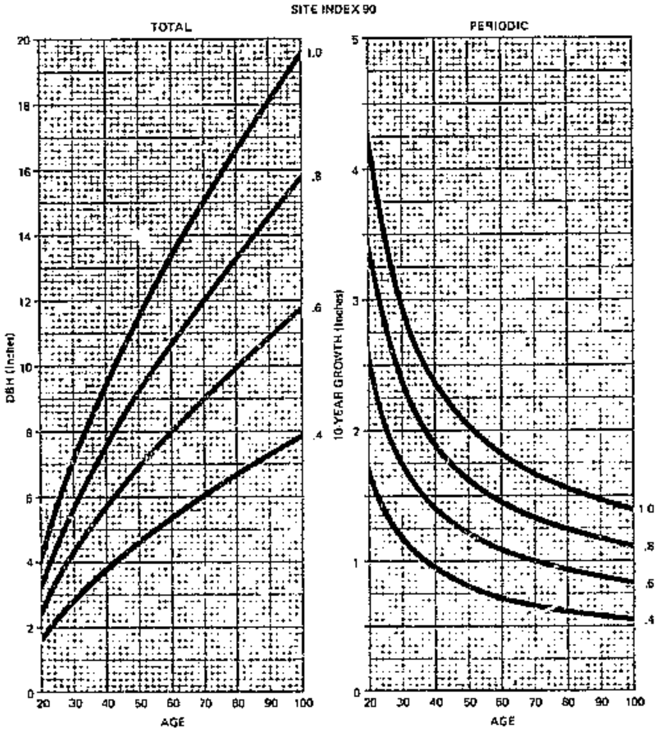


Figure 61E

Potential Diameter Growth
of Western Larch on the
Tsuga heterophylla-Pachistima myrsinites
and Thuja plicata-Pachistima myrsinites
Habitat Types



APPENDIX F: WESTERN LARCH CUBIC- AND BOARD-FOOT YIELD TABLES

The following tables are based on Wikstrom's and Roe's (Intermountain Forest and Range Experiment Station) analyses of L. J. Cummings' (Northern Rocky Mountain Forest and Range Experiment Station) yield data. The equation for estimating total cubic-foot yield in trees 0.6 inch d.b.h. and larger (tables 33-36) is:

$$\text{Ln ft}^3\text{ vol./acre} = -7.03317 - 72.1299\left(\frac{1}{A}\right) + 3.07121(\text{Ln SI}) + 2.38666(\text{Ln NI}) - 0.36349(\text{Ln SI})(\text{Ln NI}),$$

where:

Ln = natural logarithm

A = age

SI = site index

NI = Normality Index

$$= \frac{\text{actual basal area}}{\text{normal basal area}} \times 100$$

$R^2 = 0.99.$

Yields in cubic feet for trees 5 inches and larger and 8 inches and larger are estimated using the ratio of volume in these trees to the total volume. The curved ratios were used to derive the partial volumes for tables 34 and 35 from the total cubic-foot volumes. The ratio of total (0.6 inch and over) cubic-foot volume (table 33) to those trees 5 inches and over (for table 34) $= -0.79406 + 25.0439\frac{1}{A} + 35.111\frac{1}{SI} + 0.00001685A^2 - 0.000949\frac{A^2}{SI}$;

$R^2 = 0.85.$

The ratio of total (0.6 inch and over) cubic-foot volume (table 33) to those trees 8 inches and over (for table 35) $= 8.00494 - 1.00683(\text{Ln NI}) - 0.00927A - 0.86344(\text{Ln A}) + 0.003047A(\text{Ln SI})$;

$R^2 = 0.88.$

Board-foot (International 1/4-inch) yield (table 36) for trees 8 inches and larger was developed by applying board-foot:cubic-foot ratios to the cubic-foot volumes in table 35.

