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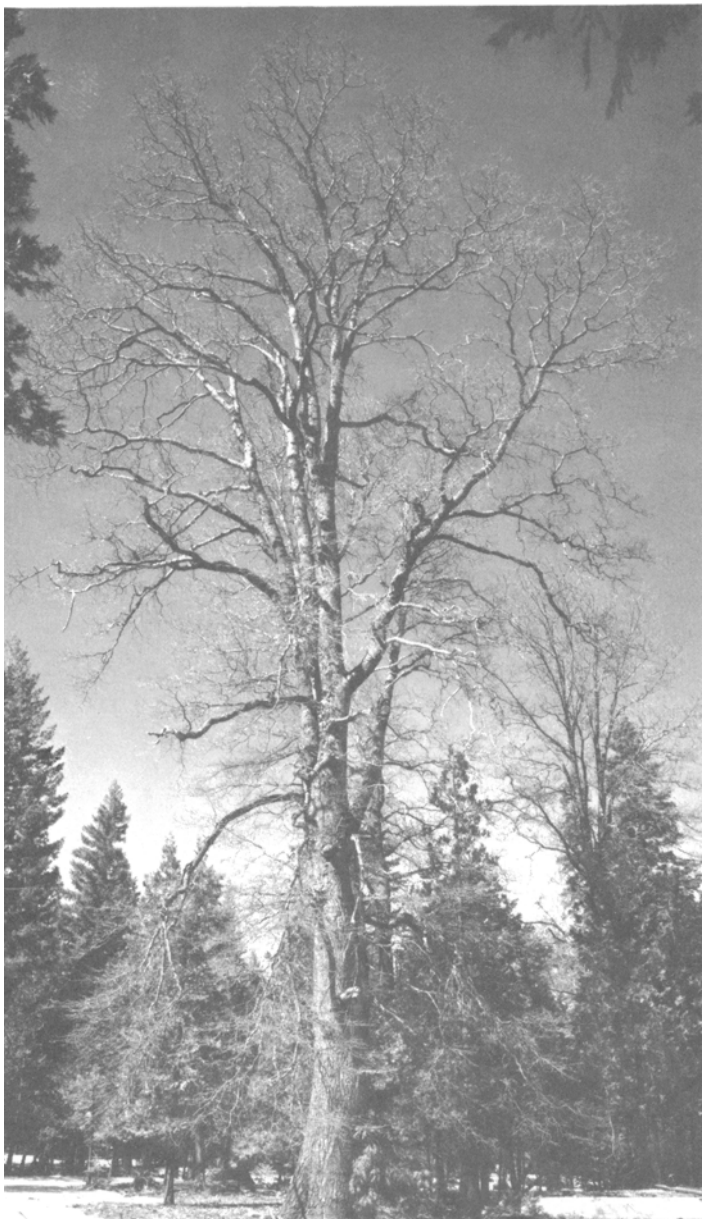
SILVICAL CHARACTERISTICS OF CALIFORNIA BLACK OAK

(Quercus kelloggii Newb.*)*

Philip M. McDonald



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McDonald, Philip M.

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Describes the climatic, edaphic, physiographic, and biotic habitat conditions of the natural range of California black oak *(Quercus kelloggii* Newb.) and how this tree reproduces, grows, and dies.

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The Author

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Cover: This venerable monarch, growing near Shingletown, Shasta County, California, is 121-feet tall, 16.4 feet in circumference at breast height and is 180 years old.

California black oak *(Quercus kelloggii* Newb.*)* excels all other California oaks in volume (Dickinson 1958), distribution, and altitudinal range. Yet this deciduous hardwood has had little commercial use even though its wood closely resembles that of its valuable, heavily used counterpart–red oak–in the eastern United States. Grain and figure make California black oak attractive for paneling and furniture; its hardness and finishing qualities, for flooring; its strength properties, for pallets, industrial flooring, and other uses (Malcolm 1963).

First collected in 1846 near Sonoma, California, by Karl Hartweg, an explorer of the London Horticultural Society (Jepson 1910), the species was not described until 10 years later by John Torrey. In 1857, John Newberry renamed it *kelloggii* in honor of Albert Kellogg, a pioneer California botanist and physician (Kellogg 1882). In later botanical works, the species was called *Q. californica,* commonly Kellogg's oak. These names have long fallen from favor and today the species is generally known by but one common name: California black oak.

The first known introduction of the species to other countries was in 1878, by an English earl who had visited California. Thirty-two years later Elwes and Augustine (1910) described the trees as 30 feet tall and growing robustly.

California black oak has a north-south range of about 780 miles *(fig. 1).* In Oregon, its natural range extends from just north of Eugene southward through the valleys west of the Cascade Range. It is especially frequent along lower slopes in semi-arid sections of the Klamath and Cascade Mountains but never grows near the Pacific Ocean. In California, the species is found in the northern Coast Range from the Oregon State line to Marin County and then intermittently in the Santa Cruz and Santa Lucia Mountains. It becomes more common on the San Bernardino, San Jacinto, and Agua Tibia Mountains, extending to just south of Mt. Laguna but not reported in Baja California.[1] In California's Sierra Nevada, the species grows abundantly along the west side, from Lassen Peak to near Kings Canyon. It then becomes intermittent southward to the Tehachapi Mountains, where it becomes more abundant. California black oak is generally confined to the westside, but a few stands have been found along the eastside of the Sierra Nevada. It approaches the Nevada State line northeast of Beckwourth Pass but is not reported in Nevada.

HABITAT CONDITIONS

Climatic

California black oak grows in a climate having hot dry summers and cool moist winters. Average annual precipitation varies widely. In the southwestern Oregon valleys, it exceeds 30 inches (Sterner 1960); in northwestern California, from 30 to 100 inches; and in northeastern California, 12 to 15 inches–the lowest amount in the natural range of the species. Throughout the range of black oak in north central and central California, annual precipitation averages 40 to 70 inches, although it may exceed 115 inches locally. Here less than 4 percent of the yearly precipitation falls from June through September. In the southern mountain ranges, precipitation averages about 36 inches. Data on average annual snowfall are incomplete, but black oak grows where snowfall ranges from 0 to 80 percent of total precipitation. In black oak's zone of maximum development, snowfall accounts for 10 to 50 percent of the year's precipitation.

Average mean daily temperatures range from 31°F. to 46°F. during January and from 66°F. to 82°F. in July. The last killing spring frost usually occurs between March 15 and June 9, and the first killing frost in fall comes between August 30 and November 30. The number of days free of killing frosts ranges from 82 to 270 (Sprague 1941; U.S. Weather Bureau 1965). Over an 18-year period, the maximum temperatures recorded at a 3,700-foot elevation in the center of black oak's zone of maximum development was 103°F.; the minimum was 5°F. The maximum number of frost-free days was 215 and the minimum was 116 (U.S. Weather Bureau 1949-1967).

[1]Personal correspondence with Ira L. Wiggins, Biology Department, Stanford University, April 21, 1966.

