Thuja plicata Donn ex D. Don Western **Redcedar**

Cupressaceae Cypress family

Don Minore

Western redcedar *(Thuja plicata),* also called Pacific redcedar, giant-cedar, arborvitae, canoe-cedar, and shinglewood, is the only *Thuja* species native to western North America. Extant redcedar volumes are estimated to be 824 million m^3 (29 billion ft^3) in British Columbia (43) and 228 million m^3 (8 billion ft^3) in the United States *(16).* Most of this volume is in mature trees, which have tapered, often-fluted bases, drooping branches, thin fibrous bark, and small scalelike leaves arrayed in flat sprays. Many have forked tops (fig. 1). They often reach ages of 800 to 1,000 years. One particularly large specimen in Washington has a d.b.h. of 592 cm (233 in), a height of 54.3 m (178 ft), and a crown spread of 16.5 m (54 ft). The wood is valuable and extensively used in a wide variety of products.

Habitat

Native Range

Western redcedar grows along the Pacific coast from Humboldt County, CA (lat. 40" 10' N.), to the northern and western shores of Sumner Strait in southeastern Alaska (lat. 56" 30' N.) (fig. 2). In California, it is common only in the lower Mad River drainage and the wet region south of Ferndale in Humboldt County; it is found elsewhere only in isolated stands in boggy habitats *(19).* North of the California-Oregon border, the coastal range broadens to include the western slopes of the Cascade Range north of Crater Lake and the eastern slopes north of about latitude 44° 30' N. *(12).* Optimal growth and development of western redcedar are achieved near the latitudinal center of its range-Washington's Olympic Peninsula.

North of the Olympic Peninsula and Vancouver Island, the coastal range narrows again and is restricted to the Coast Ranges and offshore islands. A few scattered stands are found between the Coast Ranges and the Selkirk Mountains near the southern border of British Columbia, but redcedar's coastal range is essentially isolated from its interior range.

The interior range extends south from the western slope of the Continental Divide at latitude 54" 30' N. in British Columbia through the Selkirk Mountains into western Montana and northern Idaho (2). The southern limit is in Ravalli County, MT (lat. 45" 50 N.). With the possible exception of a few trees east of the Continental Divide near the upper end of St. Mary Lake, Glacier County, the eastern limit of the

Figure *l-Mature western redcedar with forked top (Courtesy of Edmond C. Packee, Macmillan Bloedel Ltd.)*

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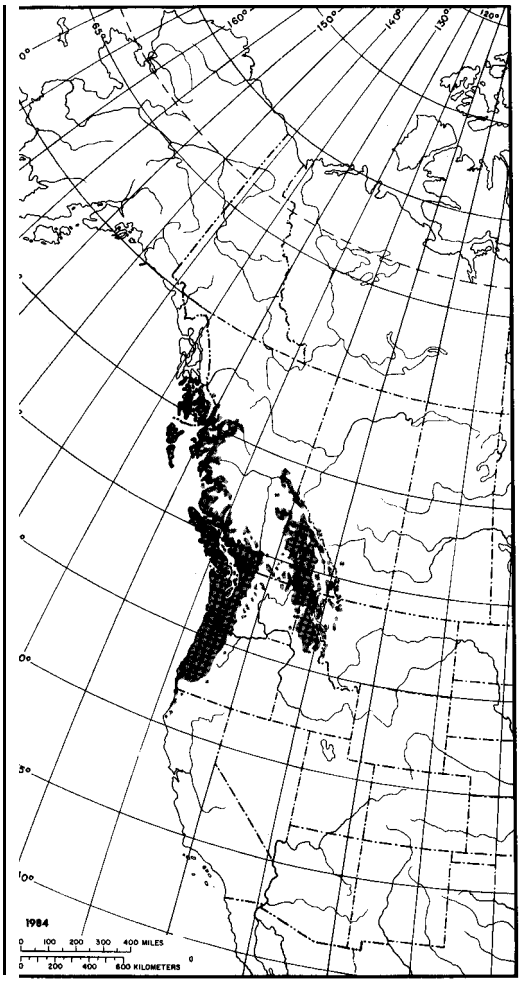

Figure 2—*The native range of western redcedar.*

range of redcedar is near Lake McDonald in Glacier National Park, MT.

