# *Abies magnifica* A. Murr. California Red Fir

## Pinaceae Pine family

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Red fir *(Abies magnifica)* dominates large areas of high country that are a major source of water, especially in California. For this reason it has long been an important forest tree. Only recently has red fir assumed significance as an unusually productive source of wood *(17)*. Relatively little detailed, coherent silvical information is available, however.

North of Mount Lassen in northern California, red fir shows morphological and perhaps ecological characteristics that have led to its common designation as Shasta red fir *(A. magnifica* var. *shastensis) (8,9,22)*. Here, the varieties are referred to collectively as red fir and are identified only when differences warrant.

## Habitat

### Native Range

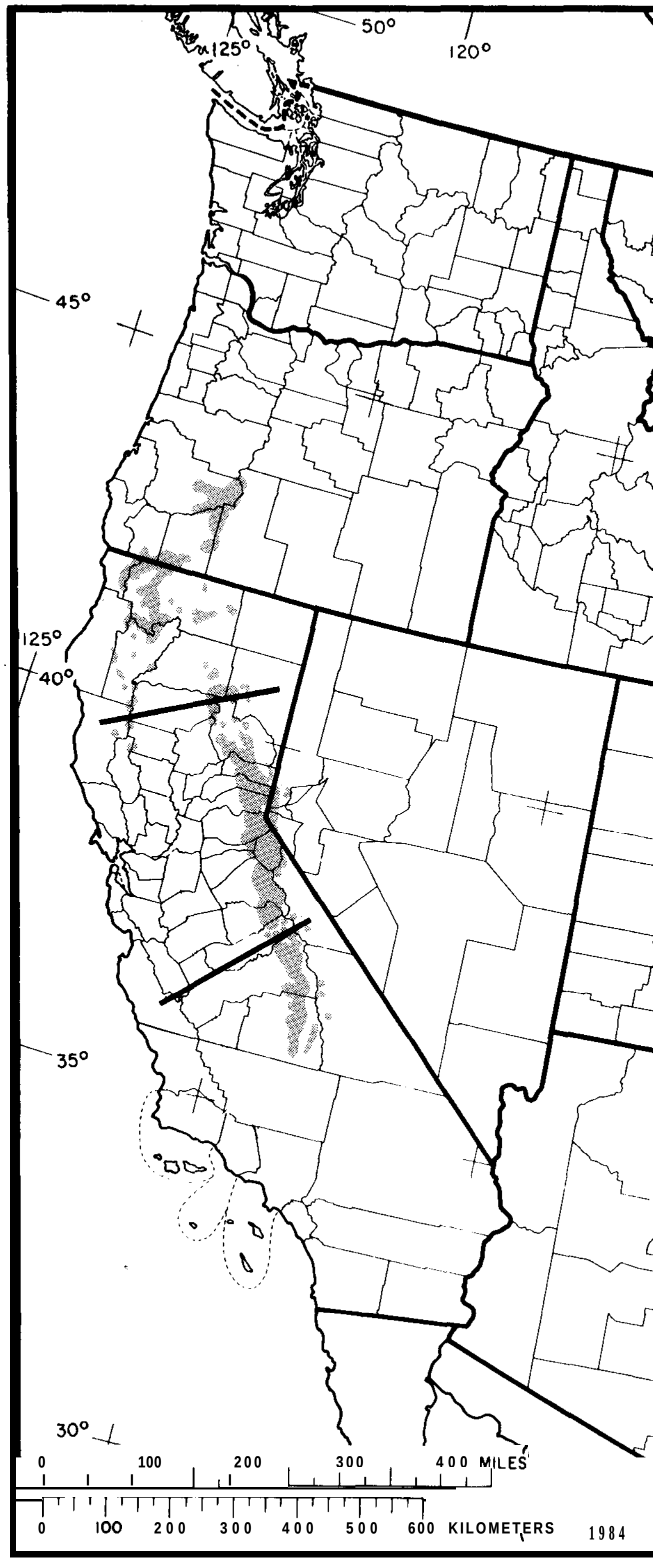


**Figure** *l-The native range of California red fir.*

In California and southern Oregon, red fir (fig. 1) is limited to high elevations. Its range extends from the central and southern Cascade Mountains of Oregon southward to Lake County in the Coast Ranges of northwest California and Kern County in the southern Sierra Nevada, from about latitude 43” 35’ to 36” 50’ N. Red fir is found outside these states only along the western border of Nevada, a few kilometers east of Mount Rose in Washoe County *(8,9,22)*.

Lower elevational limits begin at 1620 to 1800 m (5,300 to 5,900 ft) in the Cascade and Siskiyou Mountains and increase toward the south, reaching to 2130 m (7,000 ft) in the southern Sierra Nevada. Upper elevation limits also increase to the south, beginning at 2010 to 2190 m (6,600 to 7,200 ft) in the Cascade and Siskiyou Mountains, and reaching 2740 m (9,000 ft) in the southern Sierra Nevada. Red fir can be found growing at lower elevations in canyons and other protected places where significant cold air drainage keeps soil and air temperatures low *(31)*. In the California Coast Ranges, Shasta red fir is found generally between 1400 and 1830 m (4,600 to 6,000 ft) *(8,9,33)*.

### Climate

Climate for the red fir zone can be classified in general as cool and moist to cold and moist. It is

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relatively mild for high-elevation forests, with summer temperatures only occasionally exceeding 29” C (85” F) and winter temperatures rarely below -29” C (-20” F). One notable climatic feature is a 4- to 5-month summer dry spell. Between April (or May) and October, precipitation from scattered thundershowers is negligible. Almost all precipitation occurs between October and March, with 80 percent or more as snow. Snowpack can exceed 4 m (13 ft) in the Sierra Nevada, and snow can accumulate to more than 2 m (7 ft) in Oregon and northwestern California (9,391. Total precipitation ranges from 750 to 1500 mm (30 to 60 in).

