Abies lasiocarpa (Hook.) Nutt. Subapline Fir

Pinaceae Pine family

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Subalpine fir, the smallest of eight species of true fir indigenous to the western United States, is distinguished by the long, narrow conical crown terminating in a conspicuous spikelike point (fig. 1).

Two varieties are recognized: the typical variety ***(Abies lasiocarpa*** var. ***lasiocarpa)*** and corkbark fir ***(Abies lasiocarpa*** var. ***arizonica).*** The latter, readily distinguished by its peculiar, whitish, corky bark, is restricted to the Rocky Mountains of southern Colorado and the Southwest. Other common names for the typical variety include balsam, white balsam, alpine fir, western balsam fir, balsam fir, Rocky Mountain fir, white fir, and pino real blanco de las sierras; for corkbark fir, alamo de la sierra (44).

Habitat

Native Range

Subalpine fir is a widely distributed North American fir (fig. 2). Its range extends from 32" N. latitude in Arizona and New Mexico to 64" 30 N. in Yukon Territory, Canada. Along the Pacific coast, the range extends from southeastern Alaska, south of the Copper River Valley (lat. 62" N.), the northwestern limit; east to central Yukon Territory (lat. 64" 30' N.), the northern limit; south through British Columbia along the east slopes of the Coast Range to the Olympic Mountains of Washington, and along both slopes of the Cascades to southern Oregon. It is not found on the west slopes of the Coast Range in southern British Columbia or along the Coast Range in Washington and Oregon, but it does occur on Vancouver Island *(2,9)*. It is also found locally in northeastern Nevada and northwestern California (43). Except where noted above, subalpine fir is a major component of high elevation Pacific Northwest forests.

In the Rocky Mountain region, subalpine fir extends from the interior valleys of British Columbia west of the Continental Divide and south of the Peace River (lat. 55" N.), south along the high elevations of the Rocky Mountain system to southern New Mexico and Arizona. In the north, its range extends from the high mountains of central British Columbia, western Alberta, northeastern Washington, northeastern Oregon, Idaho, Montana, to the Wind River Mountains of western Wyoming. In Utah, it commonly occurs in the Uinta and Wasatch Mountains, but is less abundant on the southern plateaus. The range extends from southern Wyoming, through the high

Figure *1-Mature subalpine fir on the Fraser Experimental Forest, Colorado.*

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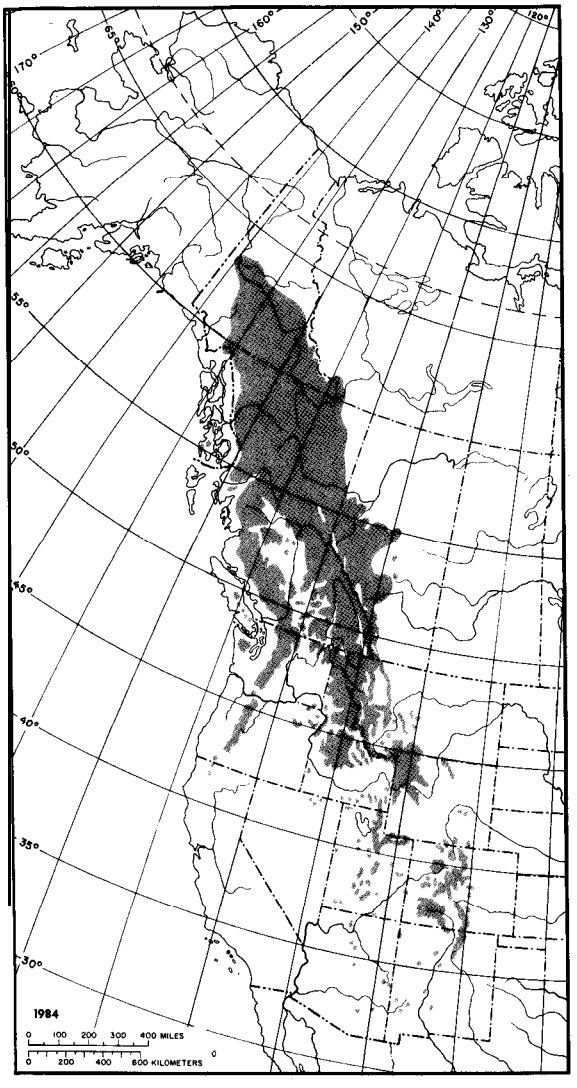

Figure *2-Natural range of subalpine fir (Abies lasiocarpa).*

mountains of Colorado and northern New Mexico, and westward through northeastern Arizona to the San Francisco Mountains *(2,9)*. Subalpine fir is a major component of the high-elevation forests of the Rocky Mountains.

