

# *Quercus douglasii* Hook. & Arn.

# Blue Oak

Fagaceae Beech family

Philip M. McDonald

Blue oak (*Quercus douglasii*), named for its blue-green foliage, is also known as iron oak, mountain white oak, or mountain oak. This species is currently underutilized and unmanaged. Silvicultural systems for it are unknown. Blue oak is often found in extensive open stands in the interior foothills where it grows slowly on dry, loamy, gravelly, or rocky soils. It is used locally for fenceposts and fuelwood, and the acorns are an important food for several kinds of wildlife.

## Habitat

### Natural Range

Blue oak (figs. 1, 2), a California endemic, has a north-south range of about 740 km (460 mi). Its distribution, in general, surrounds California's Central Valley. Northern limits are Montgomery Creek in Shasta County and southern limits are in the Liebre Mountains of Los Angeles County and the Santa Ynez Valley of Santa Barbara County. Blue oaks are scattered over the landscape above Mission Santa Barbara less than 5 km (3 mi) from the Pacific Coast, and on Santa Cruz and Santa Catalina Islands (11).

### Climate

Hot dry summers and cool wet winters typify the climate where blue oaks are found. The mean maximum July temperature averages 32° C (90° F) and the mean January minimum -1° C (30° F). Temperatures for stands outside the main distribution, especially at higher and lower elevations and on the border of the Mojave Desert, vary much more. Mean July maximum temperatures range between 21° and 38° C (70° and 100° F) and mean January minimums from -12° to 2° C (10° to 35° F). The frost-free growing season varies from 150 to 300 days.

Annual precipitation averages 510 to 1020 mm (20 to 40 in) within the main distribution of blue oak. At extremes of the natural range, 1520 mm (60 in) in Shasta County and 250 mm (10 in) in Kern County bracket the annual fall of moisture. Throughout, most of the precipitation is rain, although snow occasionally blankets the land. Most precipitation (60

to 90 percent) occurs between November 1 and April 30.

### Soils and Topography

Soils from a variety of parent materials support blue oak. They are characteristically shallow, skeletal, infertile, thermic, and moderately to excessively well drained. Textures range from gravelly loam through stony clay loam. Soils with extensive rock fragments in the profile commonly support this oak; as much as 50 percent of the surface area of a soil may be covered with stones or rock outcrops. Blue oaks are found on soils with depths of 51 to 102 cm (20 to 40 in), but scattered trees grow on soils ranging from 30 to 51 cm (12 to 20 in). Soil orders for blue oak are Alfisols and Inceptisols, occasionally Mollisols. More than 40 soil series in California have been identified by the California Cooperative Soil-Vegetation Survey and the National Cooperative Soil Survey as supporting blue oak. The principal California mountain ranges and soil series are as follows:

Mountain Range and Subrange	Soil Series
Coast	
North Coast	Hulls, Laughlin, Sehorn.
Central Coast	Gazos, Hambright, Henneke, Hillgate, Los Osos, Millsap, Millsholm, Sobrante.
Central Valley floor	Arbuckle.
Cascade	
Southern	Guenoc, Toomes, Gaviota, Iron Mountain, Stover.
Sierra Nevada	Ahwahnee, Auberry, Auburn, Blasingame, Coarsegold, Guenoc, Inks, Sierra, Millerton, Stover, Toomes, Trabuco.
Transverse and Peninsular	Gilroy, Havala, Perkins, Tehachapi.

The one characteristic found most often in soils supporting blue oak is high base saturation. Values of at least 50 percent or even 90 to 100 percent are common (19). Soils within blue oak's natural range that do not support it are generally drained poorly or are of heavy clay texture, often with a hardpan near the soil surface. Deep fertile soils are seldom clothed with blue oak because this species is not competitive with the inherently taller conifers or the better adapted interior live oak (*Quercus wislizenii*) and California black oak (*Q. kelloggii*).