Best growth appears to be in areas that receive between 750 and 1250 mm (30 and 49 in) of precipitation. Growth studies on Swain Mountain Experimental Forest, in the southern Cascades of California, indicate that California red fir grew best in years with unusually low precipitation (as low as 38 percent of normal) *(29)*. Low precipitation there usually means early snowmelt and a longer growing season.

## Soils and Topography

Red fir is found at high elevations on mountain ranges that continue in active formation. The soils on which it grows are therefore young and fall into four orders, Entisols, Inceptisols, Alfisols, and Spodosols. They are classified as mesic to frigid or cryic, with mean annual soil temperatures (at 50 cm; 20 in) between 0° and 15” C (32” and 59” F). All soils but the Alfisols tend to be light colored, shallow, with minimal or no horizon development, and low in cation exchange capacity and base saturation. Most are classified in some degree as xeric because of the long summer dry period. Horizon development is relatively poor even in the mesic Alfisols. The Spodosols are developed poorly without a true leached A horizon because of inadequate warm season precipitation. In the Cascades, red fir is occasionally found on pumice deposits overlying old soils.

Decomposition of needles and other litter tends to be slow in the wet winter, dry summer climate. Organic material collects on the surface where it forms dense black mats from 2 to 8 cm (0.75 to 3.0 in) or more thick *(8)*.

Tree growth and stand development are best on the deeper soils associated with glacial deposits or Pleistocene lake beds. On steep slopes where soils are shallowest, stands are open and tree growth poor. On moderate to gentle slopes and flat ground where water does not collect, stands are closed with no understory or herbaceous vegetation *(8)* (fig. 2).

**Figure 2**—*Old-growth California red fir and California white fir forest at 1950 m (6,400 ft) in the southern Cascades. A lack of understory (right foreground) is common in mature stands on high quality sites. Trees regenerate naturally in small patches (left foreground) as the stand begins to disintegrate.*

## Associated Forest Cover

California red fir is a climax species nearly everywhere it is found. It shares climax status with white fir at the upper limit of the white fir zone, although at any given place California white fir *(Abies concolor* var. *lowiana)* or red fir regeneration may predominate *(9,33)*.

