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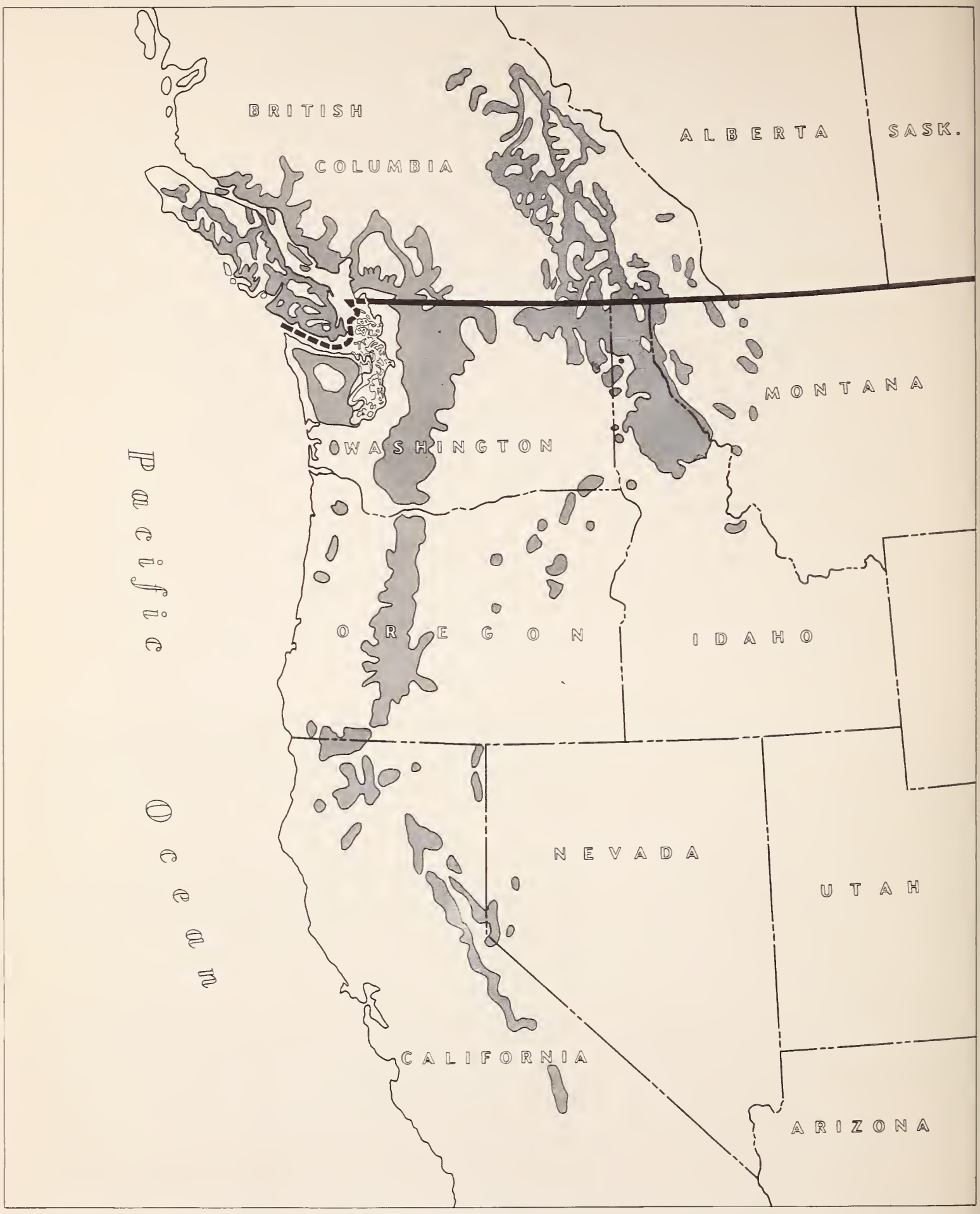

Botanical range of western white pine.

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SILVICS OF WESTERN WHITE PINE

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SILVICS OF WESTERN WHITE PINE

By

Charles A. Wellner [1/]

Western white pine (Pinus monticola), the state tree of Idaho, is frequently called "Idaho white pine" or just "white pine" and occasionally "silver pine" or "mountain Weymouth pine" (13, 59, 86). [2/]

DISTRIBUTION

Western white pine grows along west coast mountain ranges from Vancouver Island and the Homathko River on the adjacent mainland in British Columbia southward to the San Bernardino Mountains of southern California (13, 65, 75, 83). In the interior its range is from Quesnel Lake through the Selkirk Mountains of British Columbia southward into northern Idaho, western Montana, and northeastern Washington and also into the Blue Mountains of southeastern Washington and northeastern Oregon (13, 52, 65, 75, 83). The species attains its greatest size and reaches its best stand and commercial development in northern Idaho and adjacent sections of Montana, Washington, and British Columbia (1, 48).

HABITAT CONDITIONS

CLIMATIC

Western white pine is restricted in its range to the Pacific Coast type of climate and the eastward extension of that type, termed the sub-Pacific type (51), into the northern Rocky Mountains. These climatic types are marked by a predominance of winter precipitation (17).

In the region of most abundant occurrence of western white pine, the Inland Empire, which includes northern Idaho and adjacent parts of eastern Washington, western Montana, and southern British Columbia, the climate is characterized by a short summer season of scanty precipitation and low humidities with a high percentage of clear, warm, sunny days, and winters with heavy snowfall and fairly low temperatures (41).

Annual precipitation ranges from 28 to 60 inches; it increases markedly with elevation, as might be expected. Precipitation is distributed seasonally as follows:

1/ Research Forester, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agr., Ogden, Utah.

2/ Underlined numbers in parentheses refer to Literature Cited.

35 percent, winter; 24 percent, spring; 14 percent, summer; and 27 percent, fall. Growing season (May through August) precipitation varies from 5 to somewhat more than 7 inches. Snowfall averages 103 inches but ranges from 48 to 244 inches.

Average annual temperatures range from 40° to 50°F. Average July temperatures vary from 62° to 72°F. Extremes in temperature range from a low of −36° to a high of 107°F. Average growing season temperatures range from 57° to 66°F. Average length of the frost-free season is very short; it ranges commonly from 60 to 160 days, and is very irregular from year to year and from place to place.

