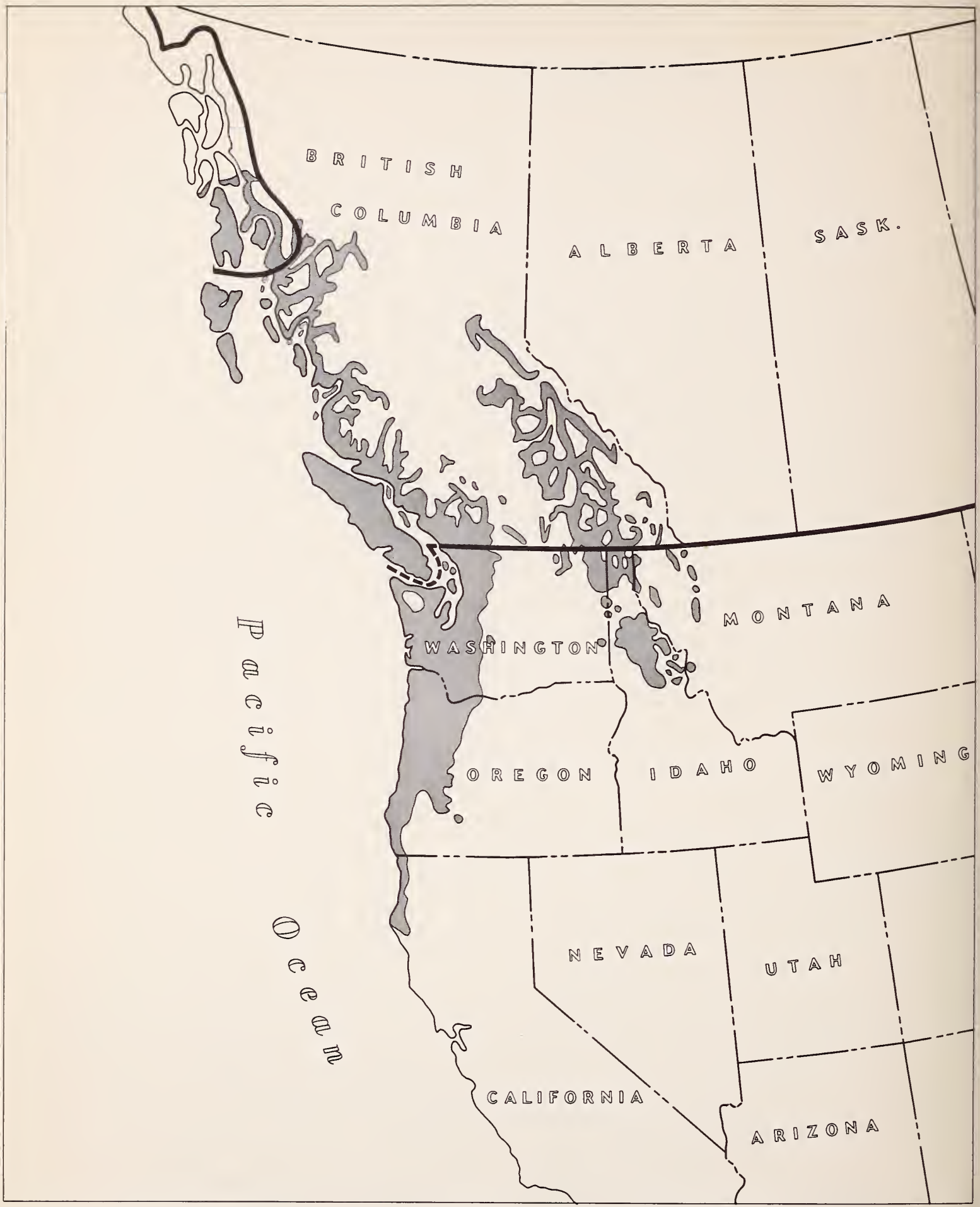
SILVICS of WESTERN REDCEDAR



Botanical range of western redcedar

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SILVICS OF WESTERN REDCEDAR

By

Raymond J. Boyd, Jr.
Forester

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U. S. Department of Agriculture
Ogden, Utah
Reed W. Bailey, Director