Throughout the Sierra Nevada, lodgepole pine *(Pinus contorta)* occupies wet sites within red fir forests. In the south, dry sites are shared with sugar pine *(P. lambertiana)*, mountain hemlock *(Tsuga mertensiana)*, or incense-cedar *(Libocedrus decurrens)*. Scattered individuals of Jeffrey pine *(Pinus jeffreyi)*, sugar pine, and western white pine *(P. monticola)* are found in northern Sierra Nevada forests and as far south as Yosemite in the southern Sierra Nevada *(32,33)*.

In the Coast Ranges of California, Shasta red fir frequently shares dominance with noble fir *(Abies procera)* and is mixed with mountain hemlock and Brewer spruce *(Picea breweriana)* at elevations generally above 1850 m (6,100 ft). On high elevation serpentine soils, Shasta red fir is occasionally found with the more common foxtail pine *(Pinus balfouriana)*, western white pine, and Jeffrey pine (33).

From the southern Cascades north into Oregon and west into the California Coast Ranges, Shasta red fir begins to lose its clear climax status, perhaps as a result of taking on characteristics of noble fir, which is never a climax species in the northern Cascades (9). Shasta red fir is replaced successionally by white fir at the lower elevations and by mountain hemlock at the upper. Major associated species include Douglas-fir *(Pseudotsuga menziesii* var. *menziesii)*, white fir, western white pine, lodgepole pine, and mountain hemlock *(9,33)*.

Red fir is found in seven forest cover types of western North America. It is in pure stands or as a major component in Red Fir (Society of American Foresters Type 207) *(7)*, and also in the following types: Mountain Hemlock (Type 205), White Fir (Type 211), Lodgepole Pine (Type 218), Pacific Douglas-Fir (Type 229), Sierra Nevada Mixed Conifer (Type 243), and California Mixed Subalpine (Type 256).

Brush and lesser vegetation are varied. Dense red fir stands on good quality sites usually have no understory vegetation. In openings resulting from tree mortality or logging, and under open stands on poor sites, many species are possible depending on location *(9,20,42)*. Currant or gooseberry *(Ribes* spp.), pinemat manzanita *(Arctostaphylos nevadensis)*, and mountain whitethorn *(Ceanothus cordulatus)* are the most commonly found brush species *(9,20,21)*. Large brush fields can dominate areas after severe fire. Fir eventually will reclaim these sites as the climax species. With some combinations of low site quality, brush species, and resident rodent population, however, reforestation can be effectively delayed for decades. Small upland meadows are common in red fir forests and provide habitats for a wide variety of sedges, grasses, and forbs.

## Life History

### Reproduction and Early Growth

**Flowering and Fruiting-Red** fir is monoecious. Male strobili (cones) are small-generally less than 1.6 cm (0.6 in) long-deep purple-red, and densely clustered on the underside of l-year-old twigs about midcrown. Female cones are borne erect on 1-year-old branches in the uppermost crown, although both male and female cones are occasionally found on the same branch. California red fir flowers from May to June, with pollen shed and fertilization in late May through June. Shasta red fir flowers from middle to late June in southwestern Oregon. Populations in the Coast Ranges of northwestern California probably follow the same schedule. Seeds begin to reach maturity in mid-August and the ripening process continues up to time of seedfall.

Cones are large, 15 to 23 cm (6 to 9 in) long, 5 to 8 cm (2 to 3 in) in diameter, and oblong cylindric in shape. Shasta red fir bracts are longer than the cone scales and are easily visible on the surface of a mature cone. California red fir bracts are shorter than the cone scales and are not visible on an intact cone. Cones of both varieties are brown when mature and have specific gravities of about 0.75 *(8,27,28,36)*.

