

# *Pseudotsuga macrocarpa* (Vasey) Mayr **Bigcone Douglas-Fir**

Pinaceae Pine family

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Distinct in appearance and conspicuous among its usually shorter associates, bigcone Douglas-fir (*Pseudotsuga macrocarpa*) provides contrast and variability to the southern California landscape. The wood of the species, although suitable for coarse lumber, is scarcely utilized because the trees are scattered and are more valuable for esthetics and watershed protection.

Because the taxonomic characteristics of bigcone Douglas-fir are similar to those of its northern "cousin," Douglas-fir, it was at least twice assigned to the genus *Abies*. Commonly, the species has been called hemlock, false hemlock, and desert fir. Colloquially, it is often referred to as bigcone-spruce, probably because its drooping lower branches, stiff needles, and upright cones remind the observer of the spruce tree. The species' accepted common name, bigcone Douglas-fir, stresses its *Pseudotsuga* lineage and the extraordinary size of its cones.

The species has been grown successfully outside the continental United States. It was unknown in Europe until the seedlings were raised at Bayfordbury, England, in 1910. Trees also have been reported growing in Sussex and North Ireland, where they reached heights of more than 18 m (60 ft) and crown spread of 12 m (40 ft) (3).

## Habitat

### Native Range

The range of bigcone Douglas-fir (fig. 1) is about 217 km (135 mi) from north to south and about 336 km (210 mi) from east to west. Distribution of the species, in general, is confined to the Transverse and Peninsular Ranges of southern California. It is found on Mount Pinos, technically in the Tehachapi Mountains but considered transitional between them and the Transverse Ranges. Northern limits are near Mount Pinos in Kern County, and the headwaters of Labrea Creek in Santa Barbara County. Westernmost limits are Mission Canyon in the Santa Ynez Mountains, and Zaca' Peak in the San Rafael Mountains. Older publications claimed that bigcone Douglas-fir grew in central Baja California, Mexico; a more recent publication verifies that it does not

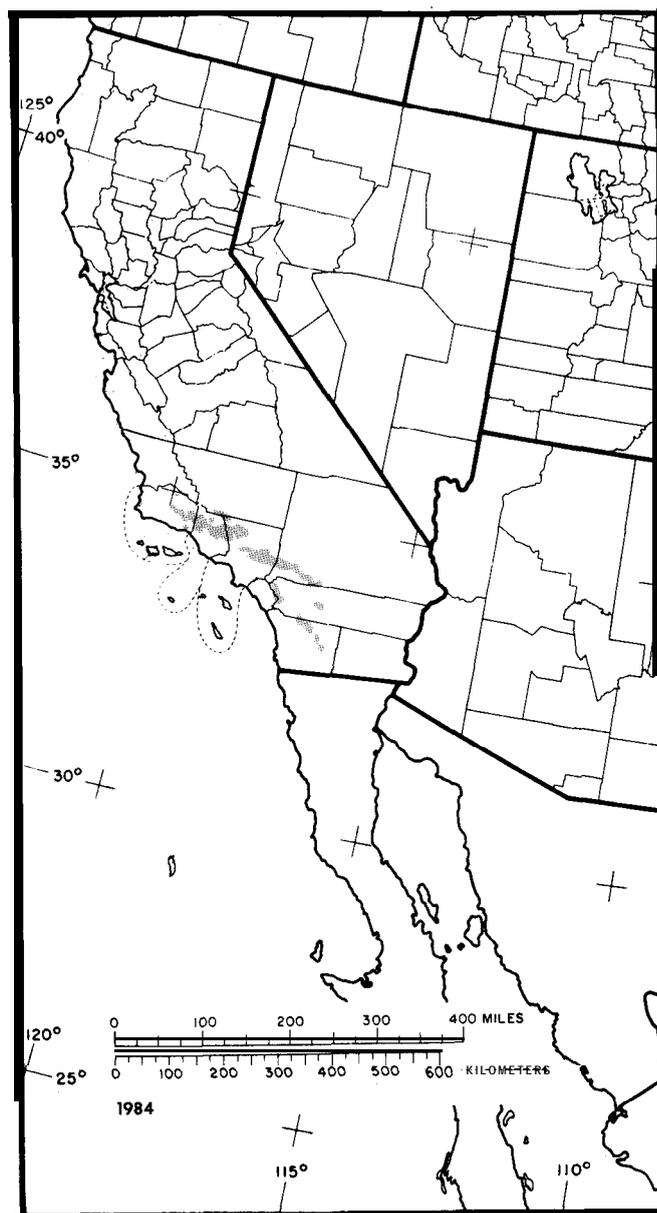


Figure 1—The native range of bigcone Douglas-fir.