FOREWORD

The SILVICS OF WESTERN REDCEDAR is the fifth publication in the series of seven silvics manuals being published by the Intermountain Forest and Range Experiment Station as part of a larger project sponsored by the U. S. Forest Service. Forest Service Experiment Stations over the Nation are issuing similar bulletins on many important North American tree species. Eventually, a single publication that will include the entire series will be issued by the U. S. Forest Service.

Information in this publication is based on selected references and unpublished data through 1957. The author will appreciate having any omissions of source material called to his attention.

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SILVICAL CHARACTERISTICS OF WESTERN REDCEDAR

By

Raymond J. Boyd, Jr.[1/]

Western redcedar (Thuja plicata) is one of the most important commercial species in the Pacific Northwest, Alaska, and British Columbia. Local common names include giant arborvitae, canoe cedar, shinglewood, Pacific redcedar, giant cedar, arborvitae, and cedar (24).[2/]

Western redcedar occurs from the coastal regions of southern Alaska (with northern limit at Sumner Strait (2)) south through the coastal ranges of British Columbia, through western Washington and Oregon to Mendocino County, California. In British Columbia it extends east to the western slope of the Continental Divide at latitude 54° 30' N. (11) and thence south into the Selkirk, Bitterroot, and Salmon River Mountains of Idaho. Its easternmost limit is the western slope of the Rocky Mountains in northern Montana. In Oregon western redcedar is found on both sides of the Cascade Range. On the west side it occurs as far south as Crater Lake, while on the eastern slopes its southern extent is limited to the vicinity of Mount Hood (34). It is rather uncommon in California and is confined to the ocean side of the coast ranges within the fog belt. Western redcedar has developed best in the fog belt of British Columbia and Washington (28). Throughout its range it occupies the humid transition and Canadian zones (1).

The commercial range of western redcedar in the United States is divided essentially into two regions (22); namely, the Inland Empire or northern Rocky Mountain region (western Montana, northern Idaho, and eastern Washington) and the West coast region (western Washington and northwestern Oregon).

1/ Forester, Intermountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture; stationed at research center, Spokane, Wash.

2/ Numbers in parentheses refer to Literature Cited, page 11.

HABITAT CONDITIONS

CLIMATIC

Throughout its range, western redcedar is confined almost entirely to regions having abundant precipitation and atmospheric humidity (34, 35). In the Puget Sound area it thrives under optimum growing conditions of abundant rainfall with cool summers and mild winters; here is its most favorable growing condition, and here it reaches maximum size. Average annual rainfall within the range of western redcedar varies from 30 to 60 inches at elevations up to 1,000 feet, and upwards to 100 inches at higher altitudes. Three-fourths of the precipitation falls during the wet season (November to April). In the Puget Sound area summer rains are infrequent. Within the fog belt, which extends about 30 miles inland from the coast, precipitation varies from 60 to 130 inches and includes fairly frequent summer rains. The mean annual temperature varies from 46° F. in the north to 52° F. in the south. The long growing season commences in April in the Puget Sound area and continues until September. Little of the precipitation falls as snow in the coastal and Sound areas, but at higher elevations a considerable part of the total precipitation is snow.[3/]

In the Inland Empire, where the western redcedar range generally coincides with that of western white pine, mean annual precipitation varies from 28 to 50 inches, depending on elevation and latitude. Average annual precipitation is about 28 inches in the northern portion and 32 to 49 inches in the middle and southern portions (15). The frost-free period, important for seedling establishment and cone development, ranges from 60 to 160 days in the Inland Empire (15). Growth of established trees is largely independent of the frost-free season, however.

