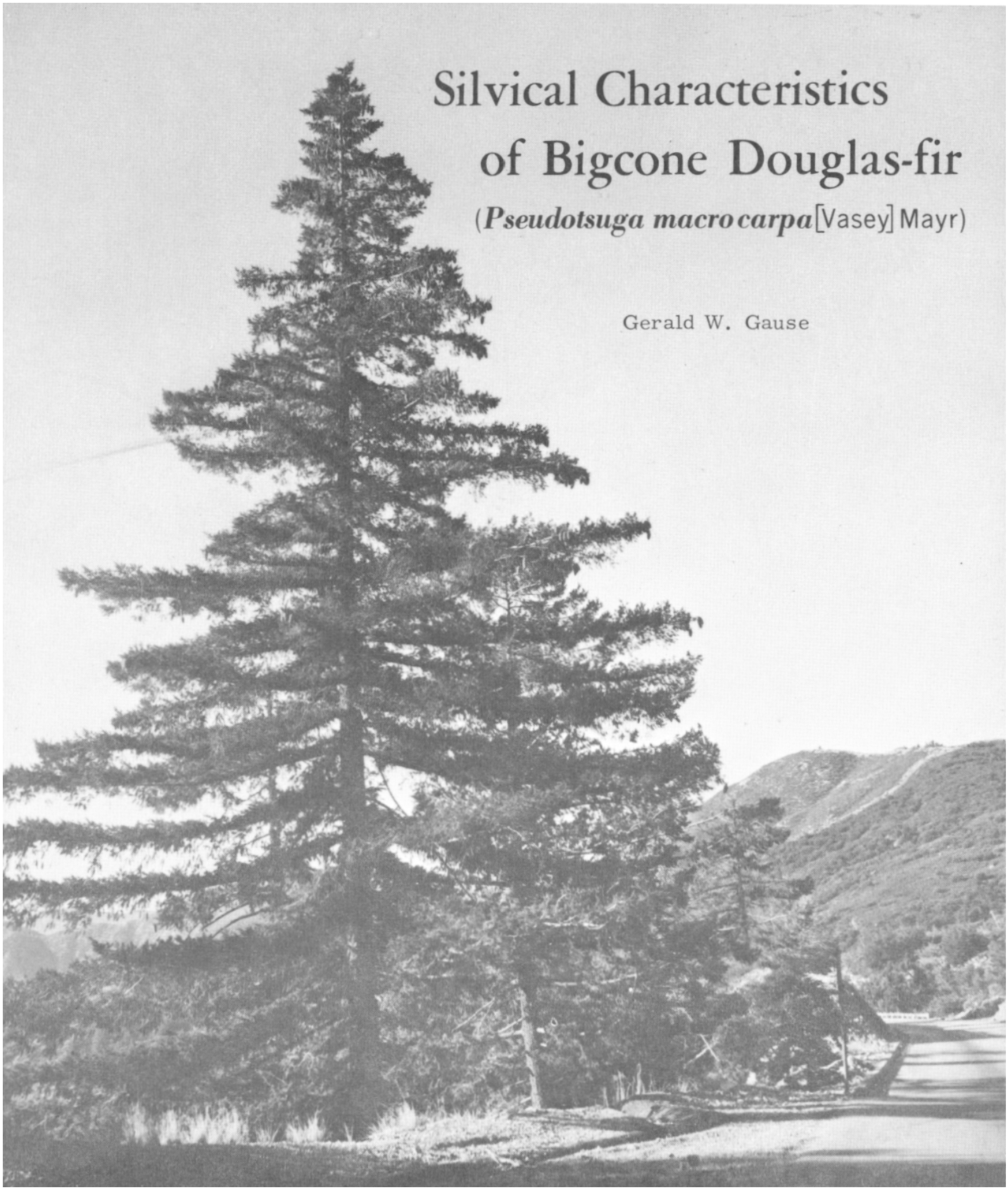
Silvical Characteristics of Bigcone Douglas-fir

(*Pseudotsuga macrocarpa* [Vasey] Mayr)

Gerald W. Gause



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Contents

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Bigcone Douglas-fir (*Pseudotsuga macrocarpa* [Vasey] Mayr) has been referred to by many common names and by several genera. Common names for this species include desert fir (Jepson 1910), bigcone spruce (Munz 1959), false hemlock (Sargent 1884), and bigcone Douglas-fir (Abrams 1923). According to Jepson (1910) and others, botanical names used in the past include *Abies Douglasii* var. *macrocarpa* Torrey (Ives 1861), *Tsuga macrocarpa* Lemmon (Lemmon 1875), and *Pseudotsuga Douglasii* var. *macrocarpa* Engelmann (Watson 1880). The name bigcone Douglas-fir both describes the species and identifies its close relationship to Douglas-fir (*Pseudotsuga menziesii* [Mirb] Franco).