(11). The southern limit of the species is near Julian, San Diego County.

### Climate

The bigcone Douglas-fir habitat has long hot summers and cool moist winters. Extremes of annual

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precipitation vary from less than 250 mm (10 in) to 1270 mm (50 in), with 510 to 1020 mm (20 to 40 in) more common. The 30-year average at 1325 m (4,350 ft) elevation on a north aspect in the San Gabriel Mountains near Glendora, CA, was 610 mm (24 in). The lowest annual precipitation recorded was 250 mm (9.9 in) and the highest 1240 mm (49 in).

Snowpacks persist rarely in the range of the species, except at high elevations. Snow may fall, however, as early as October, or as late as May. During the rainy season, fog has been reported to add to the moisture available for tree growth (14,15). During the summer, thunderstorms, hailstorms, or cloudbursts are common on higher mountains. Because much of this precipitation quickly evaporates, it does not foster tree growth (15).

Specific temperature data within the range of bigcone Douglas-fir have not been reported other than for one station at 730-m (2,400-ft) elevation in the San Gabriel Mountains. The 22-year average mean for November through April was  $9^{\circ} \pm 2^{\circ}$  C ( $49^{\circ} \pm 3.7^{\circ}$  F). Highs of above  $27^{\circ}$  C ( $80^{\circ}$  F) and lows of below freezing were recorded in each of the 6 months. Annual temperatures at low to middle elevations in the mountain ranges of southern California where bigcone Douglas-fir grows seldom exceed  $41^{\circ}$  C ( $106^{\circ}$  F) or drop below  $-12^{\circ}$  C ( $10^{\circ}$  F).

### Soils and Topography

Soils on which bigcone Douglas-fir grows are derived from a wide variety of parent materials. Of 16 stands sampled throughout the range of the species, 4 grew on metasedimentary parent materials (sandstone and schist), 10 on granitics, and 2 in contact zones where the parent material was primarily granitic. The soil orders where bigcone Douglas-fir is most frequently found are Inceptisols and occasionally Alfisols. Soil series on metasedimentary material are probably Laughlin and Friant; in contact zones, Oak Glen; and on granitics, Tollhouse, Cieneba, Crouch, and two others that resemble Tish Tang and Neuns. Soils show a broad range of depth and development (7). Some are shallow and poorly developed; others are deeper and better developed. Many are droughty. Bigcone Douglas-fir is capable of becoming established on soils too dry for other conifers.

Topography where the species is found is variable. Much of the terrain is rough and steep, strongly dissected by permanent and ephemeral streams. Slopes vary from 1 to 93 percent. Some stands occupy precipitous slopes of sheltered canyons, others are found on mostly steep broken slopes intermixed with cliffs and avalanche chutes, and still others thrive on

gentler slopes and level ground. For all stands in the Santa Ana Mountains, average angle of slope is 34.5 degrees (1). The species is well represented on all aspects, north slopes in particular.

Elevations of the bigcone Douglas-fir habitat range from 275 m (900 ft) on cool moist north slopes of canyon bottoms to 2400 m (7,875 ft) on warm south-facing plateaus. As elevations increase, the aspect best suited to bigcone Douglas-fir shifts from cooler to warmer. Many combinations of slope, aspect, soil, and elevation, therefore, support bigcone Douglas-fir.

### Associated Forest Cover

Bigcone Douglas-fir has been listed in at least three vegetation classifications. One author placed the species in the California Coast Range forest, considering it an endemic and relic species. Another suggested that, in the San Bernardino Mountains at least, bigcone Douglas-fir was a member of the Live Oak Woodland and the Bigcone Douglas-fir vegetation types (4). Among forest cover types, bigcone Douglas-fir is listed as a common associate in Canyon Live Oak (Society of American Foresters Type 249) (5).

