Larix occidentalis Nutt. Western Larch

Pinaceae Pine Family

Wyman C. Schmidt and Raymond C. Shearer

Western larch *(Larix occidentalis),* a deciduous conifer, is also called tamarack and western tamarack; less commonly used names are hackmatack, mountain larch, and Montana larch (17). It is largest of the larches and is the most important timber species of the genus. Western larch is used for lumber, fine veneer, poles, ties, mine timbers, and pulpwood.

Habitat

Native Range

Western larch (fig. 1) grows in the Upper Columbia River Basin of northwestern Montana, northern and west central Idaho, northeastern Washington, and southeastern British Columbia; along the east slopes of the Cascade Mountains in Washington and north-central Oregon; and in the Blue and Wallowa Mountains of southeastern Washington and northeastern Oregon.

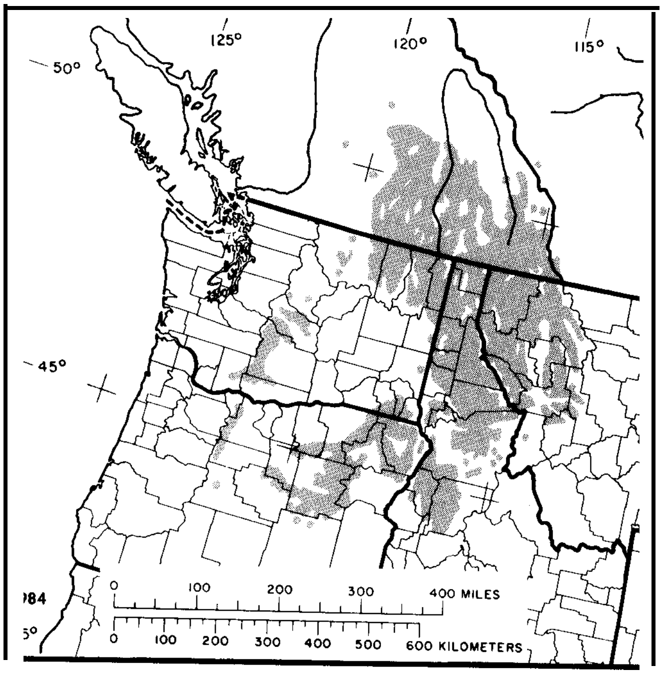

Figure *l-The native range of western larch.*

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Climate

Western larch grows in a relatively moist-cool climatic zone, with low temperature limiting its upper elevational range and deficient moistures its lower extremes (44). Mean annual temperature within the larch zone is about 7” C (45° F), but annual maximums average 29” C (84° F) and minimums average -9” C (15” F) (table 1) *(35).* Average temperatures during the May through August growing season are about 16” C (60° F) with July the warmest month. The frost-free season varies from about 60 to 160 days, usually from early June through early September. Frosts can occur any month of the year.

Annual precipitation in larch forests averages about 710 mm (28 in) in the north part of its range to 810 mm (32 in) in the south. The extremes where larch grows are about 460 mm (18 in) and 1270 mm (50 in). About one-fifth of the annual precipitation occurs during the May through August growing season, most of it in May and June. July and August are usually dry and are characterized by clear, sunny days (60 to 80 percent of the daylight hours), low humidity, and high evaporation rates (44). Elevation and geographic location affect both the amount and the form of precipitation. On midelevation sites, snow commonly blankets most larch forests from November to late April and accounts for over half the total precipitation. Snow accounts for an even higher proportion of the total precipitation in the northerly

Table l-Summary of weather data from within the range of western larch[1]

	°C	°F
Average temperature		
Annual maximum	29	84
Annual minimum	-9	15
Annual mean	7	45
Annual absolute maximum	41	106
Annual absolute minimum	-37	-34
Growing season only	15	59
	mm	*in*
Average precipitation		
Total annual	710	28
Total during growing season*	160	6
Total snowfall	2620	103

[1]Data compiled from 12 weather stations in Idaho, 10 in Montana, 3 in Oregon, and 4 in Washington using U.S. Department of Commerce Summaries for 1951 through 1960 *(35).*
[2]May through August.

higher elevation portions of larch forests. One high elevation larch site at Roland, ID, receives an average of 620 cm (244 in) of snow annually. Lower elevation sites commonly receive an average of more than 150 cm (60 in) of snow.

Soils and Topography

Western larch grows on a wide variety of soils. The most extensive soils have developed in glacial till or colluvium composed of materials derived from limestone, argillite, and quartzite bedrocks of the Precambrian belt geologic series. Larch also grows on soils developed in Recent and Tertiary alluvium and Pleistocene lake sediments. Most soils suitable for the growth of western larch are deep and well drained. Soils developed in glacial till, colluvium, and recent alluvium have nongravelly to gravelly loamy surfaces and gravelly to extremely gravelly loamy subsoils. Volcanic, ash is often incorporated into the surface horizon. Soils developed in Tertiary sediments or Pleistocene lake sediments have silt loam surfaces and silt loam, silty clay loam, silty clay, or clay subsoils.

Most soils supporting the growth of western larch are classified in two orders of the soil taxonomy: Inceptisols and Alfisols. Occasionally western larch is found on soils of the order Spodosols, but Spodosols are not extensive within the range of western larch and generally occur above the upper elevational limits of the species. A majority of the soils supporting the growth of western larch are the Cryoboralf, Cryochrept, and Cryandept great groups. Mean annual soil temperature of the soils within the great groups is about 5° C (41" F) at 51 cm (20 in). At low elevations on southern or western exposures within the range of western larch, soil temperatures are warmer and soils supporting the growth of western larch are in the Eutroboralf and Eutrochrept great soil groups.