White pine occurs over a very broad range of climate on Vancouver Island. It is found on the west coast of this island in localities where the annual precipitation is 110 inches and the frost-free period is 227 days. It also occurs at 5,000 feet elevation, where the frost-free period probably is less than 100 days.3/

Annual precipitation over most of the botanical range of western white pine is probably somewhat similar to that given above for its region of abundant occurrence.

The western white pine type in the Inland Empire appears to be limited at the lower elevations by deficient moisture and at the upper elevations by a summer heat deficiency (16, 24, 55). The environmental factors that determine upper and lower limits probably operate through control over germination and survival (23). The southern boundary of the type in the Inland Empire is not fixed by insufficient precipitation alone but by the balance of precipitation and evaporation (41).

EDAPHIC

Western white pine grows on a great variety of soils and exhibits little preference for soils of any particular parent material. In the Inland Empire it occurs on shallow to deep soils whose surface layers are composed of loess or loessiallike material. Underlying the surface layers, the soil profile is derived from decomposed granite, schist, quartzite, argillite, sandstones, and shales often very rocky in character; decomposed basalt, glacial deposits, alluvial and lacustrine deposits (30).

The origin or kind of soil may not be critically important to the growth of western white pine, but the amount of available soil moisture is of utmost importance. Growth of western white pine is best on deep, well-drained, medium- to fine-textured soils of high water-holding capacity (13, 14, 15). However, in western Washington white pine is reported to outgrow Douglas-fir (Pseudotsuga menziesii var. menziesii) and western hemlock (Tsuga heterophylla) where soils are poor and unfavorable to these species (2).

3/ Communication from R. L. Schmidt, British Columbia Forest Service.

Soils of the Inland Empire on which white pine grows are slightly to moderately acid; the range of pH is from about 4.3 to 7.0 (20). Moisture equivalents in the surface 4 inches of these soils have been found to vary between 18 and 63 percent, and at the 16- to 20-inch layer, from 7 to 40 percent[4/] (20). Moisture at the wilting point in white pine soils varies from 1 percent in extremely coarse-textured soils to 20 percent in fine-textured soils, particularly those that contain considerable organic matter.[5/]

Nitrogen content of the upper A horizon of white pine soils in the Inland Empire has been found to be about normal when compared with similar forest soils, but the organic carbon content is below normal (29).

PHYSIOGRAPHIC

Western white pine grows in characteristically mountainous country. In the northern extremity of its range on the British Columbia coast white pine extends from sea level to elevations seldom exceeding 2,500 feet (13). On Vancouver Island, white pine is frequently found as high as 4,000 feet and occasionally has been found at 5,000 feet.[6/] In the northern Cascades of Washington, white pine grows from near sea level on Puget Sound up to about 3,000 feet; farther south on the west side it grows from 2,000 to 6,000 feet, and on the east side, from 1,150 to 4,700 feet (83). In the Olympics, white pine is found from near sea level up to 1,800 feet (83). In western Oregon, white pine grows on both sides of the Cascades from 3,000 to 6,000 feet in the north and 5,000 to 7,500 feet in the south. White pine occurs in coast ranges on Iron Mountain and Rusty Butte. In the northern Sierras of California this species occurs generally at 6,000 to 7,500 feet (83). In southern California on the San Bernardino Mountains it is found at 10,000 feet, in the San Jacinto Mountains at 8,900 to 9,500 feet, and on Tahquitz Peak at 8,600 feet (83). At its northern limit in the interior of British Columbia white pine seldom grows above 3,500 feet (13), but farther southward in British Columbia it is found at 1,100 to 4,500 feet.

In northern Idaho and contiguous portions of Washington, Montana, and British Columbia, western white pine usually grows between 2,000 and 6,000 feet (41). Here the topography usually is steep and broken, and white pine occurs largely in irregular, often attenuated bodies following the more moist creek bottoms, lower benches and flats, and northerly slopes. The more extensive bodies of western white pine and the best stands are found in the wide river bottoms, less steep lower slopes, and in the more gently rolling country of the Priest, Coeur d'Alene, St. Joe, and Clearwater River basins.

4/ Copeland, Otis L., Jr., and Leaphart, Charles D. "Office report, a study of root and soil conditions in relation to the pole blight disease of western white pine." Unpublished report on file at Intermountain Forest and Range Experiment Station. 1955.

5/ Ibid.

6/ Communication from R. L. Schmidt, British Columbia Forest Service.

BIOTIC

Western white pine grows predominantly in the Canadian life zone as defined by Piper (69) and also extends into his Hudsonian zone. A more critical delineation of its range in the northern Rocky Mountains is provided by the vegetation zones of Daubenmire (18, 20, 21). It occurs as a seral species in the Engelmann spruce (Picea engelmannii)-subalpine fir (Abies lasiocarpa), and the western redcedar (Thuja plicata)-western hemlock vegetation zones (20).

Western white pine is represented in 17 cover types of western North America (78). It is a key indicator species in only one cover type, the western white pine type of the Inland Empire. In this type it may make up only a small part of the stand, sharing composition with such tree species as western larch (Larix occidentalis), Douglas-fir (Pseudotsuga menziesii var. glauca), grand fir (Abies grandis), western hemlock, western redcedar, Engelmann spruce, lodgepole pine (Pinus contorta), ponderosa pine (P. ponderosa), subalpine fir, mountain hemlock (Tsuga mertensiana), quaking aspen (Populus tremuloides), northwestern paper birch (Betula papyrifera var. subcordata), black cottonwood (Populus trichocarpa), whitebark pine (Pinus albicaulis), and Pacific yew (Taxus brevifolia); or it may occur occasionally in nearly pure stands. Usually in this type white pine constitutes about half the stand by volume (41).

