Research Contribution 8 *March 1995*

HARDWOODS OF THE PACIFIC NORTHWEST

by

Stanley S. Niemiec
Glenn R. Ahrens
Susan Willits
David E. Hibbs

College of Forestry
Forest Research Laboratory
Oregon State University

The Forest Research Laboratory of Oregon State University was established by the Oregon Legislature to conduct research leading to expanded forest yields, increased use of forest products, and accelerated economic development of the State. Its scientists conduct this research in laboratories and forests administered by the University and cooperating agencies and industries throughout Oregon. Research results are made available to potential users through the University's educational programs and through Laboratory publications such as this, which are directed as appropriate to forest landowners and managers, manufacturers and users of forest products, leaders of government and industry, the scientific community, and the general public.

The Authors

Stanley S. Niemiec is former Senior Research Assistant, Department of Forest Products, Oregon State University (OSU), Corvallis, Oregon; Glenn R. Ahrens is Research Assistant, Department of Forest Science, OSU; Susan Willits is Research Forest Products Technologist, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon; and David E. Hibbs is Associate Professor and Extension Hardwood Management Specialist, Department of Forest Science, OSU.

Acknowledgments

Supported by the Red Alder/Value-Added Research and Demonstration Program of USDA Forest Service through Pacific Northwest Research Station Cooperative Agreement PNW 92-0285 with Oregon State University.

To Order Copies

Copies of this and other Forest Research Laboratory publications are available from:

Forestry Publications Office
Oregon State University
Forest Research Laboratory
Corvallis, Oregon 97331-7401

Please indicate author(s), title, and publication number if known.

Hardwoods of the Pacific Northwest

by

Stanley S. Niemiec
Glenn R. Ahrens
Susan Willits
David E. Hibbs

Table of Contents

Introduction

The history of hardwoods in the Pacific Northwest is sometimes characterized by contradictions. Hardwoods have always been valued as useful trees: they have been a raw material resource for homes, furniture, and implements; a source of food for people and game animals; and a source of beauty in a largely evergreen landscape. Hardwoods have also been weeds, undesirable competitors with regenerative conifers. This contradiction continues today.

The current economic condition of the forest products industry and the increased emphasis in forest management on diversity and ecosystem processes continue to stress the importance of Pacific Northwest hardwoods. More people are seeking a variety of information on hardwoods, information that is scattered among many, sometimes obscure, publications or found in the experience of many individuals.

To make this diverse information more readily available, this publication brings together in one place information on the biology, management, and processing of the Pacific Northwest (western Washington and Oregon, and northwestern California) hardwood species. While we cover a long list of species and a wide range of subjects, we have also tried to be reasonably comprehensive. We have included ten species:

Common Name	Scientific Name
Bigleaf maple	*Acer macrophyllum* Pursh
Black cottonwood	*Populus trichocarpa* Torr. & Gray
California black oak	*Quercus kelloggii* Newb.
California-laurel	*Umbellularia californica* (Hook. & Arn.) Nutt.
Giant chinkapin	*Castanopsis chrysophylla* (Dougl.) A. DC.
Oregon ash	*Fraxinus latifolia* Benth.
Oregon white oak	*Quercus garryana* Dougl. ex Hook.
Pacific madrone	*Arbutus menziesii* Pursh
Red alder	*Alnus rubra* Bong.
Tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.

In each chapter, what is and is not known about a given species is described according to the same list of topics (see box for principal topics). In many cases, very little is known. Although most of the book is written for people with some background in forestry and wood products, the first chapter reviews basic principles and terminology and discusses characteristics common to all hardwood species.

The purpose of this document is to increase the knowledge of indigenous hardwood species among forest managers and wood product users, and thus promote and maintain ecosystem diversity and sustainable supplies of these species. We also hope to increase utilization options related to the economic development of hardwoods.

Principal topics covered in each chapter of Hardwoods of the Pacific Northwest:

- ***General characteristics***
- ***Biology and management***
- ***Harvesting and utilization***
- ***Wood characteristics***
- ***Related literature***

Pacific Northwest Hardwoods

General Characteristics

This chapter provides information that is general to most species and an explanation of common terminology.

Size, Longevity, and Form

In this book, a hardwood tree is considered mature when it reaches 90 percent or more of its maximum height on a given site. A clear bole refers to the portion of the tree trunk that has no branches (living or dead) and is the primary section of the tree used in wood products.

Geographic Range

No species grows well everywhere; each is adapted to a particular set of circumstances. Most of the western hardwood species of California, Oregon, and Washington have a range that is longer north-south than east-west. Some have a fairly limited range, but are quite numerous within that range. The proportion of higher-density hardwoods increases from north to south within the region.

Timber Inventory

The most recent available estimates of growing stock inventory for the major hardwood species were compiled from results of surveys made by the USDA Forest Service, Forest Inventory and Analysis unit (see Appendix 1, Table 1). This information is incomplete, however, because many agencies do not collect or report data on hardwoods, which are often grouped under the heading "lesser species."

Biology and Management

Tolerance, Crown Position

Tolerance refers to the ability of the tree to survive and grow under the cover of the forest canopy. Shading, root competition, and other factors may be involved in determining tolerance. Species are described as either intolerant, intermediate, or tolerant; these terms may be modified by "moderately" or "very."

Crown position or canopy position refers to the relative position of the crown (foliage) with respect to neighboring trees. This can be described as suppressed, intermediate, codominant, dominant, or emergent.

Ecological Role

Ecological role refers to the response of the tree to forest disturbances (fire, wind, logging, landslides, flooding) and the tree's requirements for such disturbance in order to maintain itself as a viable component in the forest. Ecological succession proceeds in the absence of major disturbances; our terminology refers to the period in the successional sequence wherein the species is most prominent (pioneer, seral, or early-successional versus climax or late-successional).

Associated Vegetation

Tree, shrub, and, in some cases, herb or grass species commonly found with each hardwood species are listed by common name. Appendices 2, 3, and 4 contain lists of common and scientific names of these plants. Common and scientific names for other organisms are listed within the text for each hardwood species.

Suitability and Productivity of Sites

For many western hardwoods, there are no established site-index curves or other guides for estimating the productivity of a site. Generally, the potential growth of a species on a given site can be evaluated by examining height growth, diameter growth, and stem form on existing trees.

The crown position and microsite location of site trees can be representative of conditions on the prospective management site. Care must be taken here, since many hardwoods may be sensitive to slight changes in topographic position or microclimate.

In the absence of representative trees, site capability can be assessed by evaluating site factors relative to known requirements for the species in terms of climate, topographic position, soils, elevation, and disturbance, as discussed in other sections.

Climate

The climate of the Pacific Northwest forests where most of the hardwoods grow is quite mild. The winters are moist and temperatures rarely are below 0 °C. The summers are dry. Annual precipitation decreases and moisture demand increases from north to south and east to west through this geographic range.

Elevation

The wide range of elevation in the Pacific Northwest creates a wide gradient of climates. Hardwoods tend to be found at the low and middle elevations; conifers are found over the whole range below the treeline.

Soils

The soils of the region are diverse. Many soils in Washington are derived from glacial debris. Farther south, the soils are generally older, with parent rock of sedimentary, metamorphic, and volcanic origins. Certain combinations of soils and topography can produce very droughty conditions.

Flowering and Fruiting

Most hardwoods have inconspicuous, insect-pollinated flowers. Red alder, however, is wind-pollinated.

Seed

The seeds of hardwoods tend to be large. Many species rely on animals for seed distribution; most hardwood seeds are an important source of food for wildlife. Only the pioneer species have small, wind-blown seed. Seed crops for some species are annual; others produce large seed crops at intervals of two or more years.

Regeneration from Seed

Trees have regenerated from seed for millennia. Strategies for accomplishing this vary by species, but all basically involve the production of lots of seed over long time periods. Natural regeneration is a slow process, especially compared to that obtained by planting seedlings.

Many species require a special type of seed bed. Generally, the very small-seeded species reproduce better on bare mineral soil. Competing vegetation can limit the success of seedling establishment by reducing the availability of water, light, or both below levels necessary for hardwood survival.

Regeneration from Vegetative Sprouts

Most hardwood species discussed here sprout from the stump after cutting or fire, providing immediate and vigorous regeneration. Generally, many more sprouts are produced than can survive over the long term. Thinning sprouts can increase the growth of residual stems.

Regeneration from Planting

Commercially available supplies of seed, seedlings, or cuttings vary among species; some species are available, but many are not. Advance inquiries and arrangements for acquisition of seed and production of planting stock are often necessary. We know very little about genetic adaptation for hardwood species. Generally, seed or vegetative propagules should be collected locally to ensure that trees will be adapted to local conditions.

The quality of hardwood planting stock can be extremely variable. In many cases, poor performance of plantings is due to poor quality stock. Generally, it is not worthwhile to plant stock of marginal quality.

Site Preparation and Vegetation Management

As with the culture of many plants, preparation of the growing site and control of competing vegetation (weeding) will allow hardwood seedlings to achieve their best potential. In forest settings, site preparation offers the best opportunity to control competing vegetation; weeding in established hardwood stands is difficult and/or expensive. With faster growing species, effective management of competing vegetation is achieved with good site preparation followed by rapid establishment of hardwood dominance. In many cases, moderate levels of competing vegetation, debris, or both will require little or no site preparation beyond the logging operation. Site preparation needs must be carefully evaluated, however. Hardwoods should not be selected for heavy brush sites because of brush control costs.

Stand Management

Natural establishment of many hardwood species often occurs via high initial density and immediate dominance over competing plants. Management of stand density is the primary avenue for reducing rotation length and improving quantity and quality of commercial yields. Diameter growth is very responsive to increased growing space. The strategy in density management is to find the spacing regime that provides optimal growth while maintaining stem quality. Moderate crowding is often necessary to maintain stem form, reduce branching and forking, and induce self-pruning. Once form and self-pruning goals are met, thinning can maintain or improve diameter growth rate.

Wide initial spacings may be appropriate with intensive culture of selected genetic stock of high-value hardwoods, or with species that produce both fruit or nut and timber crops.

Mixed-species Stands

Mixed-species stands, particularly conifer/hardwood mixes, are appealing for many reasons. Hardwoods can maintain or improve desirable soil characteristics via input of nutrients and organic matter. Mixed stands provide forest products (both special forest products and wood products) and diversity for wildlife; they mitigate fire damage and are aesthetically attractive. The challenge with management of mixed stands is the integration of differing growth patterns, sensitivities to competition, and rotation ages. The simplest approach may be to manage mixed species in monospecific patches.

Fast-growing species and stump sprouts may suppress establishing seedlings of slow-growing species. When conifers reach maximum growth potential later in a rotation, it can become difficult to maintain codominance and growth of intermixed hardwoods. Strategies for management include delaying establishment or maintaining low proportions of fast-growing species among slow growers. Later, the conifers must be thinned to provide growing space for hardwoods.

Growth and Yield

Of the Pacific Northwest hardwoods, the growth and yield of red alder is, by far, the best. For red alder, almost all of the available information comes from natural, unmanaged stands. Although there have been few research studies and thinning demonstrations of red alder and several other hardwoods, we are forced to rely heavily on this limited data base.

An important characteristic of hardwood growth is that hardwood stands do not and cannot achieve the stocking levels common for conifers. For example, a basal area of only 150 ft^2 per acre is considered high for red alder. This stocking level, however, can be achieved in a relatively short time, compared to conifers. Thus, management strategies of hardwoods tend to be based on either short rotations or high-value products.

Interactions with Wildlife

The interactions of hardwood trees with wildlife vary with species. Many hardwoods provide habitat characteristics that conifers do not; some wildlife species are dependent on hardwoods. Inclusions of hardwoods, therefore, in a landscape or forest stand increases wildlife diversity and abundance.

Insects and Diseases

All plants have their own particular insect and disease problems. In hardwoods, these problems generally do not become epidemics.

Genetics

Little is known about the levels of genetic variability of the region's hardwoods. Red alder has received the most attention; one study of Oregon white oak suggested that there is limited variability among the white oak populations in Washington.

Because little is known of the levels of genetic variability, a conservative, careful approach is required in retaining and selecting seed sources for regeneration. Seed should be collected from stands of similar climate and soils to the regeneration site. We recommend simply staying within a locally defined conifer seed zone and limiting seed movement to within a 500-ft elevation band. Within the seed-collecting area, select stands and trees within stands of better growth and form.

Harvesting and Utilization

Cruising and Harvesting

Two types of cruises are currently being used to estimate tree volumes. Both use standard sampling design and cruising techniques, including the measurement of DBH, form class, merchantable height, and top diameter, but they differ in volume estimation. One method uses standard 16-ft log lengths, and deducts for sweep, crook, rot, and other defects. It will generate consistent volume estimates without regard to manufacturing lengths and processing technology. The other method uses preferred milling lengths (usually 8, 10, or 12 ft) and attempts to fit segments between defects. Although this method may result in estimates closer to final utilization by a particular mill, the results will be highly variable and will depend on cruisers' judgement and harvesting and processing technology. We strongly recommend that volume estimates be based on cubic feet rather than board feet in order to eliminate biases within the Scribner system. Tools such as stand-volume tables or tree-volume equations are lacking or poorly developed for many hardwoods and may not yield accurate results for specific stands.

Estimates of tree quality and value are typically based on estimates of log grades and sizes. Although log grades have been developed and tested for most hardwood species, they are not often used by log buyers in the Pacific Coast region. The use of standard log grades would assist in the development of the hardwood industry, however. Purchasers often determine prices and specifications for log diameters and lengths for individual sales based on their knowledge of local timber and on the current needs of the mill.

In the past, there have been problems in adapting softwood technology to the harvesting of hardwood timber. The current emphasis on small-log harvesting is providing new technology and better trained loggers for the hardwood industry. Typically, hardwood manufacturers process shorter logs (8, 10, and 12 ft) than do softwood manufacturers; this allows much more flexibility in the log bucking process. It is important to consider log grade as well as volume during bucking. Bucking for grade makes a critical difference in the net value of the trees; bucking to variable lengths to maximize the grade and reduce the impact of crook and sweep is recommended. Proper felling and bucking techniques are essential for making a profit in the hardwood industry. Harvesting and transportation costs for hardwoods may be slightly higher than for softwoods because there are generally fewer stems per acre to be harvested, species have a higher density (heavier logs), logs tend to be more crooked, and, because of tree form, there may be more short logs.

As mentioned previously, traditional softwood log scaling rules do not necessarily provide accurate estimates of usable volumes because the hardwood manufacturers can use shorter log lengths and different lumber sizes to produce end products. In some cases, logs are sold on a weight basis to avoid inaccuracies in the log measurement systems.

Product Recovery

Logs are generally bucked at the sawmill into preferred milling lengths, which circumvents some problems with misshapen logs. Sawlogs have a minimum diameter of 6 to 10 in., depending on the species and the mill. Hardwood mills are typically smaller than softwood mills and manufacture lumber at lower production rates. Mills normally produce random-width lumber in 4/4, 5/4, 6/4, and 8/4 thicknesses, with 4/4 being predominate.

The standard grades are based on the percentage of surface measure with clear cuttings on the poorest side of the board. These clear cuttings are located between knots and other types of defects. Select grade is the exception because it is based on the best side of the board. Lumber grades are designed to be used on green lumber; in practice most of the lumber is dried and surfaced before it is graded. At the sawmill, care should be taken so that over-edging does not significantly reduce grade and recovery volume.