Western larch grows best on the more moist Eutrochrepts or Eutroboralfs and the lower elevation (warmer) Cryochrepts and Cryoboralfs. It is commonly found growing on valley bottoms, benches, and north- and east-facing mountain slopes. South and west exposures are often too severe for larch seedling establishment, particularly on the drier sites found at larch's lower elevational limits and the southern portion of its range. On moist sites found in the mid- to northern-portion of its range and on mid- to high-elevation sites, larch grows on all exposures.

Figure *2-A mature stand of western larch with an understory of the more tolerant Engelmann spruce and subalpine fir.*

Associated Forest Cover

Western larch (fig. 2) is a long-lived seral species that always grows with other tree species. Young stands sometimes appear to be pure, but other species are in the understory. Douglas-fir *(Pseudotsuga menziesii* var. *glauca)* is its most common tree associate. Other common tree associates include: ponderosa pine *(Pinus ponderosa)* on the lower, drier sites; grand fir ***(Abies grandis),*** western hemlock ***(Tsuga heterophylla),*** western redcedar ***(Thuja plicata),*** and western white pine *(Pinus monticola)* on moist sites; and Engelmann spruce *(Picea engelmannii),* subalpine fir *(Abies lasiocarpa),* lodgepole pine *(Pinus contorta),* and mountain hemlock *(Tsuga mertensiana)* in the cool-moist subalpine forests *(44).*

Western larch makes up a majority or plurality in the forest cover type Western Larch (Society of American Foresters Type 212) (43). It is included in 11 other cover types:

205 Mountain Hemlock
206 Engelmann Spruce-Subalpine Fir
210 Interior Douglas-Fir

- 213 Grand Fir
- 215 Western White Pine
- 218 Lodgepole Pine
- 220 Rocky Mountain Juniper
- 224 Western Hemlock
- 227 Western Redcedar-Western Hemlock
- 228 Western Redcedar
- 237 Interior Ponderosa Pine

Classification systems based on potential natural vegetation have been developed for much of the geographic area where western larch grows. Larch is a seral species in 13 of the 21 habitat types described for eastern Washington and northern Idaho (7). In Montana, larch is a significant component in 20 of the 64 forest habitat types *(21).* Of these 20 habitat types, larch is a major seral species in 12, and a minor seral species in 8. These habitat types are found within the following forest series: the relatively dry-warm Douglas-fir; the moist grand fir, western redcedar, and western hemlock; and the cold-moist subalpine fir.

Larch forests typically have a rich understory flora with dense herbaceous and less dense shrub layers. It is not unusual to find as many as 7 tree species and 40 undergrowth species in plots of 405 m^2 (4,356 ft^2) *(21).* On a 40-ha (100-acre) study area on the Coram Experimental Forest in northwestern Montana, 10 conifer, 21 shrub, and 58 herbaceous species were recorded *(31).* Some of the common understory species associated with larch are the following:

Shrubs

Rocky Mountain maple	*Acer glabrum*
Sitka alder	*Alnus sinuata*
Serviceberry	*Amelanchier alnifolia*
Oregongrape	*Berberis repens*
Menziesia	*Menziesia ferruginea*
Mountain lover	*Pachistima myrsinites*
Ninebark	*Physocarpus malvaceus*
Rose	*Rosa* spp.
Thimbleberry	*Rubus parviflorus*
Common snowberry	*Symphoricarpos albus*
Dwarf huckleberry	*Vaccinium caespitosum*
Blue huckleberry	*Vaccinium globulare*
Scouler willow	*Salix scouleriana*
Spiraea	*Spiraea betulfolia*

Herbs

Wild sarsaparilla	*Aralia nudicaulis*
Rinnikinnick	*Arctostaphylos uva-ursi*
Arnica	*Arnica latifolia*
Pinegrass	*Calamagrostis rubescens*
Queenscup	*Clintonia uniflora*
Fireweed	*Epilobium angustifolium*
Twinflower	*Linnaea borealis*
Beargrass	*Xerophyllum tenax*

Life History

Reproduction and Early Growth

Flowering and Fruiting-Western larch is monoecious; both staminate and ovulate flowers develop throughout the crown. Buds are found at the end of short spurlike lateral branchlets. Vegetative buds are smaller than flower buds-usually about 2.5 to 3.0 mm (0.10 to 0.12 in) in diameter, whereas flower buds range from about 3.0 to 4.8 mm (0.12 to 0.19 in) in diameter. Ovulate buds are one to one and one-half times longer than they are wide and are rounded or conical on the end. Staminate buds are usually globose and about one and one-half to two times longer than wide. Vegetative and flower buds can be detected early in the fall, about 1 year before subsequent cone crops mature. Methods of sampling buds and conelets have been devised for forecasting larch seed crops on individual trees, as well as stands (24).

Pollen and seed conelets appear several days before vegetative buds open-usually from about April 15 to May 15 (44). Conelets are generally very conspicuous, varying from bright red to green. Pollination occurs in late May and early June (33). Cones complete their development in one season and mature by mid- to late-August, reaching 2.5 to 4.5 cm (1.0 to 1.8 in) in length.