In the 16 other cover types in which western white pine occurs, always as a seral species, it is present as a scattered tree, either singly or in small groups, and stands in which it predominates are local and rare (78). These 16 cover types are: Engelmann Spruce--Subalpine Fir, Red Fir (Abies magnifica), Interior Douglas-Fir, Larch--Douglas-Fir, Grand Fir--Larch--Douglas-Fir, Ponderosa Pine--Larch--Douglas-Fir, Lodgepole Pine, Western Hemlock, Pacific Silver Fir (Abies amabilis)--Hemlock, Western Redcedar--Western Hemlock, Western Redcedar, Pacific Douglas-Fir, Douglas-Fir--Western Hemlock, Port Orford Cedar (Chamaecyparis lawsoniana)--Douglas-Fir, Interior Ponderosa Pine, and Jeffrey Pine (Pinus jeffreyi).

Floristic richness is a characteristic of the forest types in which western white pine grows. The more common associated shrub species in the Inland Empire are (20, 45, 55, 64)[7/]: Douglas maple (Acer glabrum var. douglasii), Sitka alder (Alnus sinuata), thinleaf alder (A. tenuifolia), Saskatoon serviceberry (Amelanchier alnifolia), bearberry (Arctostaphylos uva-ursi), water birch (Betula fontinalis), redstem ceanothus (Ceanothus sanguineus), snowbrush ceanothus (C. velutinus), bunchberry dogwood (Cornus canadensis), redosier dogwood (C. stolonifera), Oregon wintergreen (Gaultheria ovatifolia), creambush rockspirea (Holodiscus discolor), western trumpet honeysuckle (Lonicera ciliosa), bearberry

7/ Unpublished records from permanent sample plots, Intermountain Forest and Range Experiment Station.

honeysuckle (L. involucrata), Utah honeysuckle (L. utahensis), Oregongrape (Mahonia aquifolium), creeping mahonia (M. repens), rusty menziesia (Menziesia ferruginea), American devilsclub (Oplopanax horridus), myrtle pachistima (Pachistima myrsinites), mallow ninebark (Physocarpus malvaceus), whitestem gooseberry (Ribes inerme), prickly currant (R. lacustre), western black currant (R. petiolare), sticky currant (R. viscosissimum), baldhip rose (Rosa gymnocarpa), Spalding rose (R. spaldingi), western red raspberry (Rubus idaeus aculeatissimus), western thimbleberry (R. parviflorus), Barclay willow (Salix barclayi), Bebb willow (S. bebbiana), Scouler willow (S. scouleriana), Sitka willow (S. sitchensis), blueberry elder (Sambucus cerulea), blackbead elder (S. melanocarpa), Greenes mountainash (Sorbus scopulina), birchleaf spirea (Spiraea betulifolia), subalpine spirea (S. densiflora), shinyleaf spirea (S. lucida), common snowberry (Symphoricarpos albus), big whortleberry (Vaccinium membranaceum).

LIFE HISTORY

The following phenological occurrences are for white pine in the Inland Empire (8, 19)[8/]: Diameter growth begins about May 1, and leader growth usually begins during the first week in May. Leaf buds usually open between May 15 and the first week in June. Leader growth stops between mid-July and the first week in August. Diameter growth essentially ends about the last of August. Old needles usually turn a straw yellow between the middle of August and the first week in September and drop soon thereafter. Needle retention is usually for 3 to 4 years.

SEEDING HABITS

Flowering and fruiting.--Western white pine flower buds are formed during July and August but are not discernible until the following spring. The time when staminate and pistillate strobili are first apparent varies with the geographic and altitudinal distribution of the species. In northern Idaho staminate strobili, oval, about one-third of an inch long (74), and borne in clusters of 15 to 25 on branches of the middle crown, are distinguishable about June 1. Here pollen dissemination begins the last week in June and ends about the middle of July. Time of flowering between years may vary as much as 3 weeks and is strongly associated with spring temperatures (8). Within individual trees and within localities, maxima of pollen shedding and ovulate flowering are practically coincident. No phenological barriers to either selfing or crossing appear to exist (8). Most western white pines are self-compatible and self-fertile (7). However, under natural pollination, crossing appears to exceed selfing (80). Pistillate strobili, greenish yellow to bright pink on stalks at the tips of the upper branches, are first visible about mid-June. The erect conelets are from 1/2 to 1-1/2 inches long at the time of pollen dissemination, and they grow to 1 to 2 inches by the end of the first growing season. The cones,

8/ Unpublished records, Intermountain Forest and Range Experiment Station.

nearly all produced in the highest quarter of the crown (41), become pendulous and are a green to red-brown to dark purple in the second summer. They reach mature size, from 2 to 13 inches long (75, 79, 99) in mid-August of the second year. The cones at maturity turn a light brown, and the seeds are ripe from about the end of August to the middle of September.

Seed production.--The number of sound seeds per cone is variable. One study (99) counted from 6 to 184 seeds per cone with an average of about 90 seeds; another study,[9/] from 80 to 220, with an average of about 145; and a third study (79), from 2 to 234, with an average of 92.

In comparison with its associated species, western white pine bears relatively few cones. A crop of 40 cones is rated good; one of 100 cones per tree is infrequent (41). The greatest recorded number of cones observed on one western white pine tree was about 850 on a 55-inch, 400-year-old veteran on the Priest River Experimental Forest in northern Idaho.

Cone production of western white pine in the Inland Empire has been observed to begin as early as at 10 years of age (67); however, such young trees bear cones infrequently and then only two or three cones per tree. Several 7- to 8-year-old western white pine trees on the Kitsap Peninsula west of Puget Sound were observed bearing cones.[10/] Western white pines at Placerville, California, have borne ovulate flowers at 7 years of age (73). Cone production increases as trees become older until by the age of 40 years seed production is fairly abundant, and at 70 years of age seed production is both frequent and abundant (41). It continues to increase with age until trees are about 20 inches in diameter; after that, seed production appears to have little relation to age or diameter but depends on individual tree vigor and character of crown (41) or possibly on heritable capacity to set and bear cones.

Most western white pine seed is borne by vigorous dominant or codominant trees. Good-vigor trees become effective seed producers at diameters of about 14 inches and may bear seven times as many cones as poor-vigor trees, which are ineffective seed producers at any diameter (41).

Cones are borne by western white pine at irregular intervals. In stands, complete cone-crop failures are rare; some cones are produced almost every year, but the quantity produced varies markedly from year to year. Good cone crops occur every third to fourth year; however, the productivity of individual areas departs widely from this average (41).