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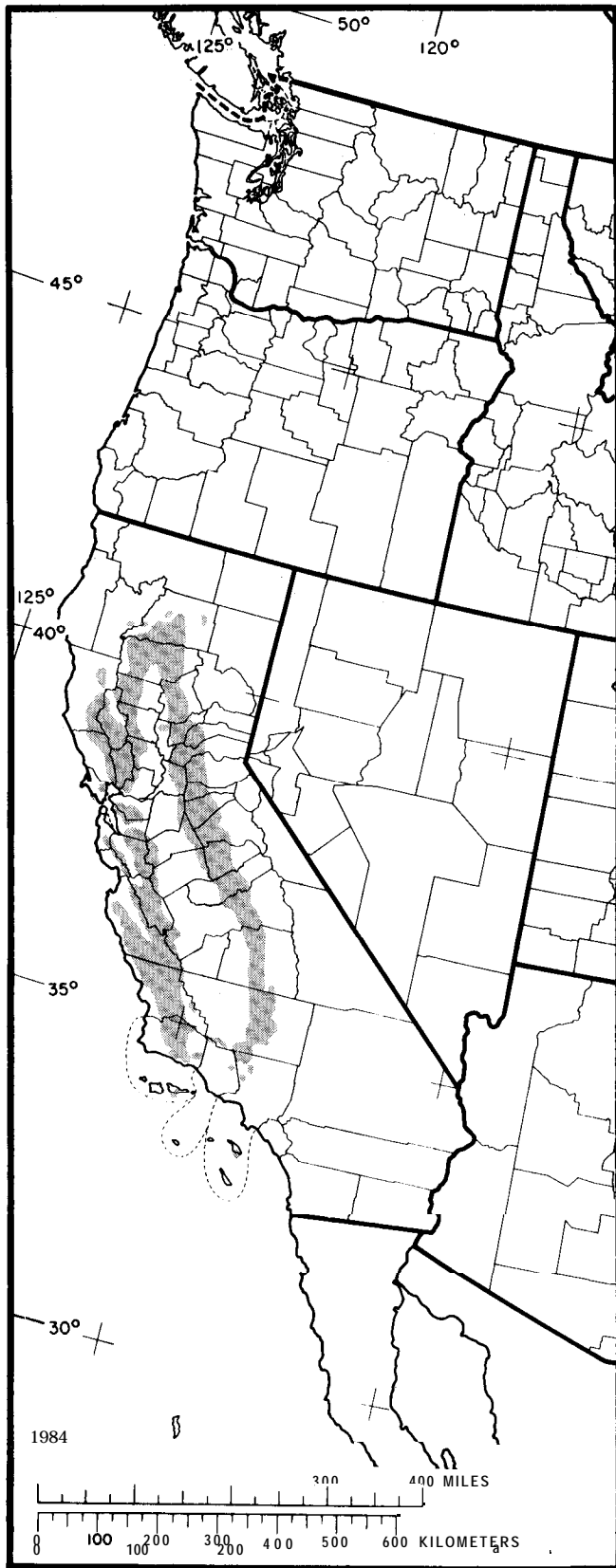


Figure 1-The native range of blue oak.

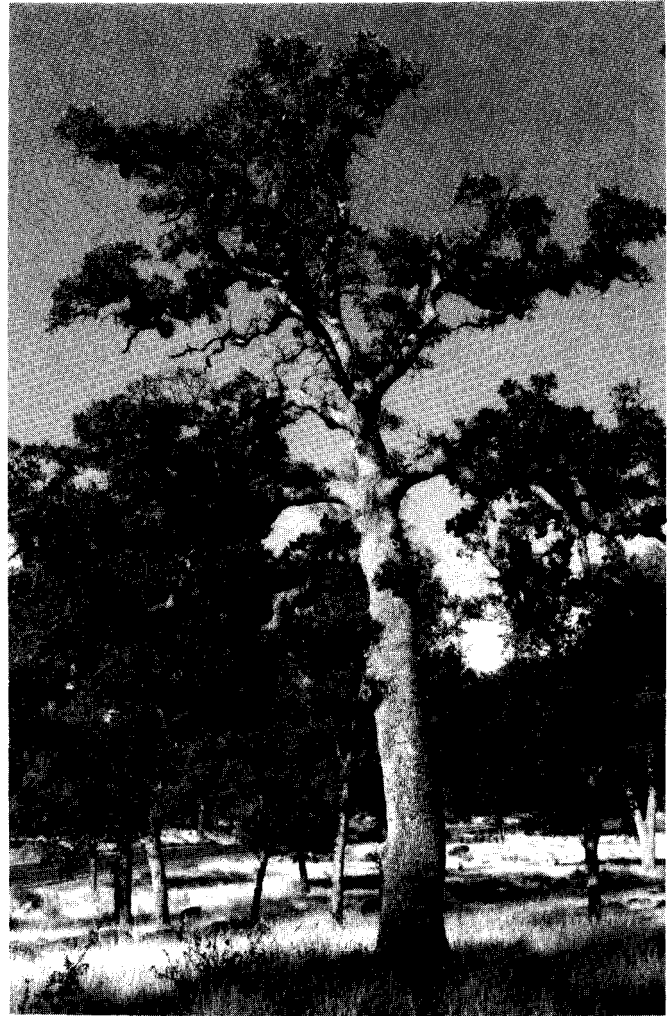


Figure 2-A white-barked blue oak in Shasta County, CA, 12 m tall and 81 cm in d. b.h.