Cones usually begin to open by early September, but in cool-moist summers cone opening may be delayed a month or longer. More than 80 percent of the seeds usually are dispersed by mid-October (44). Cones open when they have dried to a moisture content of 35 to 40 percent, opening at the same time on individual trees, but varying substantially among trees in the same stand (39). Cones usually fall from the tree during the following winter, but many may stay attached through the next summer.

Seed Production and Dissemination-Larch is a good seed producer, but cone crops vary substantially by year and location. Long-term records of larch seed production in Montana show that good seed crops are produced at about 5-year intervals with fair to poor crops in the intervening years (44). Two good crops or several poor crops, however, may occur in close succession. Overall, the ratio of good or fair to poor seed crops is about 1 to 1.

Cone production is infrequent on larch trees less than 25 years old, although trees as young as 8 years occasionally produce cones. Larch starts bearing abundant cone crops from 40 to 50 years and continues bearing heavily for 300 to 500 years (35). Only dominants and codominants produce significant numbers of cones (44).

Cone production usually is a function of crown size because larch bears cones throughout the crown. Trees with the largest crowns produce the most cones. During a good cone year, production ranged from a low of 56 cones in one tree with 45 major branches to a high of 2,090 cones in another tree with 95 major branches. Also, vigorous, full-crowned, mature trees averaging 56 cm (22 in) in diameter produced about five times as many seeds as 36-cm (14-in) trees in the same stand and age class (44).

A mature cone may have as many as 80 filled seeds per cone, but the average is about half that number (39). Seed viability is related to cone-crop size, ranging from a low of 5 to 10 percent viability in poor crops to 70 to 80 percent in good crops. Young trees usually produce seeds of higher viability than overmature trees.

Larch seeds are small and lightweight, averaging 302,000/kg (137,000/lb) (45). Because of their relatively large wing, they are dispersed to greater distances than the heavier seeds of Douglas-fir and subalpine fir, but to about the same distance as the light seed of Engelmann spruce (37). Larch seed may be dispersed 240 m (787 ft) from clearcut boundaries under normal wind conditions (fig. 3). Although the seeds traveling that distance are only about 5 percent of that falling within the timber, they may amount to 100,000/ha (40,000/acre) in a heavy seed year-more than is adequate to restock favorable seedbeds. Overstocking often occurs near the seed source when bare soil is exposed. Seeds are disseminated more uniformly in seed tree and shelterwood cuttings than in clearcuts.

Seed production in mature natural stands of larch may exceed 1.2 million seeds per hectare (0.5 million seeds/acre) in a heavy seed crop. Records at Coram Experimental Forest indicate that small rodents eat only about 1 to 3 percent of the seeds during the overwintering period (41). In contrast, rodents usually feed heavily on the larger seeds of Douglas-fir and ponderosa pine during this same period.

Larch seed germinates about the time of snowmelt, from late April to early June, usually 1 to 2 weeks before associated tree species (38). Germination is epigeal (45). Natural stratification of larch seeds during the winter prompts rapid and complete germination. Without stratification, spring-sown larch seeds germinate slowly and erratically, with some seeds holding over until the next season. Artificial stratification methods using cold-moist conditions work well for preparing seed for field germination. These same seed treatments, as well as those using stimulants, such as hydrogen peroxide, are particularly useful for testing germinative energy and capacity (26). Air temperatures of about 27" C (80° F) are ideal for larch seed germination, but seeds germinate at temperatures 10" to 15" C (17" to 27" F) cooler than that.

Seedling Development-Western larch is a seral species well adapted to seedbeds exposed by burning (9) or mechanical scarification (35,401. Seedbeds of undisturbed litter, humus, sod, and areas with heavy root competition are poor for larch seedling survival.

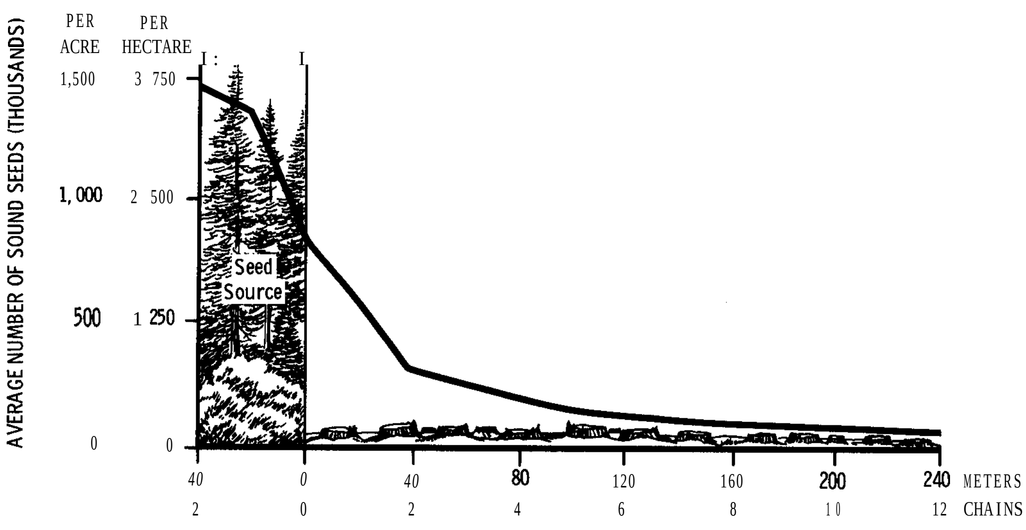

Figure 3-Dispersal characteristics of sound western larch seed from a seed source along a clearcut boundary.