Average rates of lumber grade recovery from northwestern hardwood logs are generally similar to rates for related eastern hardwood species within comparable log grades (Appendix 1, Table 2).

Wood Properties

Characteristics

These properties describe the texture, color (for both heartwood and sapwood), odor or taste, and the cellular structure of the wood. In the latter group, consideration is given to the pore patterns, description of the annual growth increments, and prominence of various cell types.

The pore structure of end-grain surfaces is identified as either diffuse porous, ring porous, or a combination of both, which then is termed either semi-diffuse or semi-ring porous. Diffuse porous woods have little or no variation in pore size within an annual growth increment. Ring porous woods have a few large pores at the start of each growth increment that change to small, more numerous pores for the remainder of the annual growth. If the transition from large to small pores is gradual or if the initial pores are not extremely large, then the wood is described as semi-ring or semi-diffuse porous. The visibility of the start of each growth increment also helps to identify woods. For many diffuse porous woods, that beginning is difficult to discern without magnification. For ring porous woods, the start of each growth increment is very prominent. Diffuse porous woods are red alder, bigleaf maple, and Pacific madrone; ring porous woods are the oaks, tanoak, and ash. Ring porous woods are also more coarse and grainy when viewed on tangential (flat-sawn) surfaces. The size and volume of the wood rays—cells that appear as ribbon-like strands extending across the grain in the radial direction, which transport fluids and nutrients laterally—also help to identify woods. Rays can be very fine and visible only with magnification, or very large and prominent. When radial surfaces are exposed during sawing, their structure can enhance the surface appearance and create unique patterns.

Weight

Specific gravity or density is an excellent descriptor of wood and is correlated to many important wood attributes such as mechanical strength, shrinkage, and cutting forces associated with machining. Specific gravity often receives first attention when the potential of a species is assessed (Appendix 1, Table 3).

Basic specific gravity is the weight divided by the volume; it directly relates the wood weight to the weight of water (considering equal volumes). Water has a specific gravity of 1.00, so a wood with a specific gravity of 0.50 weighs half as much as water. The specific gravity is typically given for wood that is green (freshly cut), ovendry (0 percent moisture content), and at 12 percent moisture content, which approximates many in-service conditions. For wood, specific gravity is calculated on the ovendry weight and the green-wood volume.

It is important to recognize that wood is a natural material that results from considerably diverse origins, life histories, and growth conditions. As such, the values given for a specific wood represent average values and do not indicate the variability or the range of values possible.

Mechanical Properties

It must be emphasized that the mechanical properties we present have been summarized from several sources (Appendix 1, Table 3). Sampling and testing procedures may have varied; therefore, the values should be considered only for comparison purposes between species and for determination of possible appropriate end uses. Test results reported here are based on the ASTM procedures of D 143. As with specific gravity information, the values given are averages and do not indicate the possible range and variability of the material.

Drying and Shrinkage

We have noted the response of individual woods to air- and kiln-drying, and the types of degrade likely to occur. Shrinkage data from green to ovendry is given to provide information about changes in size and in-service stability.

Kiln schedules are provided for each species, as kiln efficiencies vary considerably; however, these schedules should be considered as conservative starting points. These schedules are also based on specific stacking and stickering procedures. Any changes in kiln design or function, stacking, stickering, or pre-drying/air-drying should be noted. These changes may require schedule alteration to prevent excessive degrade of material.

Some pre-drying treatments and post-drying reconditioning may help minimize degrade (as with Pacific madrone) but the exact procedures are for the most part either proprietary or experimental.

All moisture content (MC) data are based on an ovendry basis using the following formula:

$$\text{MC percent} = [(\text{wet weight} - \text{dry weight})/\text{dry weight}] \times 100$$

Machining

Much of the information on the machining, adhesive bonding, and finishing of hardwoods is subjective. Judgement, rather than test data has determined some of the evaluations, and the use of different sources has further complicated the situation.

We have described the machinability of wood, such as its tendency to chip and tear during planing and shaping; the smoothness of the final machined surface; and the dulling of tooling. We have included recommendations for tooling geometry as well.

Adhesives

Glue-joint quality for side grain joints is given. Quality and in-service performance of glue joints depend on the density of the wood (lower density woods generally bond better than higher density woods), the quality and newness of the machined surfaces, the type and quality of the adhesive, and, for long-term performance, the effectiveness of the finish in excluding moisture and protecting the wood.

Finishing

In this section, we have considered the application and appearance of clear interior coating and associated coloring systems used for furniture, cabinets, or flooring. Finish quality depends on surface preparation and quality, the grain/pore structure of the wood, and the uniformity of color between heartwood and sapwood.

Durability

Information in this section describes the natural resistance of the heartwood to decay fungi during ground-contact exposure. If the wood is particularly susceptible to insect attack, we have noted the specific types of insects and damage. We have also indicated whether a wood is specifically susceptible to staining during handling, storage, or exposure to certain metals.

Uses

The uses of hardwood lumber are many and varied. Higher quality material is utilized in products such as veneers for paneling and hardwood plywood, cabinets (both as solid wood and from hardwood plywood), furniture, doors, and moulding and millwork. Intermediate grades tend to be used for furniture, solid paneling, and flooring. Lower grades serve utilitarian applications such as pallets, boxes and crating, and small cut-stock applications that avoid the defects. Very low-grade material and residues can be used for particle-board-type composites, pulp for paper and container board, or fuel or agricultural mulches. Care should be taken so that the higher value products are considered before these resources are processed for high-volume, low-value end uses, as is often the case.

The development of products from indigenous hardwoods species has not been fully explored. As a result, many opportunities exist for creating employment and for supporting economic diversification with entrepreneurial innovation, increased entrepreneurial, corporate, and governmental sector research and development, and market opportunity analysis.

Related Literature

BOLSINGER, C.L. 1987. Major findings of a statewide resource assessment in California. P. 291–297 *in* Proceedings of the Symposium on

Multiple-Use Management of California's Hardwood Resources. T.R. Plumb and N.H. Pillsbury, tech. coords. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-100.

BOONE, R.S. 1988. Dry Kiln Schedules for Commercial Woods—Temperate and Tropical. USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. General Technical Report FPL-GTR-57. 158 p.

GRATKOWSKI, H. 1961. Brush problems in southwest Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 53 p.

HARLOW, W.M., E.S. HARRAR, and F.M. WHITE. 1979. Textbook of Dendrology. McGraw-Hill, New York. 510 p.

LITTLE, E.L., Jr. 1979. Checklist of United States Trees (Native and Naturalized). USDA Forest Service, Washington D.C. Agriculture Handbook 541. 375 p.

McDONALD, P.M. 1983. Local volume tables for Pacific madrone, tanoak, and California black oak in north-central California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-362. 6 p.

McDONALD, P.M., D. MINORE, and T. ATZET. 1983. Southwestern Oregon-northern California hardwoods. P. 29-32 *in* Silvicultural Systems for the Major Forest Types of the United States. R.M. Burns, tech. compil. USDA Forest Service, Washington, D.C. Agriculture Handbook 445.

NATIONAL HARDWOOD LUMBER ASSOCIATION. 1982. Rules for the measurement and inspection of hardwood and cypress. Memphis, Tennessee.

OVERHOLSER, J.L. 1977. Oregon Hardwood Timber. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 16. 42 p.

PANSHIN, A.J., and C. de ZEEUW. 1980. Textbook of Wood Technology. 4th edition. McGraw-Hill Book Co., New York. 722 p.

PILLSBURY, N.H., and M.L. KIRKLEY. 1984. Equations for total, wood, and saw-log volume for thirteen California hardwoods. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-414. 52 p.

RAETTIG, T., G.R. AHRENS, and K. CONNAUGHTON. 199?. Hardwood supply in the Pacific Northwest: a policy perspective. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. In preparation.

SNELL, J.A.K., and S.N. LITTLE. 1983. Predicting crown weight and bole volume of five western hardwoods. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-151. 37 p.

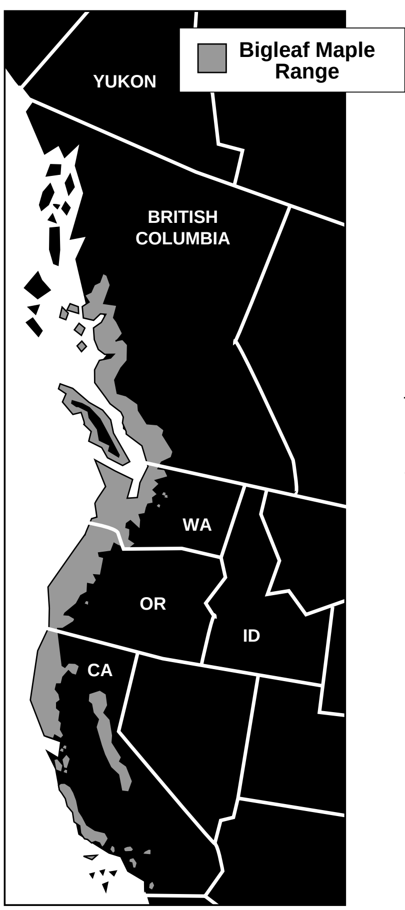
STROEMPL, G. 1983. Thinning clumps of northern hardwood stump sprouts to produce high quality timber. Ontario Ministry of Natural Resources, Toronto, Ontario. Forest Resource Information Paper 104. 27 p.

USDA FOREST SERVICE. 1987. Wood Handbook: Wood as an Engineering Material. Forest Products Laboratory, Madison, Wisconsin. Agriculture Handbook 72. 466 p.

Bigleaf maple
Acer macrophyllum

Oregon maple
Large-leaf maple
Broadleaf maple

General Characteristics



Bigleaf maple is second to red alder among native hardwood species in abundance and in commercial importance in the Pacific Northwest. It is the only western maple that reaches commercial size, yet its potential as a commercial species has not been fully recognized.

Size, Longevity, and Form

Mature bigleaf maple trees range from 50 to 100 ft in height (101 ft maximum) and 12 to 36 in. in DBH (133 in. maximum). Bigleaf maple is moderately long-lived; some individuals may reach 300 years of age. Height growth becomes negligible after 50 to 70 years. In forest stands, maples often develop clear (50 to 70 percent of total height), well-formed stems with narrow crowns. Open-grown trees have broad, rounded crowns on short, branching boles. The root system of bigleaf maple is shallow and spreading on wet or shallow soils.

Geographic Range

Bigleaf maple is native to the Pacific Northwest at low to middle elevations from San Diego to Vancouver Island (lat 33 to 51°N). It usually grows from near the Pacific Ocean to a maximum of 186 miles inland.

Timber Inventory

Substantial volumes of bigleaf maple occur in every subregion of the Northwest (Appendix 1, Table 1). Maple is most abundant in the

Puget Sound region of Washington and the Northwest region of Oregon. About 18 percent of the total hardwood volume in the Pacific Northwest is bigleaf maple.

Biology and Management

Tolerance, Crown Position

Bigleaf maple occurs as a dominant, codominant, or intermediate tree in even- or uneven-aged stands. It is quite tolerant and commonly establishes in forest understories, where it can persist for long periods. Maple in the understory can quickly respond to release when openings are created in the overstory. It also has the capacity to grow rapidly and maintain dominance under favorable conditions in the open sun.

Ecological Role

Bigleaf maple increases in abundance during intermediate to late stages of succession. It can follow willow and alder in riparian succession. On drier upland sites, bigleaf maple can replace oaks and Pacific madrone in the absence of significant disturbance.

The abundance of bigleaf maple also increases after disturbance in stands with an established maple component. Basal sprouts stimulated by cutting or burning can dominate other vegetation in the new stand. Removal of overstory trees can stimulate rapid growth on bigleaf maple in the understory.

Associated Vegetation

Bigleaf maple is commonly found in association with almost all other tree species in its range. The greatest abundance of bigleaf maple is in the foothills of the Cascade and Coast ranges. Its most common associates are Douglas-fir, grand fir, red alder, Sitka spruce, western redcedar, western hemlock, Pacific dogwood, and Pacific madrone. Common shrub and herb associates include serviceberry, salal, red huckleberry, devil's-club, Pacific rhododendron, thimbleberry, salmonberry, vine maple, and hazel. Herbaceous associates include maidenhair fern, western swordfern, ladyfern, red woodsorrel, false lily-of-the-valley, prince's-pine, spreading sweetroot, and twinflower.

Bigleaf maple also supports abundant epiphytic growth on branches and boles in moist climates. Common epiphytes are licorice fern, club moss (*Selaginella oregana*), and other mosses (*Hylocomium splendens*, *Leucolepis menziesii*, *Isothecium stoloniferum*, and *Neckera menziesii*) and lichens (*Cladonia*, *Nephroma*, and *Crocynia* spp.).

Suitability and Productivity of Sites

Bigleaf maple grows best on river terraces, flood plains, and seepage areas. Good performance is also common on upland sites if soils are deep and moisture is abundant. Bigleaf maple will establish and grow on a wide variety of sites, including relatively harsh, dry areas in southwestern Oregon; however, growth and stem form may be poor. The suitability of prospective sites should be carefully evaluated before management of bigleaf maple is attempted.

There are no established guides or site-index curves for estimating the productivity of a site for bigleaf maple. Good potential for growth of bigleaf maple on a site is indicated by the following:

- Top height of existing mature trees is 80 to 100 ft
- Rapid juvenile height growth of >3 ft per year
- Sustained height growth from age 15 to 30 of 1 to 2 ft per year
- Continuing diameter growth on mature trees.

Climate

Bigleaf maple is commonly found across a wide range of climates, from the cool, moist (temperate rain forest) conditions of the Olympic Peninsula to the warm, dry (Mediterranean) conditions of southwestern Oregon. Within its range, precipitation varies from 22 to 260 in. (560 to 6600 mm) annually, and from 2 to 46 in. (50 to 1170 mm) during the growing season. Average temperatures range from a minimum of 28 °F (January) to a maximum of 81°F (July). Where maple is most prolific, the climate is mild and humid, with moderate precipitation during the growing season.

Bigleaf maple can grow on relatively hot, dry areas, such as upland sites in southwestern Oregon. Maple tolerates moisture stress as low as -20 bars (-2 MPa, nocturnal), which is a low value for broadleaved deciduous trees. Planted maple seedlings are susceptible to heat-girdling and sunscald on the lower stem, however.

We have little information concerning susceptibility of bigleaf maple to cold, ice, and snow. A low tolerance to cold and snow is indicated by the absence of maple at higher elevations and by its narrow coastal range. Cold temperatures probably limit the northern occurrence of bigleaf maple.

Elevation

Bigleaf maple usually grows at low to middle elevations (near sea level to 3000 ft) in the central part of its range. In southern California, it may be found from 3000 to 7000 ft; at the northern end of its range it seldom occurs above 1000 ft in elevation.

Soils

Bigleaf maple is found on soils that vary from shallow and rocky to wet gley. Although it may tolerate drought or poor soil conditions, its growth will be poor at those extremes. It grows best on deep, well-drained soils with abundant moisture, conditions that occur most commonly on river terraces, flood plains, and seepage areas.