Blue oak grows within a fairly wide elevational range—from the valley floor in the north to the midslopes of Mount Pinos in the south. Corresponding elevational limits are 50 to 1800 m (165 to 5,900 ft). At the north end of the Sacramento Valley and in the foothills of the southern Cascade and Klamath Mountains, the general elevational range of blue oak is 152 to 610 m (500 to 2,000 ft). The species is common between 76 and 915 m (250 and 3,000 ft) in the central Coast Range, and between 168 and 1370 m (550 and 4,500 ft) in the Transverse and Peninsular Ranges. On west slopes of the Sierra Nevada, the species is abundant in the foothills at an elevational range of 152 to 915 m (500 to 3,000 ft) (35).

## Associated Forest Cover

Blue oak is the principal component of the forest cover type Blue Oak-Digger Pine (Society of American Foresters Type 250) (25). In general, it is neighbor to California Black Oak (Type 246) and Pacific Ponderosa Pine (Type 245) at higher elevations and to the annual grass Savannah at lower elevations. In the northern Coast Range, and in the foothills of the Klamath Mountains, Oregon White Oak (Type 233) often abuts Blue Oak-Digger Pine. In portions of its range, the upper elevational border of blue oak often grades into more dense stands of interior live oak and chaparral. Similarly at lower elevations, it blends into more open stands of valley oak (*Quercus Zolata*). Throughout, dense stands and scattered patches of chaparral are often present. A grassy understory almost always can be found beneath blue oak trees. Stands of scrubby oaks sometimes bridge the gap between oak trees and woody shrubs in parts of the blue oak range. For most of the range, blue oak should be regarded as a component of a mosaic that includes Savannah, chaparral, other deciduous and evergreen oaks, and at least one common conifer.

The paleobotanic record of blue oak shows a Miocene progenitor, *Quercus douglasoides*, which apparently inhabited a wider natural distribution than its modern counterpart. In the next epoch, the Pliocene, blue oak's fossilized equivalent, *Q. orindensis*, grew in a habitat of dry open slopes bordering valleys. It was associated with several chaparral species, a few elements of the broad-sclerophyll forest, several riparian species, and an occasional redwood and fir (7).

The California oak woodland, in general, is recognized as climax, but the successional status of blue oak is not clear. A substantiating tenet of climax is that the same vegetation returns after each gross disturbance. Fire and grazing are, and have been, chronic to the point that the present stands are still recovering from them. That the oak woodland exists after all this disturbance, and that its boundaries have remained rather constant, support the designation of climax (10).

The most common tree associate of blue oak is Digger pine (*Pinus sabiniana*); however, blue oak extends farther into valleys, but not as far into montane regions as the pine. Blue oak is usually the majority species, Digger pine inevitably the taller. Other occasional conifer associates are ponderosa pine (*Pinus ponderosa* var. *ponderosa*), knobcone pine (*P. attenuata*) and, in a more limited area, Coulter pine (*P. coulteri*). California juniper (*Juniperus californica*) and singleleaf pinyon (*Pinus monophylla*)

are infrequent associates in the Tehachapi and Piute Ranges of southern California.

Interior live oak and valley oak are the most common hardwood associates of blue oak. Others are California black oak, coast live oak (*Quercus agrifolia*), Oregon white oak (*Q. garryana*), toyon (*Heteromeles arbutifolia*), California redbud (*Cercis occidentalis*), and California buckeye (*Aesculus californica*).

Shrub associates of blue oak in its main distribution are neither abundant nor diverse. Principal shrub associates are: common manzanita (*Arctostaphylos manzanita*), mariposa manzanita (*A. mariposa*), whiteleaf manzanita (*A. viscida*), buckbrush (*Ceanothus cuneatus*), poison-oak (*Toxicodendron diversilobum*), yerba santa (*Eriodictyon californicum*), foothill gooseberry (*Ribes quercetorum*), and chaparral coffeeberry (*Rhamnus californica tomentella*).

Grasses are particularly abundant in the natural range of blue oak. Originally they were of the bunchgrass type, *Stipa* (needlegrass) being the most common genus. Introduced annual grasses, especially the wild oats (*Avena fatua* and *A. barbata*) have replaced the perennial grasses almost completely. Other annual grasses common beneath blue oak are members of the genera *Bromus* and *Hordeum*.

Blue oak adapts well to harsh environments, especially aridity. In mid-August of a dry year, valley oak and coast live oak on alluvial soils indicated a minimum (predawn) moisture stress of only 2.03 to 5.07 bars (2 to 5 atmospheres). Nearby blue oaks on an upland soil showed 27.36 bars (27 atmospheres) of stress (10). Blue oak sheds its leaves when stress becomes prohibitive, thus conserving moisture. This ability to withstand more severe moisture stress than its associates contributes to the pattern of blue oak distribution over the landscape.