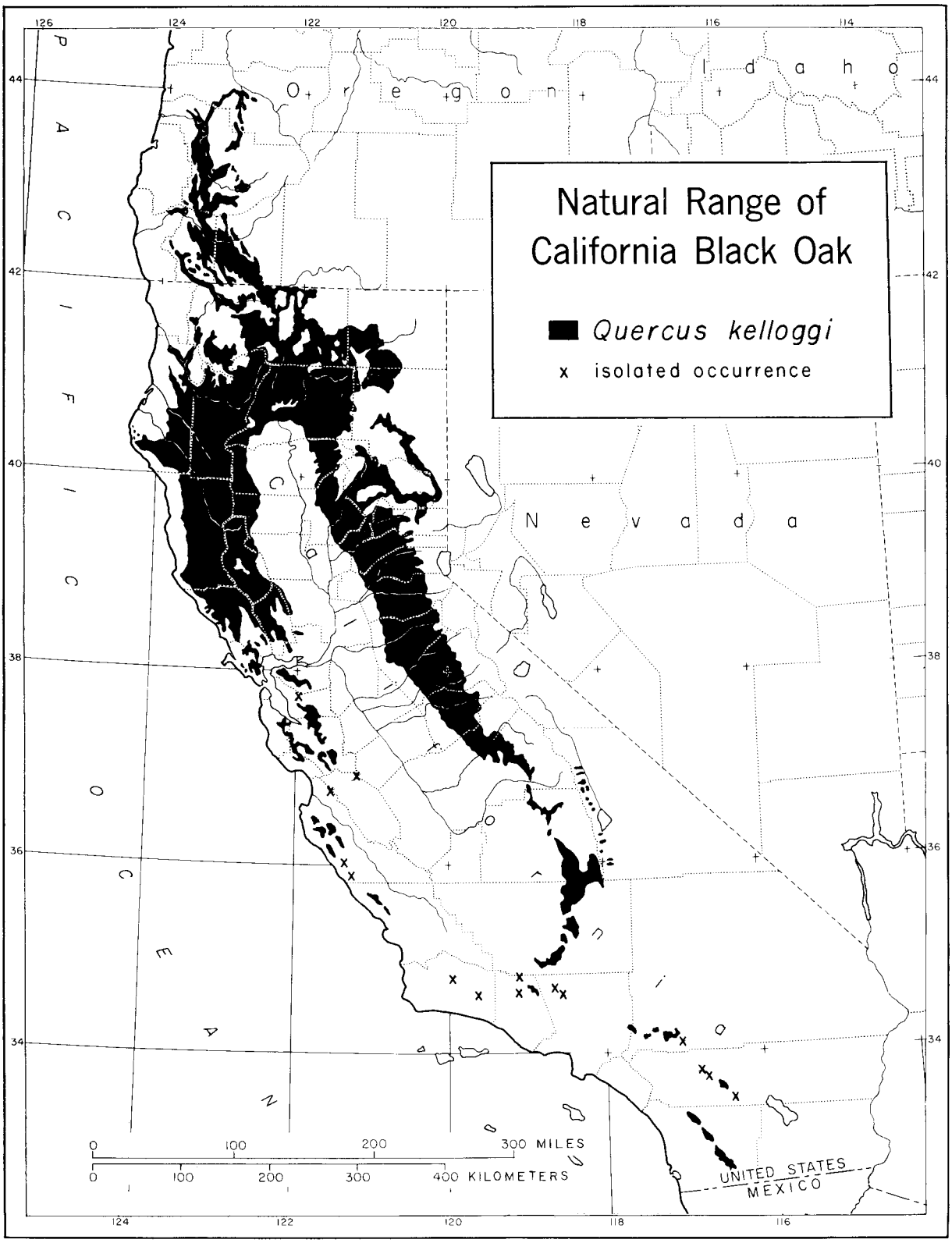

Figure 1.– *Natural range of California black oak.*

Edaphic

Probably the most important single soil variable that limits the occurrence of California black oak is internal drainage. Black oak is not found growing "with its feet wet." It is adapted to soils derived from diverse parent materials: andesite, basalt, granite, pumice, quartz diorite, sandstone, schist, shale, and volcanic tuffs and breccias. It is rarely found in serpentine soil. Occasionally it grows on soils derived from ultra-basic parent material, but mostly where above-average amounts of calcium seem to offset the deleterious effects of magnesium.

Soil textures favoring this oak range from medium textured loams and clay loams to the more coarse textured gravelly clay loams and sandy loams. Increasing clay content in the surface soil usually means a decreasing incidence of black oak. In fact, black oak rarely is found on soils with clay topsoils, particularly if the clay is of the heavy, sticky type. It commonly grows on thin soils and rocky slopes, but always at the cost of abundance or form, or both. In general, black oak grows best on the medium to coarse textured, deep, and well drained soils.

At least 75 soil series in California[2] and 14 in Oregon have been identified as supporting California black oak. Many of the important Oregon soil series are also present in California. Most of the important soils in California *(table 1)* support forest vegetation rather than oak-woodland or woodland-grass vegetation. The forest soils are mostly found at higher elevations where temperatures are cooler and precipitation is greater.

The best black oak stands in the Coast Range and Klamath Mountains are found on deep, slightly acid loams and gravelly clay loams derived from sandstone and shale. In the southern Cascade Range and northern Sierra Nevada, black oak grows best on deep loams and clay loams derived from metavolcanic rocks. In the central and southern Sierra Nevada and in the Transverse and Peninsular Ranges, black oak grows best on deep, acid to moderately acid sandy loam soils derived from granitic rock.

Like many deciduous hardwoods, black oak generally has a moderating influence on the pH of the surface soil. The large amount of organic material furnished annually to the forest floor may account for this influence. A 75 to 100-year-old black oak stand on the Sierra National Forest, California, contributed 1,380 pounds per acre of litter each year. Total organic matter above the mineral soil amounted to 39,100 pounds per acre (Jenny et al. 1949).

Physiographic

California black oak grows within a wide elevational range–from the level gravelly floors of low valleys to alluvial slopes, rocky ridges, and high plateaus. Most of the terrain is rough, steep, and strongly dissected by major streams and ephemeral drainages.

In Oregon, the elevational range of black oak varies from 450 feet near Eugene to over 1,000 feet on the low rounded hills in the Umpqua River drainage (Gratkowski 1961). It also occurs on the eastern slopes of the Coast Range and the western slopes of the Cascades within this elevational range. In south central Oregon and the Klamath Mountains, it grows at higher elevations (2,000-3,000 feet) (Whittaker 1960).

In California's Coast Range, black oak grows from about 500 feet along the Mattole River in Humboldt County to 6,000 feet in the Yolla Bolly Mountains. Black oak reaches its lowest elevation (200 feet) in the Napa and Santa Rosa valleys. Most black oak in the central portion of the Coast Range grows between 1,000 and 5,000 feet, gradually increasing in elevation but narrowing in range to 4,000-6,500 feet in Santa Barbara and eastern Ventura Counties. Farther south in the Transverse Range it is found at elevations of 4,600 to 7,000 feet (Horton 1960; Wright 1966). In the San Jacinto Mountains, it reaches 8,000 feet and at its southernmost extension in the Peninsular Range of San Diego County it grows within the 5,000-6,000 foot elevation.

The elevational range of black oak in California's Cascade Range is from about 600 feet in western Shasta County to 6,250 feet in south central Shasta County. In the Sierra Nevada, lower elevational limits for black oak range from 1,500 feet in the north to 4,000 feet in the south. Upper limits increase north to south from about 6,500 to 7,800 feet.

Black oak is most abundant and attains its largest size on the west-facing slopes of the southern Cascade Range and Sierra Nevada, from Shasta County southward through Tulare County, California *(fig. 2).* Here it grows best on gently sloping benches, canyons, and draws with north and east aspects, although in deep canyons it grows equally well on nearly all aspects except southwest. Extensive stands of excellent development are also found in eastern Mendocino and Humboldt Counties of the north Coast Range.

[2]California soil series are identified by the California Cooperative Soil-Vegetation Survey and the National Cooperative Soil Survey. They are available from the Director, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley, Calif. 94701.

Table 1.—Principal *California mountain ranges and soil series where black oak is found*

Mountain range	Sub-range	Range of counties	Soil Series
Coast	North Coast	Humboldt southward through Marin and Contra Costa	Boomer Cohasset Hugo Josephine Los Gatos Neuns Sheetiron Sites Tyson
Coast	Central Coast	Alameda southward through San Luis Obispo	Ben Lomond Boomer Felton Hugo Los Gatos Mindego Sheridon
Coast	Transverse and Peninsular	Santa Barbara southward through San Diego	Coarsegold Crouch Holland Shaver
Cascade	Southern	Siskiyou southward through part of Butte, Lassen, and Plumas	Aiken Cohasset Cone Forward Jiggs Letterbox Lyonsville McCarthy Nanny Shasta Sites Supan Tournquist Windy
Klamath	– –	Mainly Siskiyou, Trinity, and Shasta	Behemotosh Boomer Chawanakee Dubakella Horseshoe Hugo Josephine Kinkel Mariposa Marpa Neuns Sheetiron Sites Tatu
Sierra Nevada	Northern	Part of Lassen, Butte, and Plumas southward through Placer	Aiken Bonta Chawanakee Cohasset Fiddletown Haypress Holland Mariposa McCarthy Sites Tish Tang
Sierra Nevada	Central	El Dorado southward through Madera	Aiken Chaix Chawanakee Cohasset Fiddletown Crozier Hotaw Holland Horseshoe Mariposa McCarthy Musick Shaver Sites Stump Springs
Sierra Nevada	Southern	Fresno southward through Kern	Chawanakee Corbett Fiddletown Heitz Holland Musick Shaver Sheetiron Stump Springs

North and east aspects are most favorable in the central and southern parts of black oak's range, but it is found on just the opposite aspects in its northwesternmost locale. In Humboldt and northern Mendocino Counties, black oak grows on the warmer, drier south and southwest aspects.

The interaction of elevation and aspect often is of major importance. For example, at elevations below 1,000 feet bordering the Sacramento Valley in north central California, black oak occurs only in sheltered draws or on north slopes. With increasing elevation, favorable aspects increase until at 2,500 to 3,000 feet all aspects are generally favorable if soil depths are sufficient. Above 3,500 feet, north and east facing slopes are often devoid of black oak though other vegetation does well. In the southernmost mountains, black oak grows on the west-facing slopes, but only where deep soil, cool temperatures, and adequate moisture prevail.

Biotic

California black oak is a component of six forest types (Soc. Amer. Foresters 1954). It is the prime constituent of the California black oak type (No. 246) and important in two others: oak-madrone (No. 234) and Pacific ponderosa pine-Douglas-fir (No. 244). It becomes important in the ponderosa pine-sugar pine-fir (No. 243) and Pacific ponderosa pine (No. 245) types after severe disturbance or fire, and it is a minor component in the canyon live oak type (No. 249).

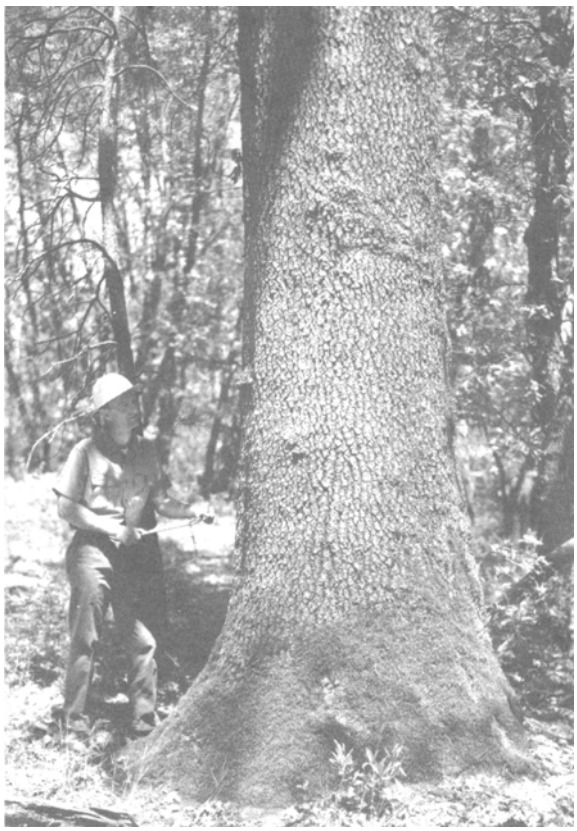

Figure 2.—A *mature black oak in the Shasta-Trinity National Forest, Shasta County, California.*

Cooper (1922) considered the oak-madrone forest a climax type "since it represents a degree of mesophytism between that of the chaparral and the conifer forest." Show[3] and others (Biswell et al. 1966; Horton 1960; Soc. Amer. Foresters 1954) noted that black oak and vegetative associates are especially prevalent after logging and wildfire, and implied that such stands were subclimax.