Climate

Coastal western redcedar receives from less than 890 mm (35 in) of annual precipitation to more than 6600 mm (260 in), mostly as winter rainfall; interior western redcedar, about 710 mm (28 in) in the north, 810 to 1240 mm (32 to 49 in) farther south-about half as spring and autumn rain, one-third as winter snow *(2)*.

Although western redcedar is abundant in many forested swamps, it is sometimes found on sites that are too dry for western hemlock ***(Tsuga heterophylla)*** *(12,39,42)*, probably because the root penetration of the redcedar is better. Redcedar leaves are not protected from excessive transpiration by cutin and wax.

Trees tolerate stagnant winter water tables averaging less than 15 cm (6 in) below the soil surface on the Olympic Peninsula (32). The species dominates wet ravines and poorly drained depressions in both Glacier National Park in Montana and the Selway Bitterroot Wilderness in Idaho *(20,21)*.

Where sufficient precipitation is present, low temperature appears to limit the species' range. Length of the frost-free period abruptly decreases just above the tree's upper elevation limits on Vancouver Island. The northern limits of western redcedar lie between the 11.1" and 11.7" C (52" and 53" F) mean summer temperature isotherms in southeastern Alaska. Absolute minimum temperatures experienced by western redcedar in British Columbia are -10" to -30" C (14" to -22" F) in coastal populations, -14" to -47" C (7" to -53" F) in the interior (28). Western redcedar has a growing season of at least 120 frost-free days along the coast but as few as 75 frost-free days in some portions of its interior range. It is not resistant to frost and is sometimes damaged by freezing temperatures in late spring or early autumn.

Soils and Topography

Western redcedar can tolerate a wide range of soil properties in most localities. Soils on which it is most commonly found are in the orders Inceptisols, Ultisols, and Histosols. It is found on all landforms, soil textures, and parent materials on Vancouver Island (39). In southwestern Oregon, it grows on sedimentary, metasedimentary, gabbroic, dioritic, granodioritic, and occasionally even serpentinite and peridotite parent materials (24). Coarse sandy soils are not well suited to establishment and growth of redcedar in northern Idaho and northeastern Washington, but rocky slopes with limited soil development support redcedars in southeastern Alaska. Poorly drained organic soils also support redcedar south of Petersburg, AK. It grows on loams, clays, sands, chalk downland, and *Molina–Juncus* peat in England, but is most competitive on fine-textured lowland soils there. It grows well on shallow soils over chalk and can tolerate both acid and alkaline soil conditions (45).

Western redcedar seems able to survive and grow on soils that are low in nutrients and is found on such soils over much of its natural range. Site index is positively correlated with foliar nitrogen, sulfur, copper, boron, and chlorophyll. However, productivity may be improved by fertilization (44). When grown in well watered soil fertilized with nitrogen, phosphorus, and potassium, redcedar seedlings outgrow the seedlings of Douglas-fir ***(Pseudotsuga menziesii),*** grand fir ***(Abies grandis),*** Sitka spruce ***(Picea sitchensis),*** western hemlock, and ponderosa pine ***(Pinus ponderosa).*** Available nitrogen, calcium, and water appear to be the most important factors affecting

growth and establishment of redcedar. Established redcedars tend to raise soil cation exchange capacities, pH's, and amounts of exchangeable calcium *(1)* and thus benefit the soils in which they grow.

Western redcedar grows from sea level to 910 m (3,000 ft) in southeastern Alaska. In British Columbia, the elevational range is higher-from sea level to 1190 m (3,900 ft). Redcedar is found in the interior (fig. 3) from 320 m (1,050 ft) to 2130 m (7,000 ft).

Figure 3—*A virgin stand of western redcedar in a Kaniksu National Forest natural area in Idaho.*

The greatest range in elevation occurs in Oregon, where the species occurs from sea level to 2290 m (7,500 ft) at the rim of Crater Lake.

