

# *Abies grandis* (Dougl. ex D. Don) Lindl.      Grand Fir

Pinaceae      Pine family

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Grand fir (*Abies grandis*), also called lowland white fir, balsam fir, or yellow fir, is a rapid-growing tree that reaches its largest size in the rain forest of the Olympic Peninsula of Washington. One tree in that area measures 200 cm (78.9 in) in d.b.h., 70.4 m (231 ft) tall, and has a crown spread of 14 m (46 ft). The species also has historic significance. The famous Barlow Road snub-trees on the south side of Mount Hood in Oregon were grand firs. They were used by early settlers to control the rate of descent of their covered wagons on a particularly steep slope in their trek from east to west. Some of the rope-burned trees are still standing after 150 years.

## Habitat

### Native Range

Grand fir (fig. 1) grows in the stream bottoms, valleys, and mountain slopes of northwestern United States and southern British Columbia. Its wide geographical distribution is from latitude 51° to 39° N. and from longitude 125° to 114° W. In the Pacific coast region it grows in southern British Columbia mainly on the lee side of Vancouver Island and the adjacent mainland, in the interior valleys and lowlands of western Washington and Oregon, and in northwestern California as far south as Sonoma County. The range in the continental interior extends from the Okanogan and Kootenay Lakes in southern British Columbia south through eastern Washington, northern Idaho, western Montana west of the Continental Divide, and northeastern Oregon. The best commercial stands of grand fir are in the Nez Perce and Clear-water regions of northern Idaho (9).

### Climate

Grand fir is found on a wide variety of sites. Average annual precipitation in its territory ranges from 510 to more than 2540 mm (20 to 100 in) in western Washington and on Vancouver Island. Annual precipitation in the Blue Mountains of eastern Oregon averages 360 to 990 mm (14 to 39 in). In northern Idaho, average annual precipitation is 510

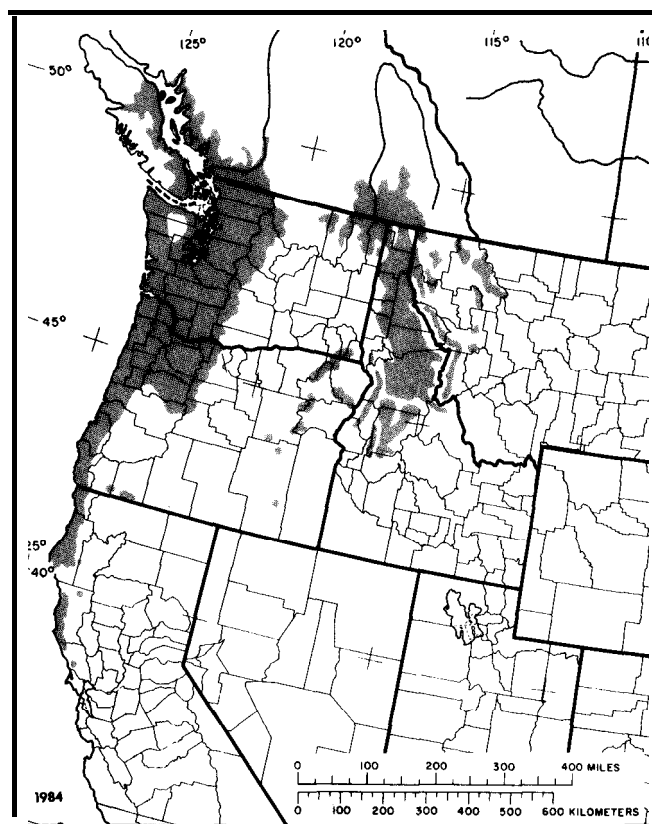


Figure 1—The native range of grand fir.

to 1270 mm (20 to 50 in). Most of this precipitation occurs during winter. Generally 15 to 25 percent of the annual precipitation occurs during the growing season, May through August. On Vancouver Island, where average annual precipitation ranges from 680 to 2820 mm (27 to 111 in), only 50 to 130 mm (2 to 5 in) of rain falls during June, July, and August. Average annual snowfall ranges from a few centimeters on some coastal sites to more than 1270 cm (500 in) in the mountains of the interior (9).