This oak or its progenitors were much more widespread in past ages than at present. The black oak-madrone forest began its development in the upper and middle Miocene as a result of increasing aridity (Mason 1947). Fossil flora in sedimentary deposits include an oak named *Quercus pseudo-lyrata* Lesq., which appears closely related to *Q. kelloggi. Q. pseudo-lyrata* has been found near Spokane and Ellensburg, Washington; in the John Day Valley and Blue Mountains of Oregon; and in northwestern Nevada. It was abundant at each location (Chaney 1925), even though each is far removed climatically from the present range of California black oak. Each of the 12 most common species in the fossil flora has an equivalent in the oak-madrone forest of today, and probable genetic lineages have been formulated for Miocene and modern species.

The most common botanical associate of black oak is ponderosa pine *(Pinus ponderosa* Laws.*)*. Wherever ponderosa pine grows, so can black oak. The two are nearly inseparable except that black oak grows on sites too poor to support pine and in certain areas within the redwood region of California where pine does not grow. Thus, in California and Oregon where the natural ranges of the two species coincide, ponderosa pine sites would be fertile ground for black oak. The converse is nearly always true.

Ponderosa pine is clearly the more aggressive species on the best sites. Above 3,000 feet in elevation, black oak often is crowded out by the thrifty pines or mixed conifers that spring up under it. It often serves as a nurse tree (Baker 1942; Barr 1946; Edwards 1957). The shade and leaf litter from black oak often ameliorate soil temperature and soil moisture during the growing season, so that dense clumps of pine, fu, and cedar develop vigorously beneath large-crowned trees while adjacent ground remains devoid of conifers (Barr 1946). At lower elevations, however, these effects decrease; at 2,500 feet pine seedlings grow well for a time but have difficulty growing through the oak, and below 2,000 feet, pines reach 3 to 4 feet in height but are weak and misshapen and in need of release (Baker 1942).

A rule of thumb is that black oak never grows through a stand of ponderosa pine, but can grow through brush (Edwards 1957). Black oak is eventually crowded out of the best sites and remains only as scattered remnants in dense mixed-conifer forests. There it often exists on "islands" of soil or terrain not favorable for conifers. An example in Tuolumne County, California, is on dry, rocky ridges with a western exposure at 5,800-6,4.00 feet (Stark 1965). Another, in Plumas County, is a fringe of black oak on dry rocky sites just above the mixed-conifer forest, at 4,500-5,500 feet.

Black oak grows either individually or in groves, some of which are quite extensive. Rarely does it exist as an understory. It usually is a component of hardwood stands or of mixed hardwood and conifer forests. Tanoak *(Lithocarpus densiflorus* (Hook. & Am.) Rehd.*)* and Pacific madrone *(Arbutus menziesii* Pursh*)* are the most common hardwood associates of

[3]Show, S. B. Report to Supervisor, Shasta Forest Reserve. April 12, 1913.

black oak. Others are:

big leaf maple *(Ater macrophyllum* Pursh*)*
California buckeye *(Aesculus californica* (Spach) Nutt.*)*
Pacific dogwood *(Cornus nuttallii* Audubon*)*
California live oak *(Quercus agrifolia* Nee*)*
canyon live oak *(Q. chrysolepis* Liebm.*)*
blue oak *(Q. douglasii* Hook. & Am.*)*
Engelmann oak *(Q. engelmannii* Greene*)*
Oregon white oak *(Q. garryana Dougl.)*
interior live oak (Q. *wislizenii* A. DC*)*
California laurel *(Umbellularia californica* (Hook. & Arn.) Nutt.*)*

Besides ponderosa pine, other conifer associates are:

white fir *(Abies concolor* (Gord. & Glend.) Lindl.*)*
grand fir *(A. grandis* (Dougl.) Lindl.*)*
western juniper *(Juniperus occidentalis* Hook.*)*
incense-cedar *(Libocedrus decurrens* Torr.*)*
knobcone pine *(Pinus attenuata* Lemm.*)*
Coulter pine *(P. coulteri* D. Don*)*
Jeffrey pine *(P. jeffreyi* Grey. & Balf.*)*
sugar pine *(P. lambertiana* Dougl.*)*
Monterey pine *(P. radiata* D. Don*)*
Digger pine *(P. sabiniana* Dougl.*)*
Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco*)*
bigcone Douglas-fir *(P. macrocarpa* (Vasey) Mayr.*)*
giant Sequoia *(Sequoia gigantea* (Lindl.) Decne.*)*
redwood *(S. sempervirens* (D. Don) Endl.*)*
California nutmeg *(Torreya californica* Torr.*)*

Shrub associates are numerous; the principal ones reported (Cooper 1922; McMinn 1951; Whittaker 1960;[4]) include 29 species *(table 2).* In parts of Shasta and Trinity Counties, California, black oak itself takes a shrub form. There–sometimes growing alone, sometimes with other shrubs–dense, tangled stands develop. Nearly impenetrable by man, but preferred habitat for deer and upland game, such shrubby stands are generally strikingly uniform in height.

Except in these shrubby stands and at black oak's lowermost elevations, most shrubs generally are not competitive, nor particularly abundant over most of the forest land where black oak abides. After heavy cutting or fire, however, some of the more aggressive shrubs often compete strongly with black oak sprouts.

Table 2. – *Principal shrub associates of California black oak*

Scientific name	Common name
Amelanchier pallida Greene	western service berry
Arctostaphylos mariposa Dudley	Mariposa manzanita
A. patula Greene	greenleaf manzanita
A. pungens H.B.K.	Mexican manzanita
A. viscida Parry	whiteleaf manzanita
Castanopsis sempervirens (Kell.) Dudl.	bush chinkapin
Ceanothus cordulatus Kell.	mountain whitethorn
C. integerrimus H. & A.	deer brush
C. lemmonii Parry	Lemmons ceanothus
C. prostratus Benth.	squaw carpet
C. velutinus Dougl.	snowbrush
Cercis occidentalis Torr.	western redbud
Chamaebatia foliolosa Benth.	Sierra mountain misery
Garrya fremontii Torr.	Freemont silk tassel
Holodiscus discolor (Pursh) Maxim.	ocean spray
Lithocarpus densiflora (H. & A.) Rehd. var. *echinoides* (R. Br.) Abrams	shrub tanoak
Photinia arbutifolia Lindl.	toyon
Prunus emarginata (Dougl.) Walp.	bitter cherry
P. subcordata Benth.	Sierra plum
P. virginiana L. var. *demissa* (Nutt.) Sarg.	western choke cherry
Purshia tridentata (Pursh) DC.	bitterbrush
Quercus garryana Dougl. var. *Breweri* (Engelm. in Wats.) Jeps.	Brewer oak
Q. vaccinifolia Kell.	huckleberry oak
Rhamnus purshiana DC.	cascara buckthorn
R. rubra Greene	Sierra coffeeberry
Rhus diversiloba T. & G.	poison-oak
Ribes roezlii Regel.	Sierra gooseberry
R. nevadense Kell.	mountain pink currant
Rosa californica C. & S.	California wild rose

When compared with 15 of its most common shrub associates in the Klamath Mountains of northern California, black oak ranked ninth in need of soil moisture, third in demands on soil, eighth in terms of tolerance, and first in rapidity of sprouting.[5]

Waring (1969) found black oak to weather severe transpirational stress quite well. In the northeastern Klamath Mountains of Oregon, it was able to withstand plant moisture stresses of 18-25 atmospheres–

[4]Show S. B. *Op. cit.*, footnote 3.

[5]Show, S. B. *Op. cit.*, footnote 3.

giving it 86-98 days within the normal growing season when soil moisture was not limiting. Few other plants were able to glean adequate moisture for this length of time. Thus presence of black oak signified sites where high moisture stresses were likely.

Numerous forbs and grasses are plentiful in the black oak range. They do not materially influence the growth of black oak in most situations.

LIFE HISTORY

Seeding Habits

Flowering and Fruiting

Flowering takes place from mid-March to mid-May–depending on elevation, physiography, and local conditions of climate. In general, trees near the coast and at lower elevations bloom earliest (Pelton 1962).