Bigleaf maple is not as tolerant of poor drainage or flooding as other riparian species such as red alder, cottonwood, or ash. Bigleaf maple appears to be somewhat tolerant of wet conditions, as indicated by its shallow, spreading root system and its common presence in wet areas. Flooding for more than 2 months during the growing season will kill maples of all ages.

Bigleaf maple does not seem to require high soil fertility, based on its competitive success over a range of soil nutrient conditions. One study indicates a high sensitivity to toxic boron in the soil. Maple is considered to be a soil-building species; leaves and litter contain relatively high concentrations of macro- and micro-nutrients.

Flowering and Fruiting

Bigleaf maple begins to produce seed at about 10 years of age. Maple is polygamous, bearing both male flowers and perfect flowers in one cylindrical raceme. The flowers appear before the leaves in early spring. The greenish-yellow flowers are pollinated by insects within 2 to 4 weeks after bud-burst.

Seed

Bigleaf maple seeds are borne in pubescent, double samaras with wings from 1.4 to 2 in. long. Seeds are triangular or oval in shape and 0.16 to 0.47 in. long. There are from 2700 to 4000 seeds/lb. Seeds ripen early in September and October, and are dispersed by the wind from October through January. Many seeds may remain on trees during this period.

Seed should be collected from healthy, well-formed trees. If the outplanting site is known, parent trees should be selected from a nearby locale that has conditions similar to the outplanting site. Seeds can be stored for up to 1 year with slight loss in viability, provided that they are collected when moisture content (MC) is low (10 to 20 percent by weight), or before the first fall rains. If seed are collected later, at higher MC, they should not be dried. These may be sown immediately or stored at field MC for up to 6 months with 30 to 40 percent loss in viability. Seeds should be stored in airtight containers at 34 °F.

Bigleaf maple seeds are typically sown in the fall, soon after collection. Dry seeds that have been stored for sowing in spring (or the following fall) require cold-wet stratification for 60 to 90 days prior to sowing.

Natural Regeneration from Seed

Most bigleaf trees produce seed every year, although the amount may vary greatly from year to year. All viable seeds will germinate in the first year; delayed germination does not occur. Seeds germinate well on both mineral and organic substrates. Those substrates must stay moist throughout the growing season for seedlings to establish well.

Germination and establishment rates are best under partial shade. Natural rates of establishment are low under dense shade or in clearcuts. Good conditions for natural regeneration occur when overstory conifers are thinned out by natural self-thinning or silvicultural thinning. Dense brush and understory vegetation inhibit natural regeneration.

Regeneration from Vegetative Sprouts

Maple has a prodigious capability to sprout from cut stems of any size, from seedlings to large trees. Sprouts provide a reliable means of regeneration from existing trees. Unmanaged sprout clumps produce too many stems and poor stem quality. Management may greatly improve the quality of stems from sprouts of bigleaf maple.

Regeneration from Planting

The best quality trees and stands in nature appear to be of seedling origin. There have been very few efforts to plant bigleaf maple in the wild. Although some forest nurseries are producing bigleaf maple on a trial basis, commercial supplies of maple seedlings are not consistently available. To ensure a supply of maple seedlings, arrangements must first be made for collection of seed and for production of seedlings at a qualified nursery. Very large (3 to 6 ft tall) nursery seedlings may be produced in one year.

Observations made on field plantings to date indicate that plantings are very susceptible to deer browse. Planted seedlings are sometimes prone to forking and poor form, particularly after they have been browsed or physically damaged. To maintain stem quality in plantations, seedlings may need to be protected from deer, planted in high densities, and correctively pruned.

Site Preparation and Vegetation Management

There are no specific studies of site preparation and vegetation management practices for bigleaf maple. The outstanding performance of bigleaf maple cultivated in nurseries and back yards indicates great potential for management of seedlings in the field. Control of competing vegetation should improve on the low rates of establishment and slow growth observed for maple in the presence of dense understory vegetation. Little or no site preparation is required with maple regenerating from stump sprouts.

Stand Management

Diameter growth of bigleaf maple is very responsive to increased growing space. Management should target a spacing regime that produces optimal growth while maintaining the benefits of crowding in young stands or clumps. Moderate crowding is necessary to reduce branching and forking and induce self-pruning. A dense canopy of bigleaf maple will also suppress competing understory vegetation, reducing the need for other vegetation management treatments.

Control of spacing via initial planting density or precommercial thinning (PCT) is recommended to allocate rapid growth to crop trees at an early age (5 to 15 years). To maintain moderate crowding, stands should not be opened too much initially. Intermediate thinning (for pulpwood, firewood, PCT) may be needed to maintain diameter growth. Bigleaf maple can continue to grow in diameter and respond to released growing space for at least 30 to 40 years.

Mixed-species Stands

The shade-tolerant bigleaf maple can be grown in any crown position in stands with mixed species or age classes. Management of mixed stands is complex; stands may require periodic treatments to maintain the growth of diverse components. Bigleaf maple stump sprouts must be controlled or thinned to prevent the early suppression of associated seedlings. Later treatments may be needed to maintain growth of bigleaf maple when intermixed conifers ultimately reach their superior height.

Delayed establishment of bigleaf maple seedlings in conifer plantations is a sensible strategy, since maple naturally establishes and grows under partial cover. Thinning and vegetation management may be needed to maintain adequate space for the growth of bigleaf maple. With even-aged mixtures or short (<10 years) delays in bigleaf maple establishment, maple sawtimber can be harvested at the same time as associated conifers.

Because this species tends to establish in patches or clumps, it may be sensible to manage bigleaf maple in monospecific patches in mixture with other trees. This management in patches approach may be applied to groups of dominant maple sprout clumps or to patches of seedlings establishing in openings.

Growth and Yield

Juvenile growth rates of dominant maple stands or patches are quite rapid, matching or exceeding those of red alder. Yields of about 4500 ft^3 per acre were estimated for 70-year-old stands of pure bigleaf maple in British Columbia. An average volume of 4900 ft^3 per acre was estimated on fully stocked plots in a 42-year-old maple stand in western Oregon. Gross annual volume growth on these plots was about 140 ft^3 per acre. On these plots, height growth after 45 years already appeared to be very slow (no measurable growth in 3 years). A rotation age of 40 to 50 years may be feasible in managed stands.

Interactions with Wildlife

Damage caused by deer and elk is probably the most important factor affecting the height and form of bigleaf maple seedlings and sprouts. The foliage and young stems of bigleaf maple are preferred browse for elk and deer, and these animals often use saplings for rubbing antlers. Seedlings and saplings are often clipped by mountain beaver. Birds and rodents feed on bigleaf maple seeds. Predation by rodents and invertebrates is a major cause of seedling mortality. Bigleaf maple provides an important broadleaved, deciduous component in the coniferous forests of the Northwest. The leaves are rich in bases and provide for a diversity of insects and other microfauna. The understory vegetation associated with maple can be quite different from that in adjacent conifer forests. A variety of birds and mammals may benefit from these distinct attributes of food and habitat.

Insects and Diseases

Young, undamaged trees are generally free of serious disease or decay. Old or damaged trees commonly have serious defects caused by wood-rotting fungi, which invade through stem and branch wounds. Root pathogens (*Armillaria* spp.) and butt rots also attack older trees. The verticillium wilt (*Verticillium albo-atrum*) can be a serious problem for ornamental trees and it sometimes kills bigleaf maple in the forest.

Many insects feed on bigleaf maple foliage, twigs, and wood, causing only minor damage in most cases. The carpenter worm (*Prionoxystus robinae*) can cause serious damage in living trees of all sizes. Roundheaded borers often damage the wood of dead and dying trees. Powderpost beetles (*Ptilinus basalis*) may rapidly infest dead trees or lumber that is improperly stored.

Genetics

In genetics research, the major interest is in cultivars for ornamental uses. A red-leaved variety of bigleaf maple (*Acer macrophyllum* Pursh forma *rubrum*) has been found in northern California. Another variety with triple samaras (*Acer macrophyllum* Pursh var. *kimballi* Harrar) is occasionally found in Washington.

Harvesting and Utilization

Cruising and Harvesting

Total tree volume in cubic feet and sawlog volume can be estimated from DBH and total height with tables or equations. Log grades developed by the Forest Service for eastern hardwoods and modified by Oregon State University appear to separate log values to the point that it may be worth grading logs for marketing. Generally, logs are priced on the basis of diameter and length specifications developed by local log buyers.

Product Recovery

Sawlogs generally have a minimum diameter of 7 to 10 in. Lumber is graded with the special NHLA rules for bigleaf maple; grades include

Selects and Better, No. 1 Shop, No. 2 Shop, No. 3 Shop, and Frame. Unlike the standard NHLA grading rules, these grades are generally based on the best face of the piece. Grades can be applied to rough, surfaced, green, or dry lumber; in practice, lumber is usually dried and surfaced before grading. One mill study conducted with NHLA standard grades rather than the modified red alder and maple grades found a percentage recovery of No. 1 Common or Better green lumber from bigleaf maple logs (80 percent and 58 percent for grade 1 and 2 logs, respectively) that is quite good compared to other hardwoods (Appendix 1, Table 2).

There are also specialty markets for figured wood from bigleaf maple, although there are no standard grades. Craftsmen, both local and distant, may pay premium prices for burls and wavy, quilted, fiddle-back, or bird's-eye grain patterns. This figured material is utilized for thin-sliced, decorative veneers for furniture and architectural paneling.

Wood Properties

Characteristics

The wood from bigleaf maple is fine-grained and of moderate weight and hardness. The sapwood is reddish-white, sometimes with a grayish cast; the heartwood is light pinkish-brown. The wood is without any characteristic odor or taste. The growth rings on the end grain are not very distinct; on the radial and tangential surfaces, however, the growth rings are generally delineated by a narrow, dark brown line, which shows the figure of the wood. The pores are evenly distributed in the growth rings (diffuse porous) and are moderately small to medium in size. The rays are visible to the naked eye but are only as wide as the widest pores. Although much of the wood is straight-grained, some highly figured wood that includes wavy, quilted, fiddle-back, or bird's-eye grain patterns is also produced.

Weight

Bigleaf maple weighs about 47 lb/ft^3 when green, and 34 lb/ft^3 when dried to 12 percent MC. The average specific gravity is 0.44 (green) or 0.51 (ovendry).

Mechanical Properties

The strength properties of bigleaf maple are exceptionally good, considering its intermediate specific gravity. While it is not as strong as the eastern hard maples, it performs better in most tests than the soft maples. Bigleaf maple is suitable for most furniture design applications, and the lower grades perform well as pallet stock. It holds nails well and is not likely to split with nailing. See Appendix 1, Table 3, for average mechanical properties for small clear specimens.

Drying and Shrinkage

Under properly controlled conditions, bigleaf maple can be successfully kiln-dried in a short time with a minimum of degrade. The most prevalent drying defects are end checks and collapse, or mold growth that causes stained wood. The average green MC is 72 percent (ovendry basis).

The radial shrinkage (green to ovendry) is 3.7 percent and the tangential shrinkage value is 7.1 percent. These values are the same as those of black cherry, and are better than those of red alder (radial 4.2 percent, tangential 7.3 percent) and Oregon white oak (radial 4.4 percent, tangential 9.0 percent). See Table 1 for an appropriate kiln schedule for 4/4, 5/4, and 6/4 lumber.

Table 1. Kiln schedule—Bigleaf maple 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 50	130	123	14.3	81	54.5	50.5
2	50 to 40	130	120	12.2	74	54.5	49.0
3	40 to 35	130	115	9.6	62	54.5	46.0
4	35 to 30	130	105	6.7	43	54.5	40.5
5	30 to 25	140	100	4.2	25	60.0	37.5
6	25 to 20	150	100	3.2	18	65.5	37.5
7	20 to 15	160	110	3.4	21	71.0	43.5
8	15 to final	180	130	3.5	26	82.0	54.5

Equalize and condition as necessary.

Machining

Bigleaf maple wood retains many of the favorable machining (planing, shaping, boring, and turning) characteristics of the eastern hard maples, while allowing for greater production feed rates because of its lower density. Best results for planing were obtained with hook angles of 20°. As with other fine-grain, hard woods, surface scratching associated with sanding (swirls and cross-grain) can be a problem, although not to the same degree as with the hard maples.

Adhesives

There appear to be no reliable test results available that deal directly with the newer synthetic adhesives, but communication with local users indicates that bigleaf maple performs satisfactorily with good quality joints if conditions are well controlled. The glue line can be visible when darker resins are used because of the wood’s light color.

Finishing

Bigleaf maple finishes well and there is no need to fill the grain. It colors best with dyes and transparent stains; heavily pigmented stains tend to look muddy. With careful color selection, the straight-grained wood can be stained to resemble cherry. Figured bigleaf maple is exceptionally beautiful when clear-coated.

Durability

Bigleaf maple is not a durable wood when exposed to conditions favorable to decay. When properly seasoned, the wood is relatively stable and is not apt to split or surface check in use.

Uses

Bigleaf maple is used for furniture, veneer, paneling, hardwood plywood, musical instruments, moulding, pallets, turnery, pulpwood, and firewood.

Related Literature

BASTENDORFF, K.M., and A. POLENSEK. 1984. Strength and stiffness of red alder and bigleaf maple pallet materials. Forest Products Journal 34(7/8):51-56.

FRIED, J.S., J.R. BOYLE, J.C. TAPPEINER II, and K. CROMACK Jr. 1990. Effects of bigleaf maple on soils in Douglas-fir forests. Canadian Journal of Forest Research 20:259-266.

FRIED, J.S., J.C. TAPPEINER II, and D.E. HIBBS. 1988. Bigleaf maple seedling establishment and early growth in Douglas-fir forests. Canadian Journal of Forest Research 18:1226-1233.

MINORE, D., and J.C. ZASADA. 1990. Bigleaf maple. P. 33-40 *in* Silvics of North America, Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

NADKARNI, N.M. 1984. Biomass and mineral capital of epiphytes in an *Acer macrophyllum* community of a temperate moist coniferous forest, Olympic Peninsula, Washington State. Canadian Journal of Botany 62:2223-2228.

WOLLIN, A.C., and J.R. PFEIFFER. 1955. Oregon maple log and lumber grading. Oregon Forest Products Laboratory, State Board of Forestry and School of Forestry, Corvallis. Report No. G-4. 21 p.

Black cottonwood
Populus trichocarpa

Western cottonwood

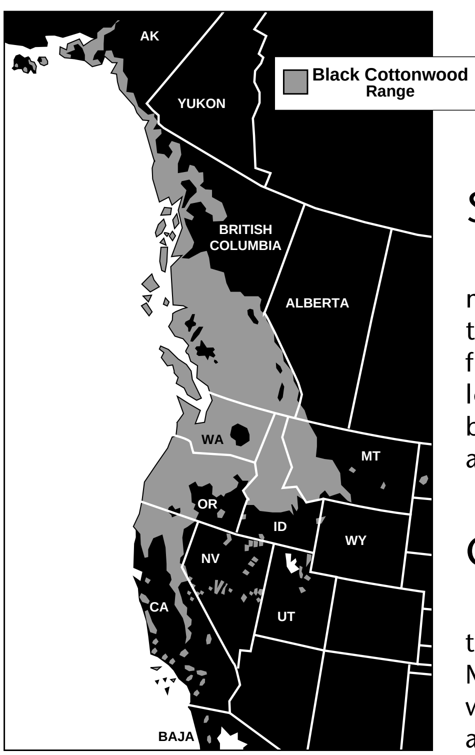
Balsam poplar

Balsam cottonwood

California poplar

General Characteristics

Black cottonwood is a large deciduous tree belonging to the willow family (Salicaceae). It is one of the largest of some 40 species of *Populus* and is the tallest, fastest-growing hardwood in the western United States. Cottonwood is a well-known, common tree along rivers and streams throughout the West.