The species was discovered in 1858 by an expedition led by Lieutenant J. C. Ives, who sighted the tree in San Felipe canyon between Banner and Julian in San Diego County, California (Ives 1861; Jepson 1910). Early botanical writers were perplexed by the similar taxonomic characteristics of bigcone Douglas-fir and Douglas-fir. But growth habits, wood characteristics, and cone size distinguished one species from the other. And no intermediate types have been found (Jepson 1910).

Bigcone Douglas-fir averages about 70 to 80 feet in height. A pyramidal crown composed of long lenticular branches gives it a sparse or thin appearance. The lower branches are long, and bend downward as the trees become older. Short, gray lateral stems or twigs droop downward from the main branches in numerous clusters. The 1-year-old twigs on the trees are red-brown and then become light gray the following year. The bole and lateral branches of the pole trees are gray and sometimes occur with balsam blisters. On mature trees the bark is rusty red-brown, 2 to 5 inches thick, with deep wide furrows and ridges that are irregularly connected (Sudworth 1908).

The dark gray-green needles are $^3/_4$ to 1 inch long, somewhat curved with a distinct midrib. They are attached in a spiral around the twig. Needles remain on the tree from 3 to 4 years and then fade during late September, and fall off through October. Five-year-old needles have been observed on some trees at 7,000 feet elevation on the Angeles National Forest, in southern California. The needles have been reported to remain on the trees 5 years or longer (Sudworth 1908).

Habitat Conditions

Unlike Douglas-fir, bigcone Douglas-fir grows under a wide variety of altitudinal conditions and climatic influences.

Climatic

Bigcone Douglas-fir is found in a Mediterranean-type climate. According to Koopen's climatic classification (Haurwitz and Austin 1944), the Mediterranean climate is characterized by long hot summers and short unpredictable winters. Annual rainfall during a 30-year period on a north facing slope at 4,350 feet elevation in the San Gabriel Mountains averaged 24 inches.[1] The lowest recorded for the period was 9.87 inches, and the highest for any year (winter 1957-1958) was 49 inches.[1] Throughout the range of the species, annual rainfall varies between 14 and 30 inches. Summer tropical rain is sparse throughout the range and seldom increases tree growth.

In the mountain ranges of southern California, annual temperatures are considered moderate--and extremes are rare. Annual temperatures average in the high 50's. Temperatures may exceed 100°F.; winter temperatures seldom drop below 10°F.

[1] Unpublished rainfall data from 1935-1965, San Dimas Experimental Forest, Glendora, California, on file at Pacific SW. Forest & Range Exp. Sta., Glendora, Calif.