Associated Forest Cover

Pure stands of western redcedar cover some small areas, but it is usually associated with other tree species. Along the coast these include black cottonwood *(Populus trichocarpa),* bigleaf maple *(Acer macrophyllum)*, western hemlock, mountain hemlock *(Tsuga mertensiana),* Sitka spruce, western white pine *(Pinus monticola)*, lodgepole (shore) pine *(P. contorta)*, Port-Orford-cedar *(Chamaecyparis lawsoniana),* Alaska-cedar *(C. nootkatensis),* incense-cedar *(Libocedrus decurrens),* Douglas-fir, grand fir, Pacific silver fir *(Abies amabilis)*, red alder *(Alnus rubra)*, Pacific madrone *(Arbutus menziesii),* and Pacific yew *(Taxus brevifolia).* Several of these species (black cottonwood, western hemlock, western white pine, Douglas-fir, grand fir, and Pacific yew) are also associated with western redcedar in the interior. Subalpine fir *(Abies lasiocarpa)*, western larch *(Larix occidentalis),* Engelmann spruce *(Picea engelmannii),* white spruce *(P. glauca)*, lodgepole pine, and ponderosa pine are also associated with redcedar in the interior.

Redcedar is a major component of two forest cover types *(11)*: Western Redcedar (Society of American Foresters Type 228) and Western Redcedar-Western Hemlock (Type 227). It is a minor component of the following types:

210 Interior Douglas-Fir
212 Western Larch
213 Grand Fir
215 Western White Pine
218 Lodgepole Pine
221 Red Alder
222 Black Cottonwood-Willow
223 Sitka Spruce
224 Western Hemlock
225 Western Hemlock-Sitka Spruce
226 Coastal True Fir
229 Pacific Douglas-Fir
230 Douglas-Fir-Western Hemlock
231 Port-Orford-Cedar
232 Redwood

Some associated shrub species are listed in table 1. Several occur in both interior and coastal environments, but Rocky Mountain honeysuckle *(Lonicera utahensis)* and clematis *(Clematis columbiana)* are associated with redcedar only in the interior, whereas salmonberry *(Rubus spectabilis)* and red huckleberry *(Vaccinium parvifolium)* are found only on the Pacific slope. Pacific rhododendron *(Rhododendron macrophyllum)* is an abundant associate in coastal California, Oregon, and

Table 1—Shrub species often associated with western **redcedar** in coastal and interior portions of its native range.

Coastal	Interior	Both Coastal and Interior
Oregongrape *(Berberis nervosa)*	Mountain alder *(Alnus tenuifolia)*	Western serviceberry *(Amelanchier alnifolia)*
Stink currant *(Ribes bracteosum)*	Creeping western barberry *(Berberis repens)*	Rustyleaf menziesia *(Menziesia ferruginea)*
Alaska blueberry *(Vaccinium alaskaense)*	Common juniper *(Juniperus communis)*	Thimbleberry *(Rubus parviflorus)*
Box blueberry *Naccinium ovatum)*	Cascade azalea *(Rhododendron albiflorum)*	Oceanspray *(Holodiscus discolor)*
Red huckleberry *Naccinium parvifolium)*	Red raspberry *(Rubus idaeus)*	Devilsclub *(Oplopanax horridum)*
Salmonberry *(Rubus spectabilis)*	Blue huckleberry *(Vaccinium globulare)*	Pachistima *(Pachistima myrsinites)*
Pacific rhododendron *(Rhododendron macrophyllum)*	Rocky Mountain honeysuckle *(Lonicera utahensis)*	Baldhip rose *(Rosa gymnocarpa)*
Sal al *(Gaultheria shallon)*	Clematis *(Clematis columbiana)*	Common snowberry *(Symphoricarpos albus)*
		Ovalleaf huckleberry *(Vaccinium ovalifolium)*

Washington, but it is rare and confined to isolated locations in south-coastal British Columbia. Salal *(Gaultheria shallon)* also is an abundant associate. Its range extends farther south than that of redcedar, but the northern limits of salal are nearly the same as the northern limits of western redcedar in coastal Alaska.