9/ Brewster, D. R. Memorandum and curves on western white pine seed production study. Northern Rocky Mountain Forest and Range Experiment Station. 1916.

10/ Communication from R. T. Bingham, U.S. Forest Service.

Yield of germinable seed in fully stocked stands varies considerably. One study (99) in northern Idaho found yields from 16,500 to 184,800 seeds per acre. More extensive studies (41) gave average annual yields per acre of about 40,000 seeds in an old overmature stand and 3,500 seeds in a 75-year-old stand.

A bushel of western white pine cones will produce about 12 ounces of cleaned seed. The number of seeds per pound varies from a low of 14,000 to a high of 32,000 and averages 27,000 (87).

Amounts of western white pine seed available for regeneration are reduced seriously by insects and small rodents. The cone beetles, Conophthorus monticolae and C. lambertianae, and cone moths, Dioryctria abietella and Eucosma rescissoriana, cause serious seed losses in some years (5, 50). Western white pine seeds are a favorite food of tree squirrels (Tamiasciurus hudsonicus richardsoni) which cut, gather, and cache the cones. However, squirrel caches are the principal source of cones for collectors of western white pine seed for artificial regeneration.

Seed dissemination.--Seed dissemination begins in late August or early September. About 15 percent of western white pine seed reaches the ground before September 1, and 85 percent by the end of October (41).

Wind is the major disseminator of western white pine seed; squirrels, mice (especially the white-footed mouse, Peromyscus maniculatus artimiside), and various birds play a very minor role in dissemination. Occasionally mice caches of seed germinate and come up in dense clumps.

White pine seed usually is disseminated within a short distance from the parent tree. Records show that seed sufficient to produce adequate reproduction is distributed not farther than 400 feet from the parent tree (41). In some observed instances white pine seed has been disseminated for distances of half a mile or more, but not in quantities sufficient to be relied upon for adequate natural regeneration. Some white pine seed traveled as far as 2,600 feet when released at an elevation of 200 feet in a 13-mile-per-hour wind (49).

Seed storage.--Seed of western white pine is stored naturally in the duff when it falls from the parent tree (41, 44). Tests have shown that about 40 percent of the seeds are viable after one winter's storage and about 25 percent after two winters' storage (41). Slightly less than 1 percent retain viability after 3 or 4 years' storage, and only an occasional seed remains viable after 6 years (41). However, western white pine retains a high level of viability for longer periods when stored carefully under artificial conditions. Two seed lots stored for 15 and 16 years in 5-gallon cans with tight lids at 41°F. had viability of 35 and 40 percent, respectively (77).

VEGETATIVE REPRODUCTION

Western white pine does not naturally reproduce itself by sprouting or layering. In fact, western white pine cuttings are extremely difficult to root. In one test (9) involving more than 8,000 trials, only two cuttings rooted, and both of these were from trees less than 5 years old. Limited success was attained at Montana State University in rooting western white pine cuttings from trees less than 15 years old.[11/] The only instance of success in rooting cuttings from older trees was a trial (27) that gave 6-percent success with untreated cuttings from a 56-year-old vigorous tree.

Western white pine can be grafted readily on rootstocks of the same species (9, 71). Successful unions have been made of western white pine scions on stocks of ponderosa pine, lodgepole pine, lodgepole pine X jack pine (Pinus banksiana) (hybrid), Douglas-fir, and Engelmann spruce (6). However, none of these grafts survived more than 2 years. Western white pine scions were grafted successfully on sugar pine (Pinus lambertiana) rootstocks at Placerville, California,[12/] and on eastern white pine (Pinus strobus) and hybrid (western white pine X eastern white pine) rootstocks in northern Idaho.[13/]

GERMINATION

Seed of western white pine exhibits dormancy (54, 87, 88, 89) which is normally overcome by stratification at 32° to 40° F. for about 90 days (87). This period is inadequate for seed from young trees; a stratification period of 120 days has been found to be better for such seed.[14/] Western white pine seed normally germinates in the spring in soil wet to field capacity by melting snow (41). In northern Idaho germination begins in late April or early May on exposed sites but is a month or more later at higher elevations and on protected sites such as north slopes where snow lingers late (41). It is practically completed by July 1 on exposed sites and by August 15 on protected sites (41). Soil temperatures probably control the beginning of germination (41, 53), and drying out of the topsoil or duff probably stops germination (41). Light appears to have little importance in natural germination of western white pine seed (41). Appreciable percentages of western white pine seed stored in the duff germinate in the shade of dense young to overmature stands (38, 40). Germination is markedly affected by the character of the surface-soil material. Mineral surfaces, burnt or unburnt, are better than duff surfaces (40, 41). Under greenhouse conditions, however, where a favorable degree of moisture was maintained, germination was the same on ash, duff, mineral, and rotten-wood surfaces (31).

11/ Communication from the late C. W. Waters, Montana State University, Missoula.

12/ Communication from J. W. Duffield, Greeley Nursery, Olympia, Wash.

13/ Communication from R. T. Bingham and A. E. Squillace, U.S. Forest Service.

14/ Ibid.

The germinative capacity of western white pine seed averages about 48 percent, with a low of zero percent and a high of 95 percent (53, 66, 87).

Western white pine can be successfully spot sown on freshly burned north-facing slopes and flats within the western white pine type where protection from rodents is provided (76).

SEEDLING DEVELOPMENT

Establishment.--A high percentage of seedlings dies in the first season. In a study of 15 cutover areas in northern Idaho, 43 percent of white pine seedlings died in the first year after germination, 7 in the second year, 5 in the third, 5 in the fourth, 3 in the fifth, and 2 in the sixth, or a total of 65 percent during the first 6 years after germination. Studies of mortality during the critical first year indicate that early season losses are due principally to biotic agents. Of these, damping-off fungi are the most important. Insects, rodents, and birds sometimes cause serious seedling losses (40, 41).

As the season advances and the soil begins to dry, biotic losses largely cease, and mortality thereafter is due principally to physical agents. Insolation, causing high surface soil temperatures, is the most important agent of mortality on exposed sites. Temperatures are highest on duff; hence this surface is especially hazardous on the more exposed sites (40, 41).