**Seed Production and Dissemination-Califor**nia red fir can begin producing seed when only 35 to 45 years old; Shasta red fir produces seed when about 5 years younger (36). Heavy seed crops-adequate for reliable regeneration-are produced every 1 to 4 years by California red fir (22) and about every third year by Shasta red fir *(12)*.

Seeds are wind-disseminated after cones disintegrate on the trees in late September to mid-October and are dispersed primarily by the prevailing southwesterly winds *(14)*.

In an exceptional year, seed production for both varieties can exceed 1.4 million per ha (570,000/acre) within a stand and along the edge of an opening *(11,14)*. The more frequent “good to heavy” crops may only reach 10 percent of that value. Seed production varies with tree age, size, and dominance. The best, most reliable producers are mature, healthy dominants, Immature fir can produce heavy seed crops, but production is more erratic than that of mature trees *(18)*. California red fir seeds average 14,110/kg (6,400/lb). Shasta red fir seeds tend to be smaller and average 16,095/kg (7,300/lb) (36).

Because cones are borne almost exclusively in the uppermost crown, any top damage caused by insects, diseases, or mechanical agents (for example, wind and snow) directly reduces cone production. Large old trees are prone to such damage. Trees which have lost their tops, however, can frequently develop new terminals and resume cone bearing.

Studies in California indicate that mature dominants along the edge of a clearcutting produce up to twice as many cones as similar trees in closed stands *(18)*. Regeneration data, also from California, indicate that mature trees left in seed tree or shelterwood cuts increase seed production (25).

The number of Shasta fir seeds falling into a clearing decreases rapidly with distance from the stand edge. At a downwind distance equal to about 2 to 2.5 times tree height, seedfall is nearly 10 percent of the stand edge value (11). Dispersal of the heavier California red fir seeds is generally limited to 1.5 to 2 times tree height *(13)*. Germination rates in standard tests are relatively low for both varieties, generally less than 40 percent (36). Even lower field germination rates (5 percent or less) can produce adequate regeneration.

**Seedling Development-Red** fir seeds germinate in the spring immediately after snowmelt or in, on, and under the snow *(10,14)*. Germination is epigeal. Seeds that germinate several centimeters above ground in the snowpack rarely survive. Seeds that fall before the first permanent snows of winter, therefore, are more effective in producing seedlings. Initial survival is best on mineral soil, perhaps, as in white fir, because presence of appropriate mycorrhizal-forming fungi is increased in the absence of organic layers (3).

Openings created in mixed red and white fir stands in both northern and southern Sierra Nevada tend to regenerate more readily to red fir. Fifty to 80 percent of the regeneration will be red fir, even when the surrounding stand is dominated by white fir *(25,32)*.

Two long-standing assumptions-that red fir growth is extremely slow for the first 20 to 30 years and that snow damage limits height growth-do not appear valid. Recent evidence indicates that beyond the first 5 years, slow growth is not inherent *(16,24)* and snow damage is significant for relatively few seedlings *(17)*. Extended periods of slow early growth appear to result from environmental conditions, such as prolonged shading and browse damage.

**Vegetative Reproduction-Under** natural conditions red fir does not reproduce vegetatively either by sprouting or layering. Vegetative propagation from cuttings is possible but the techniques currently available are at an early stage of development.

## Sapling and Pole Stages to Maturity

**Growth and Yield-Red** fir volume production is impressive. Normal yield tables for unmanaged stands indicate that a 160-year-old stand on a high site-18 m (60 ft) at 50 years-can carry 2320 $m^3/ha$ (33,150 $ft^3/acre$). Average sites-12 m (40 ft) at 50 years-carry 1470 $m^3/ha$ (21,000 $ft^3/acre$) at the same age. These volumes are possible, at least in part, because of the stand density that red fir can maintain. Basal areas on high sites can be well in excess of 126 $m^2/ha$ (550 $ft^2/acre$) and on average sites in excess of 96 $m^2/ha$ (420 $ft^2/acre$). In addition, the normal yield tables indicate that stand mean annual increment continues to increase until age 140 (37). Less ideal stands will support slightly less basal area, and mean annual increment may culminate sooner. The capacity of the species to respond to decreases in stand density is impressive, even at the advanced age of 100 years. In stands of white and red fir thinned to 50 percent of their basal area, the remaining trees increased growth sufficiently that overall stand growth was not significantly reduced *(30)*.