Corkbark fir is found mixed with subalpine fir on scattered mountains in southwestern Colorado; northern, western, and southwestern New Mexico; and in the high mountains of Arizona *(44)*.

Climate

Subalpine fir grows in the coolest and wettest forested continental area of western United States (58). Temperatures range from below -45" C (-50" F) in the winter to more than 32.2" C (90° F) in the summer. Although widely distributed, subalpine fir grows within a narrow range of mean temperatures. Mean annual temperatures vary from -3.9" C (25° F) to 4.4" C (40" F), with a July mean of 7.2" C to 15.6" C *(45"* F to *60"* F), and a January mean of -15.0" C to -3.9" C (5° F to 25" F) *(10,26,47)* (table 1). Average precipitation exceeds 61 cm (24 in), much of which falls as snow. More than half the precipitation occurs from late fall to late winter in the Pacific Northwest and west of the Continental Divide in the Rocky Mountains north of Utah and Wyoming. East of the Divide, in the Rocky Mountains north of New Mexico and Arizona, the heaviest precipitation comes in late winter and early spring. In the Rocky Mountains and associated ranges in Arizona and New Mexico, most precipitation comes during late summer and early fall *(5,10,58)*. However, cool summers, cold winters, and deep winter snowpacks are more important than total precipitation in differentiating where subalpine fir grows in relation to other species.

Soils and Topography

Information on soils where subalpine fir grows is limited. In the Pacific Coast region, soil parent materials are mixed and varied. Zonal soils in the subalpine fir zone are Cryorthods (Podzolic soils), or Haplorthods (Brown Podzolic soils) with well developed but ultimately thin humus layers. Haploxerults and Haplohumults (Reddish-Brown Lateritic soils), developed from volcanic lava; Xerochrepts (Regosolic soils), developed from shallow residual material; and Lithic (Lithosolic soils) are also common in some localities. Dystrandepts (Bog soils) and Haplaquepts (Humic Gley soils) occur on poorly drained sites. Soils are more acid than in lower elevation forests, with pH typically ranging from 4.5 to 5.9 *(22,61)*.

In the central and southern Rocky Mountains subalpine zone, soil materials vary according to the character of the bedrock from which they originated. Crystalline granite rock predominates, but conglomerates, shales, sandstones, basalts, and andesites commonly occur. Glacial deposits and stream alluvial fans are also common along valley bottoms. Of the great soils-group, Cryorthods (Podzolic Soils) and Haplorthods (Brown Podzolic Soils) occur extensively on all aspects. Cryochrepts (Sols Bruns Acides) occur extensively on the drier aspects. Aquods (Ground-Water Podzolic Soils) are found in the more poorly drained areas. Cryoboralfs (Gray-Wooded Soils) have fine-textured parent material and support low-density timber stands. Haploboralls (Brown Forest Soils) occur mostly in the lower subalpine zone along stream terraces and side slopes. Lithics (Lithosolic Soils) occur whenever bedrock is near the

Table 1—Climatological data for four regional subdivisions within the range of subalpine fir.

Location	Average temperature						Annual precip.		Annual snowfall		Frost each period
	Annual		July		January						
	°C	°F	°C	°F	°C	°F	cm	in	cm	in	days
Pacific Northwest	-1 to 4	30-35	7-13	45-55	-9 to -4	15-25	61–254+	24–100+	1524+	600+	30-60
U.S. Rocky Mountains											
Northern[1]	-4 to 2	25-35	7-13	45-55	-15 to -9	5-15	61-152	24-60	635+	250+	30[4]–60
Central[2]	-1 to 2	3035	10–13	5055	-12 to -9	10-15	61-140	24-55	381-889+	150–350+	30[4]–60
Southern[3]	-1 to 4	30-40	10-16	50-60	-9 to -7	15-20	61–102+	24–40+	508	200+	30[4]–75

[1]Includes the Rocky Mountains north of Wyoming and Utah, and associated ranges in eastern Washington and Oregon
[2]Includes the Rocky Mountains of Colorado, Wyoming and Utah.
[3]Includes the Rocky Mountains and associated ranges of New Mexico and Arizona, and the plateaus of southern Utah.
[4]Frost may occur any month of the year.

surface. Aquepts (Bog Soils) and Haplaquepts (Humic Gley Soils) occur extensively in poorly drained upper stream valleys *(31,61)*.