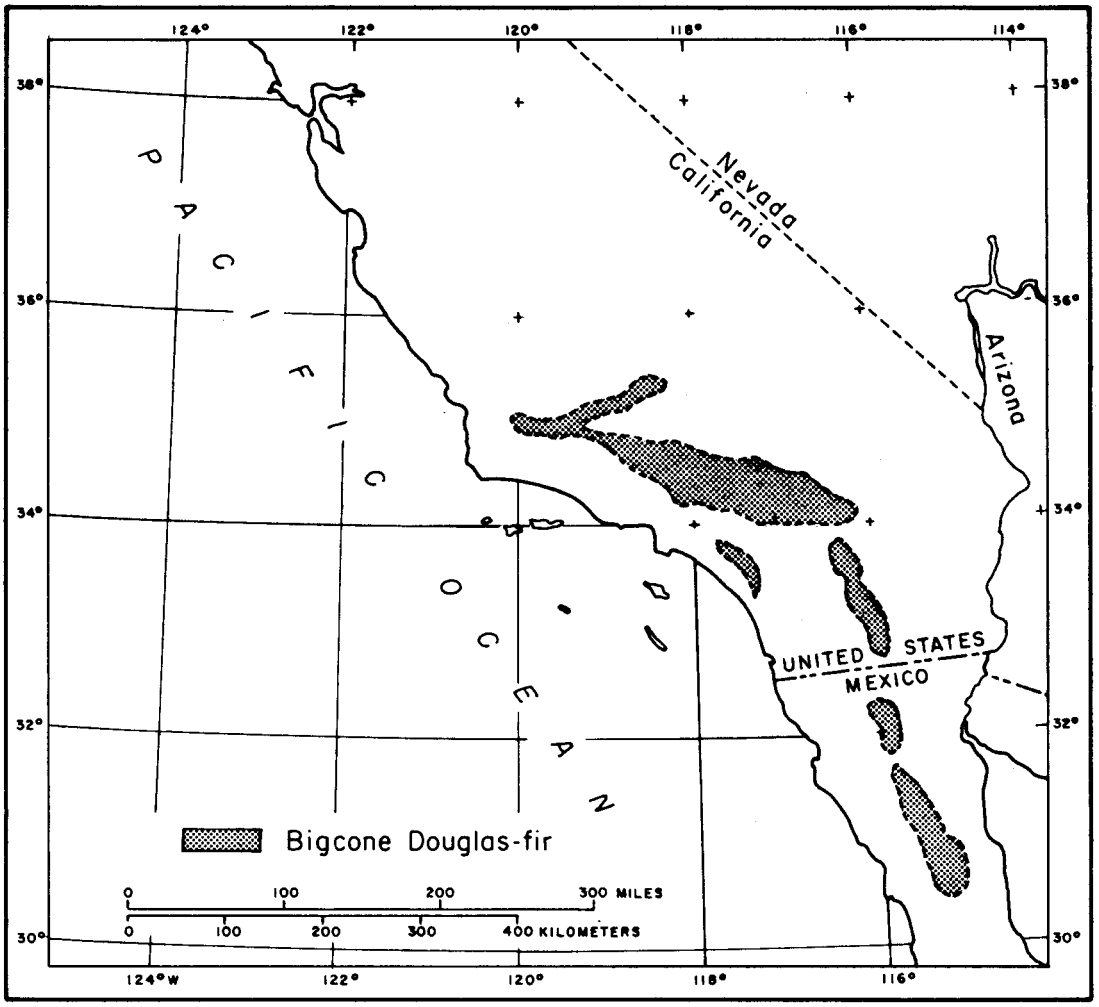

Figure 1.-- *Botanical range of bigcone Douglas-fir.*

Edaphic

The species grows on a variety of well-drained soils of igneous, metamorphic, and sedimentary origin. The residual soils were developed from a wide range of decomposed granitic rock. They form the major soil types found on all sites throughout the range of this species. Soils of igneous origin[2] include the Wilson, Mixed Wilson, and Red Wilson series.

In the Transverse, Coastal, and Peninsular Ranges, the species grows on the San Gabriel Compromise and Wilson Series .[2] The tree is also found on the Violin Sedimentary soil series in all three ranges.[2]

The more abundant and aggressive stands of pole and sawtimber trees grow on the San Gabriel series, mainly along canyon edges and exposed ridges on north slopes, where moisture is more abundant the year around for prolonged growth. The poorest stands are found on soils derived from an anorthosite mineral, where trees appear suppressed and over-aged for their size.

Alluvial soils support numerous isolated stands on terraces or benches well above major streams and riverbeds. Bigcone Douglas-fir is also found on soils in riverbottoms on south-facing slopes where moisture is available.

Physiographic

The northern limits of bigcone Douglas-fir are 34° 50′ north and 120° 10′ west in the San Rafael Mountains of Santa Barbara County, some 21 miles from the most southerly extension of Douglas-fir in California *(fig. 1)* (Griffin 1964). The species

[2] Published soil maps of southern California mountain ranges on file at the Pacific Southwest Forest and Range Experiment Station, Glendora, Calif.

is found east of the San Rafael Mountains at the same latitude in the Tehachapi Mountains (Munz 1935). It extends further eastward to 116° 30′ west in the San Bernardino and San Jacinto Mountains. Its southern extension in California is 32° 40′ north and 116° 20′ west near Julian in the southern portion of the Laguna Mountains in San Diego County. In the central part of Baja California, Mexico, it is reported to grow around 30° 00' north, in association with the same conifers found with it in southern California.[3]

Bigcone Douglas-fir is found at elevations from 900 feet on the north slope of lowland canyons in the chaparral zone to 8,000 feet in a mixed coniferous stand on south slopes--an altitudinal range of some 7,100 feet. The tree grows at the lower elevations under xeric conditions in the chaparral covered canyons on west through north slopes. On south slopes it is found at or above 2,500 feet elevation in both the canyons and exposed ridges. In the Transverse Range, larger stands are found from 3,000 to 5,500 feet elevation on southwest through north slopes, mainly in the upper canyons. The Coastal and Peninsular Ranges support vigorous stands in westerly canyons from 2,400 to 5,000 feet. This condition can be attributed to the persistency of the marine influence throughout the year.