Bigcone Douglas-fir occupies an intermediate position between the lower elevation chaparral zone and the higher elevation mixed-conifer forest. It ranges downward into the chaparral as far as moisture conditions permit, and upward among the pines and firs as far as severe climate allows. Bigcone Douglas-fir does not extend solidly between the two types, however. The species is found in patches, in groups, and as single trees scattered among the oaks and chaparral. The continuity of stands also is broken by cliffs, slides, and areas of adverse soil.

Evidence suggesting that bigcone Douglas-fir has long occupied its present natural range is available from the fossil record. A likely progenitor of the species has been found in both the Pliocene and Pleistocene epochs (6).

Fire, or its absence, greatly influences the extent and makeup of bigcone Douglas-fir stands. In general, repeated fires kill bigcone Douglas-fir, leaving only oaks or chaparral. Less frequent, but more catastrophic fires limit bigcone Douglas-fir to scattered large trees. When fires are infrequent, stands with several size and age classes develop; when fires are absent, multiaged stands having at least some regeneration evolve (7).

In recent large fires in the eastern Transverse Range, nearly 60 percent of the trees escaped defoliation and 15 percent sprouted later, for a survival rate of 75 percent. Trees appear to have survived primarily because they were growing with large tree-size

canyon live oaks (*Quercus chrysolepis*), and in rough, broken terrain. Large canyon live oaks apparently act as a buffer against severe combustion characteristics of the chaparral nearby, and rough terrain impedes the speed and intensity of a conflagration. Survival of bigcone Douglas-fir on slopes of less than 20 degrees was only 37 percent. On slopes greater than 40 degrees, survival was more than 90 percent (10).

Throughout its natural range, bigcone Douglas-fir is almost inseparable from canyon live oak. They form a community that is remarkably stable, self-perpetuating, somewhat exclusive, and probably climax in terms of succession. In the future, only minor shifts in species composition within the community are likely (7).

In addition to canyon live oak, other tree associates, particularly at high elevations, are ponderosa pine (*Pinus ponderosa* var. *ponderosa*), Jeffrey pine (*P. jeffreyi*), singleleaf pinyon (*P. monophylla*), and sugar pine (*P. lambertiana*), incense-cedar (*Libocedrus decurrens*), and California white fir (*Abies concolor* var. *lowiana*). At middle elevations, tree associates are Coulter pine (*Pinus coulteri*), Digger pine (*P. sabiniana*), California black oak (*Quercus kelloggii*), two-petal ash (*Fraxinus dipetala*), and California-laurel (*Umbellularia californica*). Singleleaf pinyon and knobcone pines (*Pinus attenuata*), as well as curlleaf (*Cercocarpus ledifolius*) and birchleaf mountain-mahogany (*C. betuloides*) also are locally present. At lower elevations bigcone Douglas-fir, along with bigleaf maple (*Acer macrophyllum*) and white alder (*Alnus rhombifolia*), is found in riparian settings, often in deep ravines, where it escapes fire. Coast live oak (*Quercus agrifolia*), toyon (*Heteromeles arbutifolia*), California scrub oak (*Quercus dumosa*), birchleaf mountain-mahogany, laurel sumac (*Rhus laurina*), sugar sumac (*R. ovata*), and occasionally southern California walnut (*Juglans californica*) are associates of bigcone Douglas-fir (3) at lower elevations, mostly in nonriparian settings.

Many woody shrubs are found with bigcone Douglas-fir (table 1). At middle and high elevations, although scarce beneath bigcone Douglas-fir and canyon live oak crowns, they flourish in open spaces between trees or on edges of thickets. At low elevations, shrubs become abundant and well developed around scattered large firs.

A number of herbaceous species are scattered beneath bigcone Douglas-fir trees. Plants are relatively scarce and small because necessary nutrients, moisture, and light, already captured by the taller and deeper-rooted species, often are not available.