Regardless of the great soils groups that occur in the subalpine zone of the west, subalpine fir is not exacting in its soil requirements. It is frequently found growing on soils that are too wet or too dry for its common associates. Good growth is made on lower slopes, alluvial floodplains, and glacial moraines; and at high elevations on well drained, fine- to medium-textured sand and silt loams that developed primarily from basalt, andesite, and shale. Growth is poor on shallow and coarse-textured soils developed from granitic and schistic rock, conglomerates, and coarse sandstones, and on saturated soils, but subalpine fir establishes on severe sites, such as lava beds, tallus slopes, and avalanche tracks, before any of its common associates. Under these conditions it may pioneer the site for other species or it may exclude the establishment of other species *(9,23)*.

Subalpine fir grows near sea level at the northern limit of its range, and as high as 3658 m (12,000 ft) in the south. In the Coast Range of southeastern Alaska, it is found from sea level to 1067 m (3,500 ft); in the Coast Range and interior plateaus of Yukon Territory and British Columbia, at 610 to 1524 m (2,000 to 5,000 ft); and in the Olympic and Cascade Mountains of Washington and Oregon, generally at 1219 to 1829 m (4,000 to 6,000 ft), but as low as 610 m (2,000 ft) along cold stream bottoms and on lava flows, and as high as 2438 m (8,000 ft) on sheltered slopes *(9,57)*.

In the Rocky Mountains of British Columbia and Alberta south of the Peace River, subalpine fir grows at 914 to 2134 m (3,000 to 7,000 ft), but it is more abundant above 1524 m (5,000 ft); in the Rocky Mountains of Montana and Idaho and associated ranges in eastern Washington and Oregon, at 610 to 3353 m (2,000 to 11,000 ft), but it is more common at 1524 to 2743 m (5,000 to 9,000 ft) *(40,41)*; in the Rocky Mountains of Wyoming, Utah, and Colorado, usually at 2743 to 3353 m (9,000 to 11,000 ft), but it may be found as low as 2438 m (8,000 ft) and to timberline at 3505 m (11,500 ft); and in the Rocky Mountains and associated ranges of New Mexico and Arizona, at 2438 to 3658 m (8,000 to 12,000 ft), but usually on north slopes at 2896 to 3353 m (9,500 to 11,000 ft) *(9,12,46,52)*.

Associated Forest Cover

In the Rocky Mountains, subalpine fir is most typically found in mixture with Engelmann spruce *(Picea engelmannii)* and forms the relatively stable Engelmann Spruce-Subalpine Fir (Type 206) forest cover type. It is also found in varying degrees in 16 other cover types *(56)*:

SAF Type No.	Type Name
201	White Spruce
202	White Spruce-Paper Birch
205	Mountain Hemlock
208	Whitebark Pine
209	Bristlecone Pine
210	Interior Douglas-Fir
212	WesternLarch
213	Grand Fir
215	Western White Pine
216	Blue Spruce
217	Aspen
218	Lodgepole Pine
219	Limber Pine
223	Sitka Spruce
224	Western Hemlock
226	Coastal True Fir-Hemlock

Differences in elevation and latitude affect temperature and precipitation, influencing the com-

position of the forests where subalpine fir grows *(16)*.[1] In Alaska and the Coast Range of British Columbia south through the Coast Range of Washington and Oregon, mountain hemlock ***(Tsuga mertensiana)*** is its common associate. In Alaska and northern British Columbia, Alaska-cedar ***(Chamaecyparis nootkatensis)*** mixes with it; and where it approaches sea level, it mingles with Sitka spruce ***(Picea sitchensis).*** From southern British Columbia southward through much of the Cascades, Pacific silver fir ***(Abies amabilis)***, mountain hemlock, and lodgepole pine ***(Pinus contorta)*** are the most common associates under closed forest conditions. Major timberline associates are mountain hemlock and whitebark pine *(Pinus albicaulis)*. Engelmann spruce is not a constant associate of subalpine fir except on the east slopes of the northern Cascades, and on exceptionally moist, cool habitats scattered throughout the southern and western Cascades. Engelmann spruce is a major associate of subalpine fir in the mountains of eastern Washington and Oregon. Less common associates in the Pacific Northwest include western hemlock, noble fir ***(Abies procera),*** grand fir ***(Abies grandis),*** western white pine ***(Pinus monticola),*** western larch ***(Larix occidentalis),*** and alpine larch ***(Larix lyallii)*** *(2,9)*.