White pine seedling mortality from drought is most acute on heavily shaded areas where root penetration is slow and unable to keep pace with receding soil moisture (40, 41).

Frost heaving and winter killing also take a heavy toll of young seedlings unprotected by snow cover.

All factors considered, seedling establishment of western white pine is favored by partial shade on severe to moderately severe sites. On the more sheltered sites, such as north slopes, light shade to no shade is best for seedling establishment (41).

Regeneration methods silviculturally favorable to seedling establishment of western white pine include clear-cutting, seed-tree cutting, and shelterwood cutting (41).

Once well established, western white pine grows best on all sites in full sunlight (41). Shade of any amount favors its more tolerant associates.

Early growth.--Early root and shoot growth of western white pine seedlings is not very rapid. The primary root grows during the first summer about 6 to 12

inches in open situations, between 5 and 9 inches under partial shade, and only 2 or 3 inches under full shade (40). Seedlings usually average between 1 and 2 inches in height by the end of the first growing season. Dominant white pine seedlings growing in the open require about 8 years to reach a height of 4.5 feet on excellent sites and about 16 years on poor sites.

Once established, western white pine trees increase rapidly in height growth. By the time trees are 20 years old they grow in height at a rate of 2 to 3 feet a year on excellent sites and from 3/4 to 1-1/2 feet on poor sites.

The period between establishment and about 30 years of age is critical in the life of stands of the western white pine type. During this period, dominance and composition of the stand are determined; they persist naturally to maturity. Also, during this early period weeding and pruning can greatly improve both quantity and quality of western white pine growth (12, 26, 42, 43, 47, 94).

SAPLING STAGE TO MATURITY

Growth and development.--Several factors, in addition to those already described, affect the growth and development of western white pine between establishment and maturity. Fire, disease, insects, wind, snow, drought, sudden drops in temperature, suppression, and animals--all may have some effect on western white pine stands (25, 41, 57, 92).

Fire has left its mark at some time or other on practically every acre of western white pine forests (41). Western white pine is a fire species and owes its very existence to catastrophes, mainly fires, which have destroyed stands and allowed white pine to become established again (41). Among its associates western white pine is rated intermediate in fire resistance (32).

The most serious disease of western white pine is white pine blister rust, caused by the fungus Cronartium ribicola. This introduced disease seriously affects the management of the species and is increasingly limiting its distribution. However, blister rust can be controlled (11, 60, 63, 64) and research is well along in developing a blister rust resistant western white pine (10).

White pine pole blight also has made serious inroads into white pine stands more than 30 years of age (36, 37, 56, 58, 70). The cause and control of this disease are unknown. At present pole blight does not seem to be spreading to new stands and has run its course in many affected stands.

In stands between 30 and 100 years of age free of blister rust and pole blight, the principal causes of mortality are wind and snow, suppression, insects, and disease (92). These agents of mortality operate in an erratic manner and thus cause the growth pattern for any particular stand to be irregular (90, 91, 92).

Other common diseases of western white pine are those causing root and heartwood rots. Of the fungi causing root rot, the honey mushroom fungus Armillaria mellea is the most important (62); the feather-rot fungus Poria subacida and the pine root fungus Fomes annosus also cause serious damage (46). Western white pine in western Washington is reported to be resistant to Poria weirii in areas where Douglas-fir has succumbed to this root rot (2). Major causes of heartwood rot are the ring scale fungus Fomes pini and the velvet top fungus Polyporus schweinitzii. In western white pine, quantity of rot almost invariably increases with age. Average cull in the Inland Empire, measured in board feet, is about 3 percent in western white pine stands 81 to 100 years old and about 20 percent in stands 181 to 200 years old (3).

Although western white pine is attacked by many insects (50), the mountain pine beetle (Dendroctonus monticolae) gives primary concern (41). Young thrifty trees are fairly immune, but in older stands this beetle exacts an annual toll, sometimes trifling but at other times very severe (28, 41).

Animals usually do not seriously damage white pine. Porcupines (Erethizon epixanthum) and tree squirrels occasionally cause barking and girdling. Bear clawing is a frequent and widespread cause of basal scarring of western white pine trees (62). Moderate sheep grazing may be beneficial to white pine reproduction (98).

Growth rates.--Fully stocked stands of the western white pine type in the Inland Empire grow at the following rates (39):

Mean annual net increment per acre

Age	Cubic feet 1/ by site index 2/			Scribner board feet 3/ by site index		
	40	60	80	40	60	80
20	12	20	27	0	0	0
40	47	66	85	1	42	155
60	70	98	127	48	218	495
80	81	112	147	141	410	728
100	84	118	154	226	535	825
120	83	116	151	276	572	828
140	79	110	142	281	554	--

1/ In trees 0.6 inch d.b.h. and larger.

2/ Based on height at 50 years.

3/ In trees 7.6 inches d.b.h. and larger.

Tree size at maturity.--Western white pine trees growing in fully stocked stands in the Inland Empire attain the following sizes at maturity, 120 years, and the stands in which they grow produce the following net volumes at this age (39):

Site index 1/	Average dominant and codominant tree			Net volume per acre	
	D.b.h.	Height	Cubic volume	Cubic	Scribner
	Inches	Feet	Cu.ft.	Cu.ft. 2/	Bd.ft. 3/
40	11.6	88	27.5	9,980	33,100
60	16.5	132	77.0	13,950	68,700
80	22.4	175	171.7	18,100	99,400

1/ Based on height at 50 years.
2/ In trees 0.6 inch d.b.h. and larger.
3/ In trees 7.6 inches d.b.h. and larger.

Older trees have greater diameter and height than the 120-year-old trees reported above. A white pine 84 inches d.b.h. was reported in 1933 growing in the Clearwater River region of northern Idaho (68). A white pine logged in the Kaniksu National Forest of Idaho yielded fifteen 16-foot logs (68). The present record white pine tree also growing in the Clearwater River region is 81 inches d.b.h. and 219 feet tall (1).