**Table 1**-Principal shrub associates of bigcone Douglas-fir in three elevational zones

Elevation	Scientific name	Common name
274 to 1067 m or 900 to 3,500 ft	<i>Adenostoma fasciculatum</i>	Chamise
	<i>Artemisia californica</i>	California sagebrush
	<i>Ceanothus leucodermis</i>	Chaparral whitethorn
	<i>C. spinosus</i> var. <i>palmeri</i>	Greenbark ceanothus
	<i>Dendromecon rigida</i>	Bush POPPY
	<i>Eriogonum fasciculatum</i>	California buckwheat
	<i>Salvia</i> spp.	White sage
	<i>Yucca whipplei</i>	Chaparral yucca
1097 to 1676 m or 3,600 to 5,490 ft	<i>Adenostoma sparsifolium</i>	Red shanks
	<i>Arctostaphylos glauca</i>	Bigberry manzanita
	<i>A. patula</i>	Greenleaf manzanita
	<i>Ceanothus cuneatus</i>	Wedgeleaf ceanothus
	<i>C. integerrimus</i>	Deerbrush
	<i>C. leucodermis</i>	Chaparral whitethorn
	<i>C. oliganthus</i>	Hairy ceanothus
	<i>C. spinosus</i> var. <i>palmeri</i>	Greenbark ceanothus
1707 to 2438 m or 5,600 to 7,900 ft	<i>Arctostaphylos glauca</i>	Bigberry manzanita
	<i>A. patula</i>	Greenleaf manzanita
	<i>Castanopsis sempervirens</i>	Sierra chinkapin
	<i>Ceanothus crassifolius</i>	Hoary-leaf ceanothus
	<i>C. cuneatus</i>	Wedgeleaf ceanothus
	<i>Chrysothamnus nauseosus</i>	Rubber rabbitbrush
	<i>Penstemon ternatus</i>	Scarlet beardtongue
	<i>Rhamnus californica</i>	California buckthorn
	<i>R. crocea</i>	Hollyleaf buckthorn

## Life History

### Reproduction and Early Growth

**Flowering and Fruiting**-Throughout most of its natural range, bigcone Douglas-fir flowers from early March through mid-April. Male flowers generally shed pollen before female flowers become receptive—a mechanism that facilitates cross-pollination and prevents selfing. The plant is monoecious. Pollination in a given locality lasts 2 to 3 weeks. Fertilized conelets begin to enlarge in mid-July and are easily seen soon after.

Cones generally begin to dry and turn brown in August or September and most seed is released in September and October. Seeds are large and heavy and each has a rounded wing about 13 mm (0.5 in) long. Mature cones are rich dark brown and range from 11 to 17 cm (4 to 7 in) long. Some cones fall during winter, but others remain on the tree for at least a year.

**Seed Production and Dissemination-Cone** crops of bigcone Douglas-fir usually are small. Bumper crops are infrequent. Small amounts of seed, however, are borne on a few trees nearly every year. The minimum cone-bearing age of the species is about 20 years, but cones are rare on trees younger than 40 years. Most seeds fall beneath tree crowns and only during high winds is wider dissemination possible.

Insect larvae destroy some seeds in each cone crop and, at times, most of the crop. Rodents and birds consume seeds and aid in dispersal by distributing them beyond existing stands. Deer mice, chipmunks, ground squirrels, and the western gray squirrel eat large amounts of available seeds. The squirrels often bury seeds; some of these escape notice and eventually germinate.

**Seedling Development-Natural seedbed** requirements for germination are broad. Seeds of bigcone Douglas-fir have been observed to germinate successfully on the bare mineral soils of rocky outcrops and geomorphically active areas. They also germinate well in deep litter, usually beneath an overstory of oak and bigcone fir, but heavy losses from damping-off fungi often take their toll of tiny seedlings in this environment. Germination is epigeal.

Time of germination varies with elevation. In the chaparral zone, germination begins in late March. At higher elevations, germination ends in late May, or occasionally, early June.

Seed quality tends to be poor, as indicated in such early descriptions as "large number imperfect" and "a considerable percentage not fertile" (14,15). In a laboratory test of seed stratified for 28 days in moist vermiculite with a day temperature of 30° C (86° F) and night temperature of 20° C (68° F), 31 percent of seeds germinated.