Average annual temperatures range from 6° to 10° C (43° to 50° F); the average growing season temperature is 14° to 19° C (57° to 66° F). The frost-free season varies, ranging from about 60 to more than 250 days, and is very irregular from year to year. Frosts may occur in any month in the interior. The average growing season ranges from only 100 to 140 days in northern Idaho, 185 days on the Olympic Peninsula in western Washington, and 250 or more days in northern California (9).

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## Soils and Topography

Grand fir seems to grow equally well on soils derived from a variety of parent materials, including sandstone, weathered lava (rock), or granite and gneiss. In the Pacific coast region and in the Willamette Valley of Oregon it grows most abundantly on deep, rich alluvial soils along streams and valley bottoms and on moist soils provided with seepage. In the inland regions it grows best on rich mineral soils of the valley bottoms, but it also grows well on shallow, exposed soils of mountain ridges and pure pumice soils in central and eastern Oregon, provided moisture is adequate (9). Most of the soils that support grand fir have been classified as Spodosols.

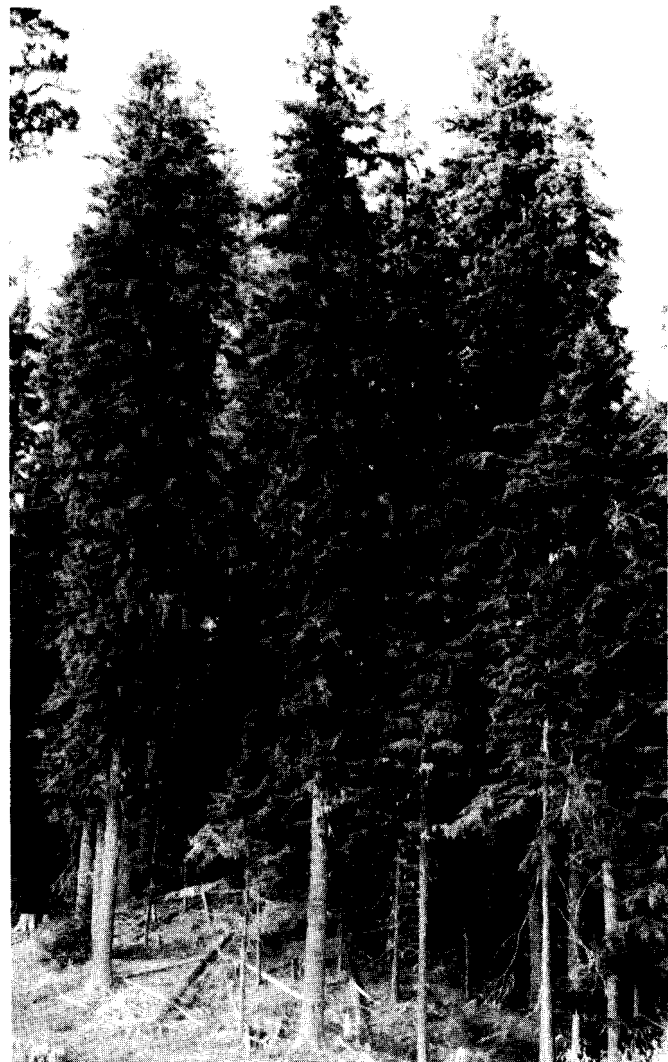
Grand fir grows on Vancouver Island and the adjacent mainland of British Columbia at elevations between sea level and 305 m (1,000 ft). In the southern interior of British Columbia it grows only in the moist valleys of such rivers as the Kootenay, Columbia, and Okanogan and their tributaries. Grand fir is predominantly a lowland species in western Washington, Oregon, and British Columbia. In western Washington it grows in valleys and stream bottoms having high ground-water levels. Elevations of these sites are usually between 180 and 305 m (590 and 1,000 ft). At elevations above 460 m (1,510 ft), grand fir is replaced by Pacific silver fir (*Abies amabilis*). Grand fir is found in western Oregon and in the lowlands of all the river regions, and in the lower west Cascades to an elevation of 915 m (3,000 ft). In northern California it grows from near sea level to about 1525 m (5,000 ft) (9).

In the eastern Cascades of Washington, 915 to 1220 m (3,000 to 4,000 ft) is the upper altitude limit for grand fir, while in the eastern Cascades of Oregon it grows at 1525 m (5,000 ft). In the Inland Empire, including the Blue Mountains of Oregon, it is found as high as 1830 m (6,000 ft) and as low as 460 m (1,500 ft), but usually between 610 and 1525 m (2,000 and 5,000 ft). In the Nez Perce region of central Idaho, it grows well at altitudes of 1220 to 1675 m (4,000 to 5,500 ft) (9).