Cultivation of hybrid poplars (*Populus trichocarpa* x. *P. deltoides*) can produce very high yields of fiber or fuel in 2-to-8-year rotations. Refer to the publication "High yield hybrid poplar plantations in the Pacific Northwest" for detailed information on plantation culture.

Size, Longevity, and Form

Mature cottonwoods attain heights of 125 to 150 ft (225 ft maximum) and diameters of 48 to 60 in. (108 in. maximum). Cottonwoods mature as early as 60 years and live at least 200 years. In forest stands, cottonwoods develop narrow, cylindrical crowns and long clear boles. Open-grown trees develop deep crowns with large branches, often on single, massive stems. Natural rooting habits are not well known; planted cuttings develop deep, spreading roots.

Geographic Range

Black cottonwood grows from Kodiak Island in Alaska (lat 62°N) to northern Baja California (lat 31°N), and eastward to the Rocky Mountains in Idaho, Montana, and Canada. In the Pacific Northwest, black cottonwood is most abundant in the Puget Sound basin and in the Columbia and Willamette river basins.

Timber Inventory

The largest inventory of black cottonwood is in Washington, where it is third in total volume after red alder and bigleaf maple (Appendix 1, Table 1). Sixty percent of the total volume (456 MMCF) of black cottonwood is found in the Puget Sound subregion. Most of the remaining volume is evenly distributed between the other regions in Washington and the Northwest subregion of Oregon.

Biology and Management

Tolerance, Crown Position

Black cottonwood is intolerant of shade. It typically maintains a dominant position in the canopy via superior growth rates. In pure stands, dominance is rapidly expressed and inferior trees die out quickly. Cottonwoods commonly occur in mixed stands as scattered, emergent trees, with crowns far above associated species.

Ecological Role

Black cottonwood is a pioneer species specifically adapted to colonizing and dominating areas disturbed by floodwaters. It is generally perpetuated in such environments by recurring floods. It also colonizes disturbed upland sites with adequate moisture. Without disturbance, cottonwood is replaced by other species on upland sites.

Associated Vegetation

Several species of willow are the major associates of black cottonwood on recent alluvium along most major rivers in the Northwest. These species include Pacific, river, northwest, and Scouler willows. Other common associates are red alder, Oregon ash, bigleaf maple, Douglas-fir, western redcedar, western hemlock, Sitka spruce, grand fir, birch, cherry, and hawthorn. Common shrubs include red osier dogwood, vine maple, hazel, salmonberry, elderberry, thimbleberry, honeysuckle, spirea, and snowberry. Herbaceous associates include western swordfern, ladyfern, horsetail, stinging nettle, hedge nettle, false Solomon's-seal, Canada violet buttercup, bittercress, angelica, enchanter’s-nightshade, golden-saxifrage, and bedstraw.

Suitability and Productivity of Sites

There are no guides for estimating site productivity for black cottonwood in Oregon and Washington. The British Columbia Forest Service has identified site-quality classes for natural cottonwood. Most of the interest in the productivity of managed stands is focused on the intensive cultivation of selected clones or hybrids, in which case productivity is quite dependent on the clone under specific conditions.

Climate

Throughout its wide range, black cottonwood grows in climates that vary from humid to arid. Cottonwood thrives in the humid climate of the coastal Northwest, although it grows along rivers in arid regions as well. In its range, annual precipitation can vary from 10 to 120 in., with about one-third falling during the growing season. Much of the precipitation may fall as snow. Temperatures range from a maximum of 60 to 117 °F to a minimum of -53 to 32 °F.

Young trees are susceptible to mortality or damage from early or late frosts. Frost cracks are common on larger trees. Stems and branches may bend or break under heavy snow or ice. Wind breakage is also common, and although their root systems are windfirm, erosion of river banks commonly topples trees.

Elevation

Black cottonwood grows from sea level to 6000 ft at the northern end of its range, to 5000 ft in the Cascade Range, and up to 7000 ft in interior mountains.

Soils

Black cottonwood grows best on deep alluvial soils with good aeration and abundant moisture. It is limited by high soil acidity, inadequate aeration, and low nutrient supplies. Although it is tolerant of winter flooding, it requires adequate drainage during the growing season. Some upland sites with deep, moist, and fertile soils are also productive for black cottonwood.

Flowering and Fruiting

Black cottonwood begins to produce seed at about 10 years of age. Male and female flowers (catkins) are borne on separate trees beginning in early March (or as late as mid-June in the north). Deciduous male catkins are 0.8 to 1.2 in. long; female catkins are 3 to 8 in. long when mature, and bear seed in capsulate fruits 0.2 to 0.32 in. long.

Seed

Black cottonwood seeds are minute, and are tufted with cottony hairs. Seed generally ripens in late May and June in the Northwest, and it is rapidly disseminated by wind and water. Viability is usually high, although it is often short-lived. Seed may remain viable for up to 1 year when dried and stored at cold temperatures.

Regeneration from Seed

Black cottonwood generally produces abundant crops of seed every year. Seedbeds must remain moist for up to 1 month for good germination and establishment. In much of the Northwest, these conditions are restricted to wet bottomlands. Cottonwood regeneration is common after logging on more upland sites in northern Washington.

Regeneration from Vegetative Sprouts

Black cottonwood sprouts readily from stumps or from buried fragments of branches. Repeated coppicing is quite successful. Regeneration also occurs from abcised shoots with green leaves, which root where they fall or are deposited by water.

Regeneration from Planting

Plantations of black cottonwood are easily established from rooted or unrooted cuttings, which allows complete control over genetic origin of stock. Successful plantings are established from unrooted cuttings of 1- to 2-year-old-wood that are 12 to 24 in. long and 0.4 to 1.2 in. in diameter. Branchwood cuttings from trees as old as 30 years have also done well. Cuttings are planted in spring to a depth of 12 to 16 in., with at least one leaf bud aboveground. Long cuttings of up to 10 ft have been used successfully in some cases; problems with inadequate rooting and poor stem form are common with long cuttings, however.

Site Preparation and Vegetation Management

Newly planted or establishing black cottonwoods are extremely sensitive to vegetative competition, particularly from grasses and herbs. Cottonwood often avoids competition from other species by establishing at high densities on new substrates and overwhelming any competing species. Complete site preparation and continued control of competing vegetation is essential for good performance in plantations. This is often accomplished with repeated mechanical cultivation and applications of herbicide.

Stand Management

Diameter growth of black cottonwood is very responsive to increased growing space. Management should target a spacing regime that produces optimal growth, while maintaining benefits of crowding in young cottonwood stands. Moderate crowding produces rapid crown closure (2 to 4 years), which suppresses competing vegetation and eliminates the need for further vegetation management treatments. For sawlog or veneer production, moderate crowding is necessary to maintain stem form, reduce branching and forking, and induce self-pruning. Typical spacings for pulpwood rotations are 6 X 6 ft to 7 X 10 ft, which accommodate tractors. Longer rotations require thinning to maintain diameter growth.

Mixed-species Stands

Black cottonwood must maintain a dominant crown position to survive and grow. To maintain other species with cottonwood, spacing and proportion of the super-dominant cottonwood must be controlled. A mixture of red alder and black cottonwood can improve the growth of cottonwood via nitrogen fixed by the red alder.

Growth and Yield

Height growth of black cottonwood often exceeds 5 ft per year for at least 10 years, and trees may reach diameters of 6 to 8 in. in that time. Various trial plantings indicate that annual yield rates from managed cottonwood can average 150 to 300 ft^3 per acre for up to 24 years. Pulpwood can be grown in 10 to 15 years and sawlogs in 20 to 25 years.

Interactions with Wildlife

Because of its large size and relatively long life, black cottonwood is a superior wildlife tree in riparian areas. Fungal decay is common in wood after weather damage to tops, producing good conditions for cavity-nesting birds. Raptors such as osprey frequently nest in cottonwood. Large trees that have toppled into streams provide structure for aquatic habitat.

Animals significantly hinder establishment of black cottonwood plantations. Voles and mice cause serious losses on grassy or herbaceous sites. Beaver are often within range, and remove many trees for dams and food. Elk and deer can devastate plantings with browsing and antler rubbing. Protection or prevention of damage may be necessary to avoid severe losses.

Insects and Diseases

Many insects feed on black cottonwood, but none have caused serious problems as yet. Fungal diseases are a significant threat. Decay fungi are common; two species are noted for significant damage in British Columbia, *Spongipellis delectans* and *Pholiota destruens*. A leaf rust (*Melampsora* sp.) causes significant problems with clones from dry areas that are planted in western Washington. *Cytospora* canker (*C. chrysosperma*) is common in natural forests and may be a threat to regeneration from cuttings.

Genetics

Black cottonwood has outstanding potential for genetic improvement and manipulation with superior clones and hybrids. Substantial natural genetic variation within the species facilitates the development of hybrids with a variety of characteristics. Currently, the best hybrids are those between selected strains of *P. trichocarpa* and *P. deltoides*, or strains of *P. maximawitzii* and *P. deltoides*.

Harvesting and Utilization

Cruising and Harvesting

Diameter at breast height and total height can be used with tables or equations to estimate total tree volumes in cubic feet and sawlog volume. Mechanized harvesting is quite suitable for typical plantations on agricultural lands (fiber farms). Harvesting of native black cottonwood may often be subject to restrictions for the protection of riparian zones.

Logs must be manufactured and delivered very soon after trees are felled. Black cottonwood is one of the least durable species when placed in contact with the soil or exposed to the weather. Logs left in damp conditions show signs of decay within a week or two.

Product Recovery

Most cottonwood is used for pulp and paper because of its softness, light color, and ease of bleaching. Black cottonwood has been successfully sawn into lumber and peeled for veneer. Demand for black cottonwood lumber is occasionally good. Lumber and veneer are often considered to be of relatively low quality and are used primarily for cores in plywood or interior furniture parts.

Wood Properties

Characteristics

Black cottonwood is a soft, light wood of uniform texture. The sapwood is almost white, and merges into the light grey or greyish-brown heartwood, which may contain dark streaks. The wood is considered semi-ring to diffuse porous. Vessels are moderately few to very numerous; pores are numerous, small, and barely visible to the naked eye. The growth rings are inconspicuous, and are differentiated by a thin grouping of pores, which gradually increase in density at the end of the growth increment. The rays are very fine and scarcely visible with a hand lens. The wood is straight-grained and odorless and tasteless when dry. When the wood is wet, it has a characteristic disagreeable odor.

Weight

Black cottonwood weighs about 46 lb/ft^3 when green and 24/ft^3 at 12 percent moisture content (MC). The average specific gravity is 0.32 (green) or 0.37 (ovendry).

Mechanical Properties

Black cottonwood is a weak wood that is rarely used in applications where high strength is required. Bending strength is classed as low, while in stiffness and toughness, black cottonwood is rated as intermediate. Because of its low density, cottonwood does not readily split during nailing. The nail-holding strength of the wood is low. In bending applications, almost 70 percent of the pieces failed. Despite these apparent shortcomings, cottonwoods show some potential as framing materials because their strength properties are comparable to those of currently used softwood species of similar densities. Appendix 1, Table 3 provides information on clear strength values, as well as comparative values for similar species.

Drying and Shrinkage

The most important consideration in drying cottonwood is recognizing its extremely high MC. Heartwood MC averages 162 percent, sapwood MC averages 146 percent. The high MC, however, does not cause an unnecessarily elongated schedule. Green 4/4 lumber can be dried in 8 to 12 days, and air-dried material can be dried in 4 to 8 days. Cottonwoods have a high tendency to warp during drying because of tension wood and wet pockets. Average shrinkage from green to ovendry is 3.6 percent radially and 8.6 percent tangentially. Table 2 provides a dry-kiln schedule appropriate for the indicated thicknesses.

Table 2. Kiln schedule—Black cottonwood* 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	above 70	140	130	12.0	75	60.0	54.5
2	70 to 60	140	126	10.0	66	60.0	52.0
3	60 to 50	140	120	8.0	55	60.0	49.0
4	50 to 40	140	105	4.9	31	60.0	40.5
5	40 to 30	140	90	2.9	15	60.0	32.0
6	30 to 25	150	100	3.2	18	65.5	37.5
7	25 to 20	160	110	3.4	21	71.0	43.5
8	20 to 15	170	120	3.5	24	76.5	49.0
9	15 to final	180	130	3.5	26	82.0	54.5

Equalize and condition as necessary.

*For wood with wet streaks, additional schedules are available.

Machining

Cottonwoods generally machine poorly. Surface roughness and torn grain result from planing and shaping; bore holes in cottonwood show considerable roughness and variation in size. The wood is subject to fuzzing and scratching when sanded, which contributes to problems in finishing. Tool wear and dulling is low because of the wood's low density. Best results in planing were obtained with a hook angle of 15°.

Adhesives

Cottonwood bonds easily with adhesives of a wide range of properties and under a wide range of gluing conditions. Weak joints are sometimes created if low-viscosity adhesives are used, or if glue spread are too low. This is because cottonwood absorbs the adhesive more readily than other hardwoods.

Finishing

Cottonwood is generally painted rather than clear-coated or stained in applications that require finishes. Cottonwood's paintability rating falls in the middle range when compared to other hardwoods. Its resistance to cupping and checking associated with outdoor exposure and weathering is very poor.

Durability

Black cottonwood is a nondurable species that will degrade rapidly if exposed to conditions favorable to decay organisms. Average service life of untreated cottonwood posts in ground contact is 4 to 5 years. Heartwood is classed as moderately difficult to penetrate with wood preservatives. The wood is moderately susceptible to sap stains and very susceptible to molds. Oxidative stains are sometimes present in cottonwood.

Uses

Cottonwood is used for veneer, pulp, pallets, interior case good parts, boxes, crates, moulding (painted), and studs.

Related Literature

BASSMAN, J.H., and J.C. ZWIER. 1993. Effect of partial defoliation on growth and carbon exchange of two clones of young *Populus trichocarpa* Torr. & Gray. Forest Science 39:419-431.

BOWERSOX, T.W., L.R. STOVER, C.H. STRAUSS, and P.R. BLANKENHORN. 1992. Advantages of an effective weed control program for *Populus* hybrids. Tree Planters Notes 43(3):81-86.

BRAATNE, J.H., T.M. HINCKLEY, and R.F. STETTLER. 1992. Influence of soil water on the physiological and morphological components of plant water balance in *Populus trichocarpa*, *Populus deltoides* and their F1 hybrids. Tree Physiology 11:325-339.

DeBELL, D.S. 1990. Black cottonwood. P. 570-576 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

HEILMAN, P.E., R.F. STETTLER, D.P. HANLEY, and R.W. CARKNER. 1990. High yield hybrid poplar plantations in the Pacific Northwest. Washington State Cooperative Extension; Oregon State University Extension Service; University of Idaho Cooperative Extension System; USDA, [Olympia, Washington]. Pacific Northwest Bulletin PNW 356.