**Rooting Habit-Root** systems of mature forest trees, including red fir, have not been the subject of much research. What little is known has been gleaned from observations of windthrown trees. Mature red fir rooting habit appears to be fairly adaptable, deep and intensive where soil conditions permit or shallow and widespread where rocks or seasonal water tables limit effective soil depth. There is no strong tendency to maintain a single, deep taproot, although rapid development of a strong taproot is critical for survival of new germinants in the dry summer climate.

On at least some sites, however, saplings and poles have large-diameter, carrotlike taproots extending more than 1 m (3 ft) deep, with very poor lateral root development in the upper 30 cm (12 in). This condition has been found on young pumice soils overlying an old, buried profile. Periodic lack of fall snow cover exposes the soil to subzero temperatures and increased temperature fluctuations. Under these conditions pumice soils are subject to ice crystal formation and severe frost heaving. Fine lateral roots are probably killed by mechanical damage during ice formation and frost heaving or, perhaps, by low temperatures.

Red fir is susceptible to windthrow after partial cutting, especially when marginal codominant and lower crown classes are left as the residual stand *(15)*. Root diseases contribute significantly to lack of windfirmness.

Root grafting between red fir trees is indicated by the occasional presence of living stumps (8).

The effects of mycorrhizal associations are beginning to be explored. Early information indicates that these root-fungi relationships are significant in establishment and early growth, especially on poor sites (3).

**Reaction to Competition-Although** red fir grows best in full sunlight, it can survive and grow for long periods in relatively dense shade. Red fir's tolerance of shade appears to be less than that of mountain hemlock, slightly less than that of white fir and Brewer spruce, but greater than that of all of its other associates. Red fir's capacity to maintain significantly more foliage under shade than white fir suggests that the tolerance difference between them is marginal *(1)*. It is most accurately classed as tolerant of shade. Red fir seedlings are slightly more hardy in full sun than white fir seedlings but become established most easily in partial shade *(14,26)*.

Red fir can carry large basal areas per unit area and maintain high growth rates for an unusually long time, partly as a result of its shade tolerance. As an understory tree it can survive more than 40 years of suppression and, unless diseased, respond to release by increasing growth dramatically. Time until growth accelerates depends on crown condition. Even mature dominants can respond to large reductions in stand density Seed production on mature dominants can increase after release *(16,25,26,38)*.

Natural regeneration of red fir can be achieved using shelter-wood and seed tree cuttings. Clearcuts work as long as the size of the opening perpendicular to the wind does not exceed seed dispersal distances. Site preparation is important ***(19).*** Recent developments in nursery and handling technologies, including manipulation of root regeneration capacity and identification of necessary storage and transportation conditions, make artificial planting commercially practical. Access to planting sites is commonly difficult in the Sierra Nevada because of heavy snowpacks that last until June and later.

It is theoretically possible to manage several age classes in a stand because of the species' shade tolerance. However, the ability of red fir to support high growth rates for extended periods in dense, even-aged stands makes even-aged management the likely choice on most sites. Patch cuttings of small areas-O.2 to 2.2 ha (0.5 to 5.5 acres)-work well where larger regeneration cuts are undesirable for visual or environmental reasons.

**Damaging Agents-Red** fir is subject to damage from abiotic agents, pathogens, insects, and animals. Little is known about the tolerance of red fir to most abiotic aspects of the environment. Initial survival of seedlings seems to be better under partial shade although growth is best in full sunlight. The early advantage of shade may be related to protection from temperatures in exposed duff and litter that can frequently exceed 70" C (160" F) early in the growing season *(14)*.