## Associated Forest Cover

Grand fir (fig. 2) is either a seral or climax species in different forest types within its range. On moist sites it grows rapidly enough to compete with other seral species in the dominant overstory. On dry sites it becomes a shade-tolerant understory and eventually assumes dominance as climax conditions are approached.

Grand fir is represented in 17 forest cover types of western North America: it is the predominant species



**Figure 2**—Mature grand fir trees in the Coeur d'Alene National Forest, ID.

in only one, Grand Fir (Society of American Foresters Type 213) (26). It is a major component of six other cover types: Western Larch (Type 212), Western White Pine (Type 215), Interior Douglas-Fir (Type 210), Western Hemlock (Type 224), Western Redcedar (Type 228), and Western Redcedar-Western Hemlock (Type 227). Grand fir appears sporadically in 10 other cover types.

In northern Idaho, grand fir is the major climax tree species in seven habitat types and is an important seral tree in the *Thuja plicata*, *Tsuga heterophylla*, and *Abies lasiocarpa* series of habitat types (5). The Montana forest ecological classification recognizes an *Abies grandis* series of three habitat types in which grand fir is the major climax tree (23). It is also a minor climax or seral tree in four other types in Montana. In central Idaho, Steele and others

(28) described an *Abies grandis* series that includes nine habitat types and five phases in which grand fir is the climax tree.

The *Abies grandis* zone is the most extensive midslope forest zone in the Cascade Range of Oregon and southern Washington and the Blue Mountains of eastern Oregon. Grand fir is the climax tree species in 12 plant associations (15,18). It is also an important component of the mixed conifer communities in the Willamette Valley and Siskiyou Mountains of Oregon (16). In addition, grand fir grows sporadically in the *Tsuga heterophylla*, *Picea sitchensis*, and *Abies amabilis* zones in the coastal forests of Washington and Oregon (11).

Grand fir sometimes grows in pure stands but is much more common in mixed coniferous and hardwood forests. In forests east of the Cascade crest, it is associated with western white pine (*Pinus monticola*), western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), and in certain areas, Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), black cottonwood (*Populus trichocarpa*), Pacific yew (*Taxus brevifolia*), white fir (*Abies concolor*), incense-cedar (*Libocedrus decurrens*), sugar pine (*Pinus lambertiana*), Shasta red fir (*Abies magnifica* var. *shastensis*), and Oregon white oak (*Quercus garryana*).

Associates of grand fir in northwestern Oregon, western Washington, and southwestern British Columbia include Sitka spruce (*Picea sitchensis*), Pacific silver fir (*Abies amabilis*), and Port-Orford-cedar (*Chamaecyparis lawsoniana*), in addition to western redcedar, western hemlock, western larch, and Douglas-fir. It also is associated with these coast hardwoods: bigleaf maple (*Acer macrophyllum*), Oregon ash (*Fraxinus latifolia*), red alder (*Alnus rubra*), black cottonwood, and Oregon white oak.

In southwestern Oregon and northwestern California, at the southern limits of the range, grand fir is found with redwood (*Sequoia sempervirens*), and at higher elevations with Shasta red fir, white fir, noble fir (*Abies procera*), subalpine fir, and western white pine.

Shrubs commonly associated with grand fir include pachistima (*Pachistima myrsinites*), bristly black currant (*Ribes lacustre*), Saskatoon serviceberry (*Amelanchier alnifolia*), Rocky Mountain maple (*Acer glabrum*), twinflower (*Linnaea borealis*), birchleaf spirea (*Spiraea betulifolia*), huckleberry (*Vaccinium* spp.), Utah honeysuckle (*Lonicera utahensis*), mallow ninebark (*Physocarpus malvaceus*), common snowberry (*Symphoricarpos albus*), baldhip rose (*Rosa*

*gymnocarpa*), princes-pine (*Chimaphila* spp.), Spalding rose (*Rosa nutkana* var. *hispida*), oceanspray (*Holodiscus discolor*), creeping hollygrape (*Berberis repens*), willow (*Salix* spp.), thimbleberry (*Rubus parviflorus*), rustyleaf menziesia (*Menziesia ferruginea*), and pyrola (*Pyrola* spp.).