Western white pine is long lived. Large white pines are often 300 to 400 years old, and occasional trees are 400 to 500 years old. The oldest white pine on record is in British Columbia; it measures 54 inches d.b.h. and is 615 years old.15/

Relative tolerance.--Western white pine usually is rated as intermediate in tolerance when compared with its associates (4, 41). It is more tolerant than western larch and lodgepole pine, about equal in tolerance to the interior variety of Douglas-fir, and less tolerant than Engelmann spruce, grand fir, western hemlock, and western redcedar (41). Because western white pine always grows in association with more tolerant species, it is always a subclimax species (20, 41).

Response to release.--Western white pine reproduction can become established under canopies that permit only 30 to 40 percent of full sunlight to penetrate beneath, and will persist for many years. However, growth under these conditions is slow and less than that of some of its more tolerant associates. These tolerant

15/ Communication from E. H. Garman, British Columbia Forest Service.

species will eventually overtop white pine under shade conditions, and finally by suppression will eliminate it from the reproduction stand. If the overwood shade is removed before white pine is thus suppressed, it responds immediately to release and grows rapidly in height (94, 97).

White pine is only intermediate in response to thinning (33, 34, 35) because of its slowness in developing new crown and roots following release. It shows greater diameter growth response to thinning than such less tolerant associates as western larch and lodgepole pine, but it gives much less response than the more tolerant grand fir, western hemlock, or western redcedar. In mature stands, diameter growth of white pine following cutting largely depends on tree vigor (95, 96). Excellent and good-vigor trees show good diameter growth response to release by cutting; fair-vigor trees show slight response; and poor-vigor trees little or no response.

Expression of dominance.--Western white pine readily expresses dominance. This is partly due to the usual mixture of species in white pine stands and also to the characteristics of the species itself, for even in pure white pine stands dominance is usually well expressed. Dominance and composition usually are expressed in stands of the western white pine type by 30 years of age and change slightly thereafter until maturity unless molded by cultural measures (93).

Western white pine does not prune itself well, even in dense stands (72).

RACIAL VARIATION

Races of western white pine have not received detailed study. It is reasonable to believe that races do occur in view of the wide and discontinuous distribution of the species. Varieties have been distinguished (74, 84) by color and shape and size of cones. According to Sudworth (84), "In 1888 and 1895 Dr. J. G. Lemmon distinguished two varieties of the western white pine, Pinus monticola minima and P. monticola digitata, based on differences he recognized in the form and size of the cones. A purple-coned form of western white pine cultivated in England was described in 1866 as Pinus porphyrocarpa A. Murray, and later, in 1892, as Pinus monticola variety porphyrocarpa Masters. In the writer's judgment, none of these forms are worthy of specific or varietal distinction." Races have been recognized also on the basis of seed weight; i.e., seed from California is heavier than that from Washington, which in turn runs heavier than that from northern Idaho (87). However, recognition of races on this basis is questioned in view of the wide variation in weight of western white pine seed within a given locality. Recent evidences (81) indicate local ecotypic variation.

SPECIAL FEATURES

NUTRIENT CONTENT OF LEAF LITTER

In one study (85) annual litter fall for western white pine, ovendry weight, was 1,205 pounds per acre. Foliage nutrient content for this species, as a percentage of ovendry weight, was: nitrogen 0.76, phosphorus 0.12, potassium 0.30, calcium 0.62, and magnesium 0.08. Nutrient content of freshly fallen white pine foliage collected in September or October in the northern Rockies was found to be as follows when expressed as a percentage of ovendry weight: nitrogen 0.54, phosphorus 0.07, potassium 0.22, calcium 0.74 (22).

PHYSICAL AND CHEMICAL COMPOSITION OF TURPENTINE

The following physical characteristics of western white pine turpentine have been reported (61):

Sample location	Density	Index of refraction	Specific rotation	Yield of turpentine
			Degrees	Percent
NE California	$.8691\frac{20}{20}$	1.4646^{23}	+20.6	18
Northern Idaho	$.8500\frac{23}{4}$	1.4687^{23}	-28.8	18-20

Turpentine collected in northeastern California contained 66 percent d-alpha-pinene, 26 percent beta-pinene, 1 to 2 percent n-undecane, and unidentified sesquiterpene. The northern Idaho turpentine contained: n-heptane, less than 1 percent; l-dl-alpha pinene, 45 percent; beta-pinene, 32 percent; l-limonene, 7 percent; n-undecane, 2 percent; bornyl acetate, 2 percent; and sesquiterpenes 4 to 5 percent (61).

LITERATURE CITED

1. Anonymous.
   1956. These are the champs. Part II. Amer. Forests 62: 33-40.

2. Allen, John W.
   1959. White pine in western Washington. Jour. Forestry 57: 573-576.

3. Anderson, I. V.
   1934. Breakage losses and cull percent of timber in the Inland Empire. U.S. Forest Serv. Northern Rocky Mountain Forest and Range Expt. Sta. Appl. Forestry Note 63, 3 pp.

4. Baker, F. S.
   1949. A revised tolerance table. Jour. Forestry 47: 179-181.

5. Barnes, Burton V., R. T. Bingham, and John A. Schenk
   1962. Insect-caused loss to western white pine cones. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Res. Note 102, 7 pp.

6. Bingham, R. T.
   1953. Development of rust resistant white pine. Ann. Rpt. 1953, Northwest Proj., Blister Rust Control, Bur. Ent. and Plant Quar., U.S. Dept. Agr.: 69-73.

7. _____, and A. E. Squillace
   1955. Self-compatibility and effects of self-fertility in western white pine. Forest Sci. 1: 121-129.

8. _____, and A. E. Squillace
   1957. Phenology and other features of the flowering of pines, with special reference to Pinus monticola Dougl. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Res. Paper 53, 26 pp., illus.

9. _____, A. E. Squillace, and J. W. Duffield
   1953. Breeding blister-rust resistant western white pine. Jour. Forestry 51: 163-168.

10. _____, A. E. Squillace, and J. W. Wright
   1960. Breeding blister rust resistant western white pine. II. First results of progeny tests including preliminary estimates of heritability and rate of improvement. Silvae Genetica 9: 33-41.