Flowers on black oak are unisexual. The plant is monecious. Staminate flowers are long (3.5 to 7.5 cm.) hairy aments that emerge from buds in the leaf axils of the previous year's growth *(fig. 3).* The 5 to 9 stamens in each ament have bright red anthers and pale green filaments. The calyx is light green. Pistillate flowers are borne singly or 2 to 7 on a short stalk that originates from leaf axils of the current

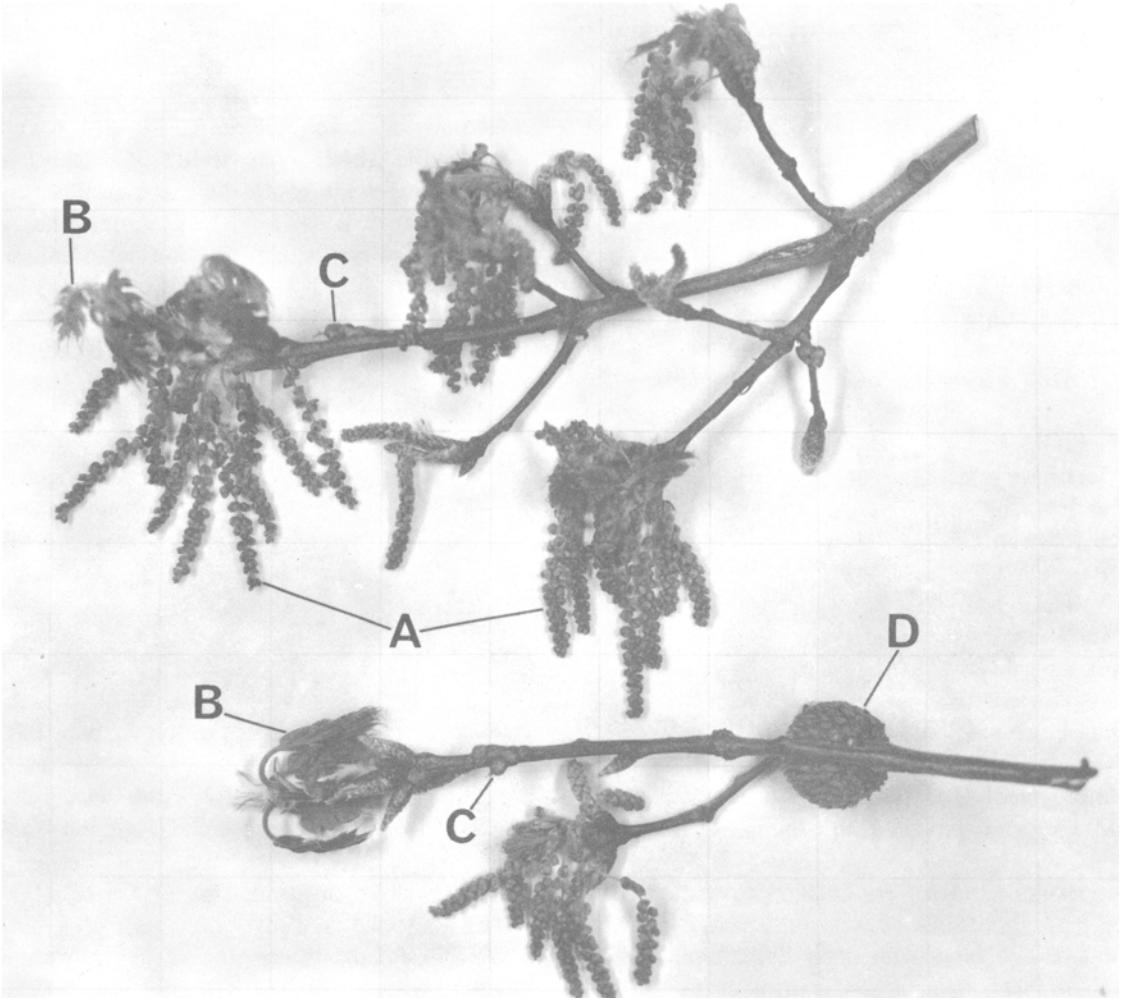

Figure 3.–*Flowering twigs.* A, *staminate flowers;* B, *just emerged leaves;* C, *immature acorns;* D, *cup of last year's acorn.*

year's growth. The stigmas are dark red (U.S. Forest Serv. 1948).

Acorns mature the second year. Early in the second summer the acorn is completely covered by the cup forming a globe-shaped knob about 1/4 inch in diameter (Jepson 1910). When mature, the light brown, thinly scaled cup encloses from 1/4 to 3/4 of the length of the acorn. The oblong (occasionally ellipsoid) acorns occur either singly or in clusters of two or three and vary widely in shape and size *(fig. 4)*. Sizes range from 3/4 to 1-3/4 inches long and from 3/8 to nearly 1-1/2 inches in diameter.

Seed Production

Abundant seed crops for entire stands are produced at 2- to 3-year intervals (Roy 1962; Sudworth 1908), but individual trees or groves of trees bear some seed nearly every year. In natural stands, black oak must be 30 years or older before it produces viable seed. It produces some seed sporadi-

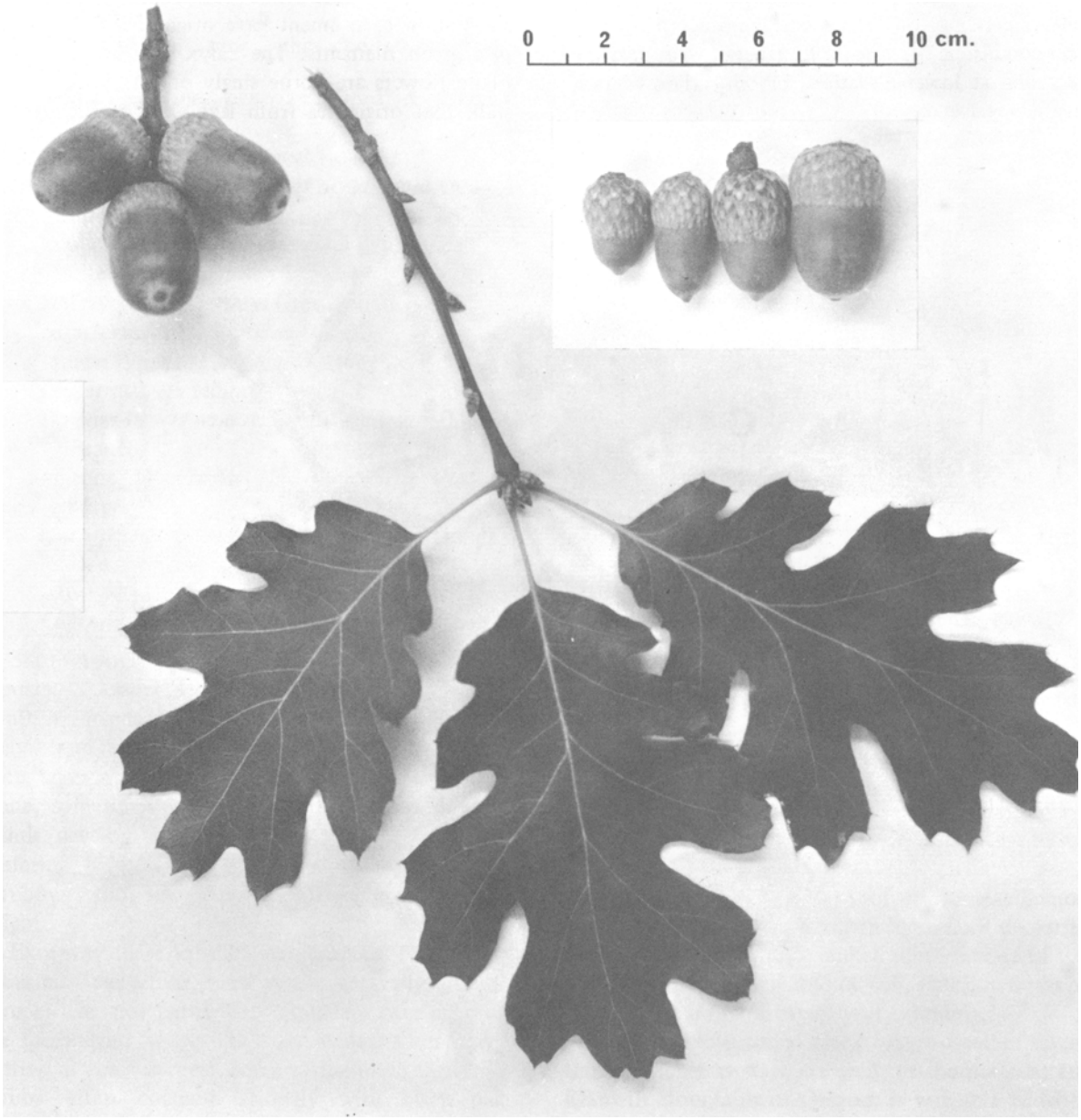

Figure 4.–*Typical leaves, twig, and acorns of California black oak.*

cally between ages 30 and 75, but seldom large quantities before 80 to 100 years. Abundant acorn production continues at least to 200 years. In 1967, a year when the over-all acorn crop rated as fair, I estimated seed production on a single 150- to 200-year-old tree at 6,500 acorns.

The number of acorns per pound reported for black oak range between 16 (Wolf 1945) and 115 (U.S. Forest Serv. 1948). A pound of the largest size of acorn in figure 4 would contain 52 acorns.

Insects destroy many acorns–damage to nearly 60 percent of the annual crop has been reported in one locality.[6] Another pest is a species of cynipid *(Andricus* spp.*)* which heavily infests the acorns and forms galls in the kernels. Developing acorns are attacked by the filbert weevil *(Curculio uniformis* LeConte*)* and by larvae of the lepidopterous filbert-worm *(Melissopus latiferreanus* Walsingham*)*. These two insects in some places infest up to 95 percent of the acorns and destroy most of a crop (Keen 1958).

Seed Dissemination

Mature acorns fall during September and October (Dixon 1934; U.S. Forest Serv. 1948), either just before or during leaf fall. Once they are on the ground, temperature can be critical. If the acorns are exposed, the often hot fall weather can cause severe drying. In August 1967, I found that mature acorns lying in light litter beneath felled trees had coty-ledons withered to about half normal size 9 days after the felling. Acorns from the same trees but shaded by leaves and branches for about 3 weeks contained full sized cotyledons and germinated readily.