## Life History

### Reproduction and Early Growth

**Flowering and Fruiting-Blue** oak is monoecious; its flowers are unisexual. Staminate flowers are borne in slender drooping catkins, one or more from lower axils of leaves of the previous year. Pistillate flowers are greenish-yellow and originate from leaf axils of the current year (26). Blue oak flowers from late March to mid-May, depending on elevation, aspect, climate, and reproductive capability of individual trees. In general, trees at lower elevations and on warmer aspects bloom first. On long continuous hillsides, however, blooming is first on

midslopes-above areas of cold air ponding and below ridgetops.

Acorns mature in one growing season. When about half size, the cup covers about half the acorn, but at maturity the cup encapsulates only 10 to 20 percent of it. The elliptical, often tear-shaped acorns form singly or in clusters of two, rarely three, and are variable in size and shape. Fully developed acorns range from 2.5 to 4.0 cm (1.0 to 1.6 in) in length and from 12 to 21 mm (0.5 to 0.8 in) in diameter. Acorns range in color from light green during development to yellowish-green in early September, to medium-dark brown at maturity.

**Seed Production and Dissemination-**Abundant seed crops are produced every 2 to 3 years, with bumper crops every 5 to 8 years (26). In other years at least a few trees are fruitful.

Aborted acorns begin falling in July and are mostly gone from the trees by late August. Insect-infested acorns fall in late August to mid-September, usually preceding the fall of mature acorns. Most sound acorns fall between mid-September and the end of October. They average 45/kg (100 seed/lb) and range from 25 to 82/kg (55 to 180/lb).

Seed crops vary in size. On one area the acorn crop ranged from 0.14 to 25.31 kg (0.31 to 55.81 lb) per tree per year; on another an average-sized blue oak produced 215 acorns per square meter (20/ft<sup>2</sup>) of collecting ground during a good seed year or 73 kg (160 lb) of acorns per tree.

Data relating acorn production to tree size are scanty. A single blue oak in Shasta County, 34 cm (13.5 in) in d.b.h., 11.6 m (38 ft) tall, and 4.3 m (14.0 ft) in crown width, produced an estimated 3,750 acorns during an especially productive year. At least some roots of this tree, however, extended beneath a well-watered lawn. An examination in December beneath this and nearby trees showed that all developed acorns had been consumed or carried away.

Two insects produce larvae that destroy many acorns before maturity. Developing acorns are attacked by the filbert weevil (*Curculio uniformis*) and by the filbert worm (*Melissopus latiferreanus*). Larvae of the filbert weevil are short, fat, glistening, white, legless worms. They mine inside the acorn and destroy its contents. Larvae of the filbertworm often hollow out the acorn, leaving behind a mass of webbing and frass (5).

Acorns are eaten by at least a dozen species of songbirds, several upland gamebirds, several small mammals (mostly rodents), and a few large mammals. Although many acorns are consumed, some are dropped or lost-aiding in the dissemination of the

oak. Principal consumers of blue oak acorns include the acorn woodpecker, scrub jay, band-tailed pigeon, California quail, western gray squirrel, and the California ground squirrel (21). The acorns are a valuable foodstuff, along with green and dead leaves, for deer, cattle, sheep, and hogs (8).

For the acorn woodpecker, acorns are the "staff of life." Those from blue oak enable this bird to widen its natural range to include extensive areas of the Central Valley and surrounding foothills (30). For band-tailed pigeons, crop and stomach analyses indicated blue oak acorns constituted 5.8 percent of total food volume in November (32).

Western gray squirrels were collected below the chaparral zone in Mendocino County where blue oak was the majority species. Acorns amounted to 38 percent of total yearly diet and were consumed each month from September through April (34). In Madera County, CA, ground squirrels consume blue oak acorns each month of the year. Acorns constitute 1 to 56 percent of this rodent's total diet each month (3). Acorns of blue oak are critical to migrating deer who leave a dried-up summer range in the Sierra Nevada and travel to a winter range at lower elevations. Acorns picked up en route provide energy and protein not only for travel, but also help to ensure healthy animals during the breeding season.

**Seedling Development-**On the basis of frequency and magnitude of seed crops, blue oak has the potential to reproduce adequately from seed. During the last 50 to 80 years, however, it appears to have reproduced poorly. In Tulare County, only 7 percent of 405 trees, as determined from increment cores, were less than 60 years old (22). In southern Shasta County, on a green fuelbreak 30.5 m (100 ft) wide along a highway, only blue oaks remained in some places, with several grasses and a few woody shrubs below. The oaks were evenly spaced and formed a parklike stand which might be expected to reproduce well, but when 0.8 km (0.5 mi) of the fuelbreak was examined, only eight seedlings were found (24).