The growing season is roughly the 4-month period from May through August, or about 120 days. The beginning of spring growth is probably limited by temperature, and growth ceases when soil moisture is depleted in August or early September. In the Puget Sound area the growing season continues from April through September.[4/] Length of the growing season varies so much with latitude and altitude that it is not easily defined.

The climate is characterized by a short summer season having scanty precipitation, rather low humidities, and a high percentage of clear days. Winters are long, snowfall is heavy and temperatures are fairly low. Precipitation in the Inland Empire is classified as the sub-Pacific type--distinguished from the Pacific type by the fact that in this sub-Pacific type only a small proportion of the total falls in winter, whereas a large proportion occurs in spring and fall (21). Thirty-five percent of the total precipitation in the

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3/ Personal communication from N. P. Worthington, Pacific Northwest Forest and Range Experiment Station.

4/ Ibid.

Inland Empire falls as snow; 50 percent is divided equally between spring and fall; 7½ percent falls in June, and the remainder is divided equally between July and August. Average annual temperatures range from 42° F. in the central part of the region to 50° F. at its southern border (15).

EDAPHIC

Little is known about the optimum soil texture classes and types, for western redcedar. It grows on a wide variety of soils from deep rich loams to shallow gravelly sands. More important than depth, texture, or fertility is the amount of available soil moisture (12, 22). Occasionally redcedar grows on moderately dry and warm sites, but its growth is poor (35). Both good soils and abundant moisture are necessary for best development. Larsen (23) found that cedar requires soil conditions in which moisture does not fall below 12 percent in August.

Daubenmire (5) has studied some of the soil characteristics of widely scattered stands in northern Idaho representing the three associations in which cedar is climax. In these stands the pH in the first 5 decimeters of mineral soil varied from about 5.1 to 7.1. Most of the soils studied could be characterized as slightly to moderately acid. Spruce-fir associations located at higher elevations have more acid soils, and the lower elevation associations have less acid soils, but none are strongly basic. Soils under individual cedar trees exhibit higher pH than soils under hemlock trees in the same stand. This condition is associated with a high calcium content of cedar foliage (6, 36). Moisture equivalents in these same soils varied from 11 to 82 percent and thus represented a very wide range of soil texture and structure (5).

PHYSIOGRAPHIC

Because it grows best in moist soils, western redcedar is generally found on stream bottoms, moist flats, terraces, and gentle lower slopes and in moist gulches and ravines (26, 34, 35). The environment of a north aspect is generally more suitable than the more severe southerly aspect.

Throughout its north-south range on the Pacific coast it occurs down to sea level. In Alaska it is confined to the islands and to the western side of the coastal ranges to an elevation of about 3,000 feet. In coastal British Columbia it grows on the islands and extends up the coast range to an elevation of 2,400 feet. In the Olympic Mountain coast ranges and west slopes of the Cascades in Washington it rarely exceeds an elevation of 4,000 feet. In Oregon it extends generally to 5,000 feet but in one location to 7,000 feet (34). On the east slope of the Washington Cascades and in the northern Rocky Mountain region of northeastern Washington, northern Idaho, and Montana, it is found between 2,000 and 7,000 feet (35). The upper limit in the British Columbia Selkirk range is 4,500 feet (11). Within the United States its growth is not commercially important above the 3,000-foot elevation in the coastal region or above 5,000 feet in the Inland Empire (34, 35).

BIOTIC

Western redcedar is a component of the following forest cover types described by the Society of American Foresters (33): western redcedar, western redcedar--western hemlock, western hemlock, western white pine, Douglas-fir--western hemlock, Pacific Douglas-fir, Sitka spruce, Sitka spruce--western hemlock, Pacific silver fir--hemlock, Port Orford cedar--Douglas-fir, redwood, larch--Douglas-fir, and Engelmann spruce--subalpine fir. The first three of these types make up the greater part of the climax forests of the Pacific Northwest and the humid interior region. For the most part, the extensive western white pine and Douglas-fir types are subclimax to these three climax types. The remainder of the types are largely climax in which cedar associates with the climax species in various proportions (5, 33).