A blue-gray mold also damages fallen seed. I have examined undisturbed acorns about 2 months after leaf fall and some rain. The mold was visible in the circular scar formed by the absent cup, and had progressed well within the acorns. Jaeger (1920) reported that Indians would gather only freshly fallen acorns to avoid the mold.

Because the acorns are large and heavy, most of them fall directly beneath the tree crowns. Few bounce or roll very far on steep slopes covered by duff, leaves, and litter. Dissemination by animals is important—not so much because of the numbers of acorns moved, but because some of them are moved beyond the parent tree and enhance the spread of the species. The western gray squirrel *(Sciurus griseus)* and the scrub jay *(Aphelocoma coerulescens)* are the most important disseminators, for they bury the acorns, often after carrying them some distance from the seed source.

Acorns are eaten by at least 14 species of song and game birds, many species and subspecies of small mammals (mostly rodents), and mule and black-tailed deer (Martin et al. 1961; Jameson 1952).

Deer are prodigious consumers of acorns. They eat some in the fall and many in early and late winter, when bucks, does, and fawns root about in the fallen leaves and snow for them. Acorns are also avidly searched for in the spring, particularly in areas just exposed by melting snowbanks (Dixon 1934). On the Tehama winter deer range, where black oak makes up but 6 percent of the total vegetative cover, its leafage and acorns constituted 27.8 percent of the total monthly diet of mule deer in October and 21 percent in May (Leach and Hiehle 1957).

Black oak acorns form part of the diet of the band-tailed pigeon only in autumn, being 3.2 percent in September and 7.7 percent in November (Smith 1968).

Seedling Development

Germination and Establishment

California black oak can reproduce adequately from seed. For example, more than 45 black oak seedlings per square meter were found under a 26-inch tree.[7] At Challenge Experimental Forest and elsewhere in Yuba County, California. many black oak seedlings have become established on exposed mineral soil after logging and site preparation.

Nevertheless, seedlings are less important than sprouts in establishing stands. Seedlings extend the species into new areas; sprouts keep black oak in the same area and result in the establishment of many more stands than do seedlings.

Stands on new areas may become established from acorns disseminated by animals and birds. They are also established by seedlings that spring up under isolated trees and nearby conifers. If the overstory is then burned, broken, or destroyed the oak seedlings become free to grow. Even if seedlings are damaged during removal of the overstory, they promptly sprout. These sprouts prosper and form new black oak stands.

Natural seedbed requirements for germination are not rigid. Either undisturbed leaf litter or, to a lesser extent, moist, well aerated mineral soil are good seedbeds. Establishment is almost nonexistent on

[6]Radtke, L. B. Forest insect conditions on the Hoopa Indian Reservation. 1939. (Typewritten.)

[7]Personal correspondence with Dale O. Hall. U.S. Forest Service, February 14, 1966.

heavy clay soils or soils compacted by logging machinery, because the new radicle cannot penetrate the soil far enough and fast enough to avoid searing soil surface temperatures.

Germination occurs in the spring when warm weather begins. It probably is regulated by light, temperature, moisture, and depth of soil or litter. Thus germination, both in magnitude and timing, is highly variable. Germination is hypogeous; that is, the acorn remains below ground. The radicle is first to emerge and grows downward for some time, often 10 to 15 days, before the hypocotyl appears above ground. This process benefits the seedling both in getting to and staying in available soil moisture, and in minimizing transpirational losses. Sometimes a single acorn may put forth several hypocotyls, particularly if upward progress is hampered by a stony or crusty soil. Burying the acorn 3 to 4 inches deep also leads to several hypocotyls. Genetic character seems to govern the number of above-ground stems, too, because acorns from one parent tree will result in more multi-stemmed progeny than those from another, other factors being constant.

Under optimum conditions, about 15 days elapse between sowing and the beginning of germination (Mirov and Kraebel 1937). In nature, the germination period can be several weeks. Germinative capacity is highly variable and changes with the degree of insect infestation and amount of mold, among other factors. Germination has been reported as high–95 percent–(Mirov and Kraebel 1937) and as scanty (Sudworth 1908). In a 1966 test by the Pacific Southwest Station, total germination was 32 percent with sound acorns sown in fall and allowed to over-winter; 30 percent germinated in 91 days.

Before germination can begin, the seed requires a period of after-ripening to overcome dormancy. Over-wintering in the forest floor normally breaks dormancy under natural conditions. Stratification in moist peat or leaf mold for 30 to 45 days at 32° to 45°F. is recommended for artificial regeneration (U.S. Forest Serv. 1948).

Acorns can be stored in sacks in a cool room for 1 to 2 months if they are not allowed to overheat or dry out (Mirov and Kraebel 1937). Mold is often a problem, and control measures need to be applied before storage. In general, little is known about storage criteria and conditions, or even if storage is possible for periods exceeding 6 months. The classical storage criteria of a low moisture content and a just-below-freezing temperature are fatal to black oak acorns. They must be stored at a high moisture content which precludes storage at temperatures below freezing. Under these conditions, the acorns sprout; hence some means of inhibiting sprouting may be the key to long-term storage.

Early Growth

Black oak seedlings often reach a height of 2 to 4 inches and a taproot length of 9 inches in the first 28 days of growth. During the first growing season, seedlings only 4 to 6 inches tall may extend their taproots as deep as 30 inches. Lateral root development is slow–the longest lateral on a 30-inch taproot being only 1 inch. The fast growing vertical root makes black oak seedlings well adapted to cope with the hot dry summers characteristic of their range.

Soil moisture is seldom a limiting factor during early growth, and seedlings become established in dense shade beneath trees and shrubs or in full sunlight. In dense shade, seedlings grow spindly and may be only 10 to 12 inches high when 10 years old. The spindly stems often topple over, remain prone for a distance of a foot or more, and then turn upward again. With removal of the overstory, the spindly stems sunscald back to the root collar and resprout, usually with a single stem. Annual growth rates for seedlings are probably slow to moderate for the first few years and better in full sunlight than under partial shade.

Damage to young seedlings by late spring frosts normally is minimal. When damage does occur, the seedlings may sprout from below ground.

Vegetative Development

Black oak sprouts profusely after cutting or fire. Most sprouts develop from latent buds which lie under the bark at, or slightly above, the root collar. But a tree must be damaged extensively before sprouts from the root collar appear. Oak boles often "feather" profusely after defoliation or severe breakage without a single sprout from below ground. Removal of bark from up to three-fourths of the basal circumference of a tree often induces sprouting on the bole, but not beneath the groundline.

Sprouts may also appear from the top of the stump (stool sprouts) or occasionally from lateral roots near the soil surface. Stool sprouts are undesirable for two reasons: they are weakly attached to the parent stump, and they are prone to heart rot at an early age (Edwards 1957). Fortunately, stool sprouts are scarce. When present they almost always are growing on an abnormally high stump (higher than 18 inches), a very large stump (old tree), or on stumps so surrounded by logging debris that only the cut surface is exposed.

The size and vigor of the parent tree determine the number of sprouts and their height and crown spread. In general, stumps from larger trees produce both a larger number of sprouts and more vigorous ones *(table 3).* Only very old, moribund trees fail to produce any sprouts after cutting.

In nearly all sizes of trees, low stumps produce many more sprouts than high stumps. High-stumping older, larger trees result in undesirable stool sprouts, and often no sprouts from below ground.

Sprouts grow vigorously *(table 4).* Although deer browse the sprouts to some degree each year throughout most of the range of black oak, the rapid early growth of sprouts can put them beyond the reach of deer in two growing seasons. Occasionally browsing is fatal. In Mendocino County, for example, a deer population of 1 per 6 acres practically eliminated oak over large areas of the Coast Range.[8]

Sunscald and breakage also damage young sprouts. Normally, only the outermost sprout stems are affected by sunscald. Breakage occurs because of the surprisingly weak connection of the sprouts to the root collar. The slightest side pressure often is enough to break off a sprout. For this reason, thinning of first-year sprouts is impractical.

Because of rapid height growth, young sprouts outdistance other vegetation, including coniferous associates, allowing black oak to be dominant for many years. After the living crown has moved

[8]Personal correspondence with William M. Longhurst, Zoologist, Hopland Field Station, Univ. Calif. March 8, 1966.

Table 3,–*Sprout development in California black oak relative to size and vigor of parent stump, Yuba County, California, 19681*

Stump		4-year-old sprouts		
Diameter class (inches)	Diameter growth of last 10 rings	Average number of sprouts per clump	Mean height of 3 tallest sprouts per clump	Mean crown diameter of sprout clumps
	Inches		*Feet*	*Feet*
< - 8.0	0.44	17	7.1	3.5
8.1 - 12.0	.73	28	7.8	4.6
12.1 - 16.0	.64	42	7.8	5.0
16.1 - 20.0	1.70	43	8.4	4.9

[1] Basis: 29 (52- to 55-year-old) parent stumps; high site, overstory completely removed.

Table 4. –*Sprout development of California black oak following cutting, Yuba County California, 19681*

Time after cutting (years)	Sprouts per clump	Mean height of three tallest sprouts per clump	Crown diameter of sprout clump
	Number	*Feet*	*Feet*
1	– –	2.2	1.9
2	33	4.9	3.9
3	32	7.1	4.0
4	31	7.9	4.7

[1] High site, overstory completely removed, no browsing or injury.

considerably up the bole, black oak then begins its role as a nurse tree, allowing conifers to progress toward equal or dominant positions in the stand. The vigorous, abundant sprouting of black oak after logging or fire helps reduce soil erosion and protects valuable watersheds as well.

Propagation by layering, rooting of cuttings, or grafting has not been reported. But the wartime shortage of cork in the 1940's stimulated the grafting of cork oak *(Quercus suber* L.*)* onto black oak stocks. In a greenhouse trial, 70 percent of the grafts were successful (Mirov and Cumming 1945).