HEILMAN, P.E., and F.G. XIE. 1993. Influence of nitrogen on growth and productivity of short-rotation *Populus trichocarpa* X *Populus deltoides* hybrids. Canadian Journal of Forest Research 23:1863-1869.

HSIANG, T., and G.A. CHASTAGNER. 1993. Variation in *Melampsora occidentalis* rust on poplars in the Pacific Northwest. Canadian Journal of Plant Pathology 15:175-181.

KELLOGG, R.M., and E.P. SWAN. 1986. Physical properties of black cottonwood and balsam poplar. Canadian Journal of Forest Research 16:491-496.

McLENNAN, D.S. 1990. Spatial variation in black cottonwood (*Populus trichocarpa*) foliar nutrient concentrations at seven alluvial sites in coastal British Columbia. Canadian Journal of Forest Research 20:1089-1097.

ROGERS, D.L., STETTLER, R.F., and P.E. HEILMAN. 1989. Genetic variation and productivity of *Populus trichocarpa* and its hybrids. III. Structure and pattern of variation in a 3-year field test. Canadian Journal of Forest Research 19:372-377.

SACHSSE, H. 1975. A comparative of important wood properties of the *Populus trichocarpa* cultivar "Senior." Mitteilungen. Verein fuer Forstliche Standortskunde und Forstpflanzenzuchtung 24:68-77.

CALIFORNIA BLACK OAK
QUERCUS KELLOGGII

BLACK OAK

KELLOGG OAK

General Characteristics

California black oak is a deciduous member of the beech family (Fagaceae). It is the most abundant oak on the West Coast and is most similar in form and wood quality to eastern red oaks.

Size, Longevity, and Form

Mature California black oaks (>90 years old) attain heights of 50 to 110 ft (130 ft maximum) and diameters of 14 to 40 in. (108 in. maximum), and may live 500 years. In closed stands on good sites, California black oaks develop narrow, thin crowns on straight, clear boles. Open-grown trees have broad crowns with multiple stems that fork repeatedly. A scrubby form of California black oak is common on marginal sites. The root system is usually composed of a surface root system and several deep vertical roots, which may spread laterally over bedrock; some roots penetrate cracks in the rock. Seedlings have a tap root.

Geographic Range

The native range of California black oak extends from Eugene, Oregon (lat 44°N), to the San Pedro de Martin Mountains of Baja California (lat 32°N). It grows in the valleys of southwestern Oregon and is abundant on the west side of the Sierra Nevada and in the northern and central Coast Range of California.

Timber Inventory

Among hardwoods on the West Coast, the inventory of California black oak (2662 MMCF) is second only to that of red alder. In the

Pacific Northwest, it is restricted to southwestern Oregon, with a total volume of 131 MMCF (Appendix 1, Table 1).

Biology and Management

Tolerance, Crown Position

California black oak is intolerant of shade for most of its life. Young seedlings can persist in the shade; saplings can survive as intermediate trees, growing tall and thin towards the light. California black oak will grow towards openings, leaning as much as 15 to 20 degrees. Older trees cannot survive continued overtopping.

Ecological Role

California black oak may function as a climax species in transitional environments between conifer forest and chaparral. Over much of the range, it is probably a persistent subclimax species maintained by resprouts after periodic fire. On better sites in the absence of disturbance, California black oak is eventually replaced by more shade-tolerant or competitive associates (tanoak, Douglas-fir, California white fir, pines). Under harsh conditions, conifer regeneration is often restricted to sheltered areas under black oak; the black oak serve as nurse trees.

Although fire kills trees of all ages, periodic fires probably have maintained California black oak populations in many areas. Populations appear to be declining after decades of fire suppression. Prescribed burns of moderate to low intensity are recommended to improve regeneration of California black oak from seed.

Associated Vegetation

California black oak is the dominant tree over large areas classified as the black oak forest type, and it is a major component in other forest types dominated by conifers. The most common tree species associated with California black oak are ponderosa pine, Douglas-fir, tanoak, Pacific madrone, and Oregon white oak. Common shrub associates include greenleaf manzanita, whiteleaf manzanita, deerbrush, bear-clover, oceanspray, and poison-oak. Understory vegetation is generally sparse under California black oak, although shrubs may become abundant and competitive after fire or cutting.

Suitability and Productivity of Sites

To evaluate site productivity for California black oak, site index should be estimated where possible, using methods described by Powers (1972). In general, good ponderosa pine sites in the range of California black oak are also good black oak sites. The presence of tanoak with California black oak is also an indicator of good productivity for black oak. Early growth of stump sprouts is often independent of site quality; thus, older trees should be used to assess productivity.

Climate

California black oak is adapted to a climate characterized by hot, dry summers and cool, moist winters. Its climate has an average annual precipitation range of 30 to 70 in., with extremes of 12 to 110 in. Less than 5 percent of this moisture falls from June to September. California black oak grows best in a zone where 10 to 50 percent of the precipitation occurs as snow. Mean daily temperatures in this climate range from a minimum of 31 to 46 °F in January to a maximum of 66 to 82 °F in July.

California black oak has a high tolerance to drought. Deep roots help it avoid drought; it also withstands high levels of moisture stress. Black oak leaves are injured by extreme heat after cool, wet weather. Planted seedlings are susceptible to dieback from late spring frosts. Branches and boles may break from heavy snow or ice, particularly at forks. Sound, healthy trees are windfirm.

Elevation

In Oregon, California black oak is found at elevations of 450 to 3000 ft. In California, it is most abundant at elevations of 1000 to 6000 ft in the north and 4000 to 7800 ft in the south. It is often restricted to north aspects at low elevations, and south to west aspects at high elevations. At middle elevations, it is found on all aspects.

Soils

California black oak grows best on deep, well-drained soils of medium to coarse texture. It is found on soils from a wide variety of parent materials across a wide range of textures. California black oak is often found on shallow, rocky soils, although its growth and form are poor. It seldom grows on clay soils, particularly clay topsoils. It does not tolerate poor drainage or flooding. California black oak may prefer relatively high levels of soil nutrients; fertilization greatly stimulates growth of seedlings in the wild.

Flowering and Fruiting

California black oak starts to produce seed as early as 30 years of age, but does not usually produce heavily before age 80. It flowers in spring, from mid-March to mid-May, depending on the environment. Separate male and female flowers are borne on the same plant. The greenish-red male flowers arise from leaf axils of the previous year, forming hairy aments 1.4 to 3.0 in. long. Female flowers emerge from leaf axils of the current year.

Seed

California black oak acorns mature during the second summer after pollination. The acorns are 0.7 to 1.7 in. long and 0.4 to 1.5 in. wide, and number from 52 to 147/lb. Acorns should be collected from late September to early November. The first acorns that fall (mid-August to mid-September) are usually infested with insects. Acorns should be collected soon after they fall to reduce losses in viability from extreme temperatures and losses to animals.

California black oak acorns require after-ripening and should either be planted immediately or stored under cool, moist conditions (33 to 34 °F) until spring planting. Germination capacity is quite variable, ranging from 21 to 95 percent; average rates were 31 to 38 percent in one large-scale test.

Natural Regeneration from Seed

Natural regeneration from seed is uncertain and poorly distributed. Establishment of seedlings is most frequent under parent trees. Animals transport many seeds and facilitate the occasional establishment of seedlings away from the parent tree. Seedlings establish best on undisturbed litter or loose, well-aerated mineral soil. California black oak does not usually colonize compacted or heavy clay surface soils. Seedlings rapidly develop deep taproots (to 30 in.) the first year; shoot growth remains slow for the first 6 or more years.

Regeneration from Vegetative Sprouts

Most regeneration of California black oak results from basal sprouts, which are profuse after cutting or burning. Larger parent trees produce more abundant and more vigorous sprouts than do smaller trees. Sprout development is best in completely open conditions; shelterwood cuttings are not recommended for regenerating black oak sprouts. Stumps should be cut low to the ground in order to produce more vigorous, well-formed sprouts.

Regeneration from Planting

The performance of California black oak planted on several sites in California indicates fair potential for regenerating black oak in plantations. Fertilization greatly enhances growth of planted trees. Drought and pocket gophers are the most common causes of mortality. Late spring frost causes top dieback; injured seedlings typically resprout.

Site Preparation and Vegetation Management

Little site preparation is necessary for establishing stands from sprouts. Regeneration and growth may be enhanced by burning or mechanically removing slash that shades stumps.

On California black oak sites, shrubs are often sparse and not competitive. If vegetative competition is significant on a site, however, vegetation management will benefit California black oak sprouts or seedlings. Seedlings are most vulnerable to competition. Site preparation and later control of competing vegetation may accelerate the typically long transition stage from seedling to sapling.

Stand Management

California black oak sprouts initiate at high densities, after which self-thinning and expression of dominance proceed rapidly. Thinning young sprout clumps after 4 years is probably not beneficial. Thinning in older stands can improve diameter growth (up to 2 times) while favoring better quality trees. Results of one thinning study indicate that optimum stand and tree growth may be maintained at stand densities of 100 to 125 ft^2 per acre. Thinning can increase the size and quality of epicormic branches. Density management strategies must be designed to minimize the impact of epicormic branches on wood quality. California black oak is best managed in even-aged stands or patches.

Mixed-species Stands

Top light must be maintained for good growth of California black oak in mixed stands. On good sites, associated tanoak and conifers may need to be controlled to maintain California black oak in the long term. Black oak may be used as a nurse tree to facilitate survival of conifer regeneration on low-elevation sites. Black oak is resistant to the annosus root rot (*Heterobasidion annosum*), which suggests a strategy of planting black oak in root-rot areas within conifer stands.

Growth and Yield

Seedlings grow slowly, reaching heights of 4 to 6 in. the first year, and often have slower shoot growth for 5 or more years while roots establish. Sprout growth averages about 2 ft per year for the first 10 years. Site index (50-year base) ranges from 30 to 70 ft, with an average of 50 ft. In natural stands, average diameter increment is about 1.8 in. per decade during the first 60 years, slowing to about 1.5 in. per decade by age 110.

California black oak stands in California average about 1213 ft^3 per acre, with maximum volumes of 4000 ft^3 per acre over 5 acres. One fully stocked stand of 70-year-old black oak had a volume of 5845 ft^3 per acre with an average diameter of 12 in. and height of 62 ft.

Interactions with Wildlife

California black oak acorns are an important food source for birds, rodents, deer, and bear. Fluctuations in deer populations are sometimes correlated with the acorn crop. Large, hollow trees are common and provide habitat for cavity-nesting animals. Foliage is browsed by deer and elk.

Insects and Diseases

Many species of insects live on California black oak, but they seldom have significant impact. The carpenter worm (*Prionoxystus robinae*) damages the wood of black oak; other insects causing damage include the pit scales (*Asterolecanium minus* and *A. quericola*), the Pacific oak twig girdler (*Agrilus angelicus*), the California oakworm (*Phryganidia californica*), and the fruit-tree leafroller (*Archips argyrospila*).

Heart rots (*Inonotus dryophilus* and *Laetiporus sulphureus*) cause significant damage in old trees and in trees injured by logging, fire, or weather. The shoestring root rot, *Armillaria ostoyae* (*A. mellea*) commonly attacks older trees. Black oak is resistant to the annosus root rot (*Heterobasidion annosum*), which kills many other species.

Genetics

California black oak hybridizes with *Q. agrifolia* (known as *Quercus x ganderi*) and with *Q. wislizenii* (known as *Quercus x moreha*). The latter hybrid is most common and has sparse evergreen foliage.

Harvesting and Utilization

Cruising and Harvesting

Diameter at breast height and total height can be used with tables or equations to estimate total tree volume in cubic feet and sawlog volume. California black oak trees have a tendency to split and “barber-chair” during felling so care must be taken in making the undercut and leaving holding wood.

Logs are generally weighed or sold by the truckload, and conversion factors are used to convert back into board foot volumes. The logs check easily during storage and should be end-coated to prevent splits in the lumber. Log grades have also been used to effectively separate logs of different product quality and are recommended for marketing.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 10 in. Smaller logs are chipped for pulp. Stain, discoloration, and end- and surface-checking are common problems with California black oak lumber if it is not processed within a short time after it is removed from the woods. One study found that 72 percent of the board-foot-scale was recovered as lumber; another study found that 60 percent of the weight is recovered as lumber products, 20 percent as slabs and edgings, and 20 percent as sawdust and shavings. The percentage of loss associated with edgings may be reduced if care is taken to prevent “over-edging” in the mill. Recovery of higher grade lumber from California black oak appears to be somewhat low compared to other hardwood species (Appendix 1, Table 2).

Wood Properties

Characteristics

The heartwood is light brown with pink to pale reddish-brown color; the sapwood is a pale yellowish-white to brownish-white. California black oak is a ring-porous wood, with earlywood pores that are large and distinct and form a conspicuous band with each growth ring. The latewood pores are small and numerous, and require a hand lens to view. The large earlywood vessels are almost always occluded by tyloses. Among the red oaks, California black oak has one of the lowest percentages of summer wood; for an oak, then, the wood is fairly fine-grained. The rays are numerous, short in height, and wide. When the wood is dry, it has no characteristic odor or taste. Distinctive burls are sometimes present. California black oak is commercially classed as a red oak in USDA Forest Service nomenclature.

Weight

California black oak weighs about 66 lb/ft^3 when green and 40 lb/ft^3 at 12 percent moisture content (MC). The average specific gravity is 0.51 (green) or 0.58 (ovendry).

Mechanical properties

Because of its lower specific gravity and lower percentages of summer wood, California black oak has lower clear-specimen strength values than many of the eastern red oaks. It still is an oak, however, and possesses many desirable strength properties, including parallel and perpendicular compression resistance, and side hardness. It is suitable for most furniture design applications, and the lower grades perform well as pallet stock. It holds nails well, but will split unless it is prebored or pneumatic nailers are used. See Appendix 1, Table 3 for average mechanical properties for small, clear specimens.

Drying and Shrinkage

California black oak requires special care and attention to detail during an extended kiln schedule to properly reduce MC to a level suitable for interior products such as flooring, furniture, or millwork. Drying defects can cause serious downgrade; end- and surface-checking result from uncontrolled or overly rapid drying; honeycomb, collapse, and ring failure occur from wetwood; iron stains form when tannins contact certain metals; and grey sapwood staining will result if there is poor air circulation. Additionally, the wood can be inhabited by bacteria, which will complicate drying but will not affect the quality of the final dry product. The green MC of California black oak averages 105 percent (ovendry basis). Shrinkage values for green to ovendry (based on the original green size) are low, and average 3.6 percent radially and

6.6 percent tangentially. It is suggested that all the upper grades be air-dried to 20 percent MC and then kiln-dried according to a time schedule (See Table 3 for the appropriate kiln schedule).

Table 3. Kiln schedule—California black oak 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 35	110	107	19.1	90	43.5	41.5
2	35 to 30	110	106	17.6	87	43.5	41.0
3	30 to 25	120	114	15.5	83	49.0	45.0
4	25 to 20	130	120	12.2	74	54.5	49.0
5	20 to 15	140	115	6.8	46	60.0	46.0
6	15 to final	160	110	3.4	21	71.0	43.5

Equalize and condition as necessary.

