Arbutus menziesii Pursh Pacific Madrone

Ericaceae Heath family

Philip M. McDonald and John C. Tappeiner, II

Pacific madrone *(Arbutus menziesii)* is one of the most widely distributed tree species native to the Pacific coast. Named for its discoverer, Archibald Menzies, a 19th century Scottish physician and naturalist, the species is called arbutus in Canada, and madrone, madroña, or madroño in the United States. The latter name is ascribed to Father Juan Crespi, chronicler of the 1769 Portola expedition.

Although examples of fine furniture and attractive veneer from madrone are common, utilization is far below potential and management is almost nil.

Habitat

Native Range

Pacific madrone (fig. 1) ranges from the east coast of Vancouver Island and the immediate mainland of British Columbia (lat. 50° N.) southward to near Palomar Mountain, San Diego County, CA (lat. 33° N.), a north–south distance of about 1880 km (1,170 mi). The species is common along the western slopes of the Coast Ranges in Washington, Oregon, and California, southward to San Luis Obispo County, CA. It is abundant throughout much of the Klamath Mountains of Oregon and California, and from Yuba County, CA, southward through Calaveras County in the Sierra Nevada.

Climate

In western British Columbia, Washington, and Oregon, the climate best suited to Pacific madrone is characterized by mild temperatures with prolonged cloudy periods, narrow diurnal fluctuation, and limited extremes. Average January temperatures range from 2° to 8° C (36° to 46° F) and average July temperatures from 10° to 20° C (50° to 68° F). Winters generally are wet and mild, and summers cool and relatively dry with long frost-free seasons. Average annual precipitation is usually abundant, ranging from 790 to more than 3000 mm (31 to 118 in), 75 to 85 percent of which is received between October 1 and March 1, mostly as rain.

In the interior valleys and hills of the Klamath Mountains and lower west slopes of the southern Cascades, average January temperatures range from 2° to 5° C (36° to 41° F) and average July temperatures from 17° to 25° C (62° to 77° F). Average annual precipitation varies between 760 and 890 mm (30 and 35 in). The average January temperature in the heart of the Pacific madrone range in the Sierra Nevada is 5° C (41° F), and the average July temperature is 22° C (72° F). Average annual precipitation is 1730 mm (68 in).

In the Coast Ranges of California, temperatures where Pacific madrone grows average 2° to 5° C (36° to 41° F) in January and 15° to 20° C (59° to 68° F) in July. Average precipitation varies between 1140 and 1650 mm (45 and 65 in) yearly in the north to 640 to 760 mm (25 to 30 in) in the south. Some fog usually is present throughout this region.

Within the total range of this species, temperature extremes are from –21° to 46° C (–6° to 115° F) and annual rainfall from 460 to 4220 mm (18 to 166 in) *(30)*.

Soils and Topography

Soils on which Pacific madrone is found are derived from glacial deposits of porous sands and gravels and hard till in the north, through volcanic tuffs and metamorphosed sedimentary and volcanic rocks in the Klamath Mountains, to volcanic and sedimentary rocks in the California Coast Ranges. Granitic and metavolcanic rocks support the species in the Sierra Nevada. Most Pacific madrones are found on Alfisols, followed to a much lesser extent by Ultisols and Inceptisols. The soils show a wide range of textures, varying from fine-textured loams and clay loams to coarse-textured sandy loams and gravelly clay loams. Rocky soils are common, and many are less than 1 m (3.3 ft) deep. A common soil characteristic is good internal drainage and low moisture retention in summer.

Many extensive soil series have been identified as supporting Pacific madrone (table 1). In California, madrone has been found on more than 30 soil series.

Pacific madrone grows on a variety of terrain from nearly level flats and gently sloping benches to steep mountainsides. Often it is found in canyons near creeks and rivers. In general, madrone grows on all aspects but is found most often on those facing south and west. In southern California, however, madrone

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Reprinted from:
Burns, Russell M.; Honkala, Barbara H., tech. coords. 1990. **Silvics of North America. Volume 2, Hardwoods.** Agriculture Handbook 654. Washington, DC: U.S. Department of Agriculture; 877 p.