Red fir appears to be more sensitive to drought than white fir or the associated pines *(26)*, even though over most of its range there may be no precipitation for as long as 5 months during the summer. A tendency of red fir to grow poorly where snowmelt water collects, as on mountain meadows, indicates a moderate sensitivity to high soil moisture content during the growing season *(8)*.

Frosts can occur any month of the year, but damage to red fir is minimal and significant only on Christmas trees. Red fir is more frost resistant than 'white fir and about equal to Jeffrey pine *(19)*.

The importance of mechanical injury increases as intensive management of dense young red fir stands increases, Studies in Oregon and California show that conventional logging techniques used for thinning or partial cutting damaged 22 to 50 percent of the residual stand. Seventy-five percent of these wounds were at ground level where infection by a decay-causing fungus is almost certain *(2)*. Volume losses by final harvest can be considerable, although the amount varies greatly from place to place, perhaps due to type and frequency of wounds *(2)*.

Among pathogens, one parasitic plant causes major damage. Red fir dwarf mistletoe ***(Arceuthobium abietinum*** f. sp. *magnificae)* is common throughout the range of red fir and infests 40 percent of the stands in California (34). Heavily infected trees suffer significant growth losses and are subject to attack by ***Cytospora abietis,*** a fungus that kills branches infected by dwarf mistletoe and further reduces growth. Because of reduced vigor, infected trees are more susceptible to bark beetle attack and other diseases (34). Heart rots, entering through open mistletoe stem cankers, increase volume loss directly and mortality indirectly through stem breakage. Recent unpublished research suggests that losses from bole infection may be of minimal consequence in well-managed second-growth true fir stands (35).

Changes in wood structure in large stem bulges resulting from dwarf mistletoe infections reduce strength of lumber produced. Current lumber grading practices, however, are not adequate to identify the affected wood (40).

Dwarf mistletoe need not be a problem in young managed stands because four factors make damage subject to silvicultural control. Red fir can be infected only by red fir dwarf mistletoe which, in turn, can parasitize only one other fir, noble fir. Small trees (less than 1 m [3.3 ft] tall) are essentially free from infection even in infested stands. Infected young firs, free from new overstory infection, outgrow the spread of mistletoe if height growth is at least 0.3 m (1 ft) per year, and losses from bole infections are expected to be minimal in managed, young-growth stands (34,351. Silvicultural practices that can significantly reduce the impact of dwarf mistletoe include removal of an infected overstory before natural regeneration exceeds 1 m (3.3 ft) in height, and stocking control to promote rapid height growth. Different species can be favored in the overstory and understory of mixed stands during thinnings or partial cutting. Sanitation of stand edges adjacent to regeneration areas and planting a nonhost species