Sapling Stage to Maturity

Rooting Habits

Various investigators have described the rooting system of black oak as having no taproot but large spreading roots,[9] as deep and long lived (Van Dersal 1938), and with a strong taproot (Jepson 1910). Differences in age and soil probably account for these conflicting reports. Trees which start with a taproot system may develop a spreading root system later, particularly in heavy soils. An early observer reported black oak to have "strong laterals, more or less deep, depending on depth to ground water level."[10] A recent study, in Placer County, California, using radioactive water, suggested that black oak roots draw water from an 80-foot depth in fractured and jointed metamorphic rock (Lewis and Burgy 1964).

Observations of road cuts indicate that soil depth is important to rooting habit. In shallow soils, one to several vertical roots usually penetrate to rock, then become lateral and spread out to great lengths directly on top of it. At fissures, "sinker" roots penetrate the rock itself. Where the shrub form of black oak grows, a great profusion of roots become established at the soil-rock interface, and root grafting is common. Roots from one clone often overlap those from another and interclonal root grafting occurs. In such situations, the soil is fully– perhaps too fully–occupied by the black oak root systems. In deeper soils, one to several roots will grow downward almost vertically. Thus on the better soils black oak trees can have a single taproot, but a root system consisting of several deep-growing vertical roots is more likely. hi any case, black oak is notably windfirm.

[9]Lyons, George W. File Report, Silvical Leaflet; Black Oak. U.S. Forest Serv. 7 p. Typewritten, January 13, 1912.

[10]Berry, Jason B. File Report, Silvical Leaflet; California Black Oak. U.S. Forest Serv., Inyo Nat. Forest. 5 p. Typewritten, Aug. 10, 1911.

Reaction to Competition

Black oak is regarded as intolerant throughout most of its life (Edwards 1957), but its reaction to shade varies with age. It is moderately tolerant in early life, growing well in full sunlight but persisting in dense shade (Roy 1962). As a sapling and small pole, it is less tolerant and often becomes long and skinny in reaching for a position in the canopy where it can receive overhead light. Should it be overtopped, the tree either dies outright or dies back for 1/3 to 3/4 the total bole length, and the living remainder produces a few short epicormic branches. These branches may keep the tree alive for some time, but continued overtopping results in death.

The need for top light increases as the tree ages. In fact, the species is noticeably phototropic. On south-facing aspects, trees grow nearly perpendicular to the slope–straight at the sun. In dense stands, black oak often fills a "hole" in the canopy even though it has to lean 15- to 20- degrees to do so. In both cases, the "leaning" stems are perfectly straight and without the J-shape normally found in other species under similar conditions.

Most black oak stand tables show that the percentage of large diameter trees increases with age (Biswell et al. 1966). With time, smaller trees become fewer and fewer, and no new ones replace them. This lack of small trees in the understory suggests intolerance.

Growth

Nearly all black oaks that I have seen were of sprout origin, and there is much evidence that most black oak stands originate from sprouts (Edwards 1957). The remainder of this section, therefore, deals with the growth and yield of sprout stands.

Number of sprouts per clump influences growth, form, and, eventually, yield. The number per clump decreases rapidly with age; by the time the trees are pole-size, individual clumps contain 1 to 3, or occasionally 4, stems *(fig. 5).* In general, sprout persistence is greater on the poorer sites, and more stems per clump will be living at a given age than on better sites.

The form of California black oak varies greatly. On the fringe of its range and on marginal sites it assumes the shrub form. In close stands on good sites, it is tall and straight with a clear bole and thin crown. When open grown, it is prone to fork repeatedly, becoming multi-stemmed and broad crowned *(fig. 6).*

In Shasta County, California, all of these forms can often be found on the same slope and exposure: the brush form at the top of the slope, a stunted, gnarled form further down, and tall, straight trees

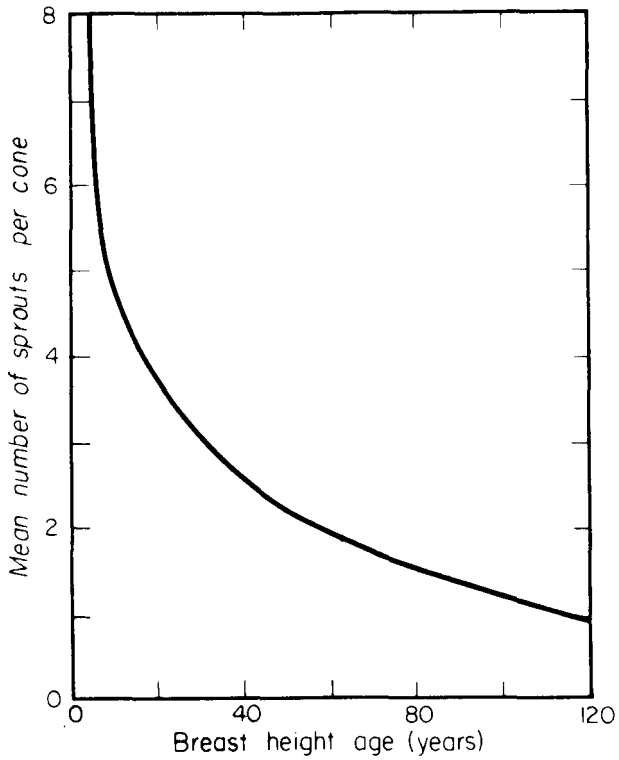

Figure 5. *–Number of sprouts by age of California black oak. Basis: 180 clones, many California sites.*

even lower. Tree form often is especially good on the toe of slopes or gently sloping benches.

Site index often increases rapidly with distance downslope, being best on relatively level benches which have deeper soils and better moisture regimes. Average site index at 50 years is about 50 feet; better-than-average, about 60 feet; and on poor sites only 35 to 40 feet *(fig. 7).* Height and age relationships are consistent on all aspects through age 40. After age 40, ranking by aspect from best to worst is: east, closely followed by north and west, with south lagging far behind *(fig. 8).*

Throughout the first 40 years of an average tree's life, it grows about 1.2 feet per year in height. The growth rate then tapers off; by age 70 the cumulative rate has decreased to 0.9 feet per year. At 100 years, the over-all growth rate will be about 0.75 feet per year.

Diameter growth tends to be slow during the first 25 years of life. Competition for position in the canopy tends to favor height growth at the expense of diameter growth. At 25 years, the average tree is nearly 35 feet tall, about 4 inches in diameter, and is one of three sprouts in the clump. From age 25 to 65, black oak puts on its best increase in diameter *(table 5).* Its growth can reach 3 rings per inch (Edwards 1957). At age 65 the tree is about 11.5 inches d.b.h. and has grown at nearly 0.2 inches per year.

Black oak in an understocked stand averages 13 to 14 inches in diameter at 65 years; in an overstocked stand, between 7 and 9 inches. After age 65, diameter growth slowly declines. By age 90 most trees are mature.

Black oak may live to be nearly 500 years old,[11] but age–diameter relationships beyond 120 years are uncertain. Trees 20 inches in diameter can range between 70 and 175 years. Sudworth (1908) reported that trees 16 to 25 inches d.b.h. were 175 to 275 years old. Trees over 40 inches d.b.h. have been noted as being 200 to 325 years old.

In contrast to these data from natural, unmanaged stands, diameter growth rates of 3 to 6 rings per inch can be expected in plantations. The height-age relationship for natural stands should hold in plantations, at least for close spacings.

[11]Lyon, George W. *Op. cit.*, footnote 9.