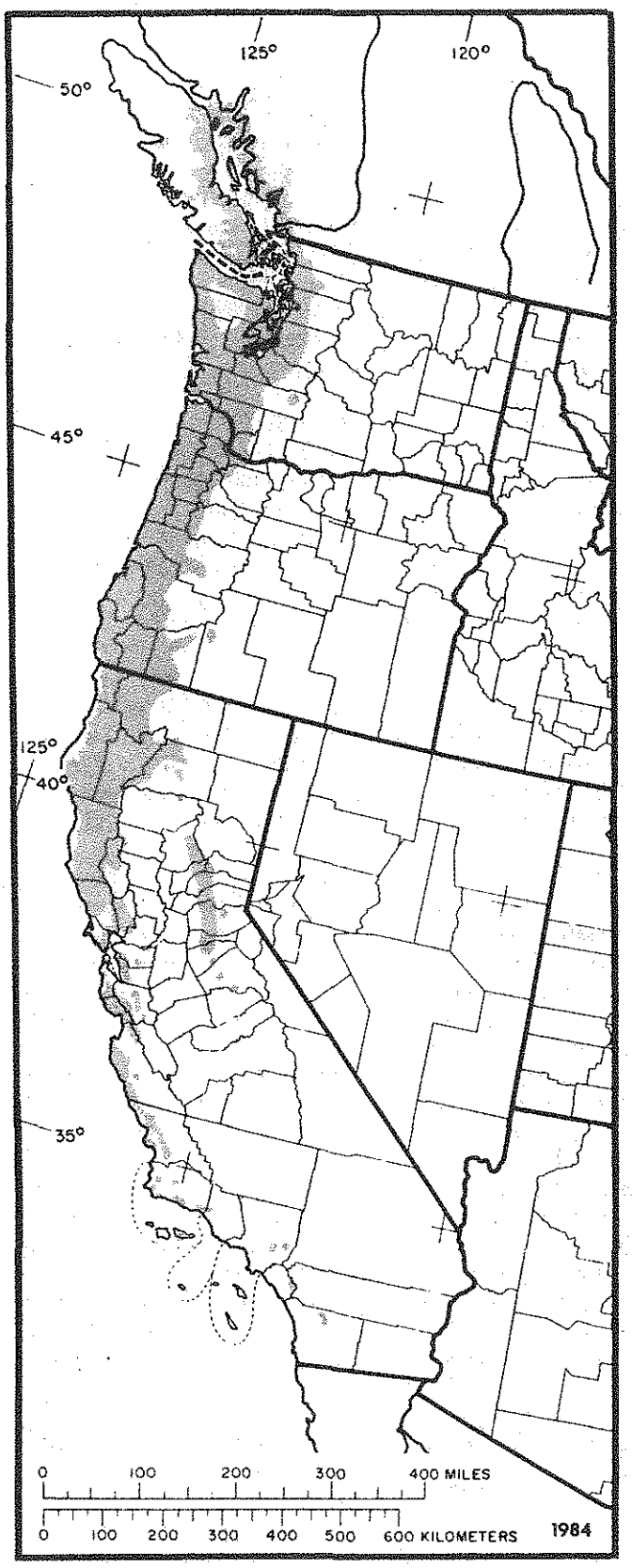

Figure 1—*The native range of Pacific madrone.*

Table 1—Principal mountain ranges and soil series where Pacific madrone is found

Mountain range	Soil series
British Columbia, Washington, and Oregon Coast	Astoria, Everett, Hoodsport, Melbourne, Olympic, Spanaway
Klamath and southern Cascade	Boomer, Hugo, Josephine, Neuns, Pollard, Ruch, Sheetiron, Siskiyou
California	
North Coast	Hely, Hoda, Hugo, Larabee, Madonna, Orick
Central Coast	Felton, Junipero, Sheridan, Sur
Sierra Nevada	Aiken, Cohasset, Holland, Mariposa, Marpa, McCarthy, Musick, Sites
Transverse and	Crouch, Shaver

often is abundant in cool canyons—about the only place in this area where the species is found.

In the northern part of its range, Pacific madrone grows at or near sea level, extends up rivers, and inhabits mountain slopes to the 915 m (3,000 ft) elevation. The species ranges from 455 to 915 m (1,500 to 3,000 ft) and, occasionally, to 1435 m (4,700 ft) in the Klamath Mountains. In the California Coast Ranges, Pacific madrone grows well from 245 to 1300 m (800 to 4,260 ft). It is found from about 365 to 1065 m (1,200 to 3,490 ft) in the Sierra Nevada but is more common between 700 and 975 m (2,300 and 3,200 ft). At the southern end of its range in the Transverse and Peninsular Mountains, madrone grows from 610 to 1065 m (2,000 to 3,490 ft).

Associated Forest Cover

Pacific madrone is a major component of the forest cover type Douglas-fir–Tanoak–Pacific Madrone (Society of American Foresters Type 234) *(4)*, and an associated species in a wide variety of others including Pacific Douglas-Fir (Type 229), Douglas-Fir–Western Hemlock (Type 230), Port Orford-Cedar (Type 231), Redwood (Type 232), Pacific Ponderosa Pine (Type 245), Pacific Ponderosa Pine–Douglas-Fir (Type 244), Sierra Nevada Mixed Conifer (Type 243), Knobcone Pine (Type 248), California Live Oak (Type 255), Canyon Live Oak (Type 249), Oregon White Oak (Type 233), and California Black Oak (Type 246).

The Douglas-Fir–Tanoak–Pacific Madrone forest cover type is characterized by Douglas-fir as the

overstory species and tanoak and madrone as secondary canopy. Regardless of stand structure and species mix in earlier stages of succession, the relative position of Pacific madrone at maturity is constant. The proportion of tanoak and madrone in the secondary canopy, however, varies widely. Higher proportions of madrone usually are found in drier locales, particularly on south aspects *(14)*.

Fossilized leaves of a species similar to modern-day Pacific madrone have been found in northwestern Nevada, the Blue Mountains of Oregon, and Tuolumne County, CA. This species and associated flora date to the Miocene epoch of 12 to 26 million years ago. In terms of species composition, the flora resembles the oak-madrone forest of the central coastal mountains in California today *(2)*.