A more definitive classification of vegetation on an ecological basis in the northern Rocky Mountain area has been made by Daubenmire (5). Western redcedar occurs in three of his habitat types, namely, the Thuja-Tsuga/Pachistima, the Thuja-Tsuga/Oplopanax, and the Thuja/Pachistima associations.

Western redcedar seldom occurs in pure stands and then only over small areas. Its numerous associates vary from area to area. In Oregon, western Washington, and northward along the Pacific Coast, western hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis), grand fir (Abies grandis), Douglas-fir (Pseudotsuga menziesii), Port Orford cedar (Chamaecyparis lawsoniana), and Pacific silver fir (Abies amabilis) are common associates. In California it grows in mixture with redwood (Sequoia sempervirens) and western hemlock. Bigleaf maple (Acer macrophyllum), red alder (Alnus rubra), and northern black cottonwood (Populus trichocarpa var. hastata) are common companions of cedar on very wet or swampy areas in the coastal region. In the upper Cascade Mountains it grows with Pacific silver fir, Alaska cedar (Chamaecyparis nootkatensis), mountain hemlock (Tsuga mertensiana), western white pine (Pinus monticola), and noble fir (Abies procera) (22). In the northern Rocky Mountains, western white pine, western larch (Larix occidentalis), lodgepole pine (Pinus contorta), grand fir, Engelmann spruce (Picea engelmanni), subalpine fir (Abies lasiocarpa), western hemlock, and northern black cottonwood are commonly associated with cedar (15). Its Alaskan associates are western hemlock and Sitka spruce (37).

Dense stands of western redcedar and its associates commonly exclude nearly all subordinate vegetation, but when stands are at all open the forest floor abounds in a wide variety of mosses, ferns, herbs, and shrubs (5). In the northern Rocky Mountains the most common shrubby associates listed by Daubenmire (5) are: Acer glabrum var. douglasii, Amelanchier alnifolia, Arctostaphylos uva-ursi, Ceanothus velutinus, Lonicera utahensis, Menziesia ferruginea, Oplopanax horridus, Pachistima myrsinites, Physocarpus malvacens, Ribes lacustre, R. viscosissimum, Rosa gymnocarpa, R. spaldingi, Rubus pedatus, Salix barclayi, S. bebbiana, S. scouleriana, S. sitchensis, Sorbus scopulina, Spiraea betulifolia, Symphoricarpos albus laevigatus, Vaccinium membranaceum.

Most of these species occur both in the coastal redcedar forests and in the Rocky Mountain forests. In addition, the following species are plentiful in the coastal forests: Acer circinatum, Mahonia nervosa, Cornus nuttallii, C. pubescens, C. stolonifera, Corylus californica, Gaultheria shallon, Holodiscus discolor, Osmaronia cerasiformis, Malus fusca, Sambucus callicarpa, and a number of species of Betula, Ribes, Rubus, Salix, and Vaccinium not found in the Inland Empire (19).

LIFE HISTORY

SEEDING HABITS

Flowering and Fruiting.--Little has been reported about the phenology of western redcedar. On the warmer sites, flowering probably commences as early as mid-April (4). At higher elevations flowering may be delayed until late May or early June. In most areas the cones mature by late August, and seedfall starts in late August or early September. In the Inland Empire, Haig (15) reports that seedfall is rather light in September, heaviest in October, and that from 34 to 40 percent of the seedfall occurs after November 1. Some seedfall continues throughout the winter in most areas. Olson (27) has reported cedar bearing seed at the age of 16 years on the 1910 burn in northern Idaho.