Blue oak seedlings were not always scarce. In 1908, Sudworth (35) reported seedlings scarce on cultivated or grazed ground but "rather abundant elsewhere." Cooper (6) noted that "typical stands of young *Quercus douglasii* have been seen where it is certain that chaparral was formerly in control." Griffin (10) also noted that "the oak produced well at an earlier period" (before 1930) in the Santa Lucia Range. Heavy consumption of acorns and damage to seedlings by deer, cattle, sheep, hogs, insects, and rodents, and especially by ground squirrels and pocket gophers, are possible reasons why blue oaks have not reproduced adequately during the past 60 to 80

years. Environmental and chemical inhibition of acorn germination as a result of introduced annual grasses is another possible reason. Single environmental and habitat factors probably are not adequate to explain the paucity of blue oak reproduction (1,23).

For successful germination, the seeds must be covered. Thick leaf litter or loose mineral soil facilitates germination and early seedling survival. Acorns will germinate on the soil surface in the rare event that temperatures remain low and moisture adequate.

Acorns of the white oak group do not require stratification for germination. Blue oak acorns can, and do, germinate within a month of seedfall. Most, however, germinate early in the spring when warmer temperatures prevail. Germination is hypogeal. Light, moisture, temperature, and the depth of soil or litter covering the acorns probably affect the timing of germination. Germinative capacity from a limited number of tests was 70 to 72 percent after 30 days (26).

Early growth of blue oak seedlings is poorly documented. One investigator seeded 25 acorns in a granitic soil in November and dug them up in March. Root length ranged from 31 to 68 cm (12 to 27 in) and averaged 49 cm (19 in) (9). After 1 year, blue oak seedlings on a gravelly loam soil in Shasta County averaged about 10 cm (4 in) above ground and 20 cm (8 in) below. A 3-year-old seedling growing in partial shade showed about 18 cm (7 in) of shoots and 28 cm (11 in) of roots. Nearby, a 5-year-old seedling was 18 cm (7 in) tall with a single taproot 66 cm (26 in) long. All eight seedlings in an area cut about 10 years ago were less than 46 cm (18 in) tall (24). All were browsed and most had died back to the root crown and resprouted at least once, often with several stems. This evidence, although limited, suggests that the annual growth rate of blue oak seedlings is probably slow.

**Vegetative Reproduction**-Two types of sprouts are found on blue oak stumps. Some form at the root collar and are root crown sprouts, and others form on the side or top of cut and burned stumps and are stool sprouts.

Blue oak produces sprouts after cutting or fire, but in general is regarded as a weak sprouter. Whether this characteristic results from lack of early sprout vigor or from lack of eventual survival is not clear. Nearly 40 blue oak stumps in a southern Shasta County fuelbreak were examined, and the average number of root crown sprouts per clump was recorded. Positions of sprouts on stumps, and stump diameters also were noted. Stump heights averaged 13 cm (5 in) (24). The trees had been cut about 10

years before the stumps were examined. Presumably most of the sprouts began growing soon after, but others could have originated later, and a few obviously were recent. Sprouts, therefore, were assumed to be as old as 10 years.

Number of root crown sprouts related weakly to stump diameter. The number of sprouts per stump increased curvilinearly from about 12 sprouts on 2-cm (1-in) diameter stumps to 27 sprouts on 15-cm (6-in) diameter stumps. Larger stumps, at least up to 22 cm (9 in) in diameter, produced a decreasing number of sprouts. Two stumps larger than 40 cm (16 in) in diameter showed no evidence of sprouting (24). In the inner Coast Range of central California, blue oak produced fewer sprouts than associated oaks and no sprouts on stumps larger than 52 cm (21 in) (18).

When height of sprouts was compared with stump diameter, no relationship was discernible. Much variation was present. Some sprout clumps looked sickly, others thrifty, still others were browsed or infested with galls, while others were free of such maladies. Some sprouts had died back for part of their length and others were dead.

Stool sprouts develop on high stumps, large old stumps, and stumps with debris piled around them. For stumps cut 13 cm (5 in) above ground, only those larger than 20 cm (8 in) in diameter produced stool sprouts. Three 20-cm (8-in) diameter stumps produced mostly stool sprouts and a few root crown sprouts. Another 20-cm (8-in) stump yielded 70 stool sprouts and a 30-cm (12-m) stump produced 12 stool sprouts (24).

### Sapling and Pole Stages to Maturity

**Growth and Yield**-Throughout the range of blue oak, about 90 percent of trees in natural stands are single stems. Some of these may fork just above groundline, but each originates as a single entity. These trees probably grew from acorns. Of the remaining 10 percent, where two or three stems are growing close together, origin could be from closely spaced acorns or from sprouts.