In western British Columbia, Washington, and Oregon, Pacific madrone intermingles extensively with Douglas-fir *(Pseudotsuga menziesii)*, western hemlock *(Tsuga heterophylla)*, Oregon white oak *(Quercus garryana)*, red alder *(Alnus rubra)*, and bigleaf maple *(Acer macrophyllum)*. Common associates in the Klamath Mountains and southern Cascades are Douglas-fir, ponderosa pine *(Pinus ponderosa* var. *ponderosa)*, California black oak *(Quercus kelloggii)*, and Oregon white oak, with sugar pine *(P. lambertiana)*, tanoak *(Lithocarpus densiflorus)*, California white fir *(Abies concolor* var. *lowiana)*, Port-Orford-cedar *(Chamaecyparis lawsoniana)*, canyon live oak *(Q. chrysolepis)*, knobcone pine *(P. attenuata)*, and bigleaf maple locally present.

In the northern and central California Coast Ranges, Douglas-fir, tanoak, redwood *(Sequoia sempervirens)*, coast live oak *(Quercus agrifolia)*, canyon live oak, and California-laurel *(Umbellularia californica)* mix with Pacific madrone. Common associates in the southern California mountains are Coulter pine *(Pinus coulteri)*, interior live oak *(Quercus wislizenii)*, California black oak, canyon live oak, coast live oak, and bigcone Douglas-fir *(Pseudotsuga macrocarpa)*.

Smaller trees *(11)* that are common throughout the range of Pacific madrone from Vancouver Island or immediate mainland of British Columbia southward through Washington, Oregon, and northern California are vine maple *(Acer circinatum)*, Rocky Mountain maple *(A. glabrum)*, black hawthorn *(Crataegus douglasii)*, Pacific bayberry *(Myrica californica)*, Sitka alder *(Alnus sinuata)*, bitter cherry *(Prunus emarginata)*, western serviceberry *(Amelanchier alnifolia)*, Pacific rhododendron *(Rhododendron macrophyllum)*, Pacific dogwood *(Cornus nuttallii)*, western dogwood *(C. occidentalis)*, red-osier dogwood *(C. stolonifera)*, Pacific willow *(Salix lasiandra)*, Scouler willow *(S. scoulerana)*, Pacific red elder *(Sambucus callicarpa)*, blue elder *(S. cerulea)*, and California hazel *(Corylus cornuta* var. *californica)*. Others, too numerous to mention, have more limited distributions within madrone's natural range.

Pacific madrone grows individually or in groves. It rarely forms large stands, and pure stands of any size are seldom seen. Madrone often is associated with two or more hardwood species in groups interspersed among conifers. The groups can be large or small, however, depending on the size of logged units or burns. In California's central Coast Ranges, mixed hardwood stands are extensive over a large portion of the forested landscape *(24)*.

Occasionally, Pacific madrone forms a woodland with other conifer and hardwood associates. In the valleys of the Umpqua and Rogue Rivers of southwestern Oregon, California black oak, Oregon white oak, and Pacific madrone form a stunted open cover on the low rounded hills. Scattered Douglas-firs occasionally are present *(6,26)*.

Several investigators have placed Pacific madrone and associated species along measured decreasing moisture gradients in the field. In coastal northern California, madrone ranked fourth of 10 species in ability to extract moisture from the soil. Another investigator placed madrone first of 10 species for this ability in the central western Cascade Range of Oregon. Plainly, madrone is found in drier environments.

Madrone also was ranked by other environmental variables. Relative to 20 northwestern tree associates, madrone was listed in the group of four species judged best adapted to warm temperatures. Further, madrone was in a group that placed fifth to seventh of 23 species ranked from high to low in tolerance of drought *(15)*. At least one author described the species as being resistant to ice damage because water quickly ran off the waxy leaves and did not freeze on them. Another stated that heavy wet snowfalls place brittle-limbed madrone at a disadvantage. The species was judged the least frost-resistant tree native to British Columbia. Occasionally, madrones in Washington and Oregon are damaged by severe frosts.

Shrub associates are fairly numerous, as could be expected for a species with a large natural range; they are greenleaf manzanita *(Arctostaphylos patula)*, whiteleaf manzanita *(A. viscida)*, bearberry *(A. uva-ursi)*, Oregongrape *(Berberis nervosa)*, buckbrush *(Ceanothus cuneatus)*, deerbrush *(C. integerrimus)*, squawcarpet *(C. prostratus)*, snowbrush *(C. velutinus)*, salal *(Gaultheria shallon)*, oceanspray *(Holodiscus discolor)*, pachistima *(Pachistima myrsinites)*, huckleberry oak *(Quercus vaccinifolia)*, western poison-oak *(Toxicodendron diversilobum)*, Sierra gooseberry *(Ribes roezlii)*, wood rose *(Rosa*

gymnocarpa), thimbleberry *(Rubus parviflorus),* salmonberry *(R. spectabilis),* trailing blackberry *(R. ursinus),* spreading snowberry *(Symphoricarpos acutus),* creeping snowberry *(S. mollis),* and evergreen huckleberry *(Vaccinium ovatum).* Only occasionally, as in the California north Coast Range forest, is the shrub layer dense *(24).* Both the shrub and herb communities tend to be sparse under mature stands.