From the mountains and interior plateaus of central British Columbia southward through the Rocky Mountain system, where subalpine fir frequently extends to timberline, its most constant associate is Engelmann spruce. Less common associates include: in British Columbia and western Alberta, white spruce ***(Picea glauca),*** balsam poplar ***(Populus balsamifera),*** paper birch ***(Betula papyrifera)***, and aspen ***(Populus tremuloides);*** in the Rocky Mountains of Montana and Idaho at its lower limits, western white pine, interior Douglas-fir ***(Pseudotsuga menziesii*** var. glauca), western hemlock ***(Tsuga heterophylla),*** western larch, grand fir, and western redcedar ***(Thuja plicata);*** and at higher elevations, lodgepole pine, alpine larch, mountain hemlock, and whitebark pine. In the Rocky Mountains of Wyoming, Utah, and Colorado, near its lower limits, associates are lodgepole pine, interior Douglas-fir, aspen, and blue spruce ***(Picea pungens)***; and at higher elevations, whitebark pine, limber pine *(Pinus flexilis)*, and bristlecone pine *(Pinus* ***aristata);*** and in the Rocky Mountains and associated ranges of New Mexico and Arizona, near its lower limits, white fir ***(Abies*** *concolor)*, interior Douglas-fir, blue spruce, and aspen; and at higher elevations, corkbark fir. Subalpine fir frequently extends to timberline in the Rocky Mountains. Other species that accompany it to timberline are whitebark pine, mountain hemlock, and occasionally Engelmann spruce in the Rocky Mountains north of Utah and Wyoming; Engelmann spruce in the Rocky Mountains north of Wyoming, Utah, and Colorado; and Engelmann spruce and corkbark fir in the Rocky Mountains and associated ranges south of Wyoming and Utah *(2,9)*.

At timberline in the Rocky Mountains, subalpine fir and Engelmann spruce form a wind Krummholz 1 to 2 m (3 to 7 ft) high. On gentle slopes below timberline, subalpine fir, Engelmann spruce, and occasionally lodgepole pine grow in north-south strips 10 to 50 m (33 to 164 ft) wide and several hundred meters long approximately at right angles to the direction of prevailing winds. These strips are separated by moist subalpine meadows 25 to 75 m (82 to 246 ft) wide where deep snow drifts accumulate ***(14).***

Undergrowth vegetation is more variable than tree associates. In the Pacific Northwest and the Rocky Mountains and associated ranges north of Utah and Wyoming, common undergrowth species include: Labrador tea ***(Ledum glandulosum),*** Cascades azalea ***(Rhododendron*** *albiflorum)*, rusty skunkbrush *(Menziesia ferruginea)*, woodrush ***(Luzula hitchcockii),*** Rocky Mountain maple *(Acer glabrum)*, twinflower ***(Linnaea borealis),*** dwarf huckelberry *(Vaccinium caespitosum)* and blue huckleberry *(V. globulare)* (cool, moist sites); queens cup *(Clintonia uniflora)*, twistedstalk ***(Streptopus*** *amplexiflolius)*, and sweetscented bedstraw ***(Galium*** *triflorum)* (warm, moist sites); grouse whortleberry *(V.* ***scoparium),*** fireweed ***(Epilobium angustifolium),*** mountain gooseberry ***(Ribes*** *montigenum)*, heartleaf arnica ***(Arnica*** *cordifolia)*, bear-grass *(Xerophyllum tenax)*, boxleaf myrtle ***(Pachystima*** *myrsinites)*, elksedge ***(Carex*** *geyeri)*, and pine grass ***(Calamagrostis rubescens*** (cool, dry sites); creeping juniper ***(Juniperus*** *communis)*, white spirea ***(Spiraea betulaefolia),*** Oregongrape ***(Berberis*** *repens)*, a mountain snowberry ***(Symphoricarpos*** *oreophilus)*, and big whortleberry *(V.* ***membranaceum)*** (warm, dry sites); and marsh-marigold ***(Caltha*** *biflora)*, devilsclub ***(Oplopanax horrida),*** and bluejoint reedgrass ***(Calamagrostis*** *canadensis)* (wet sites) (6,221.

Undergrowth characteristically found in the Rocky Mountains and associated ranges south of Idaho and Montana includes: mountain bluebells ***(Mertensia*** *ciliata)* and heartleaf bittercress ***(Cardamine*** *cordifolia)* (cool, moist sites); thimbleberry *(Rubus parviflorus)* (warm, moist sites); red buffaloberry

[1] Classification of forest vegetation into "habitat types" based on the methodology developed by Daubenmire (17) and Daubenmire and Daubenmire *(18),* and modified by others, is available for much of the western forest land. However, the classification has not been completed for all land where subalpine fir grows. Moreover, because of the great number of these habitat types and the complexity of their descriptions, they have not been included in this paper.