TABLE 33.—Total western larch volume in cubic feet per acre of all trees 0.6 inch d.b.h. and larger[1] [2]

Age	Site index					
	30	40	50	60	70	80
20	165	246	336	434	538	648
30	548	819	1,118	1,443	1,790	2.157
40	999	1,494	2,040	2,632	3,265	3,934
50	1,433	2,142	2,926	3,775	4,682	5,643
60	1,823	2,724	3,721	4,801	5,955	7,176
70	2,164	3,235	4,419	5,701	7,071	8,521
80	2,462	3,680	5,026	6,484	8,043	9,692
90	2,721	4,067	5,555	7,167	8,890	10,714
100	2,948	4,407	6,019	7,765	9,632	11,608
110	3,148	4,705	6,427	8,292	10,285	12,394
120	3,325	4,970	6,788	8,757	10,862	13,090
130	3,482	5,205	7,109	9,172	11,376	13,710
140	3,623	5,415	7,397	9,543	11,836	14,264

[1] Standard error of estimate = ±486 ft³.

[2] Values within the block lines fall within the range of the basic data.

TABLE 34.—Western larch volume in cubic feet per acre of all trees 4.6 inches d.b.h. and larger[1, 2]

Age	Site index 30	40	50	60	70	80
20	0	0	0	0	21	65
30	0	72	290	538	814	1,113
40	21	450	957	1,529	2,158	2,837
50	229	927	1,745	2,663	3,668	4,750
60	473	1,426	2,538	3,782	5,140	6,600
70	732	1,916	3,290	4,823	6,495	8,291
80	998	2,382	3,983	5,766	7,708	9,692
90	1,266	2,821	4,615	6,609	8,779	10,714
100	1,536	3,237	5,193	7,362	9,632	11,608
110	1,810	3,631	5,719	8,032	10,285	12,394
120	2,088	4,009	6,203	8,628	10,862	13,090
130	2,371	4,371	6,648	9,161	11,376	13,710
140	2,661	4,722	7,062	9,543	11,836	14,264

[1] Standard error of estimate = ±1,270 ft³.
[2] Values within the block lines fall within the range of the basic data.

TABLE 35.—Western larch volume in cubic feet per acre in trees 7.6 inches d.b.h. and larger[1, 2]

Age	Site index 30	40	50	60	70	80
20	0	0	0	0	0	0
30	0	0	0	0	177	477
40	0	0	26	459	1,014	1,687
50	0	0	524	1,264	2,185	3,275
60	0	344	1,154	2,210	3,497	5,004
70	24	775	1,841	3,200	4,834	6,728
80	285	1,234	2,540	4,179	6,130	8,375
90	562	1,696	3,225	5,119	7,353	9,909
100	844	2,152	3,883	6,004	8,489	11,319
110	1,126	2,592	4,505	6,828	9,533	12,294
120	1,403	3,014	5,088	7,587	10,485	13,090
130	1,672	3,414	5,631	8,287	11,349	13,710
140	1,932	3,791	6,137	8,927	11,836	14,246

[1] Standard error of estimate = ±1,037 ft³.
[2] Values within the block lines fall within the range of the basic data.

TABLE 36.—Western larch board-foot volume (International 1/4–inch) per acre in trees 7.6 inches d.b.h. and larger[1]

Age	Site index 30	40	50	60	70	80
20	0	0	0	0	0	0
30	0	0	0	0	442	1,350
40	0	0	53	1,148	2,880	5,331
50	0	0	1,310	3,602	6,948	11,462
60	0	860	3,300	7,072	12,344	19,215
70	60	2,224	5,928	11,360	18,708	28,056
80	821	4,011	9,093	16,298	25,807	37,688
90	1,843	6,140	12,706	21,756	33,456	47,960
100	3,097	8,608	16,697	27,618	41,511	58,519
110	4,583	11,327	21,038	33,799	49,858	68,167
120	6,257	14,286	25,542	40,211	58,506	76,466
130	8,109	17,480	30,295	46,822	67,186	84,591
140	10,143	20,850	35,288	53,562	73,975	92,599

[1] Values within the block lines fall within the range of the basic data.

APPENDIX G:
SAPWOOD DEPTH OF LARCH TREES

Sapwood depth for sample trees can be determined simply, based upon four easily measured statistics: tree age, d.b.h., vigor, and the average stand d.b.h. for trees 0.6 inch d.b.h. and larger. With these statistics and the values of K_1 and K_2 available in table 37, the sapwood depth for sampled trees can be computed quickly with the following four steps:

Step 1.—Determine the diameter inside bark of the sample tree and look up its basal area.

Step 2.—Read the unadjusted sapwood basal area (K_1) in table 37a for the sample tree. Add to this the adjustment value (K_2) from table 37b for the vigor of the sample tree and the average stand diameter of all trees 0.6 inch d.b.h. and larger.