Some associated herb species are listed in table 2. Many are common in both coastal and interior environments. However, slough sedge *(Carex obnupta)*

Table 2—Herb species often associated with western **redcedar** in coastal and interior portions of its native range.

Coastal	Interior	Both Coastal and Interior
Threeleaf anemone *(Anemone deltoidea)*	Goldthread *(Coptis occidentalis)*	Maidenhair fern *(Adiantum pedatum)*
Deer-fern *(Blechnum spicant)*	Everlasting corydalis *(Corydalis sempervirens)*	Ladyfern *(Athyrium filix-femina)*
Slough sedge *(Carex obnupta)*	Malefern *(Dryopteris filix-mas)*	Western swordfern *(Polystichum munitum)*
Pacific water-parsley *(Oenanthe sarmentosa)*	Largeleaf avens *(Geum macrophyllum)*	Mountain woodfern *(Dryopteris austriaca)*
Oregon oxalis *(Oxalis oregana)*	Roundleaf alumroot *(Heuchera cylindrica)*	Prince's-pine *(Chimaphila umbellata)*
Dwarf blackberry *(Rubus lasiococcus)*	Panicle bluebells *(Mertensia paniculata)*	Bunchberry *(Cornus canadensis)*
Youth-on-age *(Tolmiea menziesii)*	Pine drops *(Pterospora andromedea)*	Skunkcabbage *(Lysichitum americanum)*
White inside-out flower *(Vancouveria hexandra)*	Green pyrola *(Pyrola chlorantha)*	False Solomon's-seal *(Smilacina stellata)*
Evergreen violet *(Viola sempervirens)*		Pacific trillium *(Trillium ovatum)*

and Pacific water-parsley *(Oenanthe sarmentosa)* are limited to moist habitats west of the Cascades, whereas wild sarsaparilla *(Aralia nudicaulis)* and goldthread *(Coptis occidentalis)* occur with redcedar only in the interior.

Coastal redcedar plant communities in British Columbia have been classified into 24 associations under 9 alliances in the *Thuja–Rubus spectabilis* order (35). Communities listed in less detailed coastal classifications include redcedar/swordfern, redcedar/devilsclub/maidenhair fern, redcedar/maidenhair fern-laclyfern, redcedar-western hemlock/devilsclub/ladyfern, redcedar-grand fir/mountain boxwood, redcedar-grand fir/swordfern, redcedar-Douglas-fir/Oregongrape, redcedar–Sitka spruce-red alder/skunkcabbage-slough sedge, and redcedar/skunkcabbage *(12,28)*.

The redcedar/skunkcabbage plant community also occurs in the interior; where redcedar/devilsclub, redcedar/devilsclub/coolwort *(Tiarella trifoliata)*, redcedar/queenscup *(Clintonia uniflora)*, and redcedar/maidenhair fern are found *(7,28,42)*.

Life History

Reproduction and Early Growth

Flowering and Fruiting-When grown in the open, western redcedars begin to produce strobili at 10 years of age and usually every other year thereafter. Strobilus development can be artificially induced at younger ages and increased in mature trees by girdling or treating with gibberellin (8). The species is monoecious; male and female strobili are produced on different, branches of the same tree, at different heights--the reddish male strobili on lower branches and the green female strobili nearer the treetops and farther from the trunk *(38,52)*. Anthesis and pollination occur during March and April in southern stands near the coast. They occur during May and June in coastal Alaska and interior stands *(47)*.

Seed Production and Dissemination-Each mature strobilus usually produces only 3 to 6 seeds *(8)*, but the strobili are often numerous and heavy seed crops are common. In dry years, conebearing stands in the interior tend to be on high, moist sites *(14)*. Average annual seed crops vary from 247,000 to 2,470,000 seeds per hectare (100,000 to 1 million/acre) in coastal forests and from 54,000 to 274,000/ha (22,000 to 111,000/acre) in the interior. Major seedfall occurs during October and November in both ranges (2). Gibberellin-treated, containerized seed orchards should permit efficient management of seed production and harvesting (8).