Most seedling losses occur the first growing season—after 3 years seedling losses are minor (35). For example, studies on areas favorable for larch show that 54 percent of the seedlings survived the first season; 85 percent of the remaining seedlings survived the second season; and by the fifth season the remaining seedlings' survival was 94 percent. In other studies, an average of 39 percent of the larch seedlings survived the first 3 years (44).

Seedling survival is affected mostly by biotic factors early in the growing season and by physical factors late in the season. Until about mid-July mortality is caused primarily by fungi, rodents, birds, and insects. Most losses of first-year seedlings, particularly those growing on duff, are caused by fungi, usually immediately after germination. Seedlings growing on mineral soil seedbeds are far less susceptible to fungi than their counterparts growing on duff under both full sun and partial shade. Under full shade, however, susceptibility on the two types of seedbed is reversed (44). Seedling losses to animals, insects, and birds are relatively minor overall but may be heavy in specific locations and years.

Insolation is the most important physical factor affecting larch seedling survival (38). High soil surface temperatures exceeding 57” C (135” F) are not uncommon starting in late June, resulting in heat girdling of seedlings at the soil-air interface. Again, duff is the least desirable seedbed, with lethal temperatures occurring earlier in the season and on more days. Lethal soil temperatures are reached most frequently on duff, less on burned mineral soil, and least on scarified mineral soil. On south and west slopes, soil surface temperatures exceed 79” C (175” F), and few larch seedlings survive regardless of the type of seedbed (38).

Figure *4-Newly germinated seedlings **of** larch are* usually *robust and rapidly develop* a *vigorous root system.*

Drought is the major physical factor affecting mid- to late-season seedling survival. Unlike insolation, drought losses are heaviest in full shade because of the heavy competition for moisture by all the associated tree and understory vegetation.

Although aspect affects germination very little, it has a pronounced effect on seedling survival. North, northwest, and northeast exposures and gentle to flat topography provide the most favorable conditions for larch seedling survival. High surface temperatures and droughty conditions on the south and west exposures preclude survival of any significant number of larch seedlings. As a result, larch is either absent or but a minor stand component on hot, dry slopes.

Larch seedlings grow about 5 cm (2 in) the first growing season (fig. 4). In shade, root penetration may average only 2.5 cm (1 in) the first year, while its counterparts growing in the sun or partial shade may have 23 cm (9 in) roots. Seedlings growing in partial shade usually grow faster in height than seedlings in full sunlight for the first few years, but faster in full sunlight after that.

Larch seedlings break dormancy very easily. Buds usually burst by late April, well before those of any other native conifers. Shoot growth starts from late May to mid-June.

Larch seedlings grow rapidly in spite of the relatively short growing season of the Northern Rockies. Average annual height growth of about 30 cm (12 in) for the first 4 years is common (44). Of its major associates only lodgepole pine matches the rapid juvenile height growth of western larch. Douglas-fir seedlings grow at about one-half the rate of larch, and Engelmann spruce and subalpine fir seedlings grow at about one-fourth the rate of larch (28).

Vegetative Reproduction-Larch does not reproduce by sprouts. Cuttings have been successfully rooted by researchers at the Intermountain Forest and Range Experiment Station, but methods have not been fully tested at this time. One technique requires cutting 8 to 10 cm (3 to 4 in) scions from young larch trees, dipping the lower portion of the cutting in a powder mixture of 0.8 percent indolebutyric acid and 10.0 percent Captan 50 wettable powder (mixed with talc), and placing them in a rooting chamber at about 24” C (75” F). Researchers

Figure 5—*Stand of old-growth western larch at Seeley Lake, MT, Lolo National Forest, with trees up to 150 cm (59 in) in d.b.h.*

at the Intermountain Station have successfully grafted western larch.

Sapling and Pole Stages to Maturity

Growth and Yield-Western larch is long-lived and is the largest of the world larches (20) (fig. 5). Trees exceeding 230 cm (90 in) d.b.h. and 900 years of age have been found (44). Larch normally reaches 30 to 55 m (100 to 180 ft) in height at maturity and occasionally exceeds 61 m (200 ft).

Larch grows faster in height than any other conifer in the Northern Rockies for the first century, giving this highly shade-intolerant species the height advantage it needs to survive. For the first 50 years, larch and lodgepole pine height growth are similar, but thereafter lodgepole height growth declines in comparison with larch.

Differences in height growth of larch and its associated species are readily apparent at early ages. Both larch and lodgepole pine start off faster than

Table 2—Height of average dominant and codominant western larch by age and site index

Age	Site index at base age 50 years		
	12.2 m or 40 ft	18.3 m or 60 ft	24.4 m or 80 ft
yr	m	*m*	*m*
20	3	4	6
40	9	14	19
60	14	21	29
80	17	26	35
100	20	30	40
yr	ft	ft	ft
20	9	14	19
40	31	47	63
60	47	70	94
80	57	86	115
100	65	97	130