Weather, especially rainfall, can be critical to germination and early abundance of bigcone Douglas-fir seedlings. In the Santa Ana Mountains, 24,700 seedlings per hectare (10,000/acre) were present after a rainy period preceded by a year of above-average precipitation. The seedling environment, however, was not reported. New seedlings were absent during dry years (1).

Bigcone Douglas-fir does not reproduce in stands having frequent fires, nor do badly damaged stands seed back to bigcone Douglas-fir, except during a series of wet years after a severe fire. Infertile seed, destruction of seed by fire, consumption of seed by birds and rodents, and lack of suitable microsites are possible reasons for scanty reproduction. Lack of shade could be another reason. Throughout its range, bigcone Douglas-fir reproduces most abundantly in

locales undisturbed for at least 50 years, especially if shaded by canyon live oak trees. Where present, seedlings ranged in density from 140 to 1,030/ha (56 to 416/acre), with an average of 330/ha (132/acre). Advance reproduction, plants smaller than 2.5 cm (1.0 in) in d.b.h., was similar in mean and range of density (7).

Artificial regeneration of bigcone Douglas-fir began in 1905, with outplantings in Los Angeles County. Survival was about 1 percent. The species was planted extensively (9,880 seedlings per hectare or 4,000/acre) for watershed rehabilitation from 1925 to 1930 by the Los Angeles County Forestry Department. From 1953 to 1975, this Department outplanted some bigcone Douglas-firs in all but 4 years (13). Survival, unfortunately, is unknown.

Additional information on artificial regeneration of bigcone Douglas-fir is scanty. One small trial took place on a harsh site in Shasta County. Seed was germinated in a greenhouse in 1.9-liter (0.5-gal) milk cartons and 20 seedlings were outplanted as plugs when 1 year old. After five growing seasons in the field, survival was 65 percent and height averaged 53 cm (21 in) with a range of 18 to 76 cm (7 to 30 in).

Early height growth of bigcone Douglas-fir seedlings is slow, especially in deep shade. The species develops a taproot in early years, possibly at the expense of shoot growth.

**Vegetative Reproduction-Bigcone** Douglas-fir does not sprout from the root crown after cutting or fire. It has been propagated by grafting.

### Sapling and Pole Stages to Maturity

**Growth and Yield-In** deep shade, growth of bigcone Douglas-fir seedlings and saplings is suppressed severely. Saplings may be only 60 cm (24 in) tall when 40 to 50 years old (10). Growth rings often are indistinguishable. Bigcone Douglas-fir trees break through the oak overstory when 4 to 9 m (13 to 30 ft) tall and 40 to 70 years old. Breast-height diameter at this age ranges from 10 to 20 cm (4 to 8 in). Once above the oak foliage and into sunlight, growth of bigcone Douglas-fir accelerates. Annual height increment may exceed 30 cm (12 in).

In more open stands, bigcone Douglas-fir seedlings and saplings develop more quickly. Height of saplings may average 1 to 3 m (3 to 10 ft) at age 20 and from 4 to 15 m (13 to 50 ft) at age 40. From 40 to 100 years, annual increments of height and diameter may be uniform, even though amounts of annual precipitation vary. Trees in favorable growing condi-



**Figure 2**—Typical form and crown of bigcone Douglas-fir on a site of good quality, Angeles National Forest, CA. (Courtesy Edward E. Littrell, Sacramento, CA)

tions often produce thick tapering boles and long drooping branches (fig. 2).

In the Santa Ana Mountains, diameter growth rates seem to be correlated to steepness of slope, with the average diameter of trees of a given age increasing as the angle of slope decreases. The largest trees of a given age, therefore, grow on level sites. The average d.b.h. of 20-year-old trees on level ground was 20 cm (7.8 in), but only 6 cm (2.2 in) on 60 to 90 degree slopes. A possible explanation of the difference is that little, if any, soil and litter are found on steep slopes, and water holding capacity and nutrients usually are low (1).