Seeds are small-448,000 to 1,305,000/kg (203,000 to 592,000/lb) (47). They fall faster and do not fly as far as the seeds of western hemlock, Sitka spruce, and Douglas-fir, but. dissemination is adequate within 100 m (330 ft) of a seed source *(4,30)*. The seeds usually germinate well without stratification, and they retain their initial viability for at least 7 years when stored dry (5 to 8 percent moisture) at, -18" C (0° F) (8). Germination is epigeal.

Seedling Development-Most seeds escape rodent and bird predation, but seedling mortality is high during the germination period (15). Where moisture and temperature conditions are favorable, germination can occur in the autumn, winter, or spring. Almost no germination occurs after the first year, however. Seedbed quality may be critical.

Throughout the range of western redcedar, disturbed mineral soil seedbeds seem to be a major requirement for regeneration from seed *(41)*. Although unburned soil benefits redcedar more than soil that has been scorched, slash burning favors redcedar by creating more mineral soil surfaces in cutover areas. Rotten wood that is in contact with the soil is the preferred seedbed in old redcedar groves *(41)*. Partial shade is beneficial because drought and high soil temperature damage seedlings in full sunlight, and poor root penetration causes damage from drought in full shade (48).

Direct seeding in the autumn is successful where soil moisture is available, but large quantities of seed may be required to obtain adequate stocking. In the nursery, spring sowing is best; half-shaded seedbeds are recommended (47). Pelleting the seeds makes them more compatible with automated nursery sowing machinery (8). Containerized nursery seedlings can be produced in 7 months. They survive as well or better than bare-root stock when planted in coastal Oregon, Washington, and British Columbia, but 2-year-old bare-root stock tends to be most cost effective in the coastal range (6). When bare-root stock is planted, recently lifted dormant seedlings with low shoot/root ratios should be used and cold storage avoided whenever possible. Containerized stock planted in the spring appears to perform better than bare-root stock in the interior (18). Natural regeneration is important in the northern Rocky Mountains, where it, is most frequently successful on westerly and northerly aspects in western redcedar habitat types *(18)*.

Western redcedar seedlings are less tolerant of high soil temperature and of frost than are the seedlings of Engelmann spruce, grand fir, and Douglas-

fir. The exposed upper foliage of young redcedars often sunburns severely *(31).* Roots of seedlings grow more slowly than the roots of Douglas-fir and incense-cedar, but they outgrow the roots of seedling western hemlock and Sitka spruce. Shoots have a longer growth period than any associated conifer. Nonrigid leaders are produced, and neither lateral nor terminal shoots form dormant buds. Lateral shoot growth is vigorous, amounting to at least 80 percent of terminal shoot growth in young redcedars *(31).* Seedlings account for most of the western redcedar regeneration in clearcuts and other disturbed areas. On good coastal sites, they grow as tall or taller than Douglas-fir, western hemlock, and Sitka spruce seedlings during the first 5 years *(6,51).* The redcedars are subsequently overtaken by Douglas-firs (by age 10) and western hemlocks (by age 15).

Vegetative Reproduction-Three types of natural vegetative reproduction occur: layering, rooting of fallen branches, and branch development on fallen trees. The resulting "veglings" are more abundant than seedlings in mature Idaho stands *(40).* Saplings that have been knocked down in the western Cascades often regenerate when their branches root.

Redcedar clones are easily propagated by the rooting of stem cuttings. Although untreated cuttings will root, a l-minute dip in a 3,000 ppm solution or a 4-hour soak in a 200 to 400 ppm solution of indolebutyric acid improves rooting speed, the number of cuttings rooted, and the total length of roots per cutting. Ramets for seed orchards can be produced by treating cuttings with indolebutyric acid, then rooting them in a l-to-l mixture of peat and perlite (8). Young fragmented stems can be induced to bud after being soaked in a cytokinin solution, and the resulting buds can be rooted on a culture medium that contains napthalineacetic acid and kinetin (33).