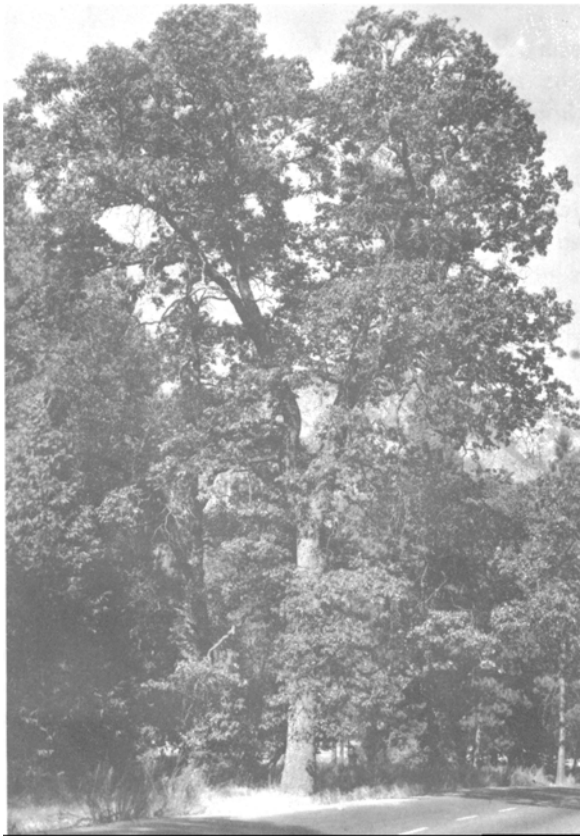

Figure 6.*–An open grown black oak in Yosemite National Park, California.*

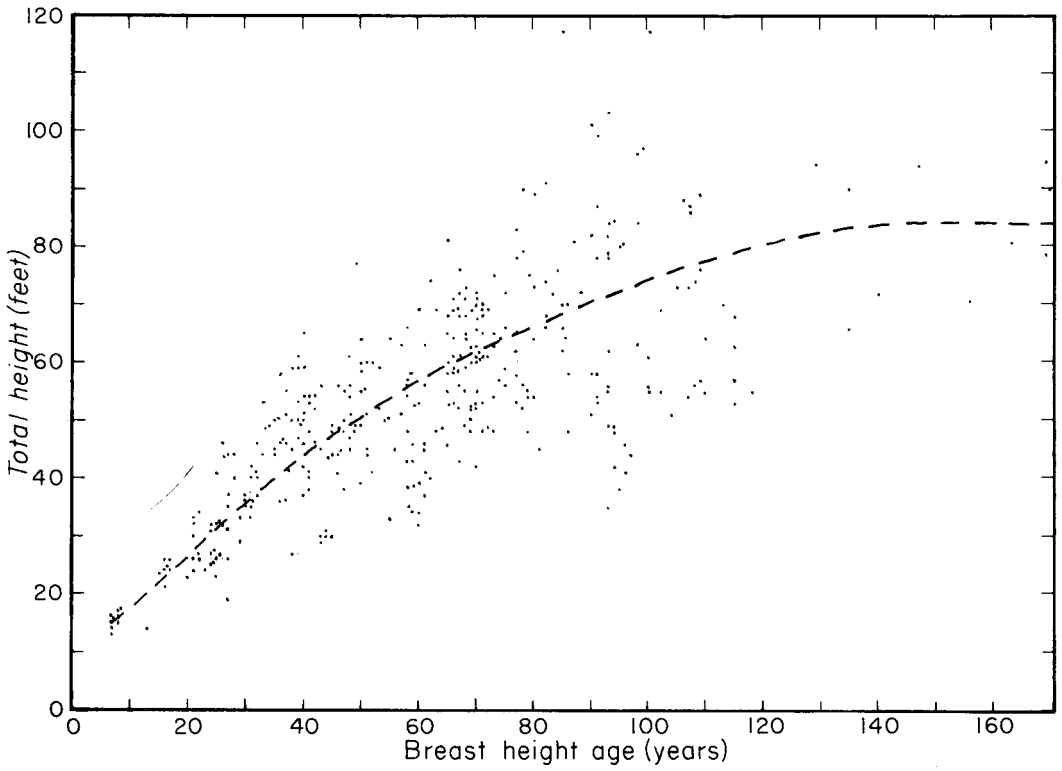

Figure 7.–*Height and age of dominant California black oak in natural stands. Basis: 393 trees, statewide California.*

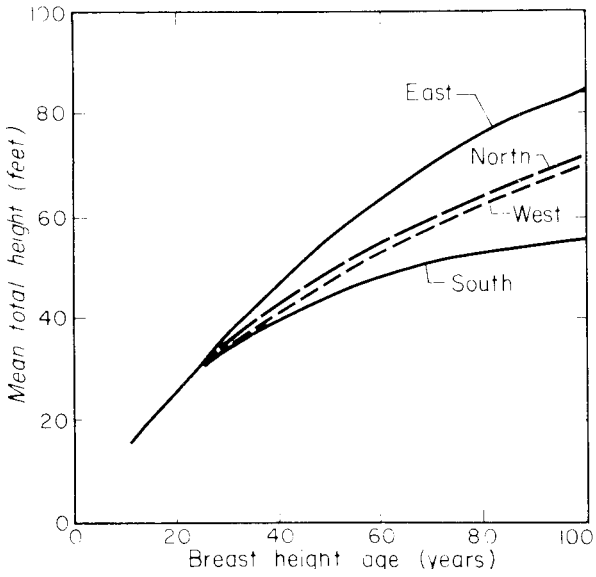

Figure 8.–*Height and age by aspect, California black oak. Basis: 393 trees, statewide California.*

Table 5. –*Diameter growth in natural stands, California black oak, 1968*[1]

Age (years)	D.b.h.	Average cumulative increment per decade	Single bark thickness	Rings per inch
	Inches	*Inches*	*Inches*	*Number*
20	3.4	1.70	0.17	13.1
30	5.4	1.80	.27	12.4
40	7.2	1.80	.37	12.4
50	9.0	1.80	.46	12.4
60	10.8	1.80	.55	12.4
70	12.2	1.74	.62	12.8
80	13.4	1.68	.68	13.2
90	14.6	1.62	.74	13.7
100	15.6	1.56	.80	14.3
110	16.6	1.51	.85	14.8
120	17.5	1.46	.89	15.3

[1]Basis: 405 dominant trees in 45 even-aged stands, many California sites.

Black oak seldom exceeds 5 feet in diameter or 130 feet in height. The largest black oak tree recorded has a circumference of 36 feet and grows in Yosemite National Park (Dixon 1961).

In terms of crown and bole weight, black oak is intermediate between Pacific madrone and tanoak (Sundahl 1966). Crown and bole weights (oven dry basis) for black oak are:

Diameter (inches):	*Age* (years)	*Crown weight* (pounds)	*Bole weight* (pounds)
6	35	60	90
10	55	130	320
14	85	200	800
18	120	300	1,700
24	– –	550	3,450

Black oaks are capable of large and rapid increases in diameter growth when freed from overstory. On a high site in Yuba County, California, several trees of good form were increment-bored 4 years after logging and site preparation. Before logging, the oaks were at least partially overtopped by large conifers. After logging they were dominant. In the first growing season after cutting, the average diameter increment increased 270 percent over the previous year. The greatest increase was 340 percent. Release was relatively uniform within the tested diameter range of 5 to 16 inches. Four years after cutting, the growth rate was 27 percent greater than that for the first year after cutting.

Yield

The sawtimber volume of merchantable California black oak has been estimated at well over 1 billion board feet in California,[12] with nearly 1.3 billion board feet claimed to be in Oregon (Metcalf 1965). Most of it is probably in trees less than 20 inches in diameter. Growing stock volumes are substantial. Because most existing stands resulted from logging and fire shortly after 1900, most of the growing stock is fast approaching the merchantability threshold.

An "average" stand *(fig. 9)* has 440 trees per acre 3.5 inches in diameter and larger at breast height, and would yield slightly over 65 cords per acre.

Principal Enemies

Fire.–Fire is black oak's worst enemy. Crown fires kill trees of all ages and ground fires often are fatal. Only a little heat causes long vertical wounds to the trunk. "A gentle lick of flame up the trunk can cause severe scorching" (Edwards 1957). At first glance the tree may appear unhurt, but the cambium is dead. Bark thickness on mature trees varies from 0.75 to 2 inches, but even the thickest bark does not provide good insulation from fire. Scars resulting from scorching often become a point of entry for fungi. On larger trees, repeated fires enlarge old scars, reducing the bole to a shell or actually toppling the tree.

Disease.–California black oak is especially susceptible to fungi. Heart rot of the bole and larger limbs of living trees, caused mainly by two pathogens, *Polyporus dryophilus* Berk. and *P. sulphureus* (Bull.) Fr. *(fig. 10),* is the principal damage (Meinecke 1914). These rots enter the tree through broken branches or open wounds created by fire or logging. Both fungi can, and often do, reduce the bole and large limbs of older, decadent trees to mere shells (Hedgecock and Long 1914). Younger trees also can have heart rot. Infection probably bridges from rotting stump to young sprouts, particularly to stool sprouts. By the time a natural black oak stand is 85 years old, heart rot has become serious, *(fig. 11)* and some stands fall apart as the disease-weakened limbs and boles are broken by wind and snow.

The hedgehog fungus *(Hydnum erinaceus* Fr.*)* also is found in the heartwood of living trees and *Polyporus adustus* (Wind.) Fr. in the sapwood, though neither are prevalent.

Another serious pathogen, *Armillaria mellea* (Vahl.) Quel. causes decay of the roots and butt of older decadent black oak. Sometimes it so weakens the root system that the tree topples over on a perfectly calm, still day; consequently *A. mellea* is a tree hazard to watch for in high-use recreation areas (Wagener 1963). This pathogen is indigenous in black oak, but younger vigorous trees do not seem to be affected by it.

Three other fungi–*Polyporus versicolor* L. ex Fr., *Stereum hirsutum* (Wild.) Fr., and *Schizophyllum commune* Fr.–are often seen on dead sapwood of living trees or on hardwood slash, but are of minor silvicultural significance.

California black oak is prone to several leaf diseases, chiefly the oak leaf fungus *(Septoria quercicola* Sacc.*)*. Other leaf diseases are the oak anthracnose *(Gnomonia veneta* (Sacc. & Speg.) Kelb.*)* (U.S. Forest Serv. 1958), powdery mildews *(Microsphaeria* and *Sphaerotheca* spp.*),* a leaf blister fungus *(Taphrina coerulescens* (Desm.*)* Tulasne), and a leaf rust *(Cronartium* spp.*).*[13] Black oak usually survives

[12]Personal correspondence with Daniel D. Oswald. U.S. Forest Service. June 23, 1966.

[13]Personal correspondence with Willis W. Wagener. U.S. Forest Service. April 11, 1966.

Figure 9.–*Interior view of a natural 70-year-old California black oak stand of average stocking, density, and growth rate. Trees average 12 inches in diameter and 60 feet in height.*

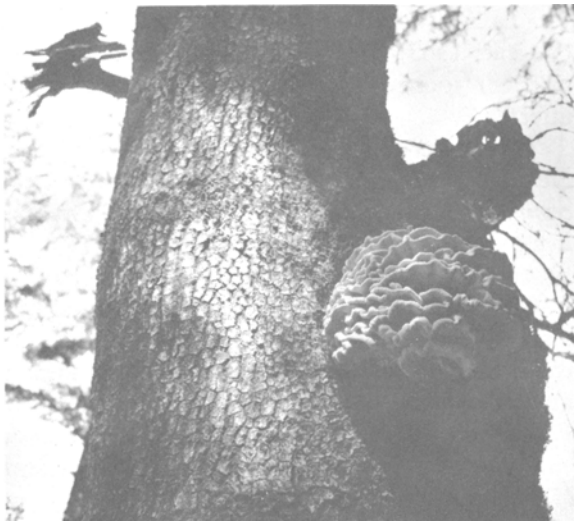

Figure 10.–*Fruiting bodies of the sulfur fungus (Polyporus sulphureus) on a living California black oak, Yuba County, California, 1967.*

repeated defoliations, but growth loss and a lowering of vigor can be expected (U.S. Forest Serv. 1958).