Above 6,000 feet elevation the species grows in the mixed conifer zone in open timberland growing with *Pinus ponderosa* (ponderosa pine), *P. jeffreyi* (Jeffrey pine), *P. lambertiana* (sugar pine), *Libocedrus decurrens* (incense-cedar), and *Abies concolor* (white fir). The species covers some 4.5° of latitude, giving it a north-south range of 315 miles.

Biotic

Bigcone Douglas-fir is found in the upper Sonoran (500 to 2,500 feet), Transition (2,500 to 6,000 feet), and Canadian (6,000 to 9,000 feet) life zones of southern California.

Adaptation of this species to the xeric chaparral brushland and its occurrence in the montane forest regions of southern California show its ability to endure and grow in a variety of ecological settings. Throughout its 315-mile north-south range, the tree occurs with a variety of vegetation. Woody and herbaceous plant associations are as follows:

• From 900 to 3,500 feet on northwest oriented canyons, north and east slopes, and canyons, bigcone Douglas-fir associates with *Heteromeles arbutifolia, Artemesia californica, Quercus agrifolia, Q. dumosa, Ceanothus leucodermis, C. spinosus* var. *palmeri, Dendromecon rigida, Rhus laurina, R. ovata, Yucca whipplei, Cercocarpus betuloides, Adenostoma fasciculatum, Eriogonum fasciculatum, Salvia apiana, S. mellifera, S. leucophylla, Juglans californica, Acer macrophylla,* and *Woodwardia fimbriata.*

• From 3,600 to 5,500 feet from northwest through south and southeast slopes, canyons and ridges, bigcone Douglas-fir associates with *Pinus ponderosa, P. coulteri, P. attenuata, P. lambertiana, P. monophylla, Quercus chrysolepis, Q. kelloggii, Acer macrophylla, Arctostaphylos glauca, A. patula, Ceanothus cuneatus, C. integerrimus, C. spinosus* var. *palmeri, C. leucodermis, C. oliganthus, Fraxinus dipetala, Adenostoma sparsifolium, Pteridium aquilinium* var. *pubescens, Woodwardia fimbriata,* and *Polypodium* sp.

• From 5,600 to 8,000 feet on south and west slopes, bigcone Douglas-fir associates with *Pinus ponderosa, P. lambertiana, P. coulteri, P. monophylla, P. jeffreyi, Libocedrus decurrens, Abies concolor, Quercus chrysolepis, Q. kelloggii, Ceanothus cuneatus, C. crassifolius, Cercocarpus betuloides, C. ledifolius, Castanopsis sempervirens, Arctostaphylos glauca, A. patula, Chrysothamnus nauseosus, Penstemon ternatus, Rhamnus californica, R. crocea, Pellaea compacta,* and *Allium* sp.

At one time more trees grew on the lower and upper ridges in the chaparral zone, but repeated fires have gradually removed them from these sites. In the chaparral zone, canyons or draws support numerous isolated relic stands that have escaped burning. These relic stands consist of partially burned and unburned islands of overmature sawtimber trees, with little or no reproduction present.

From 3,600 to 5,500 feet elevation on shaded slopes, isolated pure stands may grow in association with canyon live oak. Most of the reproduction is found in and around the periphery of oak thickets, where shaded mesic conditions are favorable.

[3] Bergen 1904; Bowers 1942; Dallimore and Jackson 1948; Ives 1961; Jepson 1910; Sudworth 1908.

Life History

Seeding Habits

Flowering and fruiting.--Flowers on bigcone Douglas-fir are monoecious. Flowering buds form in September and October on the same twig of the current year's leaves. Microsporangiate strobili form on the underside of the twig, subtended by conspicuous involucres of bud scales. Each pollen scale is tipped by an awl-shaped spur (Bergen 1904).

Dark red to yellow green megasporangiate strobili appear just behind the terminal bud or at the end of the branchlets. The scales are concealed by numerous two-lobed, long, pointed bracts. The cone is oblong, $1^1/_2$ to 2 inches long, and droops from the end of the branch.

At lower elevations, strobili bud swelling and subsequent flush may occur as early as February *(fig. 2)*. Megasporangiate strobili that flush in February are often frozen at the pedicel. The desiccated megasporangiate strobili will often remain on the tree for several months--a phenomenon also reported in Douglas-fir (Isaac and Dimock 1958).

Strobili flush of both sexes occurs in late March and early April. Homogamy seldom occurs on the same branch or the same tree. Microsporangiate strobili flush on the same tree will often burst and shed pollen before megaspronagiate strobili appear. This dichogamy either prevents pollination or allows the subsequent cross-pollination from other trees in the stand.