Life History

Reproduction and Early Growth

Flowering and Fruiting—Flowers of Pacific madrone are small, whitish, perfect, and urn-shaped. They are borne in dense racemes of terminal panicles. Madrone flowers in mid-March at lower elevations with warm temperatures, and in mid-May at higher elevations. Flowering usually ends in June.

The fruit, a berry 8 to 12 mm (0.3 to 0.5 in) in diameter, has a dry mealy flesh and generally is five-celled. Fruits mature from mid-September to mid-November. Ripe berries are bright red or reddish-orange. Yellowish-orange or even yellowish-green berries, however, also may be present in the same cluster at the same time. Number of seeds per berry ranges from 2 to 37, averaging about 20.

Seed Production and Dissemination—Pacific madrone is described as providing abundant fruit almost every year *(23).* On a good site in the Sierra Nevada from 1958 through 1977, however, bumper seed crops were produced in 2 years, light crops in 8 years, and little or no seed in 10 years. Berry production during a light seed year for three representative trees, 23, 36, and 41 cm (9, 14, and 16 in) in breast-height diameter, ranged from 13,320 to more than 107,000 per tree and seemed to relate best to the amount of living crown *(12).*

Pacific madrone first produces berries at 3 to 5 years *(23).* In the northern Sierra Nevada, the dominant sprout in a 4-year-old clump produced 62 berries. Trees 60 to 160 years old produce heavy seed crops if healthy, but the age at which berries no longer are produced is unknown.

Freshly picked red and yellow berries from the northern Sierra Nevada were weighed and numbers of berries and seeds counted. Berries numbered 1,390 to 2,490/kg (630 to 1,130/lb), and seeds 434,310 to 705,470/kg (197,000 to 320,000/lb) *(23).*

Pacific madrone berries are disseminated by gravity and consumers. Because the berries are heavy, they fall directly beneath tree crowns, generally into a thick layer of tough leathery leaves. They do not bounce or roll far. Animals, however, often carry the berries farther away from tree crowns. Madrone berries are prized as food by birds, rodents, deer, and wood rats. At least five species of birds, especially the mourning dove and band-tailed pigeon, devour berries. More than 17 percent of this pigeon's November diet and 11 percent of its December diet were madrone berries. Stomach analysis of one pigeon indicated that it had eaten 111 berries—so many that it could not fly *(25).* In the northern Sierra Nevada, snap traps baited with a single red berry caught more white-footed deer mice than those with peanut butter and wheatflakes *(12).*

Seedling Development—Germination of Pacific madrone seed is epigeal and has been described as both moderately high and fair. A test in California gave 55 percent germination after 3 months stratification at 2° to 5° C (36° to 41° F). Two other investigators recommended 3 months of stratification. A laboratory study on seed from the Sierra Nevada, however, indicated that a shorter stratification period might be adequate: seed stratified at 2° C (36° F) for 30 to 40 days with no other treatment produced 94 percent germination. Immersing seed in concentrated sulfuric acid for 1 minute before stratification also gave good results, but applying heat for 1 hour at 95° C (203° F) and then stratifying seriously impaired germination *(12).*

To evaluate seedling establishment under more natural conditions, germinating seeds in a laboratory were buried in unsterilized sandy loam and no fungicide was applied. Damping-off fungi killed most of the seedlings, and after 11 months, only 6 percent survived. Trials of seedlings from madrone berries in the laboratory and field also indicated high losses from damping-off fungi.

A comprehensive study in the Santa Cruz Mountains of central coastal California *(20)* showed that fungus attack directly killed 28 percent of madrone seedlings. An additional 22.7 percent mortality, however, was attributed to mild drought preceded by crippling from root decay fungi. Most of the remaining seedling mortality was caused by invertebrates, chiefly slugs. These pests were particularly lethal to seedlings in deep shade. None of the 276 seedlings on shady plots survived.

Losses of seedlings on sunny plots in the semi-open forest were caused mainly by fungi. Only 2 percent of the seedlings on these plots survived to August 2 of the year in which they germinated. In southwestern Oregon, all Pacific madrone seeds germinated the first year after seeds ripened. However, seedlings began to die immediately after emergence and most had died after 1 year. Cause of death, in

descending order, was lack of soil moisture, litterfall, damping off, and invertebrates. First-year mortality was 90 to 100 percent *(29)*.

In general, Pacific madrone seedlings are not abundant. They usually become established in disturbed areas, along road cuts, on bare mineral soil at the base of uprooted trees, or in semi-open forests. In the northern Sierra Nevada, seedlings are established mainly along partially shaded road cuts or in small shaded openings. Occasionally, they become established beneath woody shrubs or small trees in clearcuttings. In southwestern Oregon, percent survival after 3 years, although low, was higher in clearcuttings than in young and old stands *(29)*. The most favorable seedbed for establishment seems to be bare mineral soil free from all, or nearly all, organic material. The notable lack of madrone seedlings beneath madrone trees could be the result of toxic metabolites being formed as an end product of the interaction among fungi, duff moisture content, and invertebrates. Water-soluble leachates from senescent leaves of madrone have been demonstrated to inhibit germination and lower growth of Douglas-fir seedlings in the laboratory *(3,31)*, a finding not substantiated in the field *(17,31)*.