Tree growth is a function of many variables, especially site quality, topography, and stand density. Tree height-diameter site index curves are available (33). Taller blue oak trees frequently grow on deeper soils, near bases of hillsides, or close to ephemeral streams in canyons and draws. In Shasta County, CA, for example, two blue oaks 56 cm (22 in) in d.b.h. were located about 35 m (115 ft) apart. One was growing on an alluvial flat near a permanent stream, the other on an old terrace about 8 m (26 ft) above

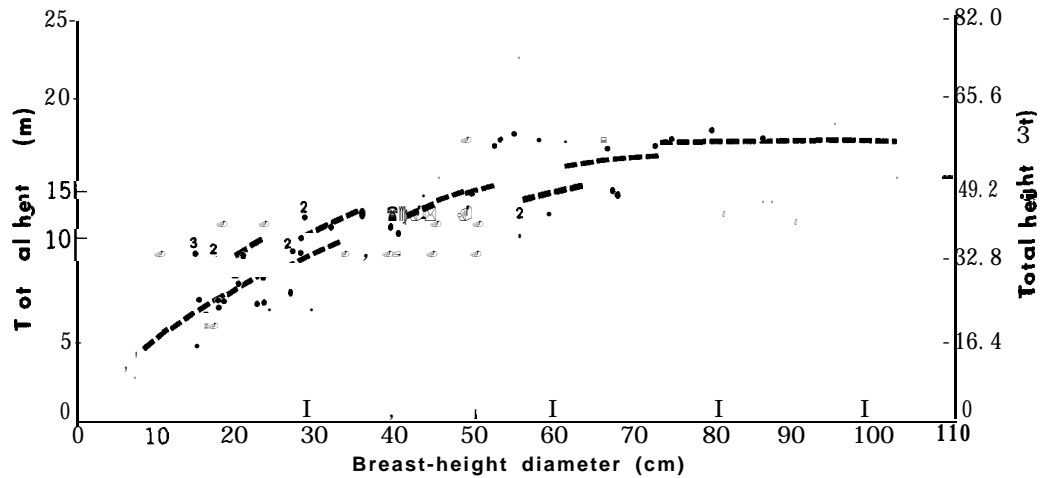


Figure 3—Diameter-height relationship of dominant blue oaks in natural stands in northern and central California.

the flat. The two trees differed in height by 10 m (34 ft) (24).

Stand density varies widely from a few trees scattered throughout the Savannah to fairly dense stands in the woodland. In the latter, stand density of blue oak can reach more than 1,000 trees per hectare (405/acre) (10). Some stands are made up of trees evenly spaced over the landscape that are remarkably similar in height, diameter, and form. Other stands vary widely, with tree diameters ranging from 8 to 76 cm (3 to 30 in), and with form varying between stunted and crooked stems to those that are straight and tall. Loose groups also are formed. Sometimes a group will consist of trees of a single size class; at other times the group will include trees of several size classes.

Data that quantify tree growth are scarce. Studies in Nevada, Placer, and Shasta Counties show that height growth in general is slow (24). After trees reach 65 cm (26 in) in d.b.h., height growth is extremely slow, or ceases (fig. 3). Blue oak seldom exceeds 125 cm (49 in) in d.b.h. or 25 m (82 ft) in height. A champion blue oak, found in Alameda County, measured 196 cm (77 in) in d.b.h., 28.7 m (94 ft) in height, and had a crown spread of 14.6 m (48 ft) (27).

Diameter-age data also are scanty. Blue oak stands in Tulare County ranged in age from 30 to over 300 years. Regression analyses (22) indicated a broad range of age, as determined at 60 cm (24 in) above mean groundline, for a given d.b.h.

D.b.h.		Predicted age	Age range
cm	in	yr	yr
12	5	81	40to 115
25	10	109	80to 120
35	14	131	85to 135