Pollination lasts 3 to 4 weeks. Staminate strobili become desiccated after pollen dehiscence; the bud scales then fall off. The dried microsporangiate remains on the tree until fall. Fertilized conelets enlarge in mid July and then mature after one full growing season--usually in late September or early October.

Seed production. -- Bigcone Douglas-fir trees rarely produce seed until they are 20 years old. Few exceptions may occur on good open sites. Heavy seed crops seldom occur. During four years' observation there was little fluctuation in the amount of seed crop.

When mature in late September and early October, the short stalked ovulate cones vary in size from $4^1/_2$ to 7 inches long, scales measure $1^1/_2$ to 2 inches long *(figs. 3, 4)*. The thick concave cones have a purbulant outer covering (Clinton-Baker 1913). Scale bracts are three-toothed, slightly exerted, with broad midribs (Munz 1959). Pitch often is emitted between the cone bracts and scales before ripening. Chocolate brown and shiny on the upper side and gray white on the under side, seeds are large and triangular in shape with a rounded wing $^1/_2$ -inch long.

Seed dissemination occurs at lower elevations during September. Trees at or above the 5,000-foot level disseminate seeds in late September through all of October. Distance of dispersal of wind blown seeds seldom exceeds several tree lengths--except when winds are heavy.

Rodents and birds play a minor role in seed dispersal and in eventual distribution developing beyond an existing stand. The more terrestrial rodents, such as chipmunks (*Eutamias* ssp.) and California ground squirrels (*Citellus* spp.), eat vast amounts of viable seed during the pouching season in fall. The Gray squirrel *(Sciurus griseus)* clips cones in August and September before the cones open. The larval stage of cone insects destroy some of the seed crop on portions of a cone before it matures.

Figure 2. -- *Megasporangiate strobili grow behind the terminal bud of the current year's growth. Microsporangiate strobili occur on the underside of the twig.*

Vegetative Reproduction

The tree will not resprout from a cut stump, but has been propagated by grafts (Dallimore and Jackson 1948). Vegetative reproduction on bigcone Douglas-fir occurs after injury. Pole trees and young sawtimber with broken terminal leaders often produce several aggressive stems that compete for apical dominance. When injury is sustained during fire or mechanical processes, numerous sprouts may develop on the bole and lateral branches. Large scale propagation methods other than the use of seed are not known.

Sprouting after fire.--Among native tree species of California, bigcone can be rated second only to redwood *(Sequoia sempervirens)* in its ability to sprout or recover from fire. This ability to recover from fire damage has enabled the species to persist in many locations where renewed fires commonly occur.

Trees completely defoliated by fire will sprout in the middle and upper one-third crown of the tree where soft unhardened woody tissue prevails under the bark. All sprouts arise from the upper surface of the limbs defoliated by the fire, giving a layered appearance to the crown foliage. Seedlings and saplings are normally destroyed by the fire and do not sprout. Larger pole and sawtimber trees defoliated will sprout vigorously. Overmature sawtimber trees seldom sprout, possibly because of a loss or decline in vigor before the fire.

Bigcone Douglas-fir trees damaged by fire usually are free from bark beetle attacks. This condition is in contrast to that found in pines, which often are attacked after a fire.

Figure 3. --*Numerous cones cluster on terminal portion of the branch, 2 months before maturity.*

Sprouting after mechanical damage.—Mechanical damage can be attributed to abrasion on branches or damage caused by windfalls, rock slides, or blasting for roadside construction.

Bole damage is one of the major causes of vegetative sprouting. Buds proliferate and subsequent stems appear profusely around the perimeter of the injured area. Sprouting following mechanical injury only in pole and younger saw-timber

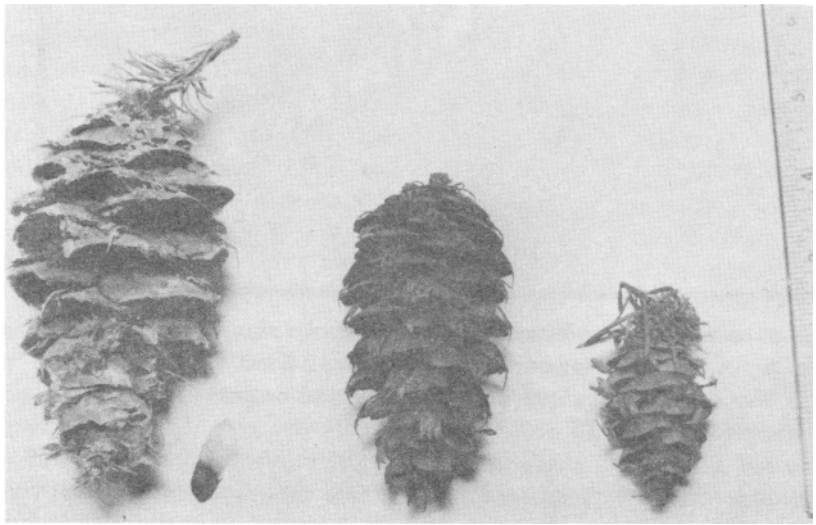

Figure 4. -- *Open mature cones of,* left to right, *Pseudotsuga macrocarpa, P. menziesii, and P. Menziesii var. glauca.*