Herbaceous species commonly found in various associations with grand fir include queenscup (*Clintonia uniflora*), false solomons-seal (*Smilacina stellata*), goldthread (*Coptis occidentalis*), Pacific trillium (*Trillium ovatum*), sweetscented bedstraw (*Galium triflorum*), pathfinder (trailplant) (*Adenocaulon bicolor*), wildginger (*Asarum caudatum*), Piper anemone (*Anemone piperi*), violet (*Viola* spp.), sandwort (*Arenaria macrophylla*), heartleaf arnica (*Arnica cordifolia*), strawberry (*Fragaria* spp.), rattlesnake plantain (*Goodyera oblongifolia*), western meadowrue (*Thalictrum occidentale*), coolwort (*Tiarella* spp.), fairybells (*Discoporum oregonum*), white hawkweed (*Hieracium albiflorum*), and sweetroot (*Osmorhiza* spp.). Graminoids frequently associated with grand fir are Columbia brome (*Bromus vulgaris*), pinegrass (*Calamagrostis rubescens*), western fescue (*Festuca occidentalis*), and sedge (*Carex* spp.). Additional species are associated with grand fir in the coastal region, where it grows with western hemlock, coastal Douglas-fir, Sitka spruce, and redwood.

## Life History

### Reproduction and Early Growth

**Flowering and Fruiting**—Grand fir trees are monoecious; male and female flowers are borne in clusters on branchlets of the previous season's growth in different parts of the same tree. Female flowers, producing cones and seeds, are short, spherical to cylindrical, and stand singly and erect on the uppermost part of the crown. Male flowers, pollen-bearing only, are ovoid or cylindrical and hang singly from the lower side of branches below the female flowers. This arrangement favors cross-fertilization. The cones mature in one season. Time of flowering may vary over several months, depending on temperatures during the weeks preceding flowering. Flowering occurs from late March to mid-May at lower elevations of most coastal locations, and in June at the higher elevations of the inland locations. The cones, mostly yellowish-green and occasionally greenish-purple, ripen from August to September of the same year, and seeds are dispersed approximately 1 mile later (32).

Extreme frosts may occasionally inhibit normal cone and seed development. Several species of insects

feed on the buds, conelets, and seeds of grand fir, sometimes destroying 10 to 25 percent of the year's seed crop (9).

**Seed Production and Dissemination**—Seed production begins at about 20 years of age and increases with age, diameter, and vigor of the tree. Eight-year observations of permanent sample plots in Idaho show that grand fir produced the fewest seeds of the species associated with western white pine. Grand fir produced no good crops and only two fair crops, while western white pine produced two good crops and three fair crops. During the same 8-year period, western hemlock produced five good crops and two fair crops (9). In the coastal forests of Washington, grand fir ranked higher than western white pine and intermediate among upper slope species in number of seeds produced per tree (22). Other sources place the interval between good seed crops at 2 to 3 years (10,32).

In the Inland Empire, a good cone crop for grand fir is considered to be more than 40 cones per tree. A fair crop is 21 to 40 cones per tree. Grand fir seeds caught annually in seed traps on two sample plots averaged 42,000/ha (17,000 acre) on the Kaniksu National Forest and 58,100/ha (23,500 acre) on the Coeur d'Alene National Forest. Eight-year observations of seed traps under a 300-year-old stand on the Priest River Experimental Forest yielded 31,600 grand fir seeds per hectare (12,800 acre) annually (9). The yield of cleaned seeds ranges from 26,200 to 63,100/kg (11,900 to 28,700/lb) and averages 40,500/kg (18,400/lb) (32).

When the cones are ripe, the scales fall away and release the large-winged seeds, leaving only the central spike. Seeds are dispersed by the wind and rodents. Most of the seeds are disseminated in the early fall, about 5 percent falling before September 1 and 80 percent falling before the end of October. Seeds sufficient to produce adequate reproduction may be distributed up to 120 m (400 ft) from the parent tree, but the average distance is about 45 to 60 m (150 to 200 ft). Seeds in the duff remain viable through only one overwinter period (9).

**Seedling Development**—Grand fir seeds germinate in the spring following one overwinter period on the ground. In natural stands, germination is quite variable but is seldom greater than 50 percent because of embryo dormancy, insect infestation, and the perishable nature of the seeds. Seeds are often so heavily infested with insects that an entire crop may be classed as a failure (9).