Early growth of Pacific madrone seedlings is slow. In the Santa Cruz Mountains, shoot and root elongation of 6-month-old seedlings in the sunny environment was 4 cm (2 in) for shoots and 10 cm (4 in) for roots; in the shady environment, 3 cm (1 in) for shoots and 4 cm (2 in) for roots. Two-year-old seedlings in the Sierra Nevada averaged 9 cm (3.5 in) tall.

Death of madrone seedlings from transplanting has been described as distressingly high, but ease of propagation from cuttings as fair.

Vegetative Reproduction—Pacific madrone reproduces mainly by sprouting. Sprouts arise from dormant buds formed at or just above the root collar and tend to be numerous. More than 300 sprouts were counted on a single low 10-inch-diameter Pacific madrone stump in the northern Sierra Nevada.

Low stumps generally produce more sprouts than high stumps. High stumps sometimes support undesirable stool sprouts that form on the edge of the cut surface or, less commonly, on the vertical portion of the stump between the ground and the top. Stool sprouts tend to become infected with heart rot at an early age and are more susceptible to dieback and death than sprouts from the root crown. Stool sprouts that survive seem to grow well, but their longevity is unknown.

Pacific madrone sprouts grow rapidly. On a site of medium quality in the Klamath Mountains, 3-year-old sprout clumps averaged 13 members per clump, 3.1 m (10 ft) in height, and 2.3 m (7.6 ft) in width *(22)*. In the northern Sierra Nevada on a good site, the annual enlargement of sprout clumps was measured in both a clearcut and a shelterwood. After 10 years, sprouts were taller, 6.7 vs 3.0 m (22 vs 10 ft); wider, 3.1 vs 2.1 m (10.1 vs 7.0 ft); contained more sprouts (15 vs 7); and possessed more volume, 52.1 vs 19.8 m^3 (1,840 vs 700 ft^3) *(12)*. In both locations, annual growth of 1.5 m (5 ft) on 2- to 5-year-old sprouts was observed for particularly vigorous members of a clump. Seven years after cutting and burning in southwest Oregon, dense stands of madrone sprout clumps spaced 2.7 by 2.7 m (9 by 9 ft) had a basal area of about 22 m^2/ha (96 ft^2/acre), 84 percent cover, and an above-ground biomass of 25,000 kg/ha (22,500 lb/acre) *(9)*. This rapid early growth, both in height and crown width, allows Pacific madrone to dominate conifer and shrub associates for many years. It also means that understory species of grasses, forbs, and shrubs are quickly excluded from madrone sprout stands following disturbance *(9)*, in spite of a leaf canopy that is more open than that of tanoak and giant chinkapin *(Castanopsis chrysophylla) (16)*.

New information is available for forecasting site occupancy of Pacific madrone for up to 6 years after disturbance. It includes equations that relate width and area of sprout clumps originating from trees greater than 1 inch d.b.h. to size of parent stem and time since cutting *(28)*, and equations that predict potential leaf area and biomass by parent tree diameter class *(7)*.

Sapling and Pole Stages to Maturity

Growth and Yield—Most of the Pacific madrone trees observed originate from sprouts (fig. 2), and their growth and form are influenced thereby. Position of the sprout in the clump, for example, often governs form. Members in the center of the clump grow straighter than those on the edge, which tend to lean outward or be J-shaped. In general, trees in the crowded forest have better form and are less branchy than those in the open.

Madrone usually is a stately tree, tall and straight of bole if on good sites in forested canyons and draws (fig. 3). But the species frequently is low and shrubby with multiple stems, if on poor sites, especially on south-facing benches and ridges.

Growth of madrone has been described as slow, especially in diameter *(27)*. In the northern Sierra Nevada on good sites, madrone trees average 5 to 6 rings per centimeter (12 to 15 rings/in) of diameter *(12)*. Here, stand density of mixed hardwoods, which include California black oak and tanoak, as well as