trees seldom occurs on older trees. Resprouting around the injured area can appear within 1 year following mechanical damage. In time, one dominant stem may protrude through the cluster of new twigs.

The apparent cause of resprouting following fire or mechanical injury can be attributed to the activation of dormant adventitious buds under the bark. Injury appears to stimulate the bud cells which eventually connect to the vascular system.

Seedling Development

Establishment.--The time of germination varies from season to season and with elevation and exposure within the stand. Naturally reseeded plots occur in canyons, usually in and around the edge of oak thickets where mineral soil, decomposed oak litter, and good drainage prevails. Seeds germinating on dry open exposed rocky areas normally die the first year. In the lower chaparral zone, germination occurs in late March; while above *5,500* feet elevation, germination is in late April and may continue until late May and early June.

Fire in and around a tree stand appears to have no effect in helping germination. In most cases a blackened exposed slope may impair any possibilities of successful seed germination.

The ability of the species to produce a long tap root and numerous lateral roots exhibits its endurance to the xeric conditions of the chaparral zone.

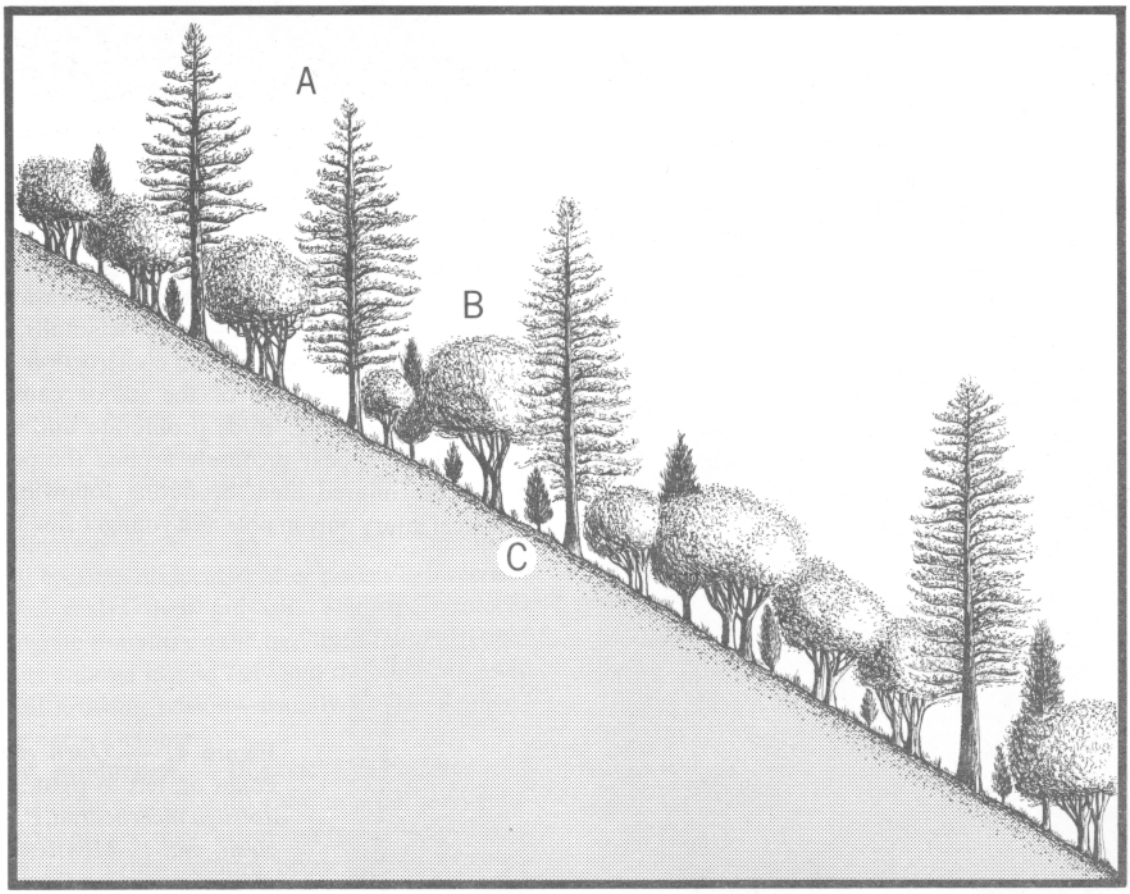

Figure 5.--*Typical profile on an unburned north through east slope, bigcone Douglas-fir:* A, *scattered overmature sawtimber, 24 to 70 inches d. b. h.;* B, *live oak woodland profile, oak crowns coalescent, forming dense shaded overstory 15 to 30 feet high, with few pole trees penetrating oak canopy;* C, *shaded profile, persistent shade, widely scattered under-sized-overaged seedlings and saplings, with a few herbaceous plants.*

Early growth.--If seedlings are growing on north slopes within a thick oak canopy 15 to 30 feet high, they become suppressed because of the almost constant shade. A tree 0.9 inch in diameter at ground level and 40 to 50 years old may be only 24 inches tall.

On slopes of southerly exposure, trees have a much higher growth rate. And seedlings on south through west slopes at higher elevations, where shading is even less, become saplings within 3 to 5 years.

Sapling Stage to Maturity