Sapling and Pole Stages to Maturity

Growth and Yield-Intermediate redcedars are distinguishable from dominants by age 5 on good sites. Codominants usually can be differentiated from dominants by age 25 (fig. 4). Mean annual height growth of the dominants is 0.5 m (1.64 ft) in 40- to 60-year-old, pure, second-growth stands on moist sites in western Washington (36). Annual radial increments of 10 mm or even 20 mm (0.4 to 0.8 in) occur on the best moist sites in the south coast region of British Columbia (39).

Pure, even-aged stands can attain volumes comparable to pure Douglas-fir stands by age 50 on high-quality upland sites in western Washington (37). Plantations should be dense (about 2,470 trees per hectare or 1,000/acre), and intermediate crown classes should be removed in a light thinning to reduce side shade at about age 25 *(22,36).* Stands of 370 to 430 crop trees/ha (150 to 175 crop trees/acre) at time of harvest may allow maximum diameter growth without causing poor form (36). Maintaining a nearly closed canopy at all times will benefit form because open-grown redcedars tend to develop excessively large limbs and multiple tops. Faster growing trees of acceptable quality can be grown at wide spacings if their lower boles are pruned *(50),* but percentages of latewood decrease significantly (49).

Volumes of 379 to 825 m^3/ha (5,418 to 11,782 ft^3/acre) were measured in 40- to 60-year-old pure second-growth stands on moist sites in western Washington (36). A yield model on medium sites in British Columbia indicates yields of 70 m^3/ha (1,000 ft^3/acre) at age 40, 350 m^3/ha (5,000 ft^3/acre) at age 115, and 595 m^3/ha (8,500 ft^3/acre) at age 270; maximum current annual increment occurs at 82 years and maximum mean annual increment at 130 years (34).

In Great Britain, the cumulative volume produced by normal western redcedar stands on poor sites is 50 m^3/ha (714 ft^3/acre) at age 20 and 953 m^3/ha (13,620 ft^3/acre) at age 80. On good sites, cumulative volume produced is 232 m^3/ha (3,315 ft^3/acre) at age 20 and 1839 m^3/ha (26,268 ft^3/acre) at age 80. The average age of maximum mean annual increment is 72 on poor sites and 58 on good sites in these British stands (22). At ages 20 and 50, cumulative volume production is lower for western redcedar than for Douglas-fir and Sitka spruce in Great Britain, but by age 80 the redcedar volume production is higher than that of Douglas-fir and spruce (45).

Growth is often much slower. Suppressed redcedar trees that are 200 years old but only 7.6 cm (3 in) in d.b.h. and 7.6 m (25 ft) tall are not unusual. Survival for such long periods of suppression may be due to the ability of the species to produce new root growth in full shade. It may also be a result of frequent root grafting. Dominant trees often support growth of the root systems and lower boles of suppressed trees (9).

Rooting Habit--Tree roots are extensive. Redcedars made up only 17 percent of the basal area but accounted for 82 percent of the root length in a mixed-species stand in northern Idaho (29). Tap roots are poorly defined or nonexistent, but fine roots develop a profuse, dense network.

Western redcedar roots usually are deeper than the roots of western hemlock but shallower than the roots of western larch, western white pine, grand fir, and Douglas-fir (30). The soils on which these species

Figure *4-A 25- to 30-year-old stand of western redcedar on Vancouver Island, BC, showing early crown-class differentiation. (Courtesy of Edmond C. Packee, Macmillan Bloedel Ltd.)*

usually grow may be responsible, however, because western redcedar, western hemlock, and Douglas-fir trees of similar size growing on similar soils have roots that penetrate to similar depths and extend over similar areas *(10)*. Shallow root systems are most frequent where soil bulk density is high. Redcedar roots cannot grow in dense soils penetrated by the roots of Douglas-fir, red alder, lodgepole pine, and Pacific silver fir (30). Redcedar root systems also tend to be shallower and less extensive on wet sites than they are on deep, moderately dry soils.