Step 3.—Subtract the adjusted sapwood basal area derived in step 2 from the total basal area determined in step 1. The remainder is the basal area of the heartwood, and its diameter may be determined from the basal area table.

Step 4.—Subtract the diameter of the heartwood obtained in step 3 from the d.b.h. inside bark determined in step 1. This difference is the diameter of the sapwood, and when divided by two it provides the radius of the sapwood or sapwood depth.

The four steps illustrated in the following example:

Given: Sample tree age	80 years
Sample tree diameter (15.6 d.b.h.i.b.)	18 inches
Sample tree vigor	Good
Average stand d.b.h. (trees 0.6 inch d.b.h. and larger)	8 inches

Step	*Basal area (B.A.)*	*Diameter breast high (D)*
	(Square feet)	*(Inches)*
1. Enter B.A. of sample tree d.b.h.i.b.	1.3273	15.60
2. Sapwood basal area $= K_1 + K_2$ $= 0.3727 + (-0.0184) =$	0.3543	—
3. Subtract B.A. Step 2 from B.A. Step 1 = (Look up diameter of B.A. Step 3 and enter diameter)	0.9730	13.36
4. Radial sapwood depth $= \frac{D_1 - D_2}{2} = \frac{15.60 - 13.36}{2} = \frac{2.24}{2} =$		1.12

Since the sapwood depth of this sample tree under the conditions described above is 1.12 inches (or greater than three-fourths inch), it would make a suitable pole to receive preservative treatment providing it has no other limiting defects. Values of K_1 for diameters and ages not shown in the tables can be obtained by interpolation.

TABLE 37 —Values for predicting sapwood basal area of western larch trees

PART A (K_1)[2]

Age (years)	Diameter breast high of sample trees (inches) OB 10 IB(8.6)[3]	12 (10.3)	14 (12.0)	16 (13.8)	18 (15.6)	20 (17.3)	22 (19.0)	24 (20.8)	26 (22.5)	28 (24.3)	30 (26.0)
	Square Feet										
40	0.1957	0.2610	0.3265	0.3917	0.4572	0.5226	0.5880	0.6534	0.7187	0.7841	0.8495
60	.1840	.2395	.2951	.3506	.4062	.4617	.5173	.5729	.6283	.6839	.7395
80	.1702	.2209	.2715	.3221	.3727	.4234	.4740	.5247	.5752	.6259	.6765
100	.1613	.2090	.2567	.3043	.3520	.3997	.4474	.4951	.5427	.5904	.6381
120	.1546	.2003	.2460	.2917	.3374	.3831	.4289	.4746	.5202	.5660	.6117
140	.1495	.1938	.2381	.2823	.3267	.3710	.4153	.4596	.5039	.5482	.5925
160	.1454	.1887	.2320	.2752	.3184	.3617	.4050	.4483	.4914	.5347	.5780
180	.1422	.1847	.2271	.2695	.3120	.3544	.3969	.4393	.4817	.5242	.5666
200	.1395	.1813	.2231	.2648	.3066	.3484	.3902	.4320	.4737	.5155	.5573

PART B (K_2)[2]

Tree vigor	Average stand diameter (inches) 4	6	8	10	12	14	16	18	20	22	24	26
	Square Feet											
Good	+0.0088	-0.0048	-0.0184	-0.0320	-0.0456	-0.0592	-0.0727	-0.0863	-0.0999	-0.1135	-0.1270	-0.1406
Fair	- .0068	- .0204	- .0340	- .0476	- .0611	- .0747	- .0883	- .1019	- .1154	- .1290	- .1426	- .1562
Poor	- .0154	- .0290	- .0425	- .0561	- .0697	- .0833	- .0969	- .1104	- .1240	- .1376	- .1512	- .1648

[1]Sapwood basal area (S_{BA}) is the area of the sapwood at breast high.

[2]$S_{BA} = K_1 + K_2$.

[3]The figures in parentheses show the diameter of these trees inside bark.