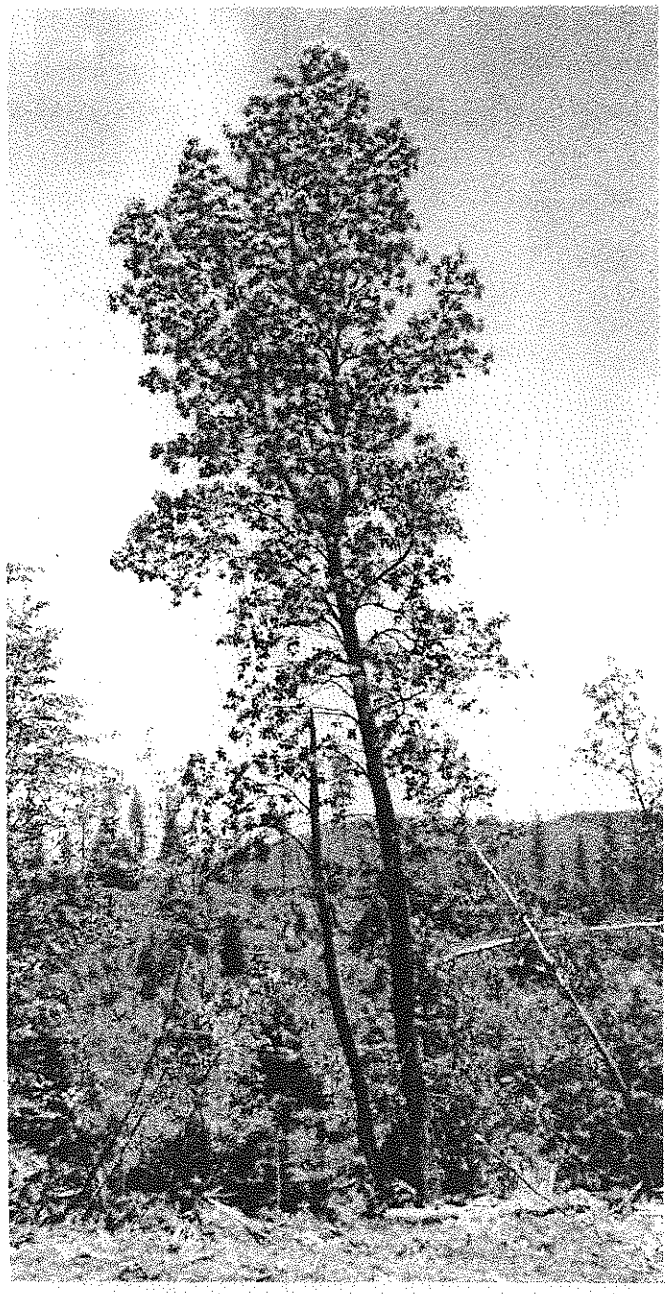

Figure 2—*Two members of a Pacific madrone clump, one of which is dead. In a few years, the other will stand alone. It is 25 cm (9.8 in) in d.b.h. and 14 m (46 ft) tall.*

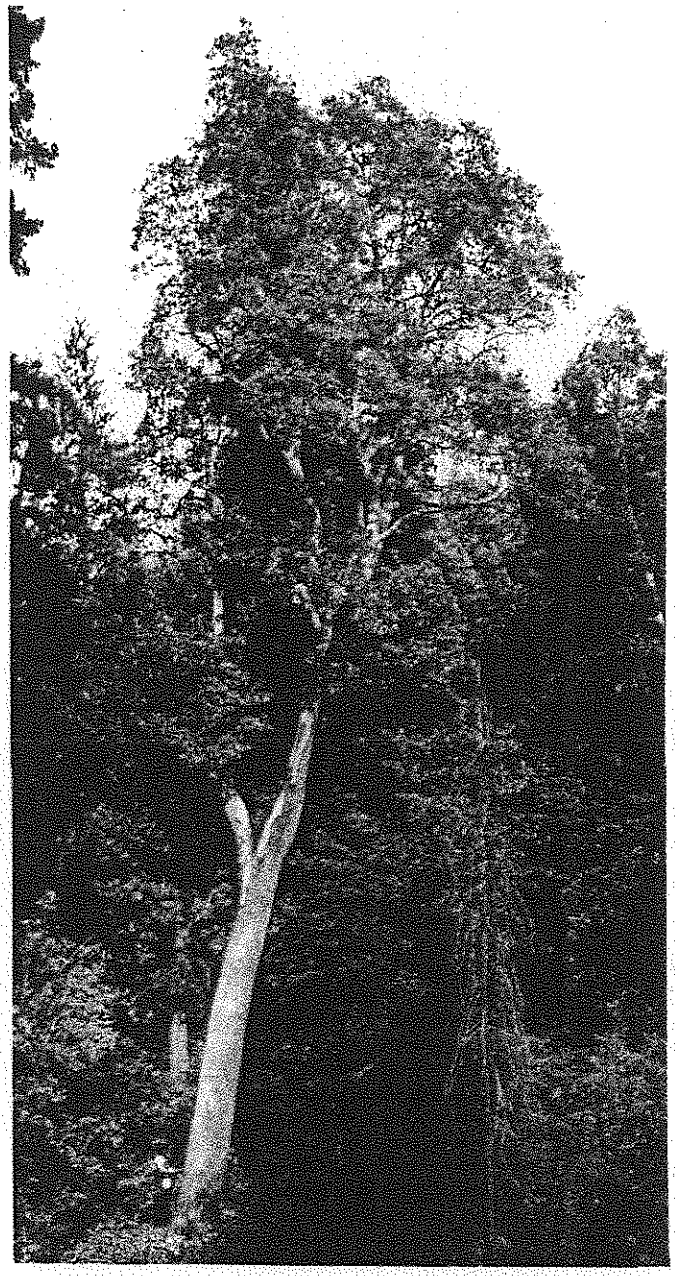

Figure 3—*A Pacific madrone growing near the bottom of a steep canyon on the Plumas National Forest, CA. The tree, 32 m (105 ft) tall and 97 cm (38 in) in d.b.h., dwarfs the man beside it.*

Pacific madrone, averages 1,630 stems per hectare (659 per acre), more than 5 cm (2 in) in d.b.h., and 45.5 m2/ha (198 ft2/acre) of basal area. As madrone generally grows in dense stands, this growth rate is probably typical of trees 55 to 65 years of age on similar sites.