Seed Production.--Western redcedar is a prodigious seed producer, ranking second only to western hemlock among the associated species (15). Average annual seed crops from 100,000 to 1,000,000 seed per acre in stands with as much as 25 percent cedar have been reported for British Columbia (30). In the same area seed crops as great as 57,000,000 seed per acre within a stand of 67 percent cedar have been reported. In the Inland Empire, Haig has reported average annual seed crops over a 7-year period of 111,000 seed per acre on cutover areas. A 14-year record of cone crops in the Inland Empire shows the average interval between good cone crops for western redcedar to be 2.8 years. During an 8-year period in which detailed records were kept, western redcedar produced good crops 4 years, fair crops 3 years, and a poor crop only 1 year (15). In studies of seed production in British Columbia, Garman (10) reports a seed yield of 1,500,000 per acre from a fair crop on four bearing trees per acre.

Seed Dissemination.--Seed is disseminated by wind, but its relatively small wing surface causes its rate of fall to be faster than that of any of its associates (32). Consequently cedar seed makes the shortest flight and is not dispersed as well as the seed of its associates. In seed release experiments in the coastal forests, Isaac (17) found that western redcedar seed was not dispersed more than 400 feet from its source when released at 150 feet elevation.

VEGETATIVE REPRODUCTION

Cedar can be propagated vegetatively (39), and natural regeneration by this means appears to be common in some areas (30). In old growth stands on good sites in British Columbia most of the advanced reproduction may be vegetative. Adventitious roots may develop on low hanging limbs, from the trunks of fallen trees that remain alive, or by living branches that fall on a wet soil surface. Growth of such reproduction is very slow. Vegetative propagation has not been reported to be common in stands within the United States.

SEEDLING DEVELOPMENT

Establishment.--The seed of western redcedar is less liable to rodent depredations than that of its larger seeded associates. Direct seeding experiments in the Inland Empire (31) and in the coastal forests (18) have shown that the small seeds of western redcedar need no protection from rodents for successful establishment of a stand. This is probably true of naturally cast seed as well.

Depending on weather conditions, seeds germinate in the fall or early in the following spring (15, 22). In the coastal areas, fall germination and seedling establishment are common (22, 34). Spring germination is more common in the Rocky Mountains (15). Adequate moisture in the seedbed assures successful germination on any natural surface (22, 26).

Compared to other species in the western white pine type, cedar has the highest greenhouse germination percentage (cedar 73 percent, hemlock 65 percent, western white pine 44 percent, and grand fir 12 percent) (15). In greenhouse germination tests where a favorable degree of moisture was maintained, Fisher (8) found no differences in germination between ash, duff, mineral soil, and rotten wood surfaces. Under natural conditions, germination is much more favorable on burned and unburned mineral surfaces than upon duff. Rapid drying of the duff and the small size of cedar seeds probably account for the poor germination on this medium (15).

Although seed production of western redcedar is prodigious, rodent depredations of the seeds minor, and germination percentage excellent under most conditions, still a very small proportion of the seeds develops into established seedlings. Reports of first-year seedling mortality vary from 44 percent in a seed-tree cutting (15) to 97 percent under a dense cedar overwood (40). In the same seed-tree cutting, the 6-year mortality was 74 percent.

It is believed that biotic agents (principally fungi) cause the greatest early mortality. Activities of these various agents are extremely variable. Haig (15) reports early first season losses of as much as 47 percent from fungi, birds, and insects. The biotic agents of mortality are active only during the early part of the growing season. After seedlings start to harden, these agents of mortality give way to the physical agents of insolation and drought. In full sunlight few of the relatively succulent cedar seedlings

can survive the scorching temperatures at the soil surface, and those which do soon die in a futile race to reach the receding soil moisture. Seedlings survive best under partial shade where there is sufficient sunlight and warmth for vigorous top and root growth. In full shade the seedlings make very poor top and root growth and soon die of drought because the necessary soil moisture is out of reach of the poorly developed root system. Only western hemlock has poorer seedling root penetration than cedar among the associated species in the northern Rockies (15).

Other factors being equal, seedling survival for the first 5 years is usually best on natural mineral soil, intermediate on duff, and poorest on rotten wood. Soil moisture again is the key to good early survival (15).