11. Boyce, John Shaw
1948. Forest pathology. Ed. 2, 550 pp., illus. New York, Toronto /etc./

12. Boyd, Raymond J.
1959. Cleaning to favor western white pine--its effects upon composition, growth, and potential values. Jour. Forestry 57: 333-336.

13. Canada, Forestry Branch
1950. Native trees of Canada. Canada Dept. Resources and Devlpmt., Forestry Branch, 293 pp., illus. Ottawa.

14. Copeland, Otis L., Jr.
1956. Preliminary soil-site studies in the western white pine type. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Res. Note 33, 4 pp.

15. _____
1958. Soil-site index studies of western white pine in the northern Rocky Mountain region. Soil Sci. Soc. Amer. Proc. 22: 268-269.

16. Daubenmire, R. F.
1943. Soil temperature versus drought as a factor determining lower altitudinal limits of trees in the Rocky Mountains. The Bot. Gaz. 105: 1-13.

17. _____
1943. Vegetational zonation in the Rocky Mountains. Bot. Rev. 9: 325-393.

18. _____
1946. The life zone problem in the northern Intermountain region. Northwest Sci. 20: 28-38.

19. _____
1949. Relation of temperature and day-length to the inception of tree growth in spring. The Bot. Gaz. 110: 464-475.

20. _____
1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monog. 22: 301-330.

21. _____
1953. Classification of the conifer forests of eastern Washington and northern Idaho. Northwest Sci. 27: 17-24.

22. Daubenmire, R. F.
1953. Nutrient content of leaf litter of trees. Ecology 34: 786-793.

23. _____
1955. Xylem layers of trees as related to weather and altitude in the northern Rocky Mountains. Ecology 36: 456-463.

24. _____
1956. Climate as a determinant of vegetation distribution in eastern Washington and northern Idaho. Ecol. Monog. 26: 131-154.

25. _____
1957. Injury to plants from rapidly dropping temperature in Washington and northern Idaho. Jour. Forestry 55: 581-585, illus.

26. Davis, Kenneth P.
1942. Economic management of western white pine forests. U.S. Dept. Agr. Tech. Bul. 830, 78 pp., illus.

27. Deuber, C. G.
1942. The vegetative propagation of eastern white pine and other five-needled pines. Arnold Arboretum Jour. 23: 199-215.

28. Evenden, James C., W. D. Bedard, and G. R. Struble
1943. The mountain pine beetle, an important enemy of western pines. U.S. Dept. Agr. Cir. 664, 25 pp., illus.

29. Ferrell, William K.
1951. Preliminary report on some forest soils of the western white pine region of Idaho. Northwest Sci. 25: 113-120.

30. _____
1955. The relationship of pole blight of western white pine to edaphic and other site factors. Univ. Idaho Forest, Wildlife and Range Expt. Sta. Res. Note 13, 7 pp.

31. Fisher, George M.
1935. Comparative germination of tree species on various kinds of surface-soil material in the western white pine type. Ecology 16: 606-611.

32. Flint, Howard R.
1925. Fire resistance of northern Rocky Mountain conifers. The Idaho Forester 7: 7-10, 41-43.

33. Foiles, Marvin W.
1955. Thinning from below in a 60-year-old western white pine stand. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Res. Note 19, 6 pp.

34. _____
1956. Effects of thinning a 55-year-old western white pine stand. Jour. Forestry 54: 130-132.

35. _____
1961. Effects of thinning seed spots on growth of three conifers in the Inland Empire. Jour. Forestry 59: 501-503.

36. Graham, Donald P.
1958. Results of some silvicultural tests in pole blight diseased white pine stands. Jour. Forestry 56: 284-287.

37. _____
1958. Results of pole blight damage surveys in the western white pine type. Jour. Forestry 56: 652-655.

38. Haig, I. T.
1932. Premature germination of forest tree seed during natural storage in duff. Ecology 13: 311-312.

39. _____
1932. Second-growth yield, stand, and volume tables for the western white pine type. U.S. Dept. Agr. Tech. Bul. 323, 68 pp.

40. _____
1936. Factors controlling initial establishment of western white pine and associated species. Yale Forestry Bul. 41, 149 pp., illus.

41. _____, Kenneth P. Davis, and Robert H. Weidman
1941. Natural regeneration in the western white pine type. U.S. Dept. Agr. Tech. Bul. 767, 99 pp., illus.

42. Helmers, Austin E.
1946. Pruning wound healing on western white and ponderosa pines. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 45, 6 pp.

43. _____
1946. Effect of pruning on growth of western white pine. Jour. Forestry 44: 673-676.

44. Hofmann, J. V.
1917. Natural reproduction from seed stored in the forest floor. Jour. Agr. Res. 11: 1-26.

45. Huberman, M. A.
1935. The role of western white pine in forest succession in northern Idaho. Ecology 16: 137-151.

46. Hubert, Ernest E.
1950. Rootrots of the western white pine type. Northwest Sci. 24: 5-17.

47. Huey, Ben M.
1950. The profit in pruning western white and ponderosa pine. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 85, 6 pp.

48. Hutchison, S. Blair
1948. Comparative marketability of pine and mixed species in the Inland Empire. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 64, 4 pp.

49. Isaac, Leo A.
1930. Seed flight in the Douglas fir region. Jour. Forestry 28: 492-499.

50. Keen, F. P.
1952. Insect enemies of western forests. U.S. Dept. Agr. Misc. Pub. 273, 280 pp., illus.

51. Kincer, Joseph B.
1922. Precipitation and humidity. U.S. Dept. Agr. Atlas of Amer. Agr. Part 2, Sec. A, 48 pp., illus.

52. Kirkwood, J. E.
1930. Northern Rocky Mountain trees and shrubs. 340 pp., illus. Stanford University, London /etc./

53. Larsen, J. A.
1922. Some characteristics of seeds of coniferous trees from the Pacific Northwest. Natl. Nurseryman 30: 246-249.

54. _____
1925. Methods for stimulating germination of western white pine seed. Jour. Agr. Res. 31: 889-909.

55. Larsen, J. A.
1930. Forest types of the northern Rocky Mountains and their climatic controls. Ecology 11: 631-672.

56. Leaphart, Charles D.
1958. Pole blight--how it may influence western white pine management in light of current knowledge. Jour. Forestry 56: 746-751.