APPENDIX H:
RELATION OF DIAMETER BREAST HEIGHT OUTSIDE BARK TO DIAMETER BREAST HEIGHT INSIDE BARK OF WESTERN LARCH[1]

Tree d.b.h.o.b. (inches)	Tree d.b.h.o.b. (tenths of an inch)									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	Diameter breast height inside bark									
	Inches									
1	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.5
2	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2
4	3.3	3.4	3.5	3.6	3.7	3.7	3.8	3.9	4.0	4.1
5	4.2	4.3	4.4	4.5	4.5	4.6	4.7	4.8	4.9	5.0
6	5.1	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8
7	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.5	6.6	6.7
8	6.8	6.9	7.0	7.1	7.2	7.2	7.3	7.4	7.5	7.6
9	7.7	7.8	7.9	7.9	8.0	8.1	8.2	8.3	8.4	8.5
10	8.6	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.3
11	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.0	10.1	10.2
12	10.3	10.4	10.5	10.6	10.6	10.7	10.8	10.9	11.0	11.1
13	11.2	11.3	11.4	11.4	11.5	11.6	11.7	11.8	11.9	12.0
14	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.8
15	12.9	13.0	13.1	13.2	13.3	13.4	13.4	13.5	13.6	13.7
16	13.8	13.9	14.0	14.1	14.1	14.2	14.3	14.4	14.5	14.6
17	14.7	14.8	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5
18	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.2	16.3
19	16.4	16.5	16.6	16.7	16.8	16.9	16.9	17.0	17.1	17.2
20	17.3	17.4	17.5	17.6	17.6	17.7	17.8	17.9	18.0	18.1
21	18.2	18.3	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0
22	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.7	19.8
23	19.9	20.0	20.1	20.2	20.3	20.4	20.4	20.5	20.6	20.7
24	20.8	20.9	21.0	21.0	21.1	21.2	21.3	21.4	21.5	21.6
25	21.7	21.8	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.4
26	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.2	23.3
27	23.4	23.5	23.6	23.7	23.8	23.8	23.9	24.0	24.1	24.2
28	24.3	24.4	24.5	24.6	24.6	24.7	24.8	24.9	25.0	25.1
29	25.2	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	25.9
30	26.0	26.1	26.2	26.3	26.4	26.5	26.6	26.6	26.7	26.8

[1] D.i.b. = 0.87407 D.o.b. − 0.185; D.o.b. = (D.i.b. + 0.185) (1.14407); standard error = 0.7 inch. For other information on bark thickness of western larch, see Brickell (1970a) and Lange (1971).

TB 1520 (1976) USDA TECHNICAL BULLETINS UPDATA
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APPENDIX I: DIMENSIONS OF WESTERN LARCH POLES[1]

Class		H-6	H-5	H-4	H-3	H-2	H-1	1	2	3	4	5	6	7	9	10
Minimum diameter and circumference at top (inches)		12.41 39	11.78 37	11.14 35	10.50 33	9.87 31	9.23 29	8.59 27	7.96 25	7.32 23	6.68 21	6.05 19	5.41 17	4.77 15	4.77 15	3.82 12
Length of pole (feet)	Groundline distance from butt (feet)[2]	Minimum circumference at 6 feet from butt (inches)														
20	4	–	–	–	–	–	–	30.0	28.5	26.5	24.5	22.5	21.0	19.0	17.0	13.5
25	5	–	–	–	–	–	–	33.0	31.0	29.0	26.5	24.5	23.0	21.0	18.5	14.5
30	5.5	–	–	–	–	–	–	35.5	33.5	31.0	29.0	26.5	24.5	23.0	19.5	–
35	6	–	–	–	–	43.0	40.5	38.0	35.5	33.0	31.0	28.5	26.5	24.5	–	–
40	6	–	–	50.5	48.0	45.5	43.0	40.0	37.5	35.0	32.5	30.0	28.0	–	–	–
45	6.5	57.5	55.0	52.5	50.0	47.5	45.0	42.0	39.5	37.0	34.0	31.5	29.0	–	–	–
50	7	60.0	57.5	55.0	52.0	49.5	47.0	44.0	41.0	38.5	35.5	33.0	–	–	–	–
55	7.5	62.0	59.5	57.0	54.0	51.5	48.5	45.5	42.5	40.0	37.0	–	–	–	–	–
60	8	64.5	61.5	59.0	56.0	53.0	50.0	47.0	44.0	41.0	38.5	–	–	–	–	–
65	8.5	66.0	63.5	60.5	57.5	55.0	52.0	48.5	46.0	42.5	39.5	–	–	–	–	–
70	9	68.0	65.0	62.5	59.5	56.5	53.5	50.0	47.0	44.0	41.0	–	–	–	–	–
75	9.5	70.0	67.0	64.0	61.0	58.0	54.5	51.5	48.0	45.0	–	–	–	–	–	–
80	10	71.5	68.5	65.5	62.5	59.0	56.0	52.5	49.5	46.0	–	–	–	–	–	–
85	10.5	73.0	70.0	67.0	64.0	60.5	57.5	54.0	50.5	47.0	–	–	–	–	–	–
90	11	74.5	71.5	68.5	65.0	62.0	58.5	55.0	51.5	48.5	–	–	–	–	–	–
95	11	76.5	73.0	70.0	66.5	63.0	60.0	56.5	53.0	–	–	–	–	–	–	–
100	11	78.0	74.5	71.0	68.0	64.5	61.0	57.5	54.0	–	–	–	–	–	–	–
105	12	79.0	76.0	72.5	69.0	65.5	62.0	58.5	55.0	–	–	–	–	–	–	–
110	12	80.5	77.0	73.5	70.0	66.5	63.0	59.5	56.0	–	–	–	–	–	–	–
115	12	82.0	78.5	75.0	71.5	68.0	64.0	60.5	57.0	–	–	–	–	–	–	–
120	12	83.0	79.5	76.0	72.5	69.0	65.0	61.5	58.0	–	–	–	–	–	–	–
125	12	84.5	81.0	77.5	73.5	70.0	66.0	62.5	58.5	–	–	–	–	–	–	–