(Shepherdia canadensis), Oregongrape, creeping juniper, mountain snowberry (warm, dry sites); and Rocky Mountain whortleberry *(V. myrtillus),* grouse whortleberry, fireweed, heartleaf arnica, groundsel *(Senecio sanguiosboides),* polemonium *(Polemonium delicatum),* daisy fleabane *(Erigeron eximius),* elksedge, boxleaf myrtle, prickly currant *(Ribes lacustre),* sidebells pyrola *(Pyrola secunda),* and mosses (cool, dry sites) *(6).*

Life History

Reproduction and Early Growth

Flowering and Fruiting-Subalpine fir flowers are monoecious. Male flowers, usually abundant, are borne in pendulous clusters from the axils of the needles on the lower branchlets. Female flowers are fewer, borne erect and singly on the uppermost branchlets of the crown. Male flowers ripen, and pollen is wind-disseminated, during late spring and early summer. Cones are indigo blue when they open in mid-August to mid-October. Seed ripens from mid-September to late-October *(45,60).*

Seed Production and Dissemination-subal-pine fir may begin to produce cones when trees are 1.2 to 1.5 m (4 to 5 ft) tall and 20 years old, but under closed-forest conditions, seed production is not significant until trees are older and taller. Corkbark fir does not begin to bear cones until about 50 years old. Maximum seed production for subalpine and corkbark fir occurs in dominant trees 150 to 200 years old *(9,60).*

Subalpine fir is a good seed producer in the Pacific Northwest and in the Rocky Mountains of Idaho and Montana, with good to heavy crops borne every 3 years, and light crops or failures in between *(24,42).* It is as good a seed producer as most associated true firs, but not as good as the hemlocks and Engelmann spruce. In one ll-year study at four locations in the Cascades, subalpine fir cone crops, based on the following criteria, were rated medium to very heavy in 6 years and very light to failure in the other 5 (24).

Number of cones/tree	Crop rating
0	Failure
I-9	Very light
10-19	Light
20-49	Medium
50-99	Heavy
100+	Very heavy

In the Rocky Mountains south of Idaho and Montana, seed production of subalpine and corkbark fir has generally been poor, with more failures than good seed years. In one study in Colorado covering 42 area-seed-crop years, subalpine fir was an infrequent seed producer. Some seed was produced in only 8 of the years, while the other 34 were complete failures (50). Similar results have been obtained from other seed-production studies in Colorado. However, because these studies were designed to sample seed production in spruce-fir stands and because Engelmann spruce made up 90 percent or more of the dominant stand basal area, these results only indicate subalpine fir seed production in spruce-fir stands, not of individual dominant fir trees *(9).*

A number of cone and seed insects of subalpine fir have been identified but their relative importance, frequency of occurrence, and the magnitude of losses are not known (39). Some seed is lost from cutting and storing of cones by pine squirrels *(Tamiasciurus hudsonicus fremonti),* and, after seed is shed, small mammals, such as deer mice *(Clethrionomys gapperi),* mountain voles *(Microtus montanus),* and western chipmunks *(Eutamias minimus),* consume some seeds (5). However, the amount of seed lost to mammals, birds, and other causes are not known.

Cones disintegrate when they are ripe. Scales fall away with the large, winged seeds, leaving only a central, spikelike axis. Dissemination beginning in September usually is completed by the end of October in the Rocky Mountains. In the Pacific Northwest, seed dissemination begins in October and usually continues into November, but pitched-up cones may extend dissemination into December. Nearly all seed is dispersed by the wind *(21,60).*

Subalpine fir seeds are fairly large, averaging 76,720/kg (34,800/lb). Little information is available on seed dispersal distances. Studies designed to measure Engelmann spruce seed dispersal show similar dispersal patterns for subalpine fir. Prevailing winds influence the dispersal pattern, with about half the seeds falling into openings within 30 m (100 ft) of the windward timber edge. Seedfall continues to diminish until about two-thirds the way across the opening, and then levels off before slightly increasing about 15 m (50 ft) from the leeward timber edge *(50).* Thermal upslope winds are important in seed dispersal in mountainous terrain at mid- to lower-elevations (54).

Subalpine fir seed viability is only fair: average germinative capacity is 34 percent and vitality transient *(60).* Observations and limited studies in the Rocky Mountains indicate that germinative capacity is often less than 30 percent (55). Some lots of stored seeds exhibit embryo dormancy, which can be broken by stratification in moist sand or peat at 5" C (41" F) for 60 days *(9,60).*

Seedling Development-Under natural conditions, fir seeds lie dormant under the snow and germinate the following spring. Although germination and early survival of subalpine fir are generally best on exposed mineral soil and moist humus, the species is less exacting in its seedbed requirements than most of its common associates. Subalpine fir has been observed to germinate and survive on a wide variety of other seedbed types including the undisturbed forest floor, undecomposed duff and litter, and decaying wood *(9,15,19)*. Subalpine fir also invades and establishes on severe sites such as recent burns, lava flows, talus slopes, avalanche tracks, and climatically severe regions near timberline (22). Subalpine fir succeeds on these open sites because of its ability to establish a root system under conditions too severe for its less hardy associates, and its ability to reproduce by layering.