Where a thick duff layer is present, many redcedar roots lie in the duff rather than in the underlying soil. Root grafting is common (9). Western redcedar mycorrhizae are of the vesicular-arbuscular type, and redcedar seedlings are more responsive to mycorrhizal inoculation than are the seedlings of redwood ***(Sequoia sempervirens)***, incense-cedar ***(Libocedrus decurrens),*** and giant sequoia (***Sequoiadendron giganteum)*** **(27).**

Reaction to Competition-Only Pacific silver fir, western hemlock, and Pacific yew are more tolerant of shade than western redcedar *(30)*. Its relative tolerance may be higher in warm than in cool areas, but redcedar is very tolerant wherever it

grows, and it may be "the species of choice" for reforesting high, brush-risk areas near the coast *(6)*. Often present in all stages of forest succession, redcedar occupies pioneer, seral, and climax positions (39). Multiple attributes seem to be responsible—redcedar invades disturbed areas as widely distributed seeds but regenerates vegetatively in undisturbed areas, tolerating competition in both (26). Nevertheless, it is usually considered a climax or near climax species.

Western redcedar is best managed on moist sites characterized by the presence of ladyfern, queenscup, mountain woodfern, oakfern *(Gymnocarpium dryopteris)*, or thimbleberry. On poorly drained sites of lower quality, fertilizing with nitrogen appears to benefit growth (37). Urea seems to be a better source of that nitrogen than ammonium nitrate (54). Redcedar can be grown in stands of mixed species where uneven-aged management is practiced or when redcedar poles are to be produced under normal even-aged management regimes. But pure stands are more suitable for the long rotations needed to produce large sawtimber, shingles, and shakes.

Where western redcedar is managed in mixed-species or uneven-aged stands, its excellent shade tolerance and long life should be considered. Redcedar is usually overtopped by Douglas-fir, grand fir, western hemlock, and western white pine. It tolerates understory conditions in mixed-species stands but often grows slowly there. In uneven-aged stands, western redcedar can maintain acceptable growth rates over long periods, but it should not be given excessive crown space. Thinning from above may release the redcedars in mixed-species stands; thinning from below is preferable in uneven-aged stands of western redcedar. In the northern Rocky Mountains, growth response to release is best on large, young redcedars with green-yellow foliage growing on northerly aspects *(17)*. Redcedars probably should not be released when overtopped, however, because much of the increased growth after their release often occurs in large branches and a spreading crown rather than stem wood *(37)*.

Most western redcedars are harvested by clearcutting the mixed-species stands in which they grow. Because of steep terrain, decay, and breakage, redcedar harvesting costs are high and lumber recovery is low (55). Redcedars should not be left as scattered seed trees, however; even those along clearcut margins may be lost to windthrow or exposure. Effects of slash-burning vary with site conditions, but low-impact spring burns tend to benefit the mycorrhizal colonization of seedlings (6).

Damaging Agents-Western redcedar is less susceptible than its associates to most damaging agents, but, as it is longer lived, damaged trees are common. Although they are as windfirm as Douglas-fir on dry sites, redcedars are often windthrown in wet environments and are not resistant to windthrow on the moist sites where growth and yield are highest. Fire resistance also varies with environment. Redcedar is more severely damaged by fire than any of its associates along the coast but is less susceptible than Engelmann spruce, western hemlock, and subalpine fir in the interior *(30)*.

Western redcedar suffers little damage from insects, but it is a host for several economically important insect species ***(13).*** One of the most important is the gall midge, ***Mayetiola thujae,*** which sometimes seriously damages redcedar seeds in Oregon, Washington, and British Columbia. Newly planted seedlings are occasionally damaged by a weevil ***(Steremnius carinatus)*** in British Columbia, and larger trees are killed by a bark beetle ***(Phloeosinus sequoiae)*** on poor sites in southeastern Alaska. The western cedar borer ***(Trachykele blondeli)*** causes degrade and cull in sawtimber.