The relationship of d.b.h. to total tree height for madrone in the northern Sierra Nevada is curvilinear. Although fitted freehand, the curve indicates that trees 20 cm (8 in) in diameter are about 15 m (49 ft) tall; those 40 cm (16 in), 23 m (75 ft) tall; and trees 60 cm (24 in) in diameter are almost 28 m (92 ft) in height (fig. 4).

When dense stands in the Sierra Nevada were given a crown thinning that reduced basal area by

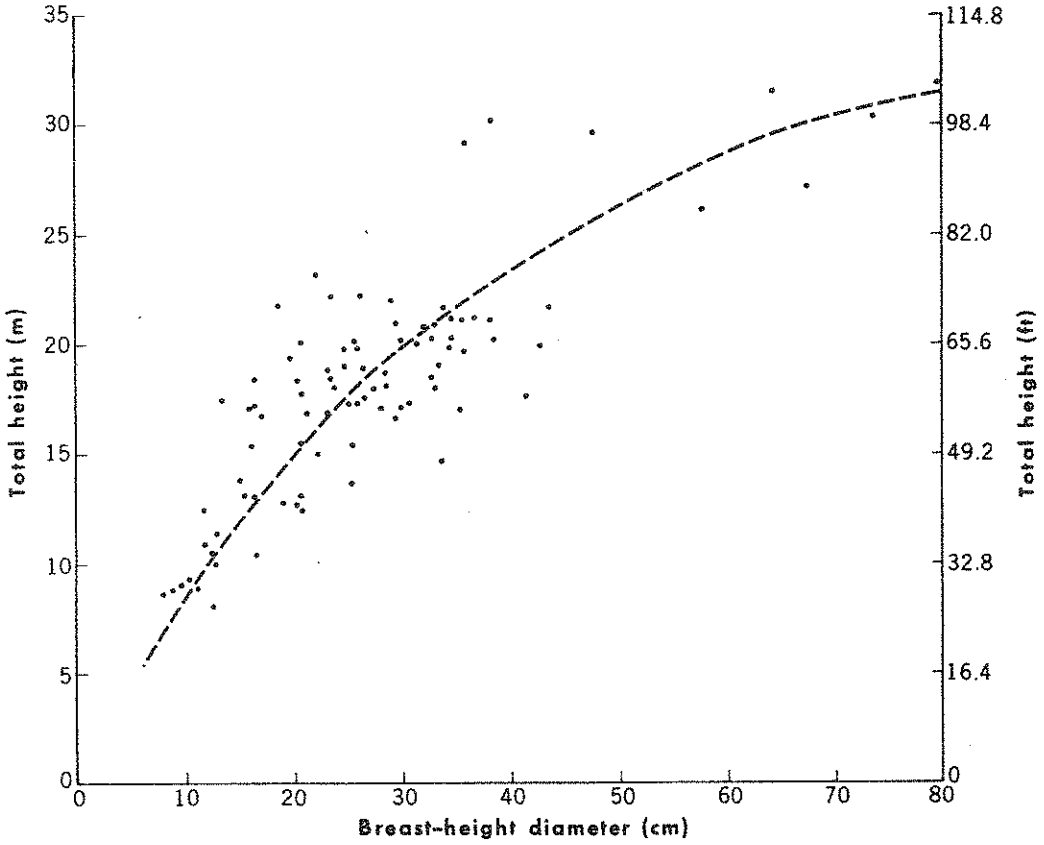

Figure 4—*Diameter-height relationship of Pacific madrone in north-central California.*

34 to 55 percent, early analyses showed that diameter growth on thinned plots was more than twice that of the control plot: 23 mm per tree compared to 10 mm (0.9 to 0.4 in) after 8 years. In thinned plots and control, diameter growth of trees was successively better as crown class increased from suppressed to dominant. Preliminary trends indicated that stands thinned below 25.3 m^2/ha (110 ft^2/acre) of basal area were too open and probably too warm for best diameter growth *(13)*. The higher density level where growth decreased from overcrowding has not been defined.

Although the longevity of madrone is not known, the species has been referred to as "giving evidence of being long lived" *(27)*. Trees 200 to 250 years old have been recorded and large specimens are estimated to be 400 to 500 years old.

Madrone seldom exceeds 34 m (110 ft) in height and 152 cm (60 in) in breast-height diameter. The largest Pacific madrone on record grows in Humboldt County, CA, and is 24 m (79 ft) tall and over 975 cm (384 in) in circumference 0.9 m (3 ft) above ground *(19)*.