57. _____
1959. Drought damage to western white pine and associated tree species. Plant Dis. Rptr. 43: 809-813, illus.

58. _____, and Otis L. Copeland, Jr.
1957. Root and soil relationships associated with the pole blight disease of western white pine. Soil Sci. Soc. Amer. Proc. 21: 551-554, illus.

59. Little, Elbert L., Jr.
1953. Check list of native and naturalized trees of the United States (including Alaska). U.S. Dept. Agr., Agr. Handb. 41, 472 pp., illus.

60. Mathews, Donald N., and S. Blair Hutchison
1948. Development of a blister rust control policy for the national forests in the Inland Empire. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta., Sta. Paper 16, 116 pp.

61. Mirov, N. T.
1954. Chemical composition of gummed turpentine of pines of the United States and Canada. Jour. Forest Prod. Res. Soc. 4: 1-7.

62. Molnar, A. C., and R. G. McMinn
1960. The origin of basal scars in British Columbia interior white pine type. Forestry Chron. 36: 50-62, illus.

63. Moss, Virgil D.
1961. Antibiotics for control of blister rust on western white pine. Forest Sci. 7: 380-396, illus.

64. _____, and Charles A. Wellner
1953. Aiding blister rust control by silvicultural measures in the western white pine type. U.S. Dept. Agr. Cir. 919, 32 pp., illus.

65. Munns, E. N.
1938. The distribution of important forest trees of the United States. U.S. Dept. Agr. Misc. Pub. 287, 176 pp., illus.

66. Olson, D. S.
1930. Growing trees for forest planting in Montana and Idaho. U.S. Dept. Agr. Cir. 120, 92 pp., illus.

67. _____
1932. Seed release from western white pine and ponderosa pine cones. Jour. Forestry 30: 748-749.

68. Otter, Floyd L.
1933. Idaho's record trees. The Idaho Forester 15: 37-39.

69. Piper, C. V.
1906. Flora of the State of Washington. U.S. Nat. Herb. Contrib. II, 37 pp.

70. Pole Blight Investigations Steering Committee
1952. Pole blight, what is known about it. U.S. Forest Serv. North.Rocky Mountain Forest and Range Expt. Sta. Misc. Pub. 4, 17 pp.

71. Porter, W. A.
1954. Testing for resistance to the blister rust disease of western white pine in British Columbia. Canad. Dept. Agr., Forest Biol. Div., Sci. Serv., 12 pp., illus.

72. Rapraeger, E. F.
1939. Development of branches and knots in western white pine. Jour. Forestry 37: 239-245.

73. Righter, F. I.
1939. Early flower production among the pines. Jour. Forestry 37: 935-938.

74. Sargent, Charles Sprague
1897. The silva of North America. II, 163 pp. Boston.

75. _____
1933. Manual of the trees of North America. 910 pp., illus. Boston.

76. Schopmeyer, C. S., and A. E. Helmers
1947. Seeding as a means of reforestation in the northern Rocky Mountain region. U.S. Dept. Agr. Cir. 772, 31 pp., illus.

77. Schubert, G. H.
1954. Viability of various coniferous seeds after cold storage. Jour. Forestry 52: 446-447.

78. Society of American Foresters, Committee on Forest Types
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D.C.

79. Squillace, A. E.
1957. Variations in cone properties, seed yield and seed weight in western white pine when pollination is controlled. Montana State Univ., School Forestry, Bul. No. 5, 16 pp., illus.

80. _____, and R. T. Bingham
1958. Selective fertilization in Pinus monticola Dougl. Silvae Genetica 7: 188-196.

81. _____, and R. T. Bingham
1958. Localized ecotypic variation in western white pine. Forest Sci. 4: 20-34.

82. Stillinger, C. R.
1944. Damage to conifers in northern Idaho by the Richardson red squirrel. Jour. Forestry 42: 143-145.

83. Sudworth, George B.
1908. Forest trees of the Pacific slope. U.S. Dept. Agr., 441 pp., illus.

84. _____
1917. The pine trees of the Rocky Mountain region. U.S. Dept. Agr. Bul. 460, 47 pp., illus.

85. Tarrant, Robert F., Leo A. Isaac, and Robert F. Chandler, Jr.
1951. Associations on litter fall and foliage nutrient content of some Pacific Northwest tree species. Jour. Forestry 49: 914-915.

86. U.S. Dept. Agr.
1949. Trees. U.S. Dept. Agr. Yearbook 1949, 944 pp.

87. U.S. Forest Service
1948. Woody-plant seed manual. U.S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.

88. Wahlenberg, W. G.
1924. Fall sowing and delayed germination of western white pine seed. Jour. Agr. Res. 28: 1127-1131.

89. _____
1924. Circumventing delayed germination in the nursery. Jour. Forestry 22: 574-575.

90. Watt, Richard F.
1951. Snow damage in a pole stand of western white pine. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 92, 4 pp.

91. _____
1952. Western white pine stands show irregular growth pattern. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 113, 1 p.

92. _____
1954. Mortality in second-growth stands of the western white pine type. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Res. Note 9, 5 pp.

93. _____
1960. Second-growth western white pine stands. U.S. Dept. Agr. Tech. Bul. 1226, 60 pp., illus.

94. Wellner, C. A.
1946. Improving composition in young western white pine stands. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 43, 6 pp.

95. _____
1952. A vigor classification for mature western white pine trees in the Inland Empire. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 110, 3 pp.

96. _____, and Raymond J. Boyd
1960. Partial cuttings in mature stands of the western white pine type. Soc. Amer. Foresters Proc. 1959: 27-32, illus.

97. _____, and M. W. Foiles
1951. What to see and where to find it on the Deception Creek Experimental Forest. U. S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Misc. Pub. 2, 72 pp.

98. Young, V. A., G. B. Doll, G. A. Harris, and J. P. Blaisdell
1942. The influence of sheep grazing on coniferous reproduction and forage on cut-over western white pine areas in northern Idaho. Univ. Idaho Bul. 37(6), 46 pp., illus.

99. Zon, R.
1915. Seed production of western white pine. U.S. Dept. Agr. Bul. 210, 15 pp.

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