Stratification under cool, moist conditions speeds germination. Grand fir seeds are typically stratified

at 1° to 5° C (34° to 41° F) for 14 to 42 days before nursery sowing in the spring. Results of greenhouse germination tests of grand fir seeds are highly variable. In three sandflat germination tests in the northern Rockies, grand fir had the lowest germination percentage among major associates of the western white pine type (9). Average percentages were grand fir, 12; western larch, 30; Douglas-fir, 41; western white pine, 44; western hemlock, 65; and western redcedar, 73. As with other true firs, germination is epigeal.

In reported tests, germinative capacity ranged from 0 to 93 percent and averaged 50 percent (32). The variability and average grand fir germination are about average for the true firs.

Grand fir seed germination begins in late April or early May on exposed sites and a month later on protected sites where snow lingers late. It is practically completed by July 1 on exposed sites and by August 15 on protected sites. Germination is best on mineral soil, but on seed-tree cuttings, grand fir germinates nearly as well on duff as on any other surface (9).

Studies of seedling survival indicate that more than 30 percent of grand fir seedlings die in the first season, and an additional 10 percent die in the second season. Losses drop off rapidly after the first 2 years, and seedlings 3 years old are fairly well established (9,24). Studies of mortality during the critical first year indicate that early season losses are due principally to biotic agents, especially damping-off fungi. Fungi-caused mortality is very irregular, however. Later in the season as the soil begins to dry and temperatures rise, mortality is due principally to heat from insolation and drought. Surface-soil temperatures are less important under shade or on sheltered sites, and under dense shade or on north slopes high temperatures do not cause death. Grand fir is relatively resistant to heat injury; it is equal to western white pine and Douglas-fir and more resistant than western larch, western hemlock, and western redcedar. Grand fir seedlings are relatively resistant to drought on areas exposed to full sun because deep initial root penetration protects them from drying of the surface soil. On heavily shaded, cool areas, drought is the most important physical cause of seedling mortality because initial root penetration is slow; even shallow drying of the surface soil may cause drought mortality despite ample soil moisture at deeper levels (9).

Initial survival and growth of grand fir are favored by a moderate overwood shade. Under full sun it is largely subordinate to faster growing, shade-intolerant species. Under partial overwood shade, grand fir is aggressive enough to form a dominant

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part of the reproduction. After 20 to 30 years, it makes most rapid growth in the open (9).

**Vegetative Reproduction-No** information is currently available.

### Sapling and Pole Stages to Maturity

**Growth and Yield-Longevity** of grand fir is intermediate among true firs; trees 250 years old are common and occasional trees may be more than 300 years old. On optimum sites in the coastal lowlands of Washington, mature grand firs reach heights of 43 to 61 m (140 to 200 ft) at 51 to 102 cm (20 to 40 in) d.b.h.; occasionally they reach 76 m (250 ft) in height and 152 cm (60 in) in d.b.h. (11). Grand fir in the redwood forests of California reaches d.b.h. and heights as great as those attained in the coast Douglas-fir region. In northern Idaho grand fir normally grows to 35 to 46 m (115 to 151 ft) in height at 64 to 102 cm (25 to 40 in) in d.b.h. On the pumice soils of eastern Oregon it attains height of 30 to 40 m (98 to 131 ft) with d.b.h. of 51 to 91 cm (20 to 36 in). On exposed ridges of the Inland Empire, heights of 15 to 21 m (49 to 69 ft) and d.b.h. of 30 to 36 cm (12 to 14 in) are common (9).

The rapid early height growth nearly equals that of Douglas-fir on the Pacific coast and western white pine in Idaho. On Vancouver Island and western Washington sites, growth of 79 to 89 cm (31 to 35 in) per year was reported. Trees 43 m (141 ft) tall at 50 years of age have been measured. In Idaho early height growth of 15 to 20 cm (6 to 8 in) on average sites and 30 to 36 cm (12 to 14 in) on optimum sites has been reported. In the dry pumice soils of eastern Oregon, average juvenile height growth up to 13 cm (5 in) per year has been reported. On these dry sites good height growth is delayed until the taproots reach ground water. At some time in the third decade, height growth receives considerable impetus and annual height growths of 51 to 89 cm (20 to 35 in) or more are common (9).