[1] Fiber stress 8,400 pounds per square inch. (from American National Standards Institute, Inc.)

[2] The figures in this column are intended for use only when a definition of groundline is necessary in order to apply requirements relating to scars, straightness, etc.

APPENDIX J:
POLE LENGTH (FEET) OF AVERAGE DOMINANT AND CODOMINANT TREES BY AGE, SITE INDEX (S.I.), AND DIAMETER CLASS (D.B.H.),[1] BASED UPON LONGEST POLE AVAILABLE[2]

Total age (years)	Pole length [1] when d.b.h. in inches is:										
	OB 10 IB (8.6)	12 (10.3)	14 (12.0)	16 (13.8)	18 (15.6)	20 (17.3)	22 (19.0)	24 (20.8)	26 (22.5)	28 (24.3)	30 (26.0)
SITE INDEX 40											
60	25	25	30	30	35	—	—	—	—	—	—
80	30	30	30	35	40	40	45	—	—	—	—
100	35	35	40	45	45	50	50	—	—	—	—
120	[4]—	40	45	50	50	55	55	60	60	—	—
140	—	—	50	55	55	60	60	65	65	70	—
160	—	—	—	55	60	65	65	70	75	75	—
180	—	—	—	—	65	70	70	70	80	80	85
200	—	—	—	—	—	75	75	75	85	85	90
SITE INDEX 50											
40	20	25	25	30	30	—	—	—	—	—	—
60	30	30	35	35	40	40	—	—	—	—	—
80	35	40	40	45	45	50	50	55	—	—	—
100	40	45	45	50	55	55	60	60	65	—	—
120	[4]—	50	55	55	60	65	65	70	70	75	—
140	—	—	60	60	65	70	75	75	80	80	85
160	—	—	—	60	65	70	80	80	85	90	90
180	—	—	—	—	75	80	85	85	90	95	100
200	—	—	—	—	—	85	90	90	95	100	105
SITE INDEX 60											
40	25	30	30	35	35	—	—	—	—	—	—
60	35	35	40	40	45	45	50	—	—	—	—
80	40	45	45	50	55	55	60	60	—	—	—
100	45	50	55	60	60	65	70	70	75	75	—
120	—	55	60	65	70	70	75	80	80	85	—
140	—	—	65	70	75	80	85	85	90	95	95
160	—	—	—	75	80	85	90	90	95	100	105
180	—	—	—	—	90	90	95	95	100	105	115
200	—	—	—	—	—	100	105	105	110	110	120
SITE INDEX 70											
40	30	30	35	40	40	—	—	—	—	—	—
60	35	40	45	50	50	55	55	—	—	—	—
80	45	50	55	55	60	65	65	70	—	—	—
100	—	55	60	65	70	70	75	80	85	—	—
120	—	—	70	70	75	80	85	90	90	95	—
140	—	—	—	80	85	90	95	95	100	105	110
160	—	—	—	—	90	95	100	105	110	115	120
180	—	—	—	—	—	105	110	115	115	120	125
200	—	—	—	—	—	—	115	120	125	130	135

[1,2,3] See footnotes end of table.