More than 200 fungi are found on western redcedar, but it is less susceptible to pathological attacks than are most of its associates. Indeed, redcedar may be a suitable alternative species on coastal Douglas-fir and western hemlock sites where soils are infected with ***Phellinus weiri, Fomes annosus,*** or *Armillaria* spp. *(37)*. Nevertheless, many attacks occur during the long lives of some redcedar trees, and the heartwood extractives that provide decay resistance are eventually detoxified through biodegradation by a series of invading fungi (25). As a result, the volume of accumulated decay in living trees is greater for western redcedar than for any other major conifer in British Columbia *(25)*, and hollow old trees are common in the interior (7).

The major seedling disease, ***Didymascella thujina,*** is a leaf blight that infects 2nd- and 3rd-year nursery seedlings. As much as 97 percent of the natural redcedar reproduction may also be killed when this blight reaches epidemic proportions (2). Epidemics are rare in North America, however, and *Didymascella* is not as damaging here as it is in Europe, where the disease seriously limited production of planting stock until cycloheximide fungicides were developed *(3,52)*.

In North America, the most important fungi attacking redcedar are root, butt, and trunk rots (23). The root and butt rots include *Phellinus weiri, Armillaria mellea,* and ***Poria subacida. Poria asiatica*** and ***P. albipellucida*** are the most important trunk rots near the coast; ***P. asiatica*** and ***Phellinus weiri***

are most important in the interior range of western redcedar (2). These rots are most evident in old stands, where much of the standing volume is often defective and unmerchantable.

Redcedar seedlings and saplings are often severely browsed by deer, elk, or rodents, and browse damage may be the most important stand-establishment problem (6).

Western redcedar is damaged more than Sitka spruce by salt spray. Its foliage is more severely damaged by sulfur dioxide than is the foliage of Douglas-fir, western hemlock, and Sitka spruce and less damaged than the foliage of subalpine fir and grand fir. Redcedar is damaged less than Douglas-fir by airborne fluorides and ozone *(30)*.

Special Uses

Shingles and shakes constitute the most important special use of redcedar. Attractive appearance, durability, lightness, and superior insulation qualities probably are responsible for its popularity as a roofing material. Wood is also used in utility poles, fenceposts, piling, paper pulp, clothes closets and chests, caskets, crates, boxes, beehives, and fish-trap floats. Perfumes, insecticides, medicinal preparations, veterinary soaps, shoe polishes, and deodorants are made from cedar leaf oil. Redcedar extractives and residues are used in lead refining, boiler-water additives, and glue extenders ***(31).*** When properly trimmed, redcedars make excellent hedges. Their drooping branches, thin fibrous bark, and flat sprays of scalelike leaves make redcedars attractive ornamental trees. The leaves are a major winter food for big game in the northern Rocky Mountains, and deer browse redcedar all year along the coast.

Genetics

Population Differences

Western redcedar seems to vary less than other northwestern conifer species. Lack of isoenzyme variation in newly germinated seedlings from western Oregon and eastern and western Washington indicates that redcedar populations contain little genetic polymorphism (5). Isoenzyme variability is also low in British Columbia (56). Leaf oil terpene composition is similar in populations at both low and high elevations in British Columbia, Washington, Oregon, Idaho, and Montana; but small differences between coastal and interior populations were recently detected by discriminant analysis of the chemical data (53). Seedlings from different seed sources usually have remarkably similar forms and growth rates when grown in the same environment. Inland populations are more tolerant of frost than those from coastal populations, however *(46)*, and plantation trials indicate that provenances from Alaska are inferior to those from Oregon and Idaho when grown in Poland ***(31).*** Seed orchards have been established in Denmark, where resistance to leaf blight and frost have been shown to be homozygously recessive (52).

Races

Several horticultural varieties of western redcedar are grown in North America. They include ***atrovirens, fastigiata,*** and ***pendula.*** Haploid and triploid varieties have been studied in Germany (31).

Hybrids

Thuja plicata x Thuja standishii hybrids are resistant to the leaf blight caused by ***Didymascella thujina (52).***

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