Among pole-size trees, growth is nearly equal to the more shade-intolerant western white pine and Douglas-fir with which it is commonly associated. Grand fir commonly outgrows the more tolerant western hemlock and western redcedar.

Grand fir has been planted successfully in many European countries, where it is considered one of the most potentially productive species (2). In England, growth of grand fir plantations was compared with that of neighboring plantations of other commonly planted species, and the rate of growth of grand fir at 40 years of age frequently equaled or exceeded



Figure 3-A 90-year-old grand fir stand. Coeur d'Alene National Forest, ID.

that of other species such as Sitka spruce, Norway spruce (*Picea abies*), and Douglas-fir (2).

Grand fir seldom grows in pure stands except in areas of the Clearwater River drainage of north-central Idaho (fig. 3). Therefore, estimates of yields have value mainly in relation to mixed stands. Grand fir ranks among the most productive species in all the associations in which it grows. East of the Cascade crest in Oregon and Washington, yields of grand or white fir stands at age 100 years range from 476 to 1330 m<sup>3</sup>/ha (6,800 to 19,000 ft<sup>3</sup>/acre) (4). In northern Idaho, where grand fir grows with western white pine, predicted yields of normal stands range from 470 to 1078 m<sup>3</sup>/ha (6,720 to 15,400 ft<sup>3</sup>/acre) at age 100 (14). Estimates of mean annual growth range from 8 to 13 m<sup>3</sup>/ha (114 to 186 ft<sup>3</sup>/acre) in Idaho (27) and 6 to 10 m<sup>3</sup>/ha (86 to 143 ft<sup>3</sup>/acre) in Montana (23). On the more fertile soils of England, growth rates of 18 to 20 m<sup>3</sup>/ha (257 to 286 ft<sup>3</sup>/acre) to age 40 have been reported (2).

**Rooting Habit-The** grand fir root system is intermediate in development among its associated tree species. The anchoring taproot does not grow as rapidly nor as deeply as dry site associates such as ponderosa pine, Douglas-fir, and lodgepole pine, but it grows faster and deeper than wet site species such as western hemlock, western redcedar, and Engelmann spruce. Seedling roots penetrate the soil rapid-

ly enough in full sunlight to survive drought conditions in duff and surface soil. Grand fir produces roots under shaded conditions, enabling it to survive in the understory. The adaptable root system contributes to the growth of grand fir over a wide range of sites and climatic conditions. A relatively deep taproot enables grand fir to survive and grow well on rather dry soils and exposed ridges. On moist sites, the taproot is largely replaced by more shallow lateral roots (9).

**Reaction to Competition-**Grand fir is classed as shade-tolerant in all associations in which it occurs. In the Willamette Valley of Oregon, it is the climax type following Douglas-fir and Oregon white oak. In the Inland Empire it is more tolerant than any of its associates except western redcedar and western hemlock. It is the climax type on sites too dry for redcedar or hemlock. In coastal British Columbia, grand fir is similar to Sitka spruce in tolerance; that is, it is slightly more tolerant than Douglas-fir. It is the least shade-tolerant of the true firs in British Columbia and is much less tolerant than western hemlock, western redcedar, or Pacific silver fir. Grand fir is a versatile species that, although quite tolerant, has a growth rate nearly equal to that of western white pine.

Grand fir is a dominant climax species in some habitat types and a long-lived seral species in other types. It usually grows in mixed-species stands where either even-aged or uneven-aged silviculture is practiced. In the zone of genetic intergrade between grand and white fir, it is not possible to separate the two species and their hybrids visually. Silvicultural prescriptions and treatments are applied as if they were one species. Where grand fir is desired under even-aged management, shelterwood cuttings are preferred because regeneration and early growth are best in partial shade. It also regenerates satisfactorily on most sites, however, following seed tree or clearcutting (3,24). Following seedling establishment, the overstory should be removed to encourage rapid growth in height and diameter.

Under uneven-aged management, grand fir regenerates adequately and commonly outgrows the more tolerant western hemlock and western redcedar as an understory tree. Certain classes of understory grand fir saplings respond positively to release while others respond negatively (8,25). Pole-size and larger grand firs respond well to release by thinning and selection cuttings if the crowns are vigorous (13).