(Con. next page)

APPENDIX J (con.)

Total age (years)	Pole length [1] when d.b.h. in inches is:										
	OB 10 IB (8.6)	12 (10.3)	14 (12.0)	16 (13.8)	18 (15.6)	20 (17.3)	22 (19.0)	24 (20.8)	26 (22.5)	28 (24.3)	30 (26.0)
					SITE INDEX 80						
40	30	35	40	40	45	45	—	—	—	—	—
60	40	45	50	50	55	60	60	—	—	—	—
80	—	55	60	60	65	70	75	75	—	—	—
100	—	—	65	70	75	80	85	90	90	—	—
120	—	—	—	80	85	90	95	100	100	105	—
140	—	—	—	—	95	100	105	105	110	110	120
160	—	—	—	—	—	105	110	115	120	125	130
180	—	—	—	—	—	—	120	125	130	135	140
200	—	—	—	—	—	—	—	135	140	145	150
					SITE INDEX 90						
40	35	40	40	45	45	50	—	—	—	—	—
60	—	50	55	55	60	65	65	—	—	—	—
80	—	—	65	70	70	75	80	85	—	—	—
100	—	—	—	80	85	85	90	95	100	—	—
120	—	—	—	—	90	95	100	105	110	115	—
140	—	—	—	—	—	105	110	115	120	125	130
160	—	—	—	—	—	—	120	125	130	135	140
180	—	—	—	—	—	—	—	135	140	145	150
200	—	—	—	—	—	—	—	—	150	155	160

[1] These tables have been developed from the following equation:
Log pole length = 0.58675 Log A + 0.71226 Log S.I. + 0.47942 Log D.B.H. − 1.23692.
R^2 = 0.76; SE = 1.228 feet.

[2] Sample trees were measured for the longest commercial pole contained in them. Pole class can often be improved by cutting back the lengths from those shown in the tables, particularly in the younger age classes.

[3] All values have been rounded to the nearest 5−foot height class.

[4] Poles that could be shown in this part of the table do not meet the minimum circumference requirements for commercial poles, nor do they have deep enough sapwood to be acceptable for good preservative treatment (i.e., 3/4−inch radial sapwood depth in standing trees).

APPENDIX K:
WESTERN LARCH CUBIC-FOOT VOLUME TABLE BY D.B.H. AND TREE HEIGHT [1,2]