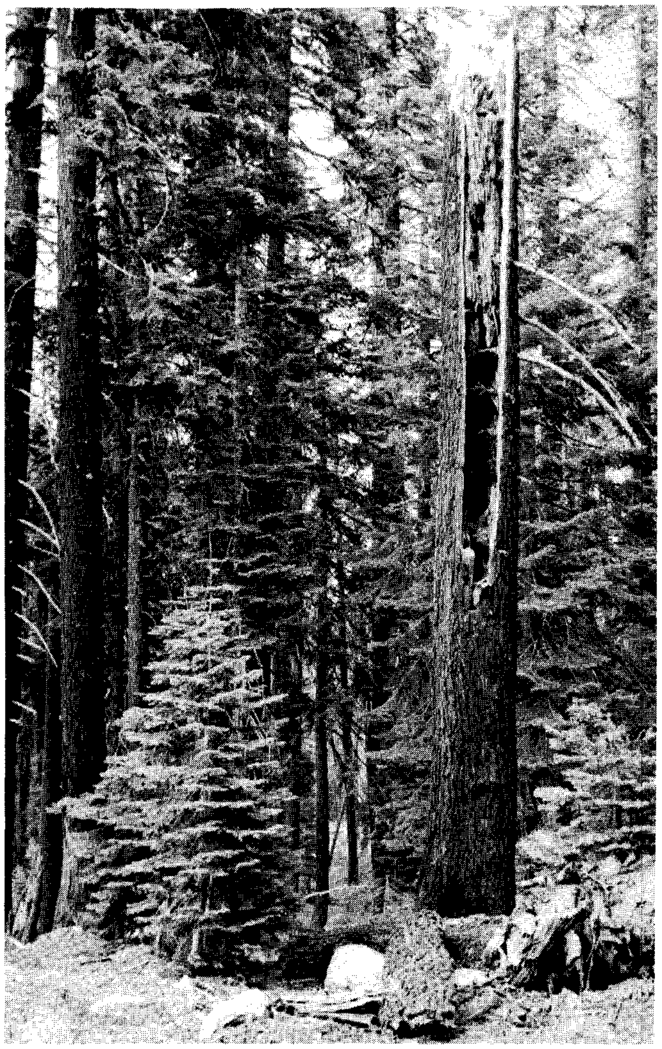

**Figure** ***S-Mature red fir broken by wind*** as ***a result*** *of* ***extensive heart rot.***

(such as white fir adjacent to a red fir stand) appropriate to the site can prevent infection from overstory trees.

Fir broom rust *(Melampsorella* ***caryophyllacearum)*** is abundant in the central and southern Sierra Nevada. This disease primarily affects branches but can infect trunks. It can cause spike tops and loss of crown and provide an entry court for heart rots. Fir broom rust can occasionally kill trees, especially seedlings and saplings (4).

Annosus root rot ***(Heterobasidion annosum)*** is present in all conifer stands and may become a major disease problem as red fir is increasingly and intensively managed. Infection is spread from tree to tree by root contact, forming disease pockets in the stand that slowly expand. Infection of freshly cut stumps or new wounds by aerially spread spores creates new infection centers that do not become evident until 10 to **20** years after infection. Annosus root rot does not usually kill red fir directly, but root damage results in considerable moisture stress and loss of vigor. The loss of vigor predisposes the tree to attack by bark beetles, notably *Scolytus* spp. Direct damage resulting from infection is restricted primarily to heart rot of butt and major roots, leading to windthrow and stem breakage (4) (fig. 3). Some degree of control is available through use of borax to prevent infection by ***Heterobasidion annosum*** in freshly cut stumps.

Other heart rots of major significance include the yellow cap fungus ***(Pholiota limonella)*** and Indian paint fungus ***(Echinodontium tinctorium).*** These fungi cause major losses in old-growth trees. Young trees are generally not affected because they have so little heartwood. Yellow cap fungus tends to be a more severe disease in California, and Indian paint fungus is more severe in Oregon. Yellow cap fungus generally enters through basal wounds. Rot can extend 15 to 18 m (50 to 60 ft) up the trunk. Indian paint fungus probably infects red fir in the same manner as it does western hemlock (2). The fungus enters through branchlets less than 2 mm (0.08 in) in diameter and can remain dormant for as long as 50 years before being activated by injury or stress (6). Dead or broken tops are other points of entry for Indian paint fungus. The resulting rot is located in the upper bole and may extend to the ground. Open dwarf mistletoe cankers serve as entry courts for several decay fungi. None of the heart rots kill directly but predispose the tree to stem breakage. No effective control is known for decay fungi, except possibly ***Heterobasidion annosum,*** other than avoiding as much root, stem, and top damage as possible during stand management (4).