**Damaging Agents-**During the period of stand development from establishment to maturity, several

factors influence stand growth and yield. Grand fir is rated medium in fire resistance among species of the western white pine type; it is less resistant than thick-barked western larch, ponderosa pine, and Douglas-fir but more resistant than subalpine fir, western hemlock, and Engelmann spruce. Fire resistance is influenced by habitat. For example, in moist creek bottoms grand fir succumbs rapidly to ground fires, but on dry hillsides it is more resistant, largely because of its deeper root system and thicker bark. The needles are quite resistant to cold during the severest part of the winter. Grand fir leaves have been subjected to temperatures of  $-55^{\circ}\text{C}$  ( $-67^{\circ}\text{F}$ ) without damage. Sudden extreme drops of temperature in the fall occasionally damage needles, but seldom are they fatal. Frost cracks and lightning scars appear more frequently on grand fir, however, than on its associates in the Inland Empire. The cracks cause little direct mortality but contribute to the spread of infection by decay fungi. Often small patches of trees are uprooted or broken by the accumulation of snow in the crowns of dense immature stands in the Inland Empire (9). In England young grand firs from Vancouver Island and western Washington are reportedly susceptible to late spring frost and drought crack (2).

Susceptibility to heart rot and decay is one of the more important factors in the management of grand fir. Indian paint fungus (*Echinodontium tinctorium*) is the most destructive fungus in forests east of the Cascade crest (17). In the Blue Mountains of Oregon and Washington, decay was reported responsible for losses of 14 percent of the gross merchantable cubic-foot volume and 33 percent of the board-foot volume in sawtimber-size grand fir trees (1). Fungi enter the tree through small shade-killed branchlets in the lower crown. After closure of the branchlet stub, infections become dormant. Years later the infections are reactivated when mechanical injuries allow air to enter the heartwood where the dormant infections are located (7). Therefore, centers of decay are closely related to logging scars, frost cracks, broken tops, and other mechanical injuries (21).

Indian paint fungus is rare in grand fir west of the Cascade crest where rapid growth rates close branch stubs quickly (7). *Armillaria* spp. and *Phellinus weiri* are the two most important root rot fungi. *Poria subacida* and *Heterobasidion annosum* also attack grand fir (17).

Numerous insects attack grand fir. The western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir tussock moth (*Orgyia pseudotsugata*) have caused widespread defoliation, top kill, and mortality. The western balsam bark beetle (*Dryocoetes confusus*) and the fir engraver (*Scolytus*

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*ventralis*) are the principal bark beetles attacking grand fir. The fir cone moth (*Barbara* spp.), fir cone maggots (*Euomyia* spp.), and several seed chalcids destroy large numbers of grand fir cones and seeds. The balsam woolly adelgid (*Adelges piceae*), often called "gout disease of fir," has destroyed grand fir in western Oregon and Washington and is a serious threat in southwestern British Columbia (12).

### Special Uses

The soft white wood of grand fir is a valued source of pulpwood. The wood also is commercially valuable as timber even though it is weaker and more prone to decay than many other species. The luxuriant foliage, symmetry, and deep green shiny color make grand fir one of the preferred species of Christmas trees grown in the Northwest. The attractive appearance of grand fir makes it valuable in recreation areas and urban plantings.

### Genetics

#### Population Differences

There are no **recognized** varieties of grand fir, although a green coastal form and gray interior form are often recognized. Five fairly distinct climatic forms of grand fir have been identified. The differences are mainly physiological and ecological (9). Provenance trials with grand fir in Europe have resulted in ranking U.S. seed origins. Seed sources west of the Cascade crest are preferred for planting in England and the lowland sites in Europe (20). Significant differences in height growth between trees from sources east and west of the Cascade crest have been reported but average growth of westside and interior seedlings is generally about the same (29). Most of the genetic variation available for tree improvement appears to be among stands but genetic gains can also be made by selecting individuals within stands.

#### Hybrids

Grand fir crosses with both the *concolor* and *lowiana* varieties of white fir. Several studies have shown hybridization and introgression between grand fir and white fir in a broad zone extending from the Klamath Mountains of northern California through southwestern Oregon and through the Oregon Cascade Range into northeastern Oregon and west-central Idaho (30). Grand fir has been crossed with several European and Asiatic species (19).

Natural hybrids have been reported between grand fir and subalpine fir in northern Idaho (6).

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