D.b.h.[3] (inches)	Height in feet																													
	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190
5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0																				
6	1.6	1.8	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1																		
7	2.8	3.2	3.6	3.9	4.3	4.6	5.0	5.3	5.7	6.0	6.4	6.7	7.1																		
8	4.1	4.6	5.1	5.6	6.1	6.7	7.2	7.7	8.2	8.7	9.2	9.7	10.2	10.8	11.3																
9	5.5	6.2	6.8	7.5	8.2	8.9	9.6	10.3	11.0	11.7	12.3	13.0	13.7	14.4	15.1																
10	6.9	7.8	8.6	9.5	10.4	11.2	12.1	13.0	13.8	14.7	15.6	16.4	17.3	18.2	19.0	19.9	20.8														
11	8.5	9.6	10.6	11.7	12.8	13.8	14.9	16.0	17.0	18.1	19.2	20.2	21.3	22.4	23.4	24.5	25.6														
12	10.2	11.5	12.7	14.0	15.3	16.6	17.8	19.1	20.4	21.7	22.9	24.2	25.5	26.8	28.0	29.3	30.6	31.8	33.1												
13	12.0	13.5	15.0	16.5	18.0	19.4	20.9	22.4	24.0	25.4	26.9	28.4	30.0	31.4	32.9	34.4	36.0	37.4	38.9												
14	13.8	15.5	17.2	18.9	20.7	22.4	24.1	25.8	27.6	29.3	31.0	32.8	34.5	36.2	37.9	39.7	41.4	43.1	44.8	46.6	48.3										
15	15.8	17.8	19.7	21.7	23.7	25.7	27.6	29.6	31.6	33.5	35.5	37.5	39.5	41.5	43.4	45.4	47.4	49.4	51.3	53.3	55.3										
16	17.8	20.0	22.3	24.5	26.7	28.9	31.2	33.4	35.6	37.8	40.1	42.3	44.5	46.7	49.0	51.2	53.5	55.7	57.9	60.1	62.4	64.6	66.8								
17			24.9	27.4	30.0	32.4	35.0	37.4	39.9	42.4	45.0	47.4	49.9	52.3	54.8	57.3	59.8	62.3	64.8	67.3	69.8	72.3	74.8								
18			27.7	30.5	33.2	36.0	38.8	41.6	44.3	47.1	49.9	52.6	55.4	58.2	60.9	63.7	66.5	69.3	72.0	74.8	77.6	80.3	83.1	85.9	88.6						
19			31.6	34.7	37.9	41.1	44.2	47.4	50.5	53.7	56.9	60.0	63.2	66.3	69.5	72.7	75.8	79.0	82.1	85.3	88.4	91.6	94.8	97.9	101						
20			35.4	38.9	42.5	46.0	49.6	53.1	56.6	60.2	63.7	67.3	70.8	74.3	77.9	81.4	85.0	88.5	92.0	95.6	99.1	103	106	110	113						
21					46.0	50.0	53.7	57.5	61.4	65.2	69.1	72.9	77.0	80.6	84.4	88.2	92.1	95.9	99.8	104	107	111	115	119	123						
22					49.9	54.1	58.3	62.4	66.6	70.8	74.9	79.1	83.2	87.4	91.6	95.7	99.9	104	108	112	117	121	125	129	133						
23					54.0	58.5	63.0	67.4	72.0	76.4	81.0	85.4	89.9	94.4	98.9	103	108	112	117	121	126	130	135	139	144						
24					58.1	62.9	67.7	72.6	77.4	82.3	87.1	91.9	96.8	102	106	111	116	121	126	131	135	140	145	150	155						
25							72.6	77.8	83.0	88.2	93.4	98.6	104	109	114	119	124	130	135	140	145	150	156	161	166						
26							77.6	83.1	88.7	94.2	99.8	105	111	116	122	127	133	139	144	150	155	161	166	172	177						
27							82.2	88.0	93.9	99.8	106	112	117	123	129	135	141	147	153	158	164	170	176	182	188						
28							87.3	93.5	99.7	106	112	118	125	131	137	143	150	156	162	168	175	181	187	193	199	206	212				
29							92.4	99.0	106	112	119	125	132	139	145	152	158	165	172	178	185	191	198	205	211	218	224				
30							97.3	104	111	118	125	132	139	146	153	160	167	174	181	188	195	202	209	215	222	229	236				
31									118	125	132	140	147	154	162	169	176	184	191	198	206	213	221	228	235	243	250				
32									124	131	139	147	155	162	170	178	186	193	201	209	216	224	232	240	247	255	263	271	278		
33									130	138	146	154	162	170	178	187	195	203	211	219	228	235	243	252	260	268	276	284	292		
34									137	145	154	163	171	180	188	197	205	214	222	231	240	248	257	265	274	282	291	299	308	317	325
35									143	152	161	170	179	188	197	206	215	224	233	241	250	259	268	277	286	295	304	313	322	331	340
36									149	159	168	177	187	196	205	215	224	233	243	252	261	271	280	289	299	308	317	326	336	345	355
37											176	185	195	205	215	224	234	244	254	263	273	283	293	302	312	322	332	341	351	361	371
38											183	193	204	214	224	234	244	255	265	275	285	295	305	316	326	336	346	356	366	377	387
39											191	202	213	224	234	245	256	266	277	287	298	309	319	330	341	351	362	373	383	394	405
40											206	211	222	234	245	256	267	278	289	300	311	322	334	345	356	367	378	389	400	411	423

[1] This volume table was derived from regression equations developed by P.D. Kemp (1957) and include cubic-foot volume inside bark from a 1-foot stump to a 4.0-inch top d.i.b.

[2] Values underlined fall outside of the range of the basic data.

[3] For trees smaller than 5.0 inches d.b.h. see Haig (1932).

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