Reaction to competition.--Among the obstacles to continued growth of bigcone Douglas-fir are lack of sunlight, inadequate moisture, and competition from other species. On unexposed shaded north slopes, saplings show little vigor. The branches of the lower one-third of the crown are usually dead. And annual growth increments can barely be distinguished.

By the time poles are 15 to 30 feet tall and 40 to 70 or more years old, they begin protruding through the thick oak canopy. Their diameter at breast height then ranges from 5 to 8 inches. Continual sunlight on the newly exposed crown and the moist shaded forest floor combine to produce vigorous growth. Once the trees protrude through to full sunlight, there is an annual increment increase of $^1/_8$ to as much as $^1/_4$ inch. Terminal growth is also accelerated. Such trees have elongated spaces between the nodes on branches. A tree that has 7 years' elongated terminal growth also has an equal increase of annual increment--dating back for 7 years.

As numerous bigcone Douglas-fir develop to sawtimber size, the canyon live oak trees are gradually shaded from the site and are found mainly on the periphery of the stand *(fig. 5)*. Pure stands of bigcone Douglas-fir found growing on south through northwest ridges and canyons from 3,500 to 5,500 feet elevation and having abundant year-round moisture are tall and aggressive for their age.

Widely spaced canyon live oak decreases competition for moisture and sunlight, thus vigorous fir trees occur with thick buttressed trunks and long lenticular branches from the ground level upward.

Pole-size bigcone Douglas-fir trees grow quickly; their terminal branch growth may exceed 12 inches annually. Saplings vary from 4 to 10 feet tall on

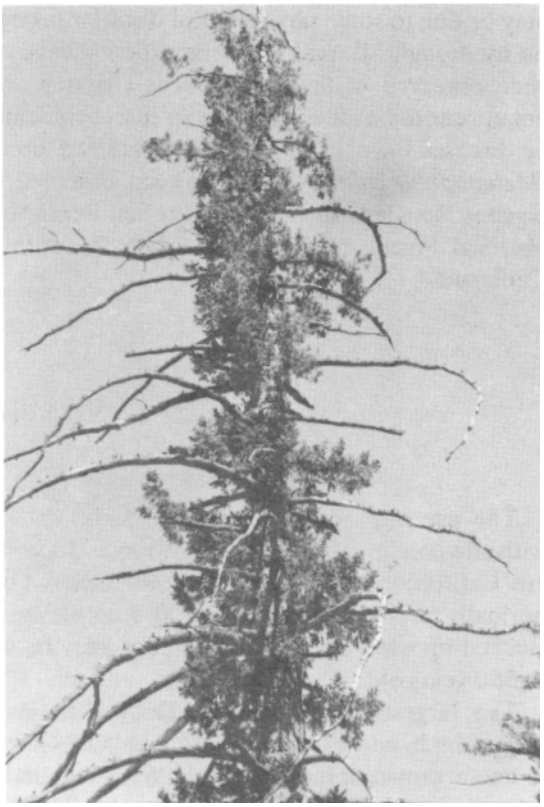

Figure 6. -- *Physiological change or disorder causes bigcone Douglas-fir to fade and lose needles. Some trees resprout, mainly along the bole after needles fall.*

open sites, pole trees from 12 to 48 feet. Annual increments are large and uniform in size, showing no effect of dry and wet years. This condition shows that the combination of full exposure and year-around moisture are beneficial for excessive prolonged growth. A decrease in increment size occurs in sawtimber trees that are older than 100 years.