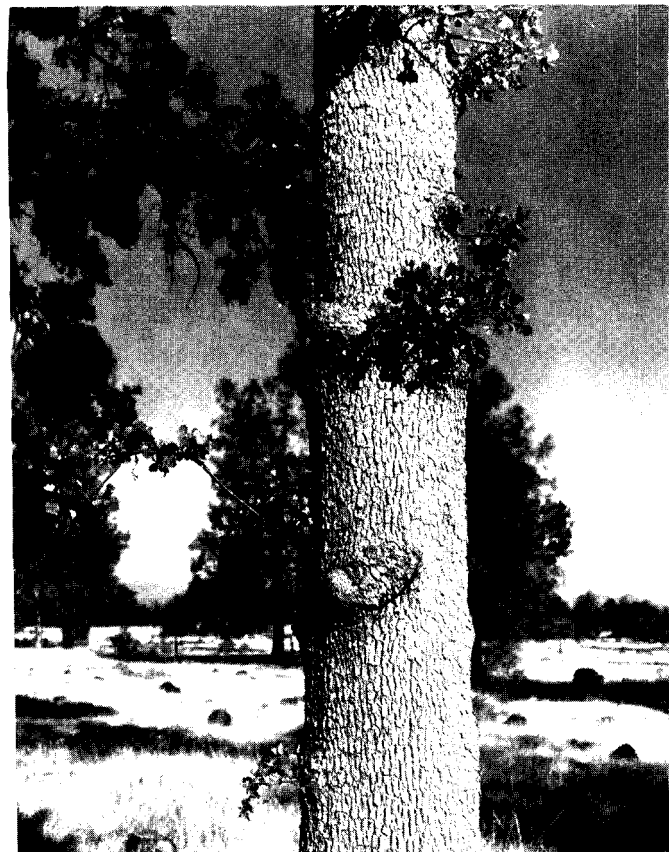


Figure 4—Epicormic branching on an older blue oak in Shasta County, CA.

On good sites in Nevada (36) and Shasta Counties (24), this relationship proved to be linear for trees up to about 65 cm (26 in) in d.b.h. Trees 20 cm (8 in) in d.b.h. were 40 years old, those 40 cm (16 in) were 82

years old, and trees 60 cm (24 in) in d.b.h. averaged about 125 years. On poorer sites, trees 36 to 51 cm (14 to 20 in) in d.b.h. were from 175 to 280 years old. A large tree in Sequoia National Park was 390 years old (22). The species is believed to live even longer.

Yield information is restricted to volume and weight tables for blue oak in California's central coastal counties (28). Selected gross volumes are as follows:

D.b.h.		Height		Volume	
cm	in	m	ft	m <sup>3</sup>	ft <sup>3</sup>
10	4	6	20	0.02	0.7
20	8	10	33	0.18	6.4
30	12	10	33	0.47	16.6
40	16	12	39	1.14	40.3
50	20	12	39	1.92	67.8

Epicormic branching is common in blue oaks of all ages (fig. 4). It is greatest on injured trees, recently released trees, and trees bordering openings. In present hardwood log grading rules, it constitutes a degrade. Blue oaks in irrigated lawns and flowerbeds produce many short, weak epicormic branches which, if removed, are replaced every year.

**Rooting Habit-**The warm dry soils typical of the blue oak habitat mandate that seedling and tree roots grow rapidly downward and stay in a zone of adequate moisture. This suggests a taproot system with one or more deep-growing members. The taproot system begins early in the life of the seedling. Acorns germinate early, before those of other oak associates, and roots grow downward in spite of low temperatures. Most available energy is channeled to development of deep roots, before shoots emerge, and continues after shoot growth begins. The ratio of leaf area to root weight is small. About 73 percent of blue oak's dry weight is allocated to below-ground material the first growing season (20). A study in Placer County, CA, showed that roots from a blue oak 7 cm (3 in) in d.b.h. extended 13 m (42 ft) to groundwater; those of three trees 10 cm (4 in) in d.b.h. penetrated to 20 m (67 ft); and those of an oak 18 cm (7 in) in d.b.h. extended to 24 m (80 ft) (17).

**Reaction to Competition-**Rarely is blue oak found in an understory. Even when growing in mixed-size groups, the smaller trees are positioned to receive considerable overhead light. The species appears to be adapted to long periods of direct sunlight and can most accurately be classed as intolerant of shade.

**Damaging Agents-**The bark of blue oak is thin, relative to other oak species, and with age becomes

deeply fissured and flaky. It catches fire easily, burns well, and does not provide much protection from fire (29). Leaves on part of the crown, however, can be killed by ground fire one year and replaced the next, with no apparent ill effect to the tree. The species, therefore, is probably better adapted to withstand the quick heat from a grassland fire than to tolerate the more sustained heat from burning chaparral.

Animal damage to blue oak is mostly from loss of foliage by deer, cattle, and other browsers, and from root injury by pocket gophers. Seedlings are particularly vulnerable to both browsers and pocket gophers.

Little has been written about diseases of blue oak, but several are prevalent. Probably the most severe are those that damage the heartwood of the trunk and large limbs. *Inonotus dryophilus* is one of these, causing a white pocket rot in the heartwood of living oaks. The sulphur conk, *Laetiporus sulphureus*, causes a brown cubical rot also of the heartwood of living oaks. The hedgehog fungus (*Hydnum erinaceum*) and the artist's fungus (*Ganoderma applanatum*) are also capable of destroying the heartwood of living oaks.