Another cause of mortality that may be important on cutover areas is smothering by the fallen leaves of deciduous shrubs. This is a primary cause of low survival on areas seeded directly to western redcedar (31).

SAPLING STAGE TO MATURITY

Growth and Yield.--Compared to most of its associates, western redcedar is a slow growing species. In the Puget Sound region under optimum conditions its average annual diameter growth is only 0.25 inch and its average annual height growth is only 1.58 feet during its first 50 years. By comparison, Douglas-fir adds 0.31 inch to its diameter and 2.04 feet to its height annually. Western hemlock is intermediate in its growth rates (22).

In young thrifty stands in the Puget Sound area, periodic annual diameter growth varies from a peak of 0.34 inch in the third decade to 0.20 inch in the seventh decade. Height growth was maximum at 2.3 feet annually in the second decade and declined to 0.61 foot in the seventh decade. At 80 years, the average diameter was 19 inches, height 101 feet, and volume 57 cubic feet, or 298 board feet per tree. Periodic annual volume growth had increased from 4.9 board feet per tree during the fifth decade to 6.4 feet per tree in the seventh (22).

In a typical mature stand that had grown under partial suppression, diameter growth was nearly uniform (varying from 0.12 to 0.18 inch per year) for nearly 200 years. Height growth was most rapid before the 30th year but was also steadily sustained for 200 years ranging from 1.0 to 0.53 foot per year. The average diameter at 80 years was 9.35 inches and the average height 63.3 feet. Volumes at 80 years were 11.5 cubic feet and 55 board feet per tree. Periodic annual board-foot growth per tree was 1.8. At 200 years the average diameter was 29.3 inches, height 131.1 feet, volumes 152 cubic and 850 board feet per tree. Annual growth was 11.0 board feet per tree (22).

An overmature western redcedar stand, Kaniksu National Forest, Idaho.

Thus, although suppressed stands of cedar do not grow nearly as rapidly as vigorous, free-growing stands, their growth is quite uniform and well sustained for at least two centuries. Generally, maximum diameter and height growth occur during the first 30 years; by that time other species have gained the lead and hold cedar in an intermediate position for many years (22).

Growth rate, sizes attained, and yield vary greatly from the best development attained in the Pacific region to the small-sized trees produced in the Rocky Mountain region. Under the most favorable growing conditions in the Puget Sound area cedar reaches enormous size: heights in excess of 200 feet, and diameters up to 16 feet (38). In the northern Rockies the larger trees are 175 feet high and 8 feet in diameter (26).

Since western redcedar usually grows in mixture with other species, separate yield tables are not available. Estimated yields in some of the best northern Idaho stands are from 25,000 to 30,000 board feet per acre. Pure stands of limited extent may yield from 60,000 to 70,000 board feet per acre (26). Stands in the western white pine type that contain cedar and hemlock generally have smaller yields than do stands in which these species are not abundant (14).

Cedar is classed as a very tolerant tree and, in fact, it germinates, grows, and even reaches maturity in the shade. Its growth is retarded in proportion to the density of the shade, however; and when competition is removed, cedar responds well to the increase in growing space. Apparently in some localities it does not fill all of the requirements of a tolerant species, however. Recent reports from British Columbia (30) describe mature commercial stands that have a notable absence of the younger diameter classes of cedar associated with abundant regeneration of western hemlock and white fir. Only in open-grown, noncommercial stands of the "cedar scrub" was there a distribution of diameter classes typical of tolerant species. This lack of advanced reproduction under heavy shade is attributed to germination failures or seedling mortality rather than to the lack of ability of the species to survive under competition. Similar conditions have been reported in southeastern Alaska, where germination appears to be adequate but seedlings fail to survive (13).