From 6,500 up to 8,000 feet, the tree is found only as widely scattered specimens growing in mixed conifer stands from southeast through westerly exposures. Reproduction is scanty in the coniferous zone. At 8,000 feet, where the species fades out, the canyon live oak also rarely appears.

Injurious Agencies

Older trees sometimes fade to an amber color and lose their needles and appear dead *(fig. 6)*. But in 2 years, they appear to sprout with renewed vigor. The cause of the fade is not known, but

may be due to some physiological disorder brought on by drought. Larval mines or galleries have not been observed in the faded trees. The tree does not appear to be afflicted by major insect epidemics or diseases on a large scale. But flathead borers *(Melanophila californica)* have been observed on bigcone Douglas-fir growing on the San Bernardino National Forest, near Angeles Camp, in southern California.[4]

Fire usually will not destroy a stand, but often reduces its size. After a fire, canyon live oak and mixed chaparral species often invade the burned-over areas of the stand.

The return of bigcone Douglas-fir as the dominant species on the site may require several hundred years. The high incidence of fires over the same areas has eliminated many stands from the upper ridges and slopes, and reduced their size.

Special Features

Longevity

The age and size of bigcone Douglas-fir vary with site conditions throughout its range. In southern California, trees larger than 40 inches d.b.h. normally are found above 5,000 feet elevation. Bucked-up windfalls, 72 inches d.b.h., may be 450 to 550 years old.

The largest known bigcone Douglas-fir is 91 inches d.b.h. and 173 feet tall. Called "Old Glory," it has a crown spread of about 65 feet,[5] and is estimated to be 600 to 700 years old. The tree is near San Antonio Canyon on the Angeles National Forest, in southern California *(fig. 7)*.

Hybridization

Hybridization of Douglas-fir with bigcone Douglas-fir was achieved in 1956 by Dr. Kim K. Ching, who devised an intensive controlled pollination program (Ching 1959).

The objective of this cross was to develop a hybrid that would have the inate [sic] wood characteristics and rapid growth rate of Douglas-fir and have the dry site adaptability of bigcone Douglas-fir. Progenies produced conclusive evidence of a successful cross, having characteristics of both parent trees. The hybrid is characterized by lower seedling mortality, a denser and more fibrous root system, longer needles, and significantly taller trees *(fig. 8)*.

Management Values

Bigcone Douglas-fir can be propagated routinely in nurseries. Collected cones set out in the open sun will open in 2 to 3 days. They can be run through a shaker to remove seeds. Dewinging is done by rubbing seeds over a 1/6-inch mesh screen (U.S. Forest Service 1948). Under open storage in diurnal room temperatures, seeds will--during a 4-year period -- lose their viability.

Figure 7. - *The largest recorded bigcone Douglas-fir tree stands near San Antonio Canyon, Angeles National Forest.*

[4] Personal correspondence with Ken Swain, entomologist, San Bernardino National Forest, San Bernardino, Calif., Oct. 6, 1966.

[5] American Forestry Association's Social Register of Big Trees.

Photo courtesy of Dr. K. K. Ching.

Figure 8.--*Nine-year-hybrids of Douglas-fir* × *bigcone Douglas-fir* (outside rows) *outgrew Douglas-fir control trees* (center row) *by 11 to 19 percent, at the Willamette Valley Plantation, Oregon State University.*

Germination of the species is epigeous. To obtain rapid growth, young seedlings should be transplanted from tar pots into 5-gallon cans and watered often. But trees should not be left in 5-gallon cans more than 1 or 2 years, because roots develop rapidly.

The species has been grown successfully outside the continental United States. It was unknown in Europe until seedlings were raised at Bayfordbury, England in 1910. Trees are also reported growing in Sussex and North Ireland, where they reached heights of more than 60 feet, with a 40-foot spread (Clinton-Baker 1913; Dallimore and Jackson 1948; Royal Horticultural Society 1932).

Since the species grows under a variety of climatic influences, it can be planted for both watershed and esthetic values at sea level up to 7,000 feet in southern California.

The combination of fast growth on fair sites, xerophytic characteristics, no specific soil requirements, and the ability to sprout after fire should be considered when planting this species along new roadside-fill zones, recreation areas, plantations, or mountain recreation residences.

The hybrid of Douglas-fir X bigcone Douglas-fir if introduced into the semiarid parts of southern California may prove to have some potential for more widespread planting in the future.

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