Although subalpine fir grows under nearly all light intensities found in nature, establishment and early survival are usually favored by shade. In the absence of Pacific silver fir, grand fir, and mountain hemlock, subalpine fir will survive under closed-forest conditions with less light than Engelmann spruce, noble fir, and white spruce (22). When grown with Pacific silver and grand fir, and/or mountain hemlock, subalpine fir does not compete successfully under closed-forest conditions. It does not compete well with the spruces, lodgepole pine, or interior Douglas-fir when light intensity exceeds 50 percent of full shade (9).

Subalpine fir is restricted to cold, humid habitats because of low tolerance to high temperatures. Newly germinated subalpine fir seedlings tolerate high solar radiation, but they are susceptible to heat girdling and drought. Seedlings are also killed or damaged by spring frosts, competing vegetation, frost heaving, damping off, snowmold, birds, rodents, and trampling and browsing by large animals, but losses are not different than for any common associate *(5)*.

The number of seeds required to produce a first-year seedling, and an established seedling (at least 3 years old), and the number of first-year seedlings that produce an established seedling vary considerably, depending upon seed production, distance from source, seedbed, and other environmental conditions. In one study in Colorado, covering the period 1961 to 1975 and a wide variety of conditions, an average of 150 seeds (range 35 to 290) was required to produce a first-year seedling. An average of 755 seeds (range 483 to 1,016) was required to produce a 4- to 13-year-old established seedling. For every established 4- to 13-year-old seedling, an average of 10 first-year seedlings were required, with a range of as few as 4 to as many as 14 *(50)*.

Early root growth of subalpine fir is very slow. The root length of first-year seedlings in one study in British Columbia averaged only 6.8 cm (2.7 in) *(20)*. No comparable data are available in the United States, but first-year penetration of corkbark fir in Arizona averaged 8.6 cm (3.4 in) (32).

Figure 3—*Subalpine fir seedlings average less than 38 cm (15 in) in height after 15 years in the open.*

Figure 4—*Subalpine fir advanced reproduction released by removal of the overstory. Trees averaged 1.0 to 1.8 m (3 to 6 ft) in height and are at least 50 years old.*

Figure ***S-Dominant subalpine firs on the Fraser Experiment Forest, Colorado. These trees are about 30 to 35 cm (12 to 14 in) in diameter,*** about ***18 m (60 ft)*** tall, ***and over 200 years old at breast height.***

Shoot growth is equally slow at high elevations. Many first-year seedlings are less than 2.5 cm (1 in) tall. Annual height growth of seedlings during the first 10-15 years usually averages less than 2.5 cm (1 in) (fig. 3).

In one study, seedlings 15 years old averaged only 28 cm (11 in) in height on burned-over slopes, 25 cm (10 in) on cutover, dry slopes, and 15 cm (6 in) on cutover, wet flats (30). In another study, seedlings grown on mineral soil averaged only 58.8 cm (24 in) after 21 years (28). Trees reach 1.2 to 1.5 m (4 to 5 ft) in height in 20 to 40 years under favorable environmental conditions. However, trees less than 13 cm (5 in) in diameter are often 100 or more years old at higher elevations, and trees 1.2 to 1.8 m (4 to 6 ft) high and 35 to 50 years old are common under closed-forest conditions *(40,51)* ***(fig. 4).***

At lower elevations, seedling shoot growth has been better. In one study in the Intermountain West, average annual height growth of subalpine fir seedlings for the first lo-years after release was 11.4 cm (4.5 in) on clearcuts and 8.1 cm (3.2 in) on partial cuts (48).

Vegetative Reproduction-Subalpine fir frequently reproduces by layering where the species is a pioneer in developing forest cover on severe sites such as lava flows and talus slopes or near timberline (22). Under closed-forest conditions, reproduction by layering is of minor importance.

Sapling and Pole Stage to Maturity

Growth and Yield-On exposed sites near timberline, subalpine fir is often reduced to a prostrate shrub, but under closed-forest conditions it attains diameters of 30 to 61 cm (12 to 24 in) and heights of 14 to 30 m (45 to 100 ft), depending upon site quality and stand density (fig. 5). Trees larger than 76 cm (30 in) in diameter and 39.6 m (130 ft) in height are exceptional (57).