Machining

The machining characteristics of California black oak are excellent. Because of its moderate specific gravity and tight grain, the feed speeds of machines can be greater for California black oak than for most of the other oaks, but still produce quality surfaces when planing, shaping, turning, boring, and sanding. The wood can be successfully bent when it is properly steamed and bending forms are utilized.

Adhesives

California black oak bonds satisfactorily and there are no unusual problems when gluing conditions are well controlled. Careful curing/drying of glue joints is required to prevent sunken gluelines from subsequent machining.

Finishing

California black oak finishes well, although it may be necessary to fill the grain to obtain a smooth finish. The heartwood/sapwood color variation can present difficulties if uniform color is desired. Dyes and transparent stains are better than heavily pigmented stains, which require the removal of any excess pigment from the wood.

Durability

The heartwood of California black oak is basically nondurable when exposed to conditions that are favorable to wood decay organisms. Iron staining will occur if ferrous products contact wet wood. Oxidative staining can additionally degrade improperly handled logs and lumber.

Uses

Black oak has been successfully peeled into veneer and used in cabinet fronts. It is used for moulding, millwork, paneling, furniture, flooring, veneer, edge-glued panels, pallets, chips for landscaping, and firewood.

Related Literature

HALL, G., and R. ALLEN. 1981. Wood products from California oaks, Cal Oak Lumber Company style. P. 362-368 *in*: Proceedings of the Symposium on the Ecology, Management, and Utilization of California Oaks. T.R. Plumb, tech. coord. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-44.

KAUFFMAN, J.B., and R.E. MARTIN. 1987. Effects of fire and fire suppression on mortality and mode of reproduction of California black oak (*Quercus kelloggii* Newb.). P. 122-126 *in* Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources. T.R. Plumb and N.H. Pillsbury, tech. coords. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-100.

KOENIG, W.D., R.L. MUMME, W.J. CARMEN, and M.T. STANBACK. 1994. Acorn production by oaks in central coastal California: variation within and among years. Ecology 75:99-109.

MALCOLM, F.B. 1962. California black oak - a utilization study. USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. Report No. 2237. 10 p.

McDONALD, P.M. 1969. Silvical characteristics of California black oak (*Quercus kelloggii* Newb.) USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. PSW-53.

McDONALD, P.M. 1983. Local volume tables for Pacific madrone, tanoak, and California black oak in north-central California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-362. 6 p.

McDONALD, P.M. 1990. California black oak. P. 661-671 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

McDONALD, P.M., D. MINORE, and T. ATZET. 1983. Southwestern Oregon-northern California hardwoods. P. 29-32 *in* Silvicultural Systems for the Major Forest Types of the United States. R. Burns, tech. compil. USDA Forest Service, Washington, D.C. Agriculture Handbook 445.

PLUMB, T.R., and P.M. McDonald. 1981. Oak management in California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-54. 11 p.

POWELL, C. 1978. The California black oak: from saddle-soaped leather to pumpkin orange. Environment Southwest 481:3-50.

POWERS, R.F. 1972. Site index curves for unmanaged stands of California black oak. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-262. 5 p.

QUARLES, S.L. 1992. Acoustic emission associated with oak during drying. Wood and Fiber Science 24:2-12.

California-laurel
Umbellularia californica

Pacific-myrtle

Oregon-myrtle

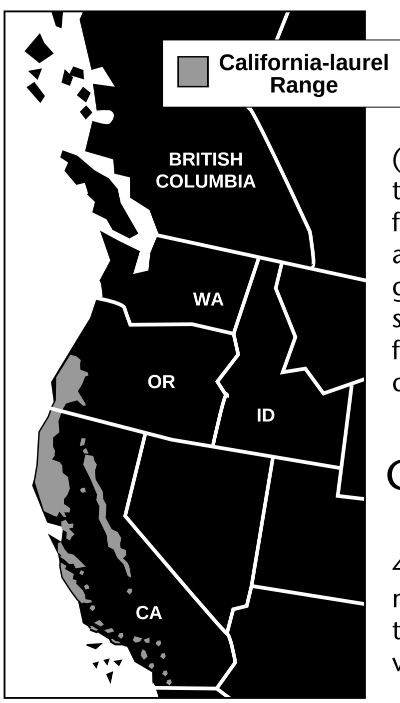
California-bay

Pepperwood

Spice-tree

General Characteristics

California-laurel is the only tree of the family Lauraceae found in the western United States. It is a broadleaved evergreen tree with distinctly aromatic "bay" leaves. Often referred to as myrtlewood, California-laurel is one of the best known and most valuable western hardwoods.



Size, Longevity, and Form

Typical California-laurels are 40 to 80 ft tall and 18 to 30 in. in diameter. On good bottomland sites, mature trees can attain diameters of 36 to 72 in. (159 in. maximum) and heights of over 100 ft (175 ft maximum). California-laurels may live at least 200 years. The trees often have forked or multiple stems with ascending branches, which form dense, round-topped crowns. In forest stands, the stems or limbs are relatively straight, vertical, and clear of smaller branches. Open-grown trees have broad spreading crowns (often wider than tree height) supported by several main stems or branches. The root system of California-laurel is wide and spreading, although it varies from shallow to deep, depending on the soil and drainage.

Geographic Range

The range of California-laurel extends from Reedsport, Oregon (lat 44°N) to San Diego, California (lat 33°N). It is not found more than 160 miles from the Pacific Coast. California-laurel is found in the Coast Ranges, the southwestern Cascade Range, and all along the western Sierra Nevada.

Timber Inventory

The total inventory of California-laurel is about 520 MMCF of growing stock, of which 93 MMCF occurs in southwestern Oregon (Appendix 1, Table 1, excluding federal lands in southwestern Oregon, for which there are no recent estimates). Many of the best trees are found in parks and riparian areas. According to some representatives of the myrtlewood industry, available supplies of the high-value, figured wood are getting scarce.

Biology and Management

Tolerance, Crown Position

California-laurel is intermediate in tolerance of shade. Seedlings establish and grow at low light levels (1 to 18 percent of full sun), and saplings and intermediate trees are common with coniferous overstories.

Ecological role

California-laurel can be a climax species, as it is long-lived and reproduces in the understory. A component of California-laurel is typically maintained by resprouting after fires in subclimax forests, which are most common outside of riparian areas. The leaf litter from California-laurel may have toxic effects on other vegetation; these toxic effects are a suspected cause for the typically sparse cover under California-laurel trees.

Associated Vegetation

On good sites, pure stands of California-laurel are generally restricted to small patches, while short or shrubby California-laurel often dominate more extensive areas. California-laurel is most commonly found in mixed stands; a great number of tree species are associated with laurel across its range. Common tree associates in the Pacific Northwest include red alder, cottonwood, willows, tanoak, Pacific madrone, wax myrtle, Oregon ash, Sitka spruce, Douglas-fir, Port-Orford-cedar, and redwood. Common shrub associates include salmonberry, evergreen huckleberry, red huckleberry, dewberry, snowberry, poison-oak, Pacific rhododendron, Oregon-grape, serviceberry, and honeysuckle.

Suitability and Productivity of Sites

The best conditions for growth of California-laurel occur on moist, protected bottomlands or lower slopes with deep soils. Large trees can develop under these conditions, even in otherwise hot and dry localities. California-laurel will establish and grow on a much wider range of sites, but it is limited to a shrubby or prostrate form on dry, rocky, or exposed sites.

The capability of a site for growing California-laurel should be evaluated by examining growth and form of older trees. Good growth potential is indicated by the following characteristics:

- Top height of at least 80 ft on mature trees, up to 150 ft on the best California-laurel sites
- Sustained height growth of 1 to 2 ft per year between ages 5 to 20 years
- Continuing diameter growth on mature trees.

Climate

California-laurel grows under conditions that range from the cool, humid climate of coastal forests to the hot, dry climates of the chaparral or interior woodlands. Within its range, annual precipitation varies from 13 to 83 in., with 0.7 to 17.0 in. falling from April to September. Temperature extremes are -13 to 118 °F, although a milder climate is more typical, with average minimums of 31 to 50 °F (January) and average maximums of 56 to 84 °F (July).

Moisture is the major factor limiting growth of California-laurel. Laurel will establish and grow in hot, dry regions but its distribution is more limited to moist microsites. Considerable damage and breakage of stems and branches is caused by snow and wind. Windthrow of laurel is common on wet soils. California-laurel crowns are commonly deformed in areas of frequent wind on coastal or ridge sites.

Elevation

Over most of its range, California-laurel grows at elevations from sea level to 4000 ft. At the southern limit of its range, it grows from 2000 to 5000 ft.

Soils

California-laurel grows on a wide variety of soils derived from alluvial, sedimentary, volcanic, or metamorphic parent materials. The best growth occurs on deep, well-watered, and well-drained soils, typically on alluvial benches, valley bottoms, and coastal slopes.

Flowering and Fruiting

Flowers may occur on stems as young as one year of age; abundant fruiting usually occurs after 30 to 40 years. Flower buds form during the fall before flowering, and flowers emerge before new leaves, beginning as early as November (far south) and continuing through late spring. Pale yellow flowers (perfect), about 0.6 in. in diameter grow in clusters (umbels) originating from leaf axils. The fruits are round drupes, which ripen in the first autumn after flowering, changing in color from green to yellow, brown, or purple when ripe.

Seed

Each fruit contains one nutlike seed (0.6 in. in diameter); there are about 300 seeds/lb of fruit. California-laurel seed may be collected from the ground during late fall and winter, although it should be collected soon after it falls to reduce losses in viability from exposure. Germination and seedling emergence occur in autumn, soon after seedfall or in late winter and spring.

Seed should be planted immediately or stored under cool, moist conditions (37 °F for up to 6 months) until spring planting. Germination of fresh seed may take up to 3 months; scarification or stratification can shorten this time to 2 months. Rates of germination are not affected by light; the highest rates occur with high humidity in moist, but not wet soil (moisture tension of -4 to -10 bar).

Regeneration from Seed

Abundant crops of seed are usually borne every year. Establishment from seed is best where seed is covered by soil, either from soil disturbance or from soil deposition after high water. Seedlings commonly establish and grow at low light levels (1 to 8 percent of full sun) under forest or brush canopies, although growth is increased with light levels that exceed 18 percent of full sun.

Regeneration from Vegetative Sprouts

California-laurel sprouts vigorously from the root collar or along the trunk with increased exposure to light. To promote development of better quality sprouts, stumps should be cut close to the ground.

Regeneration from Planting

Regeneration of California-laurel with planted seedlings has been rare. Seedlings typically develop a taproot and may be difficult to transplant unless they are grown in containers. Seedlings grow slowly for the first few years after transplanting. Under culture, seedlings appear to grow well across a range of temperature, moisture, and nutrient conditions.

Site Preparation and Vegetation Management

Little site preparation is necessary for establishing stands of sprout origin after forest clearing. Regeneration and growth are enhanced by burning or mechanically removing slash that shades stumps. Pre-established roots of the parent tree and rapid growth of sprout clumps make California-laurel a superior competitor in new stands. Rapid development of California-laurel cover at high densities of parent stumps will inhibit establishment and growth of competing species. With seedlings, or at lower densities of California-laurel sprouts, control of competing herbs and shrubs should improve the growth of young California-laurel stems.

Stand Management

There has been little management of California-laurel, and there is no available data from experimental treatments. As demonstrated for many other sprouting species, thinning dense clumps of California-laurel sprouts may be a viable method for selecting better stems and improving diameter growth. Care must be taken to avoid damage to residual trees during management activities, since California-laurel is easily invaded by wood decays. Given its strong tendency to form curved, multiple stems, maintenance of moderate and uniform stand density and evenly spaced stems may be needed to encourage straight, well-pruned stems.

Mixed-species Stands

There are many opportunities for growing California-laurel in mixed stands, as it readily establishes in the understory and may be grown in any crown position in even-aged or uneven-aged stands.

Growth and Yield

Initial growth of sprouts is rapid; seedlings develop more slowly in typical understory environments. Long-term height growth of California-laurel is slow (<1 ft per year) on many sites, but rates of 1 to 2 ft per year are possible on good sites. Diameters of 15 to 16 in. may be achieved in 50 years.

California-laurel (along with tanoak) has the highest net annual volume growth rates of any hardwood in California (3.5 percent per year). Average stand volumes for California-laurel forest types in California were 1677 ft^3 per acre with maximum volumes of 3125 ft^3 per acre. Almost half of the California-laurel stands in California exceed 100 ft^2 per acre of basal area.

Interactions with Wildlife

California-laurel provides food and cover for various animals. Seeds are an important food source for squirrels, woodrats, mice, and birds. Deer browse young shoots during the summer. Heart rot in larger trees often provides cavity nesting habitat.

Insects and Diseases

Old or scarred trees are commonly invaded by decay fungi, particularly the heart rot, *Ganoderma applanatum*. Decay is common around branch wounds and root collars. Occasional dieback of branches is caused by *Botryosphaeria* spp. A stem canker (*Nectria galligena*) is common on stems stressed by wind or snow. Although a variety of pathogens attack foliage, serious damage is rare.

Insects usually do not cause serious problems for California-laurel. The cottony cushion scale (*Icerya purchasi*) has been quite damaging in the past. Some oak bark beetles (*Pseudopityophthorus* spp.) will attack injured trees. Powderpost beetles (*Ptilinus basalis*) can cause serious damage to stored logs or lumber. A variety of insects consume foliage, although high concentrations of volatile compounds in California-laurel reduce the incidence of damage.

Genetics

There are some racial varieties of California-laurel, one of which is known for its distinctly pendulous branchelets (*Umbellularia californica* forma *pendula*).

Harvesting and Utilization

Cruising and Harvesting

Diameter at breast height and total height can be used with tables or equations to estimate total tree volume in cubic feet and sawlog volume. Log grades have not been developed. Premium prices may be paid for burls, butts, and logs 12 in. and larger in diameter.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 6 in. The relatively small volume of California-laurel that is harvested is fully utilized, and demand for California-laurel wood is high. Lumber grade recovery has not been studied.

Wood Properties

Characteristics

California-laurel is a moderately heavy, moderately hard wood with an even texture and a fine grain. The sapwood is whitish to light brown and typically thick. The heartwood is light brown or greyish-brown, frequently with darker streaks of pigment figure. The growth rings are distinct and can be delineated by a dark band of denser latewood. The wood is diffuse-porous, with evenly distributed, distant small pores that are barely visible to the naked eye. These pores are either solitary or in groups of two or three, and are encircled by a whitish sheath. The fine rays require a hand lens to see. When freshly cut, the wood has a very characteristic spicy odor, but its volatile oils impart no taste to the wood. Burls are sometimes produced and some of the wood has interlocked grain. When soaked in water, the wood darkens appreciably.

Weight

California-laurel weighs about 54 lb/ft^3 when green and 39 lb/ft^3 at 12 percent moisture content (MC). The average specific gravity is 0.51 (green) or 0.58 (ovendry).

Mechanical Properties

The strength properties of California-laurel are satisfactory for the typical uses and product applications. The wood has good resistance to indentation and splitting, but the wood has moderately low bending-strength properties. The wood holds nails and fasteners well, but holes should be prebored to prevent splitting. See Appendix 1, Table 3 for average mechanical properties of small, clear specimens.