Table 3-Average site indices for larch *(21,35)*

Ecological habitat type	Average site Index at base age 50 years	
	m	*ft*
Northern Idaho and Washington:[1]		
Abies lasiocarpa-Xerophyllum tenax	14.9	49
Abies lasiocarpa-Pachistima myrsinites	17.7	58
Tsuga heterophylla-Pachistima myrsinites; Thuja plicata-Pachistima myrsinites; Abies grandis-Pachistima myrsinites	20.1	66
Pseudotsuga menziesii-Physocarpus malvaceus	18.9	62
Pseudotsuga menziesii-Calamagrostis rubescens	16.8	55
Montana:		
Pseudo tsuga menziesii- Vaccinium caespitosum	18.0	59
Pseudotsuga menziesii-Physocarpus malvaceus	17.4	57
Pseudotsuga menziesii-Linnaea borealis	16.8	55
Picea-Vaccinium caespitosum	22.6	74
Thuja plicata-Clin tonia uniflora	19.2	63
Tsuga heterophylla-Clintonia uniflora	24.4	80
Abies lasiocarpa-Clintonia uniflora	19.2	63
Abies lasiocarpa-Linnaea borealis	17.1	56
Abies lasiocarpa-Menziesia ferruginea	20.4	67
Abies lasiocarpa-Xerophyllum tenax	15.5	51

[1]Based on Daubenmire's classification (6).

their associates. Studies on good quality sites on Coram Experimental Forest in Montana show larch and lodgepole pine growing at about twice the rate of Douglas-fir and three to four times faster than subalpine fir and Engelmann spruce for the first 20 years. On wetter sites in northern Idaho, larch and lodgepole pine typically grow much faster than western white pine, western hemlock, and western redcedar in unthinned natural stands for the first half century. In thinned stands, however, differences in height growth of western white pine and larch are nominal. By age 100, the height growth advantage larch holds over its associates typically becomes less pronounced *(35,10)*.

Site productivity accounts for the largest share of the variation in height growth of larch throughout its range. Site index curves for larch (base age of 50) show heights at age 100 ranging from 20 m (65 ft) on low sites to 40 m (130 ft) on high sites (table 2). Average site indices for larch on different ecological habitat types are given in table 3.

Physiographic position, directly interrelated with habitat type, also influences height growth. Larch grows most rapidly in height on the deep, moist soils of valley bottoms and lower north and east slopes, but poorly on the upper south and upper west slopes *(35)* :

Physiographic class	Average site index	
	m	*ft*
Valley bottoms	18.9	62
Midnorth and mideast facing slopes, lower south and lower west facing slopes and benches	18.0	59
Upper north and upper east facing slopes	17.4	57
Midsouth and midwest facing slopes	16.2	53
Upper south and upper west facing slopes	13.4	44

Seedbed conditions at the time of seedling establishment influence height growth in the formative years (27). Studies on Priest River Experimental Forest in northern Idaho showed that on the average 2-year-old larch seedlings were twice as tall on burned seedbeds as they were on bare mineral or duff-covered soil *(14)*. Subsequent studies on Coram Experimental Forest showed that these height growth differences persisted into the teenage years, with larch growing about one-third faster on burned seedbeds than on scarified or undisturbed seedbeds (35). These differences may be due to changes in nutrient availability, water infiltration into the soil, or competing vegetation. Microchemical tests showed increased levels of manganese, magnesium, nitrogen, phosphorus, and calcium in the upper soil layers of burned seedbeds *(14)*.

Stand density also affects height growth very early in the life of the stand (27). Heavy overstocking is common in young stands with densities sometimes exceeding 86,500 trees per hectare (35,000/acre). In

Table 4—Potential d.b.h. of western larch trees at age 50 and at age 100 years by ecological habitat type and site index (35)

Ecological habitat type	Age	Site index at base age 50 years: 12.2 m or 40 ft	18.3 m or 60 ft	24.4 m or 80 ft
	yr	*cm*	*cm*	*cm*
1. *Abies lasiocarpa Xerophyllum tenax*	50	13.7	19.3	—
	100	25.1	33.8	—
2. *Pseudotsuga menziesii Physocarpus malvaceus* and *Calamagrostis rubescens*	50	14.5	19.8	—
	100	26.7	35.	—
3. *Abies lasiocarpa Pachistima myrsinites*	50	—[1]	20.3	25.9
	100	—	35.8	44.7
4. *Abies grandis-Pachistima myrsinites*	50	—	20.6	26.2
	100	—	36.6	45.2
5. *Tsuga heterophylla-Pachistima myrsinites* and *Thuja plicata-Pachistima myrsinites*	50	—	20.8	26.2
	100	—	36.8	45.2
	yr	*in*	*in*	*in*
1. *Abies lasiocarpa Xerophyllum tenax*	50	5.4	7.6	—
	100	9.9	13.3	
2. *Pseudotsuga menziesii-Physocarpus malvaceus* and *Calamagrostis rubescens*	50	5.7	7.6	—
	100	10.5	13.8	—
3. *Abies lasiocarpa Pachistima myrsinites*	50	—	8.0	10.2
	100	—	14.1	17.6
4. *Abies grandis-Pachistima myrsinites*	50	—	8.1	10.3
	100	—	14.4	17.8
5. *Tsuga heterophylla-Pachistima myrsinites* and *Thuja plicata-Pachistima myrsinites*	50	—	8.2	10.3
	100	—	14.5	17.8

[1]Dashes indicate that values are outside the data base.

a g-year-old stand at Coram Experimental Forest for example, dominant larch were growing a third faster in height in stands with 12,400 trees per hectare (5,000/acre) than they were in stands with 86,500/ha (35,000/acre). Thinning these overstocked stands relieved this height growth suppression, but even the dominant trees in unthinned stands continued to grow well below their potential in height *(30).* By age 24, dominant trees in the thinned stands averaged more than 9 m (30 ft) tall, but their counterparts in the unthinned stands averaged 15 to 20 percent less *(29).*

Diameter growth measured at breast height (1.37 m or 4.5 ft) for larch largely parallels height growth and is affected by many of the same factors. Larch has the potential for rapid diameter growth, but overstocking, insects, and dwarf mistletoe often prevent full realization of this potential.