Growth is not rapid; trees 25 to 51 cm (10 to 20 in) in diameter are often 150 to 200 years old under closed-forest conditions. Trees older than 250 years are not uncommon. But, because the species suffers severely from heartrot, many trees either die or are complete culls at an early age. Few data are available on the yields of subalpine fir in natural stands. It usually grows in mixed stands and comprises only a minor part of the volume. In the Rocky Mountains and Pacific Northwest, where it grows in association with Engelmann spruce, subalpine fir usually makes up only 10 to 20 percent of the saw log volume, which may range from less than 12,350 to more than 98,800 fbm/ha (5,000 to 40,000 fbm/acre) *(30,49)*. In the Pacific Northwest and Rocky Mountains, where subalpine fir grows with other true firs and/or mountain hemlock, few trees reach minimum merchantable size before being crowded out of the stand (22). Subalpine fir in the Rocky Mountains grows in pure stands most often on sites so severe that it has little commercial value. In the Pacific Northwest, pure stands on commercial sites typically occur on southerly slopes and are usually less than 150 years old. These stands are not extensive but are distinctive ***(21).***

Managed Stands

The only data available for yields of subalpine fir in managed stands are estimated from simulations for mixed Engelmann spruce-subalpine fir stands in the Rocky Mountains south of Idaho and Montana (7). These simulations show that periodic thinning to control stand density and maintain growth rates increases the yield and size of individual fir trees in these mixed stands. Furthermore, the growth rates for fir are similar to those for spruce early in the life of the stand. However, the fir component is likely to be greatly reduced by repeated thinnings, so that the stand at the time of final harvest will be almost pure Engelmann spruce.

Rooting Habit-Subalpine fir has a shallow root system on sites that limit the depth of root penetration, and where the superficial lateral root system common to the seedling stage persists to old age. Under more favorable conditions, subalpine fir develops a relatively deep lateral root system (9).

Reaction to Competition-In the Rocky Mountains and Pacific Northwest where subalpine fir and Engelmann spruce form the spruce-fir type, and mountain hemlock and other true firs are absent or limited in number, subalpine fir is very shade-tolerant *(22)*. It is much more tolerant than spruce and other common associates such as lodgepole pine, aspen, blue spruce, and interior Douglas-fir ***(11).*** However, in most of the Cascades and in the Rocky Mountains, where subalpine fir grows with the more shade-tolerant Pacific silver fir, grand fir, and mountain hemlock, some ecologists classify it as intolerant relative to these associates (22).

Subalpine fir, together with Engelmann spruce, forms a climax or long-lived seral forest vegetation throughout much of its range. In the Rocky Mountains of British Columbia and Alberta and south of Montana and Idaho, subalpine fir and Engelmann spruce occur as either codominants or in pure stands of one or the other. Spruce, however, is most likely to form pure stands, especially at upper elevations. In the Rocky Mountains of Montana and Idaho and the mountains of eastern Oregon and Washington, subalpine fir is a major climax. Engelmann spruce may be either a major climax or a persistent long-lived seral. Pure stands of either species may occur, but subalpine fir is more likely to form pure stands, especially at high elevations (2).

Although subalpine fir is a dominant element in several climax or near-climax vegetation associations, these forests differ from the typical climax forest in that most of them are not truly all-aged. For example, in spruce-fir forests, some stands are single-storied while others are two-, three-, and multi-storied. Multi-storied stands may result from past disturbances such as fire, insect epidemics, or cutting, or they may result from the gradual deterioration of single- and two-storied stands associated with normal mortality from wind, insects, and diseases *(5)*. On the other hand, some multi-storied stands appear to have originated as uneven-aged stands and are successfully perpetuating that structure *(3,27)*.

Where subalpine fir is a component of the climax vegetation, the natural tendency is for subalpine fir to reestablish itself when destroyed and temporarily replaced by other vegetation (27). Throughout most of the Cascades and in the Rocky Mountains where subalpine fir grows with the other true firs and/or mountain hemlock, it is seral. Subalpine fir also is a pioneer on difficult sites, where its ability to reproduce by layering allows it to colonize more readily than its common associates (22).