Drying and Shrinkage

California-laurel is one of the western hardwoods that can be successfully kiln-dried when green, without first being airdried. A mild schedule is recommended to prevent surface checking and honeycomb. A suitable general schedule is shown in Table 4. End-checking from refractory wood can be a problem, so an appropriate end-coating should be applied. The green MC of the wood averages 70 percent. The shrinkage values indicate that California-laurel is a relatively stable wood; it has a radial shrinkage value of 2.8 percent (green to ovendry) and a tangential shrinkage value of 8.1 percent. For comparison, black cherry has values of 3.7 percent and 7.1 percent, respectively.

Table 4. Kiln schedule—California-laurel 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 30	120	113	14.4	80	49.0	45.0
2	30 to 25	130	120	12.2	74	54.5	49.0
3	25 to 20	140	125	9.6	64	60.0	51.5
4	20 to 15	150	125	6.8	49	65.5	51.5
5	15 to 10	180	140	4.5	36	82.0	60.0
6	10 to final	180	130	3.5	26	82.0	54.5

Equalize and condition as necessary.

Machining

California-laurel ranks very high in machinability for turning, boring, and mortising. In planing and shaping, however, chip-out difficulties arise because of the interlocked grain and the small burls sometimes present. It is advisable to consider saw-sized lumber and abrasive planing as alternatives to planer degrade. The fewest defects were obtained with hook angles of 20°. Finish sanding requires a generally fine grade of paper to avoid surface scratching.

Adhesives

California-laurel produces satisfactory glue bonds of good strength if conditions are well controlled.

Finishing

California-laurel is a very beautiful and distinctive wood when finished. It takes finishes well, without the need to fill the grain. Figured wood and burls are exceptionally attractive when clear-coated. The wood is generally not stained, but when color changes are desired, dyes and transparent stains are usually preferable to pigmented types. Thick surface coatings should be avoided.

Durability

California-laurel is a nondurable species that is susceptible to wood decay; it is not suitable where conditions are favorable to rot. It is also susceptible to powder-post beetle infestation and sap staining.

Uses

California-laurel is used for novelties and craft items, wooden ware, turnery, furniture, paneling, flooring, veneer, and gun stocks.

Related Literature

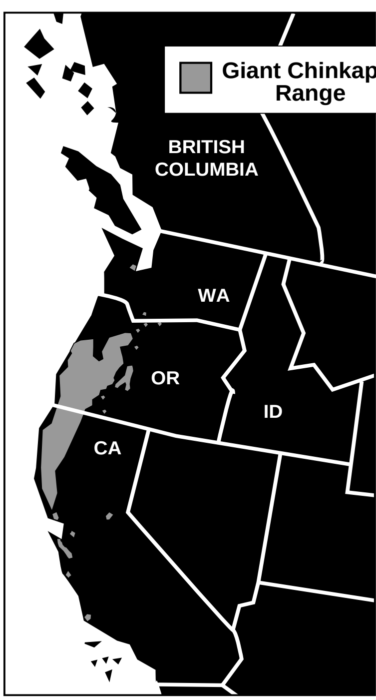
STEIN, W.L. 1990. California-laurel. P. 826-834 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington, D.C. Agriculture Handbook 654.

TINNIN, R.O., and L.A. KIRKPATRICK. 1985. The allelopathic influence of broadleaf trees and shrubs on seedlings of Douglas-fir. Forest Science 31:945-952.

GIANT CHINKAPIN
CASTANOPSIS CHRYSOPHYLLA

GOLDEN CHINKAPIN
GIANT EVERGREEN CHINKAPIN
CHINKAPIN
CHINQUAPIN
GOLDENLEAF CHESTNUT

General Characteristics



Giant chinkapin, an evergreen member of the beech family (Fagaceae), is the only tree-sized species of its genus found in the United States. Most of about 110 different species of *Castanopsis* occur in China, India, and Malaysia. With its dense, evergreen foliage (bright golden-yellow on the underside of the leaf) giant chinkapin is a distinctive, although minor, component of mixed-evergreen forests in western Oregon.

Size, Longevity, and Form

Mature giant chinkapin are typically 60 to 80 ft tall (150 ft maximum) and 12 to 30 in. in DBH (96 in. maximum). Chinkapin may live 400 to 500 years. In forest stands, giant chinkapin develops a dense, ovoid to conical crown on a straight, clear bole (50-70 percent of bole length). Chinkapin displays apical dominance even under open conditions. Open-grown trees develop a more spreading crown on a highly tapered bole. A shrub form of giant chinkapin is also common across the range of the species. Young giant chinkapins often develop a taproot, while older trees have a well-developed lateral root system.

Geographic Range

Giant chinkapin is native to the West Coast, from west-central Washington (lat 47°N) to central California (lat 35°N). The tree form of chinkapin is most common in the Coast and western Cascade ranges, from Lane County, Oregon to northern California.

Timber Inventory

The total volume of giant chinkapin in Oregon is about 86 MMCF (Appendix 1, Table 1) and is about equally divided between the West-Central and Southwest subregions. Another 50 MMCF occurs in the Northwest subregion of California. Most giant chinkapin in Washington are shrubs or small trees; their volume is negligible.

Biology and Management

Tolerance, Crown Position

The tree form of giant chinkapin is intermediate in tolerance. Chinkapins often occur in intermediate canopy positions, although they decline in vigor and may die after prolonged overtopping by associated conifers in older stands. Shrub forms of giant chinkapin are quite tolerant of shade and will persist in the understory.

Ecological Role

Giant chinkapin appears to be most competitive and persistent on droughty, infertile sites; this is where the oldest trees are usually found. Young chinkapins are also relatively aggressive and competitive during early succession on poor sites. Periodic disturbance (fire, logging, wind) may be required to maintain a component of giant chinkapin on better sites.

Associated Vegetation

Giant chinkapin rarely occurs in pure stands, but it is a minor component in many different forest types. Common associate trees are Douglas-fir, incense-cedar, sugar pine, Pacific madrone, tanoak, western white pine, western hemlock, white fir, ponderosa pine, California black oak, Port-Orford-cedar, canyon live oak, and knobcone pine. Common shrubs include Pacific rhododendron, salal, Oregon-grape, baldhip rose, dewberry, snowberry, oceanspray, hazel, poison-oak, manzanitas, modest whipplea, and prince's-pine.

Suitability and Productivity of Sites

Giant chinkapin can grow relatively well on harsh, droughty, or infertile sites. Good growth and development of chinkapin can be expected on better sites, but management may be required to maintain chinkapin among taller, more competitive associates. The capability of a site for growing chinkapin should be evaluated by examining growth and form of older trees. Good growth potential is indicated by the following characteristics:

- Top height of at least 60 ft on mature trees
- Sustained height growth of 1 to 2 ft per year for ages 10 to 30 years
- Continuing diameter growth on mature trees.

Climate

Giant chinkapin grows in a mild climate characterized by winter rain and summer drought, wherein annual precipitation ranges from 20 to 130 in., with very little falling from June to September. Snow is common at higher elevations over chinkapin's range, particularly in the Siskiyou Mountains and Oregon Cascade Range.

Judging from its superior competitiveness (relative to associated tree species) on harsh sites, giant chinkapin appears to have a high tolerance to extremes of heat, drought, and cold. The shrub form becomes more common under extreme climates.

Elevation

Chinkapin grows at elevations from sea level to 6000 ft.

Soils

The tree and shrub growth forms of giant chinkapin are found over a wide variety of soils derived from parent materials that include basalt, diorite, sediments, metasediments, and serpentine. The best development of giant chinkapin occurs on relatively deep soils that often have some nutrient deficiencies. The shrub form of chinkapin is predominant on shallow, rocky, droughty soils; the tree form is typically found on deeper soils and under more moderate moisture stresses.

Flowering and Fruiting

Trees of seedling origin produce sound seed at 40 to 50 years of age. Some fruiting occurs on younger stems; sprouts as young as 6 years old have produced seed.

Giant chinkapin is monoecious, and flowering usually begins in June or July. Male flowers form in dense catkins 1 to 3 in. long. From one to three female flowers develop within involucres either at the base of male flowers or separately on the stem. Flowers are pollinated by wind and perhaps by insects; chinkapin flowers are thought to impart a bad taste to honey.

The fruit is composed of one to three nuts within a spiny, golden-brown bur 0.6 to 1.0 in. across. Fruit ripens in the second autumn after pollination.

Seed

The seeds (nuts) are about 0.5 in. across and average about 830 to 1100/lb. Nuts are dispersed by gravity or by animals from September to December. Limited information indicates that germination rates are low

(14 to 53 percent) compared to other hardwoods. Germination is not increased by cold stratification; however, seed germinates in spring under natural conditions.

Regeneration from Seed

Little is known of requirements for natural regeneration of chinkapin. Partial shade and a light litter layer appear to favor seedling establishment. In northern California, establishment of seedlings was best on moist sites with sparse understory vegetation. Initial growth of seedlings is slow (6 to 18 in. after 4 to 12 years).

Regeneration from Vegetative Sprouts

Giant chinkapin produces vigorous basal sprouts after cutting, fire, or other injury. To promote development of better quality sprouts, stumps should be cut low to the ground.

Regeneration from Planting

There are no documented cases of regeneration of chinkapin from planted seedlings.

Site Preparation and Vegetation Management

Little site preparation is necessary for establishing stands of sprout origin. Sprout regeneration and growth may be enhanced by burning or by mechanically removing slash that shades giant chinkapin stumps.

Site-preparation treatments that leave some leaf mulch and partial protection (debris, vegetation) may be best for promoting establishment and growth of chinkapin from seed.

The response of giant chinkapin to control of competing vegetation has not been studied. Vegetation management may be required to maintain chinkapin on more fertile or moist sites where other tree species will eventually suppress it in the absence of disturbance (historically, fire).

Stand Management

Giant chinkapin sprouts initiate at high densities, after which self-thinning and expression of dominance proceed rapidly. As with tanoak, thinning young sprout clumps (at ages 3 to 10 years) is probably not effective because of the abundant resprouts.

There is no information specific to managing giant chinkapin. As for other sprouting hardwoods, it is probable that growth and quality of stems may be improved by thinning in older stands of chinkapin.

Mixed-species Stands

Giant chinkapin is most commonly found as a minor associate in mixture with conifers. Particularly on better sites, periodic disturbance (or management) is required to maintain a component of chinkapin. Under these conditions, maintenance of more open stand conditions can allow chinkapin to grow tall, relatively well-formed stems.

Growth and Yield

There is no information on volume growth within pure stands or patches of chinkapin. A chinkapin component of 1100 to 1500 ft^3 per acre comprised 11 to 21 percent of the total stand volume in 80-to-100-year-old stands of Douglas-fir (site class III to IV) in three sample stands in the Coast and Cascade ranges. Average DBH of chinkapin in these stands ranged from 7.8 to 13.4 in.

Interactions with Wildlife

There have been few studies of the specific importance of giant chinkapin to wildlife. Chinkapin nuts probably provide a nutritious food for various birds and mammals. Typical chinkapin in the understory of conifer forests provide structural canopy diversity, which can improve habitat for various animal species.

Insects and Diseases

Insects and pathogens seldom cause serious problems for chinkapin. Heart rot fungi, including *Phellinus igniarius*, commonly cause defect in old or injured stems.

Insects such as the filbertworm (*Melissopus latiferreanus*) can have significant impacts on chinkapin seed crops. One study found that nearly 100 percent of the seed crop had been attacked by insects on one of three study sites. The California oak-worm (*Phryganidia californica*), which causes serious defoliation of oak species, also attacks chinkapin and reduces its growth.

Genetics

The shrub and tree growth forms of giant chinkapin may be genetically distinct in some cases. There appear to be three ecotypes of chinkapin: the tree form common at lower elevations, a high-elevation shrub type adapted to cold temperatures and heavy snow, and a chapparal shrub adapted to dry sites. Some hybridization may also occur between giant chinkapin and evergreen chinkapin (*Castanopsis sempervirens*).

Harvest and Utilization

Cruising and Harvesting

Diameter at breast height and total height can be used with equations to estimate total tree volumes in cubic feet and sawlog volumes.

Log grades have been applied to giant chinkapin; there were large differences by log grade in the value of lumber recovered. Purchasers generally buy chinkapin as sawlogs (>10 in.) or pulp logs, without applying more detailed log grades.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 10 in.; smaller logs are chipped for pulp. One study indicates that recovery of No. 1 Common and Better grade green lumber from giant chinkapin compares favorably to other hardwoods; however, Select and Better lumber has much lower recovery than other hardwoods (Appendix 1, Table 2). The relatively small volume of chinkapin that is harvested is fully utilized, and demand for lumber is high.

Wood Properties

Characteristics

The wood of giant chinkapin is of moderately fine texture and is moderately hard and heavy. The thin sapwood is the same color or slightly lighter than the light brown, pinkish-tinged heartwood. It is a ring porous wood with large earlywood pores that are generally singular or, occasionally, in pairs. Emanating radially from the large earlywood pores are flame-shaped clusters of smaller latewood pores not readily visible to the naked eye. Still finer are the pores across the growth ring and between the flame-shaped patterns. The rays are very fine and are barely visible with a hand lens. When the wood is dry, there is no characteristic odor or taste.

Weight

Chinkapin weighs about 61 lb/ft^3 when green and 32 lb/ft^3 at 12 percent moisture content (MC). The average specific gravity is 0.42 (green) or 0.48 (ovendry).

Mechanical Properties

Because of its limited availability and its uniqueness, giant chinkapin is rarely used for building or structural applications. Instead, it is most often used for fine furniture or exceptional paneling. Giant chinkapin performs well in these applications, if the furniture is adequately designed. See Appendix 1, Table 3 for average mechanical properties of small, clear specimens.

Drying and Shrinkage

There are some distinct difficulties in kiln-drying green chinkapin. These, coupled with the uncommonness of this minor species, presently limit commercial availability. Much of the work on drying giant chinkapin was done before the mid-1950s, and indicated that chinkapin is subject to considerable collapse (excessive shrinkage in thickness) unless the wood is air-dried to below 20 percent MC before insertion into a kiln. Besides collapse, the defects of honeycomb and checking can be present. Table 5a shows a schedule for drying green, 4/4 giant chinkapin. This schedule should be considered experimental; the final quality of lumber produced by this schedule is not well demonstrated. In Table 5b, there is a schedule that could be used if the material is first air-dried to the recommended 20 percent. For chinkapin, average initial MC is reported to be 134 percent (ovendry basis). The radial shrinkage (green to ovendry) averages 4.6 percent; tangentially, shrinkage averages 7.4 percent.

Table 5a. Kiln schedule—Giant chinkapin 4/4 (green).

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 70	105	102	19.0	90	40.5	39.0
2	70 to 60	105	101	17.5	87	40.5	38.0
3	60 to 50	110	104	15.1	81	43.0	40.0
4	50 to 40	110	99	11.4	67	43.0	37.0
5	40 to 30	120	98	7.4	45	49.0	37.0
6	30 to 20	130	96	4.9	30	54.0	35.5
7	20 to final	180	135	3.8	30	82.0	57.0

Equalize and condition as necessary.

Table 5b. Kiln schedule—Giant chinkapin 4/4 (air-dried to <20%).

Step	Time (h)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	12	110	104	15.1	81	43.0	40.0
2	12	110	99	11.4	67	43.0	37.0
3	12	120	98	7.4	45	49.0	37.0
4	12	130	96	4.9	30	54.0	35.5
5	As needed to final MC	180	135	3.8	30	82.0	57.0

Equalize and condition as necessary.