Tree heights are affected by many variables, especially position on the slope. Trees generally are tallest at the base of slopes and shortest near the

ridgeline. Trees at base of slopes commonly are straight and tall, averaging 24 to 30 m (80 to 100 ft) in height, but trees on upper slopes more often are gnarled and branchy and only 9 to 15 m (30 to 50 ft) tall.

The lifespan of bigcone Douglas-fir is as long as its coniferous associates, or longer. In the Santa Ana Mountains, trees 250 or more years old are commonplace. The oldest tree sampled was 622 years old and 140 cm (55 in) in d.b.h. A 157-cm (62-m) d.b.h. monarch of indeterminate age is nearby (1). The largest living bigcone Douglas-fir grows near San Antonio Canyon on the Angeles National Forest in southern California. At 231 cm (91 in) in d.b.h. and 44.2 m (145 ft) in height, this tree deserves its name "Old Glory."

Bigcone Douglas-fir is well known for its ability to grow a new crown after severe burning. This ability has helped to sustain the species in its present natural range. New tissue, which leads to new branches, develops from the upper surface of defoliated limbs in the upper portions of the tree. Large sawtimber-sized trees, therefore, can develop new crowns, but seedlings, saplings, and overmature sawtimber usually cannot.

Boles also produce new shoots after fire, mechanical, or physiological injury. Vigorous intermediate-aged trees are particularly noted for this capability. In the Santa Ana Mountains, new shoots developed in trees that were from 13 to 114 cm (5 to 45 in) in d.b.h. and from 25 to 300 years old (1).

**Rooting Habit**—The species is described as having a strong spreading root system.

**Reaction to Competition**—In its seedling stage, bigcone Douglas-fir requires at least some shade. In moist sheltered situations, however, it reproduces successfully in the open. Saplings and small poles need increasing amounts of light for best development. Mature trees usually are found in open stands, probably as a consequence of having adequate light and moisture. In general, bigcone Douglas-fir may be classed as intolerant of shade.

**Damaging Agents**—Fire is the most injurious agent of bigcone Douglas-fir. In spite of its ability to develop new crowns after complete defoliation (fig. 3), and its thick bark (15 to 20 cm or 6 to 8 in for trees more than 100-cm or 40-in d.b.h.), trees die from fire, and particularly from repeated fires that deplete energy reserves and enlarge old wounds.

Damage by insects and disease is not reported. The California flatheaded borer (*Melanophila californica*) has been observed in the wood of a few trees. Even



Figure 3--New branches are developing on the upper parts of burned branches in this large bigcone Douglas-fir on the Angeles National Forest, CA.

trees damaged by fire seem free of bark beetle attacks. A hard pitchy wood is given as a possible reason for lack of damage from these agents. A needle-cast fungus (*Rhabdocline pseudotsugae*) has been observed on bigcone Douglas-fir needles (8). Older trees occasionally lose most of their needles, apparently from a physiological disorder, but epicormic branching along the bole usually replaces the lost crown. Damage to needles from ozone is another potential injury. However, in a sensitivity study, seedlings of bigcone Douglas-fir ranked low (11th of 13 conifer species and hybrids) in susceptibility to ozone injury (9).

Many species of animals are associated with bigcone Douglas-fir, especially deer, rabbits, and woodrats. Browsing of seedlings is a major damage. Bigcone Douglas-fir stands are preferred spring habitat for black bears in the San Bernardino Moun-

tains (12). After the sapling stage, animal damage is negligible.

### Special Uses

The wood of bigcone Douglas-fir is heavy, hard, and close grained, but not durable (15). It has less sapwood than heartwood, the latter containing pockets of resin. In the past, bigcone Douglas-fir was used locally for fuel and to a small extent for coarse lumber. Currently, it has value in watersheds and wildlife habitats for its scenic beauty

### Genetics

Varieties or natural hybrids of bigcone Douglas-fir are not known, but an artificial cross of bigcone Douglas-fir and coast Douglas-fir was achieved in 1956 at Oregon State University, Corvallis. Hybrid seedlings indicated low mortality, good height growth, and a dense fibrous root system. They showed promise for outplanting on drier sites in the Douglas-fir region (2).

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