INJURIOUS AGENCIES

Fire.--Redcedar has few important natural enemies other than fire. Its thin, fibrous bark and shallow roots make it an easy victim of fire (22, 26). In old stands fire burns out the hollow boles and leaves the tree little support. Reproduction is easily destroyed by surface fires. Studies in the coastal forests have shown that cedar is more severely damaged by surface fires than any of its associates. However, cedar grows chiefly on moist sites and is therefore less subject to fire damage than some associates. In Inland Empire stands, its relative fire resistance is rated as low-medium; Engelmann spruce, western hemlock, and alpine fir are more susceptible and in that order. The hot fires common in this region generally erase all evidence of differences in fire resistance between species except that western larch and Douglas-fir seem to have somewhat better survival than others (9).

Wind.--On the drier sites where good root anchorage is established, cedar withstands destructive winds quite well. On very wet soils, the shallow root system and poor anchorage make it more subject to windthrow (22). Tentative ratings of the windfirmness of Inland Empire species by Marshall (25) place redcedar fourth, exceeded by western larch, ponderosa pine, and Douglas-fir.

Snow.--Since much of the range of western redcedar lies within the area of heavy snowfall, some snow damage occurs. No data have been published on the importance of snow-caused mortality and damage in cedar. Snow is the outstanding cause of mortality in dense, immature stands of the western white pine type where cedar is an important component (15). However, cedar with its drooping conical crown may shed snow more readily and be less liable to direct snow damage than its associates.

Insects.--Cedar has few insect enemies and suffers little from insect damage (22). The western cedar borer (Trachykele blondeli) mines into the sapwood and heartwood of living, dying, and dead cedar. A round-headed borer, the amethyst cedar borer (Samanotus amethystinus), occasionally kills healthy trees, but usually limits its attacks to injured or dying trees.

Its range is limited to the coastal cedar forests. The western cedar bark beetle (Phloeosinus punctatus), a widespread species, attacks trunks and larger limbs and has been known to kill trees. Other less destructive insects that may occasionally cause noticeable damage are the hemlock looper (Lambdina fiscellaria lugubrosa), various cedar twig and leaf miners of the genera Gnathotrichus and Trypodendron, and various bark beetles of the genus Phloeosinus (20).

Diseases.--Cedar is not plagued by fungi to the extent that its associates are, but losses can strongly influence management. Buckland's studies (3) in British Columbia have shown that decay in stands 50 to 450 years old does not exceed growth increment but that decay in younger stands was more important than previous reports had indicated. He lists the following species of fungi, in order of decreasing importance, for the coastal areas: Poria asiatica, P. albipellucida, Fomes pini, Merulius sp., and P. subacida. In the interior, where losses from decay and incidence of infection are appreciably higher, species are as follows: Poria asiatica, P. weirii, Fomes pini, Polyporous balsameus, Merulius sp., and Poria subacida. Other extensive but less important fungi attacking the heartwood of living trees are Fomes annosus, F. nigrolimitatus, F. pinicola, Armillaria mellea, Omphalia campanella, Polyporus schweinitzii, and Coniophora arebella. Throughout the range of cedar the yellow ring rot caused by Poria weirii is probably the most serious (16). Cedar needle spot (Keithia thujina) sometimes reaches epidemic proportions in attacking seedlings and young trees. It often attacks older trees but such attacks are not as serious as those on younger trees. As much as 97 percent of western redcedar reproduction has been reported killed in its first season by this disease. It is apparently favored by high humidity and may be fostered by late spring snow cover (16, 29, 40).

Winter damage to young cedar trees can reach serious proportions. Particularly heavy damage to cedar has been reported when severe cold waves followed mild autumn weather (7).

Of greater silvical importance than the diseases and insect enemies of western redcedar itself are the enemies of its associates. Most of its arboreal companions are much more prone to insect and pathological attacks than is cedar--a factor that tends to hasten the succession of cedar to climax position.

RACES AND HYBRIDS

Tests of western redcedar from several sources in the United States and Canada have demonstrated wide variations in frost hardiness, indicative of definite racial variation in the species. Trees grown from inland seed sources were hardier than those from coastal areas (39).

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