Volume per hectare of madrone generally is low because the species seldom grows in pure stands. In the 60-year-old mixed-hardwood stand in the northern Sierra Nevada, Pacific madrone constituted nearly 16 percent of total stand volume of 44.7 m^3/ha (638 ft^3/acre).

Rooting Habit—Two- to 5-year-old madrone seedlings, growing in partial shade, showed large variation in root pattern and length. Some seedlings had a curving, twisting primary root with moderately extensive lateral development, and others had moderately twisted primary roots just below groundline that straightened and grew downward for about 23 cm (9 in).

Trees 50 to 60 years old often have a well-developed root burl from which a spreading root system develops. Some of these roots extend into organic layers near the soil surface and others slant downward. Large trees, 61 to 91 cm (24 to 36 in) in d.b.h., can produce massive root burls 122 to 152 cm (48 to 60 in) in diameter. Uprooted trees indicate a system composed of deep, spreading lateral roots.

Reaction to Competition—Young Pacific madrone seedlings need partial shade for estab-

lishment, especially in the southern portion of their range. As trees age, the need for light increases and older trees require top light for survival. In British Columbia, the species has a low shade tolerance. An appropriate overall classification for the species is intermediate in tolerance to shade. Pacific madrone probably is more subclimax than climax in successional status.

Damaging Agents—Fire is a major damaging agent to thin-barked madrone. Even the thicker bark at the base of old trees shields them little. Seedlings, sprouts, and trees all die back to the root crown after fire, but rarely are killed. Competing conifers usually are damaged badly or killed, however, allowing the fast-growing madrone sprouts to establish dominance.

Animal damage to Pacific madrone is minor. Deer eat berries and browse tender shoots of low crowns and young trees.

Insect damage is minor, and not economically significant. Several types of insects cause minor damage, including defoliators, leaf miners, wood borers, and bark beetles *(5)*. One of the most commonly observed types of damage on madrone leaves is the sinuous track of the larva of *Marmara arbutiella*. Damage, however, is relatively minor. The fall webworm *(Hyphantria cunea)* commonly deforms young trees and sprouts.

The pathology of Pacific madrone is characterized by many leaf spots, one leaf rust, a spot anthracnose, a tar spot, at least four cankers, and a root disease. A major cause of dieback and death of Pacific madrone is *Fusicoccum aesculi* (asexual stage), *Botryosphaeria dothidea* (sexual stage), which presently is virulent in northern California. This fungus disease, known as "madrone canker," begins on branch tips and moves inward. Symptoms of the disease are a dieback of branch tips followed by a dark wine-red discoloration of the bark that turns black after the branch dies. Continued advance of the infection leads to a wedge-shaped canker that eventually encircles and kills the branch. The blackened surface of the dead branch looks like fire damage. Cankered areas often spread from branches to bole and expand into the heartwood of the tree. Twigs, branches, and whole trees can be killed by this canker. Occasionally, branch dieback stops at a node. Sometimes several members of a sprout clump die back and sometimes all the sprouts in a clump succumb. Spores produced in the outer bark are probably spread by rain and wind, and also by insects *(10)*.

The disease probably was widespread and causing insignificant damage in forest stands, but has become a serious problem over the past 10-12 years. Changing environmental conditions are thought to have encouraged the outbreak of this disease. This pest has been reported as damaging Pacific madrone in the northern half of its range in California and has been observed in Oregon and Washington. The common twig fungus *(Botryosphaeria ribis)* infects madrone but is not common. A serious disease of madrone is a canker *(Phytophthora cactorum)* that can affect its culture in occasional situations. Cankers of this species appear to originate at ground-line and spread up the bole for an unknown distance. Early symptoms are browning and death of new leaves and a thinning of the crown. By the time these symptoms are obvious, extensive basal cankering usually has taken place *(8)*. Another canker *(Hendersonula toruloidea)* is fairly widespread on madrone in British Columbia. Annosus root rot *(Heterobasidion annosum)*, which killed more than 100 trees in Amador County, CA, in 1976, is a pest of high potential damage *(1)*.

Several species of fungi cause serious damage to the heartwood of madrone trees. The most important are *Phellinus igniarius, Fomitopsis cajanderi (Fomes subroseus)*, and *Poria subacida*. In the mixed conifer-hardwood forest of northwestern California, living madrones with fungus-infected heartwood are heavily utilized by cavity-nesting birds *(21)*.

Special Uses

Wood of Pacific madrone is moderately dense and strong, and extremely hard. When dry, its color, grain, and figure resemble that of black cherry. It is especially handsome in rotary-cut veneer *(18)*. The wood is well suited for use as bobbins, shuttles, novelties, and tobacco pipes and is recommended for furniture, paneling, flooring, interior trim, charcoal, and odor-free food-storage units *(32)*. Early Californians preferred madrone charcoal over that from other species for manufacturing gunpowder.

Nearly all of the products mentioned have been manufactured in the past. Current utilization is for some of these products as well as fuelwood.

The smooth reddish-orange bark of trunk and limbs, shiny green leaves, and colorful berries have led to use of madrone as an ornamental.

Genetics

Other than possible horticultural varieties, no natural varieties or hybrids are known.

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