Potential diameter growth curves have been developed for western larch on different combinations of habitat type and site index to provide a basis for evaluating tree and stand conditions (table 4) *(35).*

These projections, based on relatively open trees, show larch at age 50 reaching diameters ranging from a high of 26 cm (10.3 in) on high to 14 cm (5.4 in) on low quality sites; at age 100, 45 cm (17.8 in) to 25 cm (9.9 in).

Larch diameter growth is very sensitive to stand density. For example, in g-year-old stands on Coram Experimental Forest, overstocking of 86,500 trees per hectare (35,000/acre) had already restricted diameter growth of the dominant trees to half that of their counterparts in stands with 12,400/ha (5,000/acre) (27). At age 19 and 24, dominant trees in these unthinned stands (with about 37,100/ha or 15,000/acre) continued growing at about half the rate of their counterparts in thinned stands (with about 1,000 trees per hectare or 400/acre). For example, at age 24, dominant trees in thinned stands averaged nearly 13 cm (5 in) compared to about 8 cm (3 in) for dominants in unthinned stands (29). Elsewhere, 30- to 50-year-old stands in Montana showed about the same diameter relationships, with crop-trees in unthinned stands growing at about half their potential *(25).*

Basal area increases rapidly to about age 40 years, decelerates, and nearly levels off after age 100. At age 100, basal area of larch forests approaches 69 m^2/ha (300 ft^2/acre) on high quality sites and about 46 m^2/ha (200 ft^2/acre) on low quality sites. On high sites, the average annual increase in basal area is about 0.7 m^2/ha (3 ft^2/acre) for the first century. Average increase during the 100- to 200-year period is only about one-tenth the rate noted in the first 100 years. As basal area stocking approaches site potential, increment drops off rapidly-the site is fully occupied.

Table 5—Total volume of western larch trees 1.5 cm (0.6 in) and larger in d.b.h. (35)

Age	Site index at base age 50 years		
	12.2 m or 40 ft	18.3 m or 60 ft	24.4 m or 80 ft
yr		*m³/ha*	
20	'17	30	45
40	105	184	275
60	191	336	502
80	258	454	'678
100	308	544	*'813*
yr		*ft²/acre*	
20	'246	434	648
40	1,494	2,632	3,934
60	2,724	4,801	7,176
80	3,680	6,464	'9,692
100	4,407	7,765	*'11,608*

'Values in italics are extrapolated beyond the range of the basic data

Larch forests can produce heavy timber volumes. The increase in volume follows a similar pattern as basal area but peaks later. Because of their influence on diameter and height growth, site quality, age, and stocking level play the major roles in volume yield. Projected cubic yields for larch forests at age 100 range from 308 m^3/ha (4,407 ft^3/acre) on low quality to 813 m^3/ha (11,608 ft^3/acre) on high quality sites (table 5). With full stocking (but not overstocked), 544 m^3/ha (7,765 ft^3/acre) is a reasonable objective by age 100 on medium quality sites for larch forests.

Rooting Habit-Larch develops a deep and extensive root system, but little information is available about its root growth. Root lengths on first-year natural seedlings usually reach 5 cm (2 in). Under good nursery conditions, well-developed fibrous roots 20 cm (8 in) or longer develop on 1-O growing stock. Observations in soils under young larch stands indicate extensive fibrous rooting in the top 50 cm (20 in), substantially less in the 50-100 cm (20-40 in) depths, and practically none at greater depths. Soil water depletion studies verify these observations in young larch stands (29). Heavy rooting at depths greater than the above has been observed along roadcuts through old-growth stands. Evaluations of roots of windfallen overmature larch show that nearly all of them were infected with root rots (35). Apparently, these rots play an important role in wind stability of overmature trees, but their importance in young trees is not known.

Reaction to Competition-Larch is the most shade-intolerant conifer in the Northern Rockies. Only during the seedling stage can it tolerate partial shading. If larch is overtopped its crown rapidly deteriorates, and its vigor declines severely.

Because of its intolerance to shade, larch grows in even-aged stands or age-classes. Its primary associates are usually the same age as larch but often give the appearance of being younger because they grow slower than larch and form the lower strata in the stand. As larch stands mature, however, shade-tolerant associates continue to establish and form younger understories.

Fire is essential to the maintenance of western larch in natural forest stands. Most fires that occur on mountain slopes are usually small and of low or moderate intensity *(8)*. Fire intensity, however, increases on steep slopes with heavy fuels, or on dry ridgetops. These fires thin stands, reduce fuels, rejuvenate undergrowth, and prepare seedbeds that promote mixed conifer stands with small pockets of regeneration dominated by seral species, particularly western larch. Intense fires often create definite even-aged stands. At Coram, multiple burns occurring at less than 50-year intervals favor lodgepole pine or shrub fields. Historically, within the mixed conifer/pinegrass communities of the Blue Mountains of Oregon, underburns occur at lo-year intervals and maintain western larch and other seral species in the stands *(15)*. Here, all species, including western larch, often overstock and can stagnate unless periodic fires release some trees. Without fire, grand fir and Douglas-fir replace the seral species.