The ecophysiology of subalpine fir in relation to common associated species is becoming better understood *(33,34,35,36)*. What is known about the general water relations of subalpine fir can be summarized as follows: (1) needle water vapor conductance (directly proportional to stomata1 opening) is controlled primarily by visible irradiance and absolute humidity difference from needle to air (evaporative demand) with secondary effects from temperature and water stress; (2) nighttime minimum temperatures below 3.9" C (39" F) retard stomata1 opening the next day; (3) stomata function well from early spring to late fall, and high transpiration rates occur even with considerable snowpack on the ground; (4) leaf water vapor conductance is lower than that of Engelmann spruce, lodgepole pine, and aspen, the common associates of central Rocky Mountain subalpine forests; (5) subalpine fir trees have a larger total needle area per unit of sapwood water-conducting tissue than the other three species; and (6) subalpine fir trees have a slightly lower needle area per unit of bole or stand basal area than Engelmann spruce, but greater than lodgepole pine or aspen. At equal basal area, annual canopy transpiration of subalpine fir is about 35 percent lower than spruce, but 15 percent higher than lodgepole pine, and 100 percent higher than aspen. These high rates of transpiration cause subalpine fir to occur primarily on wet sites, generally in association with Engelmann spruce *(37,38)*.

Both even- and uneven-aged silvicultural systems can be used in stands where subalpine fir is a component *(1,5,8)*. The appropriate even-aged cutting methods are clearcutting and shelter-wood cutting and their modifications. The seed-tree method cannot

be used because of susceptibility of subalpine fir to windthrow. The uneven-aged cutting methods are individual tree and group selection and their modifications. In spruce-fir stands, shelterwood and individual-tree-selection methods will favor subalpine fir over Engelmann spruce, lodgepole pine, and interior Douglas-fir *(4)*. In stands where subalpine fir grows with Pacific silver fir, grand fir, and/or mountain hemlock, clearcutting and group shelterwood or group selection cutting will favor subalpine fir *(22)*.

Damaging Agents--Subalpine fir is susceptible to windthrow. Although, this tendency is generally attributed to a shallow root system, soil depth, drainage, and stand conditions influence the development of the root system. The kind and intensity of cutting and topographic exposure to wind also influence the likelihood of trees being windthrown *(5)*.

Subalpine fir is attacked by several insects (39). In spruce-fir forests, the most important insect pests are the western spruce budworm *(Choristoneura occidentalis)* and western balsam bark beetle *(Dryocoetes confusus)*. The silver fir beetle *(Pseudohylesinus sericeus)* and the fir engraver *(Scolytus ventralis)* may at times be destructive locally *(25)*. In the Cascades, the balsam woolly adelgid *(Adelges piceae)*, introduced from Europe, is the most destructive insect pest. This insect has caused significant mortality to subalpine fir, virtually eliminating it from some stands in Oregon and southern Washington (22).

Fir broom rust *(Melampsorella caryophyllacearum)* and wood rotting fungi are responsible for most disease losses *(13,29,53)*. Important root and butt rots are *Gloeocystidiellum citrinum, Coniophora puteana, Armillaria mellea, Coniophorella olivaea, Polyporus tomentosus* var. *circinatus,* and *Pholiota squarrose.* Important trunk rots are *Haematostereum sanguinolentum, Phellinus pini,* and *Amylostereum chailletii.* Wood rots and broom rust weaken affected trees and predispose them to windthrow and windbreak (5).

Subalpine fir bark is thin, especially on young trees, and lower limbs persist after death (9). These characteristics make subalpine fir susceptible to death or severe injury from fire.

Special Uses

Throughout much of the Rocky Mountains, subalpine fir has no special or unique properties. In the high Cascades and in the Rocky Mountains of Idaho and Montana, it is a forest pioneer on severe and disturbed sites. By providing cover, subalpine fir assists in protecting watersheds and rehabilitating the landscape. Forests in which subalpine fir grows occupy the highest water yield areas in much of the West.

The species also provides habitat for various game and nongame animals, forage for livestock, recreational opportunities, and scenic beauty. However, these properties are indigenous to the sites where subalpine fir grows rather than to any special properties associated with the species *(1,5)*.

Fir is used as lumber in building construction, boxes, crates, planing mill products, sashes, doors, frames, and food containers. It has not been widely used for pulpwood because of inaccessibility, but it can be pulped readily by the sulfate, sulfite, or groundwood processes (59).

Genetics

Population Differences

Information on subalpine fir population differences is virtually nonexistent. Undoubtedly, any species with the range in elevation and latitude of subalpine fir will exhibit differences in growth, phenology, dormancy, resistance to heat and cold, etc. among different populations.

Races and Hybrids

Corkbark fir is the only recognized natural geographical variety of subalpine fir *(43)*. Like many species with wide distribution, it has probably developed unknown races and hybrids, and there is some evidence that natural introgressive hybridization between subalpine and balsam fir occurs where they grow together in Canada. Horticultural and ornamental cultures have been recognized (45). These include:

1. Abies lasiocarpa cv beissneri a dwarf tree bearing distorted branches and twisted needles.

2. A. 1. cv coerulescens a beautiful tree with specially intensive bluish needles.

3. A. 1. cv compacta. A dwarf tree of compact habit.

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