Insects from five genera attack red fir cones and seeds. Losses can be significant. Cone maggots *(Earomyia* spp.) cause the most damage. Several chalcids ***(Megastigmus*** spp.) and cone moths ***(Barbara*** spp. and ***Eucosma*** spp.) can occasionally cause heavy local damage to seed crops, especially in poor seed years ***(13).***

Cutworms *(Noctuidae)* can be a problem in nurseries and may be especially damaging in natural regeneration areas. Cutworms were responsible for more than 30 percent of the seedling mortality in a study on Swain Mountain Experimental Forest in California ***(14).***

The white fir needleminer ***(Epinotia meritana)*** is the only foliage feeder of consequence on established red fir. Even during outbreak phases the damage caused is apparently minor and temporary *(13).*

The most severely damaging insect pest on red fir is the fir engraver *(Scolytus ventralis)*. This bark beetle is found throughout the range of red fir and causes severe damage nearly everywhere. Losses under epidemic conditions can be dramatic. Anything that reduces tree vigor-*Annosus* root disease, dwarf mistletoe, *Cytospora* canker, overstocking, drought, or fire damage-increases susceptibility to fir engraver attack. Several other species of bark beetles *(Scolytus* spp., *Pseudohylesinus* spp.), the roundheaded fir borer *(Tetropium abietis),* and the flatheaded fir borer *(Melanophila drummondi)* frequently join in attacking and killing individual trees. In epidemic conditions, however, mortality is caused primarily by the fir engraver. Maintenance of stand health and vigor is the only known control *(13).*

Locally, small rodents can cause significant loss of seed and occasionally girdle seedlings. Squirrels cut and cache cones. Pocket gophers limit regeneration in many areas, particularly clearcuts, by feeding on fir seedlings during winter and spring. Pocket gophers in combination with meadow voles and heavy brush can prevent conifer establishment for decades. Where gopher populations are high, damage to root systems of mature trees can be extensive, although not often identified. In extreme conditions, winter and spring feeding at root crowns can kill trees up to at least 94 cm (37 in) in diameter at breast height (23). Direct control is difficult and expensive. Indirect control by habitat manipulation offers some possibilities.

Spring browsing of succulent growth by deer can retard height growth for many years. Normally, trees are not killed and in most instances can grow rapidly once browsing pressure is removed. In managed stands, reduced height growth can result in significant production loss. Red fir may be damaged less by deer or rabbit feeding than white fir.

## Special Uses

Red fir is a general, all-purpose construction-grade wood used extensively as solid framing material and plywood. Good quality young red fir, known as "silvertip fir" from the waxy sheen on their dense, darkgreen needles, bring top prices as Christmas trees. These trees are cultured in natural stands and plantations where early growth is slower than most species used as Christmas trees, and some individuals are cultured for as long as 11 years before harvest.

Detailed and exact wildlife censuses for large areas do not exist and any listing of species numbers associated with a major forest type is an approximation. There are, however, about 111 species of birds found in the red fir type of California, 55 of which are associated primarily with mature forests. Perhaps because of the dense nature of most true fir forests, there are only about 52 species of mammals commonly present and only 6 of those are generally associated with mature forests. Few reptilian species are found at the high elevations and only four are generally present in the red fir type.

## Genetics

In the northern part of its range, California red fir appears to merge and hybridize with noble fir, a northern species with morphological and ecological similarities. Bracts that extend beyond the scales on mature cones are characteristic of noble fir. North of Mount Lassen, red fir has similar exserted bracts. South of Mount Lassen, bracts on red fir are shorter than the scales and are not visible on intact mature cones. Changes in seed weight, cotyledon number, and cortical monoterpenes in both species indicate a broad transition zone between latitudes 40" and 44" N. Similarity with noble fir increases to the north and west (41). The two species can be artificially cross-pollinated with no apparent difficulty as long as red fir is the female parent. Success is reduced by more than 70 percent when red fir is the male parent *(5,36)*. Discussion continues about the relationship of California red fir, Shasta red fir, and noble fir; however, the fact that exserted bracts also appear on a large southern Sierra Nevada population of red fir that has characteristics in common with both California red fir and Shasta red fir only adds to the controversy *(41).*

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