True mistletoe (probably *Phoradendron flavescens* (Pursh) Nutt. var. *villosum* (Nutt.) Engelm. in Rothr.) often is seen on open-growing black oak *(fig. 12)* or in the uppermost crowns of trees growing close together. Damage consists of an undetermined loss of growth increment but the over-all effect probably is minor.

Climatic fluctuations also cause injury. For example, black oak leaves were extensively damaged by high temperatures immediately following cool, rainy weather. This damage covered an extensive area of northern California in 1941 (Mielke and Kimmey 1942). In February 1968, unusually wet, heavy snows caused severe crown and bole breakage in black oak at elevations of 2,300 to 2,800 feet in the northern Sierra Nevada.

Large swellings often are found on the bole and branches of black oak *(fig. 13)*, but little is known of their origin or morphology. Wounding or some unusual growth stimulus are two possible causes of this phenomenon. Surprisingly, no undue tendency

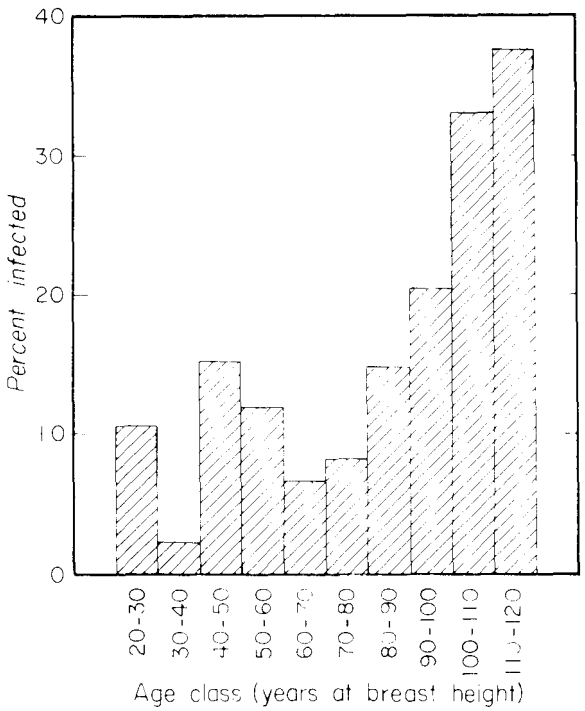

Figure 11. – *Incidence of heart rot at breast height in 375 sound-appearing dominant black oaks, many California sites. (Percentages shown are minimal because obviously decayed trees were not included. Only incipient rot was putrid in the sample trees. Growth rings were clearly visible in all cases.)*

for breakage is associated with these swellings either on living or standing-dead trees.

Animals.–Black oak foliage is browsed during all seasons, but especially in spring when new growth is tender (Robinson 1937) and in winter when twigs are eaten (Leopold et al. 1951). Deer eat reproduction, sprouts, and low foliage. Even in midsummer, newly germinated seedlings with acorns attached are often consumed by deer (Dixon 1934). Cattle also browse black oak (U.S. Forest Serv. 1937), but their numbers are declining.

Insects.–Many insects derive their sustenance from black oak. The damage is usually secondary, reducing growth but seldom killing the tree. Among sucking insects, the pit scales *(Asterolecanium minus* Lindinger and *A. quercicola* Bouche*)* have the greatest potential for damage (Brown and Eads 1965; Pritchard and Beer 1950). But the most destructive insect probably is the carpenter worm *(Prionoxystus robiniae* Peck*)*. Larvae of this insect mine the sapwood and heartwood of trunk and limbs and cause injuries that appear later as defects in lumber (Keen 1952).

Other insects are capable of heavy damage, especially when infestations become epidemic. The oak twig girdler *(Agrilis angelicas* lion)) is the most important insect affecting oak in southern California during drought years (Brown and Eads 1965). Sometimes oak bark beetles *(Pesudopityophthorus* spp.*)* attack and kill weakened trees, but normally, damage is confined to injured, felled, or recently killed trees (Keen 1952).

Defoliators also can damage black oaks. The California oakworm *(Phryganidia californica* Packard*)* is noted for defoliating trees in northern California. In 1968, the fruit-tree leaf roller *(Archips argyrospilus* Walker*)* caused apparently heavy damage over a wide area in the Sacramento River drainage in northern California. Many trees were left virtually leafless, but by mid-July evidence of the attack could scarcely be found.

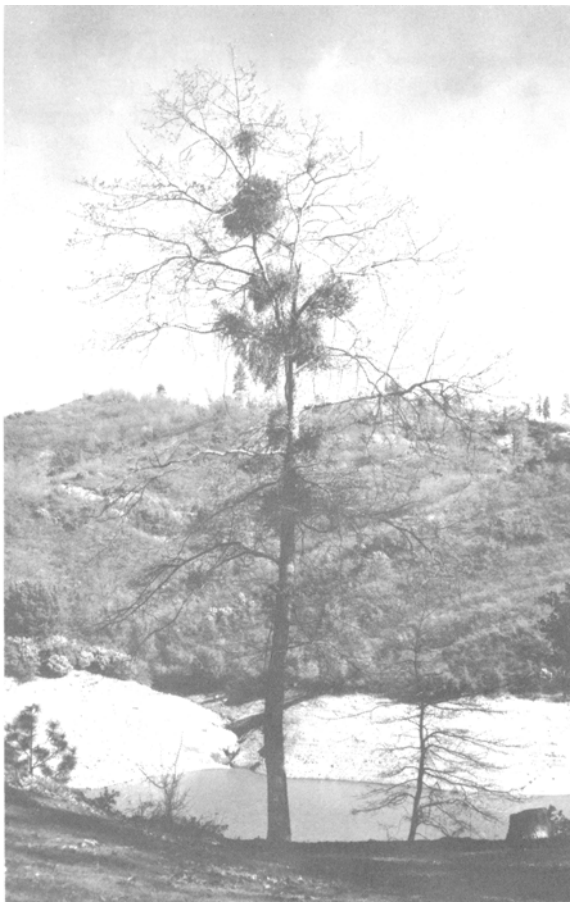

Figure 12.–*Tufts of true mistletoe. This sun-loving, virtually enemy free pest, infests a California black oak overlooking an arm of Shasta Lake.*

Figure 13.–*A large swelling (probably a noninfectious gall) on an otherwise healthy black oak, Yuba County, California.*

RACES AND HYBRIDS

Two natural hybrids are recognized: *Quercus* x *ganderi* C. B. Wolf *(Q. agrifolia* x *Q. kelloggii)* and *Quercus* x *morehus* Kellogg *(Q. kelloggii* x *Q. wislizenii)* (Munz 1959). Another hybrid, *Quercus* x *chasei* McMinn, Babcock, and Righter *(Q. agrifolia* x *Q. kelloggii)* has been described in Monterey and Santa Clara Counties (Munz 1959).

Of the hybrids, *Q. morehus* is by far the most widespread, ranging throughout California and even found, though rarely, in south central Oregon (Little 1953). The tree is distinguished readily in the winter by its rather sparse evergreen foliage in contrast to the completely deciduous black oak. New leaves in spring form a dense mass of shiny green foliage on the hybrid.

No varieties of black oak are reported, but one form–*cibata* Jepson–is described as a low or semi-prostrate shrub (McMinn 1951). It grows primarily in Shasta County and along the easternmost edge of Trinity County, California. It may occur in Tehama and Tulare Counties.[14] This form is generally found at elevations from 3,000 to 6,500 feet. Between 2,000 and 3,000 feet, it grows in mixture with the shrubby Brewer oak, gradually grading to pure Brewer oak below 2,000 feet. The soils on which the shrub form grows are almost always exposed, shallow, droughty, and often unstable, being chiefly old slides, talus slopes, and colluvial material. Slopes are often steep (70 to 80 percent). The roots fully occupy all available soil, and the great profusion of stems normally forms extremely dense stands. Increment borings from these shrubs have shown the over-all growth rate to be slow and 5 times as rapid the first 2 to 6 years as in the remaining 31 to 46 years. The shrubs average 4 to 8 feet in height and about 3 inches in diameter 1 foot above the ground.

Although described as a true shrub form, there is a question about its status as a botanical form. No criteria are known for distinguishing between it and the scrawny, scrub black oak tree.

SPECIAL FEATURES

The forks of open grown black oak were put to good use in the 1870-1880's in Mendocino County, California. Those of specific dimensions were used as "naturally assembled" ship keels and ribs.

Black oak leaves were said to be highest of the California oaks in food value for fattening cattle (Mackie 1903). And the acorns, high in edible oils, are a potential source of thousands of tons of human food (Wolf 1945). California Indians shelled and ground acorns into a flour or meal, leached it to

[14]Personal correspondence with James I. Mallory. U.S. Forest Service. September 14,1968.

remove the bitter taste, and made soup, bread, and a form of pudding. Sometimes the meal was leached through cedar twigs for flavor. Occasionally it was allowed to accumulate mold. This mold was scraped off, kept in a damp place, and used to heal boils and sores (Sweet 1962).

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