A disease of blue oak roots that sometimes extends a short distance up the bole is the shoestring fungus rot, *Armillaria mellea*. This fungus gradually weakens trees at the base until they fall. A white root rot caused by *Inonotus dryadeus* also has been reported on blue oak.

Several fungi attack dead sapwood, particularly if the tree is on the ground and in the shade. Two common sapwood decomposers are *Polyporus versicolor* and *Stereum hirsutum*.

A number of diseases attack leaves of blue oak, but most have not been identified. Powdery mildews, especially *Sphaerotheca lanestrus* and *Microsphaera alni*, are common. An unknown disease of blue oaks growing in well-watered lawns kills nearly every leaf on the tree in midsummer. The leaves turn brown and persist until the usual time of leaf fall. Normal leaf development takes place the next spring.

True mistletoe (*Phoradendron villosum* subsp. *villosum*) often infects older open-grown blue oaks. Its effect on them is undetermined although the pest must cost its host a certain amount of growth increment.

A large number of insects infest blue oak. One study recorded 38 species of insects in 21 families inhabiting blue oak (4). Two additional insects, a leaf skeletonizer and a wood borer, are recorded in another study (14). No part of the tree is spared. Sucking and chewing insects attack the twigs and leaves, boring insects infest the roots, trunk, and limbs, and other insects ruin twigs and acorns.

## *Quercus douglasii*

Many of the insects are found in low numbers, but when epidemics occur, damage can be severe. A local but intensive epidemic of the fruit-tree leafroller (*Archips argyrospila*), for example, was noted in Contra Costa County in the early 1970's (3). Blue oaks were badly defoliated by this insect in June; by mid-July a second crop of leaves had taken their place.

More than 40 species of cynipid wasps form galls on blue oak (38). Galls range from small to large, dull to brightly colored, round to oblong, and smooth to spiny. They were found on every part of the tree: the roots, catkins, buds, acorns, stems, and leaves. Of those on stems and leaves, many are firmly attached; others eventually fall to the ground. Two of the most interesting are formed by the spined turban gall wasp (*Antron douglasii*) and jumping oak gall wasp (*Neuoterus saltatorius*). The turban gall wasp creates from one to four bright purplish-pink galls on the underside of a leaf. The adult jumping oak gall wasp stings the underside of mature blue oak leaves and then lays its eggs inside the leaf. Larvae emerge in July and August and form a light-tan gall less than 0.02 cm (0.06 in) in diameter. These galls fall to the ground about mid-August, often in large numbers, the movement of the larvae causing the ground to seemingly come alive. Possibly the jumping around is an attempt by the larvae within to find cracks and crevices in which to hide, and thereby escape from enemies and bad weather.

## Special Uses

Although strong, hard, and heavy, the wood of this oak currently has little or no commercial use, not so much because of its qualities, but because of the short stature and poor form of the tree. Products have been limited to fenceposts and fuelwood, with the latter use increasing greatly in recent years.

Throughout the range of blue oak, especially on its margins and in the Coast Ranges, woody shrubs have been eliminated to encourage forage for livestock, leaving the blue oaks and valley oaks. In other areas, oaks have been reduced greatly or eliminated and a Savannah formed with the intent of producing more forage for livestock. When many trees are removed, large increases in forage occur (15,16). When blue oak density is low or moderate, however, the grass seems to be taller, has more nutrients, produces more biomass, grows earlier, and stays greener longer in the growing season under oaks (12,13). Furthermore, living oak roots hold the soil in place on steep slopes and reduce the incidence of mass movement downslope into permanent and ephemeral streams. Elimination of the oaks, therefore, could be a dubious practice.

Blue oak has been used for decoration: large branches hollowed out by heart rot are sawn into sections, cleaned, coated with resin and hardener, and filled with dried seedstalks, for use as wall hangings and table centerpieces.

Blue oak acorns were a favored food of California Indians. On a scale of 1 (preferred) to 3 (undesirable) they rated blue oak acorns 1.5 (2). The acorns average about 4,994 calories per kilogram (2,265/lb) and are a potential source of human food.

## Genetics

Blue oak hybridizes with its white oak associates, particularly valley oak, Oregon white oak, California scrub oak (*Q. dumosa*), and turbinella oak. In most instances the natural hybrids formed by these crosses are fertile and cytologically normal.

The binomial for *Quercus douglasii* x *turbinella* is *Quercus* x *alvordiana* Eastw. and the common name is Alvord oak (37). The Alvord oak is distributed widely from Monterey County southward into the Tehachapi Mountains and is the dominant oak in some foothill woodlands instead of blue oak (11).

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