Although larch normally remains in the dominant position, understory trees and other vegetation vigorously compete with larch for available water and nutrients. In one harvest-cutting study, diameter growth of residual mature seed trees after logging increased 67 percent over prelogging growth (44). When all understory trees were also cut, the seed trees increased an additional 36 percent in diameter increment.

Even-aged silviculture systems of shelterwoods, seed-tree cuttings, and clearcuts best fit the ecological requirements of larch forests. They provide an adequate seed source and the microsite conditions needed for establishing the new seedlings. They are also compatible with the site preparations of prescribed burning or scarification needed to reduce the duff layers and vegetative competition for the new seedlings. Prescribed burning most closely approximates the natural wildfires that historically have perpetuated larch forests. No detrimental impact on site quality has been attributed to harvesting or prescribed fire on the soil microflora *(16)*.

Conversely, uneven-aged silviculture systems have limited utility in most larch forests. Not only does the residual stand show little overall growth response after partial cuttings, the growth increases that do occur are mainly on the more tolerant and generally less desirable species, such as subalpine fir. In addition, partial cuttings discriminate strongly against larch and its shade-intolerant associates in the regeneration process, and larch becomes a minor stand component in stands it formerly dominated. Prescribed burning or scarification needed to regenerate larch are very difficult in partial cuttings. For management considerations other than timber production, such as esthetics or wildlife, there may be rationale for uneven-aged silviculture systems in some larch forests. Even here, however, it should be recognized that these practices violate the normal regeneration sequence in most of these forests, accelerate the succession to tolerant species, and increase insect and disease problems. Studies on Coram Experimental Forest have demonstrated many of the problems with single-tree selection cuttings. Even with special care, it is extremely difficult to use group-selection cuttings in old-growth larch forests.

Exceptions to the above are possible in some of the drier phases of Douglas-fir and grand fir habitat types, particularly in the Blue Mountains of Oregon and some lower elevation areas of western Montana. Here, natural underburns at 20- to 30-year intervals perpetuated more open-grown stands and allowed the establishment of western larch and ponderosa pine regeneration under the main forest canopy *(1,15)*. Uneven-aged silviculture systems that mimic these natural conditions are plausible in these types of larch forests,

Thinning in young western larch stands, preferably before age 20, enhances the growth of diameter and height during the juvenile years when response potential is greatest. Drastic reduction in the densities found in most unthinned stands is advisable. Studies in young larch show that larch responds well in diameter, height, and crown retention under a fairly broad range of densities after thinning, usually exceeding what were thought to be maximum growth rates *(30)*. Even at ages 30 to 50, larch responds well to release *(25,36)*. By this age, however, overstocking has reduced the crown and response is usually delayed. Timing and extent of response is a function of length and severity of overstocking. Individual tree growth once lost can never be regained.

Branch turnups following thinning can be a problem in young larch stands. If a tree is cut off above a live branch, it may turn up, reform the tree, and reduce the effectiveness of the thinning (35). Older larch sometimes produce sprouts from adventitious buds on the upper bole of the tree after thinning of older stands, but this effect may not have practical significance. The amount of sprouting increases with the severity of the thinning (25).

Preliminary studies of fertilization in Montana *(2)* show a positive diameter growth response to fertilization with nitrogen, but the effects last only about 3 years. Similar studies in Idaho showed a short-term diameter growth response to nitrogen *(13),* but neither study showed any height increase.

Damaging Agents-Mature larches are the most fire-resistant trees in the Northern Rockies because of their thick bark, their high and open branching habit, and the low flammability of their foliage. Poles are moderately resistant, but seedlings and saplings have very little resistance to tire *(44).*

Larch is moderately to highly resistant to windthrow because of its extensive root sytem. Isolated old-growth seed trees or those along cutting boundaries, however, are susceptible to windthrow, particularly those on upper slopes and ridgetops, or those in narrow canyons and saddles where winds are channeled (35).

Because larch is deciduous, its branches seldom accumulate excessive amounts of either snow or ice. Early fall or late spring snows occasionally catch larch with a full complement of needles and cause severe bending. After a heavy June snow on the Coram Experimental Forest, young larch were completely flattened, but they recovered surprisingly well with little apparent long-term damage (34).

Young larch is extremely sensitive to noxious fumes, but because it is deciduous, the tree accumulates fewer harmful deposits than other conifers. Fluorine and sulfur dioxide are both harmful, but fluorine is the more toxic. Fluorides at levels of 30 to 35 p/m produce toxic needle effects (5).

Dwarf mistletoe ***(Arceuthobium laricis)*** is the most damaging disease-causing parasite of larch. It can infect seedlings as young as 3 to 7 years old and continue throughout the life of the tree (49). In addition to killing tree tops, reducing seed viability, creating conditions suitable for entry of other diseases and insects, and causing burls, brashness, and some mortality, it decreases height and diameter growth. Basal area growth reductions can be expected as follows (22): light infection, 14 percent; medium infection, 41 percent; and heavy infection, 69 percent.

Infected residual-stand overstories left after logging or fires promptly infect understory stands. Mistletoe seed can be ejected as far as 14 m (45 ft) (42). Thus 50 evenly-spaced, diseased trees per hectare (20/acre) may infest understory trees with just one crop of mistletoe seeds. Proper harvest-cutting systems, particularly clearcutting, can substantially reduce the mistletoe problem.

Three other important diseases are found in larch: needlecast caused by ***Hypodermella laricis,*** the quinine fungus ***Fomitopsis officinalis***, and red ring rot caused by ***Phellinus pini***. Many other less common but potentially dangerous fungi, such as ***Encoeliopsis Zaricina,*** infect larch but have not caused significant problems in the past *(35).*

Larch casebearer ***(Coleophora laricella)*** and western spruce budworm ***(Choristoneura occidentalis)*** are currently the two most serious insect pests of western larch (35). Casebearer was first detected in the Northern Rockies in 1957 and since then has spread throughout virtually the entire larch forest type ***(11).*** Introduced and native parasites, plus adverse weather conditions on many larch sites, appear to be reducing the casebearer problem, however. Severe defoliation by the casebearer can substantially reduce tree growth, but mortality usually is low.

Western spruce budworm has been a persistent problem wherever heavy populations of budworm overlap the range of larch ***(12).*** The most serious damage to larch is severance of the terminal leader, which results in an average loss of about 25 to 30 percent of the height growth for that year (32).

Other insect species affecting larch include the larch sawfly ***(Pristiphora erichsonii)*** and the larch bud moth ***(Zeiraphera improbana)*** that cause heavy, but sporadic, damage. The western larch sawfly ***(Anoplonyx occidens)***, the twolined larch sawfly ***(Anoplonyx laricivorus)***, and the larch looper ***(Semiothisa sexmaculata incolorata)*** also damage larch from time to time. Bark beetles are not generally a serious problem for larch, but the Douglas-fir beetle ***(Dendroctonus pseudotsugae)*** occasionally attacks weakened trees. At times, the engraver beetle ***(Ips plastographus)***, the larch engraver ***(Scolytus laricis)***, and the false hemlock looper ***(Nepytia canosaria)*** damage larch.

Damage from larger animals is relatively minor. Rodents, because of their seed- and seedling-eating habits, can greatly influence seedling establishment. Larch is apparently unpalatable to most big game species. In addition, most larch forests occur in areas of heavy snowpack not suitable for winter game range (35). Bears, however, can be a local problem. They strip the bark on the lower bole of the most vigorous trees in young sapling and pole-sized stands during the spring of the year and often kill the trees.

Special Uses

Western larch forests are valued for their multiple resource values. The seasonal change in hue of larch's delicate foliage from light green in the spring and summer, to gold in the fall, enhances the beauty of these mountain forests.

Because larch is an aggressive pioneer species, it quickly reforests areas denuded by natural or man-caused disturbances, providing protection for those important watersheds in the Columbia River Basin. Western larch is an important component of high water-yielding forests-areas where management can influence water yield through harvest cuttings *(19)* and young stand culture (29).

Larch forests provide the ecological niches needed for a wide variety of birds and animals. Hole-nesting birds comprise about one-fourth of the bird species in these forests, and studies on Coram Experimental Forest show that broken-topped larch is a preferred site for the hole-nesters ***(18).*** Deer, elk, moose, and the black and grizzly bear are widespread and numerous throughout the range of larch.

Larch timber is used extensively for lumber, fine veneer, long-straight utility poles, railroad ties, mine timbers, and pulpwood (35). Larch wood is strong and hard and contains about 4 to 23 percent arabinogalactan. It is the best domestic source of this water soluble gum used for offset lithography and in food, pharmaceutical, paint, ink, and other industries. Arabinogalactan has the consistency of honey and contains 16 percent volatile pinene and limonene (44).

Timber harvesting practices in larch forests are now utilizing more of the woody biomass formerly left in the woods after logging. Studies in the last decade have aimed at characterizing this biomass and the environmental consequences of removing biomass from larch forests (46). Typically, large volumes of standing live and dead tree biomass are found in old-growth larch forests *(3).* For example, of the 512 m^3/ha (7,318 $ft^3/acre$) found on a larch study area on Coram Experimental Forest in western Montana, 55 percent was in standing green trees, 20 percent in standing dead, and 25 percent in down material. In addition to tree biomass, shrubs and herbs account for additional biomass ***(31).*** In terms of weight, the average total biomass was 325 t/ha (145 tons/acre) with the following distribution:

	Pd.
Standing green and dead 7.6 cm (3 in) diameter and larger	49
Crown material less than 7.6 cm (3 in) diameter	12
Down wood 7.6 cm (3 in) diameter and larger	11
Down wood less than 7.6 cm (3 in) diameter	3
Shrubs and herbs	2
Litter	1
Duff	22

Genetics

Population Differences

No differences in cold hardiness of l-year-old larch seedlings were detected from 78 populations before frost in early September *(23).* Regardless of geographic origin, 2-year-old seedling populations separated by 1000 m (3,300 ft) tended to differ by 1.4 days in bud burst, 1.1 weeks in bud set, and 8 cm (3.1 in) in height (21 percent of the height variance) when growing in the average test environment.

Races and Hybrids

Races of western larch are not known. Putative natural hybridization of western larch and subalpine larch ***(Larix lyallii)*** occasionally occurs in areas where their distributions overlap *(4).* Even where the geographic ranges of the two species overlap, usually elevations of 300 m (1,000 ft) or more separate them. Interspecific hybrids of western larch and Japanese larch ***(Larix leptolepis)*** were taller and more vigorous than open-pollinated western larch progenies at the end of the first and second growing seasons (48).

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