Specific procedure for partially air-dried stock (less than 20 % MC)—Set the dry-bulb temperature at the value prescribed in Step 1. With the vents closed, add steam spray only as needed to keep the wet-bulb depression from exceeding 10 °F, but do not allow the depression to become less than 5 °F, or moisture will condense on the wood. After the prescribed dry-bulb temperature has been reached, run a minimum of 12 hours on each of the first four wet-bulb depression steps of the schedule (still allow for the minimum 5 °F wet-bulb depression limit during changes). Then adjust to the conditions prescribed for the moisture content of the controlling samples at the last step.

Machining

Giant chinkapin is a good wood for machining. It does not plane as well as the oaks or Pacific madrone, but there are fewer defects than with similar runs of walnut, red alder, and maple. Shaping and turning operations must be carefully controlled. Chinkapin sands well, with a minimum of both scratching and fuzzing.

Adhesives

Giant chinkapin bonds well with a wide variety of adhesives if conditions are moderately well controlled. The joint strength of chinkapin is considered to be excellent.

Finishing

From the limited literature on this subject, it appears that there are no apparent difficulties in staining or coating this wood. Its light brown color is very pleasant when clear-coated. Although filling is recommended for high-gloss finishes, the open grain characteristics of this wood allow for dramatic highlighting with glazes or lightly pigmented stains.

Durability

Information on the natural resistance of chinkapin to wood-decay organisms is very limited and conflicting. The heartwood is classified as nondurable in one source and "somewhat more than moderately durable" in another. Infestation with powder-post beetle (*Ptilinus basalis*) often occurs if the wood is stored improperly, and sap staining can affect its appearance.

Uses

Chinkapin is used for furniture, veneer, paneling, doors, and firewood.

Related Literature

HARRINGTON, T.B., J.C. TAPPEINER, II, and R. WARBINGTON. 1992. Predicting crown sizes and diameter distributions of tanoak, Pacific madrone, and giant chinkapin sprout clumps. Western Journal of Applied Forestry 7:103-108.

McDONALD, P.M., D. MINORE, and T. ATZET. 1983. Southwestern Oregon-northern California hardwoods. P. 29-32 *in* Silvicultural Systems for the Major Forest Types of the United States. R.M. Burns, tech compil., USDA Forest Service, Washington, DC. Agriculture Handbook 445.

McKEE, A. 1990. Giant chinkapin. P. 234-239 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

PRESTEMON, D.R., F.E. DICKINSON, and W.A. DOST. 1965. Chinkapin log grades and lumber yield. California Agriculture Experiment Station, Berkeley, California. California Forestry and Forest Products No. 42.

ROY, D.F. 1955. Hardwood sprout measurements in northwestern California. USDA Forest Service, California Forest and Range Experiment Station, Berkeley, California. Forest Research Note 95. 6 p.

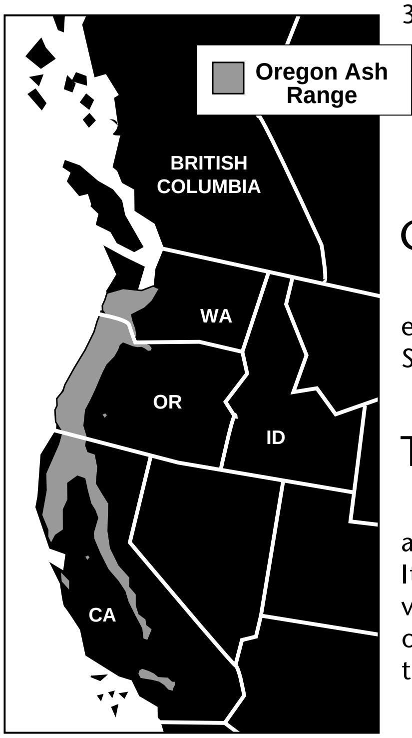
OREGON ASH
FRAXINUS LATIFOLIA

General Characteristics

Oregon ash, a member of the olive family (Oleaceae), is one of 16 species of ash in the United States. It is the only ash native to the Pacific Northwest.

Size, Longevity, and Form

Mature Oregon ash attain heights of 60 to 80 ft and DBH of 16 to 30 in. Ash may live at least 250 years. In forest stands, Oregon ash develop short, narrow crowns with small branches on long, straight boles. Open-grown trees have broad, rounded crowns with large limbs on short boles. The root system of ash is moderately shallow, wide-spreading, and densely fibrous.



Geographic Range

Oregon ash is native from northern Washington (lat 48°N) to southern California (lat 35°N) on the west side of the Cascade Range and the Sierra Nevada. It is most common in valleys and along rivers.

Timber Inventory

The total inventory of Oregon ash (about 184 MMCF) is scattered across all subregions of Oregon and Washington (Appendix 1, Table 1). It is most abundant in the Columbia Basin and tributary streams and valleys in northwestern Oregon and southwestern Washington. The availability of Oregon ash for timber harvest is significantly restricted by regulations governing forestry practices in riparian areas and wetlands.

Biology and Management

Tolerance, Crown Position

Oregon ash is intermediate in tolerance, and commonly occurs in intermediate or codominant crown positions. Young seedlings will grow in fairly dense shade. Overtopped trees of any age can respond to release with openings in the overstory.

Ecological Role

Oregon ash is a long-term dominant in riparian areas along slow streams and in other poorly drained areas subject to seasonal flooding. It may replace cottonwood on heavy soils and on swampy ground with poor drainage during the growing season. Oregon ash seedlings will also colonize wet areas in grasslands and abandoned fields.

Associated Vegetation

Tree species commonly associated with Oregon ash are black cottonwood, red alder, white alder, bigleaf maple, Oregon white oak, California-laurel, California sycamore, and various willows. Douglas-fir, grand fir, and ponderosa pine are associated with Oregon ash on the drier margin of typical ash sites. Understory vegetation is sparse under dense stands; sedges often dominate under ash. Common shrub associates include snowberry, hawthorn, serviceberry, mockorange, crabapple, and himalaya berry.

Suitability and Productivity of Sites

Oregon ash is particularly suited to heavy soils and poorly drained areas, which are often too wet for any other tree, including cottonwood. Ash may grow very well outside of such areas, although management may be required to maintain it. Growth and stem form are often quite poor on poorer sites; the suitability of sites should be evaluated before effort is invested in management of Oregon ash.

The capability of a site for growing Oregon ash should be evaluated by examining growth and form of older trees. Good growth potential is indicated by the following:

- Top height on mature trees of at least 60 ft
- Sustained height growth of 1 to 2 ft per year at ages 5 to 20 years
- Continuing diameter growth on mature trees.

Climate

Oregon ash thrives in a mild, humid climate characterized by relatively cool, humid summers and wet, mild winters. In this climate, annual precipitation ranges from 20 to 118 in., with very little rain in July and August; mean annual temperatures range from 46 to 54 °F.

The bottomlands where Oregon ash is most common provide a relatively cool, moist environment, even in hot interior valleys. Oregon ash has a fairly high tolerance to summer drought; however, it generally ceases growth and drops its leaves when conditions become hot and dry. Oregon ash that establish on drier sites often persist in a stunted, crooked form.

Elevation

Oregon ash usually grows at elevations from sea level to 3000 ft, although it may be found as high as 5000 ft.

Soils

Oregon ash typically grows on deep, poorly drained clays or silty clay loams that are rich in humus. It will also grow on sandy, rocky, and gravelly soils in riparian areas or areas with seasonal flooding. Oregon ash also grows on upland forest soils adjacent to more typical ash habitat.

Flowering and Fruiting

Oregon ash begins producing seed at about 30 years of age. Male and female flowers grow on separate plants. The greenish-white flowers (male and female) are borne in dense panicles, which appear at the base of new foliage in April or May. The fruits are oblong to elliptical samaras 1 to 2 in. long. They ripen in August or September, turning from green to light brown.

Seed

The winged seeds (10,000 to 14,000/lb) are dispersed by wind during September and October. Ash seeds can remain viable for more than one year; they usually require moist, cold stratification in order to germinate. Germination rates are medium to high.

Regeneration from Seed

Open-grown trees produce good seed crops almost every year. In forest stands, heavy crops of seed are produced every 3 to 5 years. Wet or moist soils high in organic matter provide the best conditions for germination and establishment of Oregon ash. Although many seeds are transported by flood waters, few seedlings establish from seeds deposited on sandy or gravelly stream beds. Seedlings commonly establish in the understory of existing riparian forests after floods that deposit silt. Ash seedlings also establish in wet grasslands or fields, particularly after disturbance such as plowing (in the absence of fire or grazing).

Regeneration from Vegetative Sprouts

Oregon ash sprouts vigorously from the root collar after cutting. Stumps should be cut low to the ground in order to produce well-formed sprouts of good quality.

Regeneration from Planting

The performance of Oregon ash has been poor to fair in limited outplanting trials. There are no known examples of operational forest plantations. Oregon ash is widely planted and does very well in ornamental applications, which indicates its potential for good performance in managed plantations.

Site Preparation and Vegetation Management

Little site preparation is necessary for establishing stands of sprout origin. Both mechanical and chemical treatment options may be limited on typical, wet Oregon ash sites. Although Oregon ash would probably benefit from control of competing vegetation on a site, established seedlings seem to grow well amidst substantial competition in old fields.

Stand Management

Oregon ash is not generally managed for timber production. Young ash trees grow fairly rapidly, but are commonly crooked or forked. Young stands are typically dense; early thinning to allocate stand growth to well-formed trees can improve stand quality. Older ash trees also respond to thinning; the diameter growth of crop trees doubled after crown-thinning in a dense, 45-year-old stand.

Mixed-species Stands

The shade tolerance of young Oregon ash trees and the ability of overtopped trees to respond to openings provide flexibility for management of ash in mixed species or age classes. Oregon ash are often mixed with cottonwood and bigleaf maple in bottomland forests, where flood waters maintain a variable disturbance regime. Management of these areas must integrate the range of growth rates, shade tolerance, and regeneration needs among associated species.

Growth and Yield

Growth of Oregon ash is moderately rapid for the first 60 years (1 to 2 ft per year). Thereafter, height growth is negligible and top height is relatively short (60 to 80 ft), although good diameter growth may continue. Early growth of stump sprouts is quite rapid (3 to 4 ft per year). There are few estimates of volume growth or yield for Oregon ash. Measurements in a pure stand of 45-year-old Oregon ash showed an average height of 70 ft and basal area of 140 to 160 ft^2 per acre, which yield approximate volumes of 3200 to 3800 ft^3 per acre. Annual growth was about 70 ft^3 per acre in both lightly thinned and unthinned stands.

Interactions with Wildlife

Ribbonlike forests of Oregon ash along streams and sloughs provide an important forest habitat in valleys that are otherwise cultivated farm or pasture. Oregon ash provide food and habitat for beaver and nutria, which also significantly damage the trees. Deer and elk also browse Oregon ash seedlings and stump sprouts.

Insects and Diseases

Weevils (*Thysanocnemis* spp.) destroy significant amounts of seed (up to 60 percent). Various other insects feed on twigs and foliage and may be pests in ornamental plantings. A variety of fungi cause leaf spot and powdery mildew. True mistletoe grows on Oregon ash. A heart rot causes extensive defect in older trees, and hollow "stovepipe" ash are prevalent in some stands.

Genetics

Some of the stand-to-stand variation in the form of Oregon ash may have a genetic basis. There are no recognized varieties of Oregon ash, although it may hybridize with velvet ash (*F. velutina*) in the southern Sierra Nevada.

Harvesting and Utilization

Cruising and Harvesting

There are no equations or tables for calculating tree volume. Log grades have not been developed. Premium prices may be paid for logs 12 in. and larger. Harvesting of Oregon ash may often be subject to restrictions for protection of riparian zones or wetlands.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 6 in. The relatively small volume of sawlogs that are harvested are fully utilized, demand for lumber is relatively high. Lumber grade recovery has not been studied.

Wood Properties

Characteristics

The wood of Oregon ash is moderately hard and heavy, with distinct growth rings. The sapwood is nearly white and is wide. The heartwood is a yellowish-brown, with a slight greyish cast. The wood is somewhat lustrous. It has no characteristic odor or taste. Oregon ash wood is ring porous; the earlywood vessels are large, forming a band that is 2 to 4 pores in width and distinctly visible to the naked eye. The transition to latewood is abrupt. Latewood pores are small, barely visible to the naked eye. The variability between earlywood and latewood is especially apparent on flat-sawn surfaces, where the denser latewood markedly contrasts with the porous, grainy earlywood. Rays are not easy to distinguish with the naked eye.

Weight

Oregon ash weighs about 48 lb/ft^3 when green and 38 lb/ft^3 at 12 percent moisture content (MC). The average specific gravity is 0.50 (green) or 0.55 (ovendry).

Mechanical Properties

Because Oregon ash is moderately hard and heavy, it is rated intermediate in bending strength and stiffness. Its impact resistance, however, is rated as high. Its hardness and compressive strength is good; thus it is well suited for most furniture, paneling, or flooring applications. Nail and screw splitting are less problematic than with other, more dense woods such as oak. The nail-holding ability of Oregon ash is good. Appendix 1, Table 3 provides information on clear strength values for Oregon ash, as well as comparative values of other species.

Drying and Shrinkage

Under moderately controlled conditions, Oregon ash dries rapidly and with minimal degrade. Drying defects are most often associated with wetwood, or are caused by uncontrolled air-drying, which results in surface- and end-checking. Sapstains and sticker stains can also degrade the wood. Green MC of Oregon ash wood averages 49 percent. Shrinkage values for Oregon ash dried from green to ovendry are 4.1 percent radially and 8.1 percent tangentially. These values are similar to other ash species. Table 6 provides an appropriate dry-kiln schedule. For thicker stock, contact the Forest Product Department at OSU for additional schedules.

Table 6. Kiln schedule—Oregon ash 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 35	130	123	14.3	81	54.5	50.5
2	35 to 30	130	120	12.2	74	54.5	49.0
3	30 to 25	140	125	9.6	64	60.0	51.5
4	25 to 20	150	125	6.8	49	65.5	51.5
5	20 to 15	160	120	4.5	31	71.0	49.0
6	15 to final	180	130	3.5	26	82.0	54.5

Equalize and condition as necessary.

Machining

Oregon ash machines without much difficulty. It planes and shapes favorably; ash is comparable to bigleaf maple in shaping qualities, and slightly below the oaks in planing qualities. It turns well and, when holes are bored in ash, the holes are smooth with minimal size variation. Fuzzing from sanding is rare, although surface scratching can be apparent, especially on the latewood parts of flat-sawn boards. The best results in planing are obtained with tooling that has a 25° hook angle. Tool wear is moderate.

Adhesives

Oregon ash bonds satisfactorily and there are no unusual problems when conditions are well controlled. Because of its light color, the glue line can be visible on sapwood if darker resins are used.

Finishing

The natural luster of Oregon ash is enhanced with clear finishes or transparent dyes. The earlywood vessels may require filling to minimize surface texture. Heavily pigmented stains tend to darken the more porous earlywood without penetrating the denser latewood. Color variation between sapwood and heartwood can present problems if a uniform color is desired. Surface scratching in the dense latewood can sometimes be a problem.

Durability

Oregon ash is a nondurable species that is susceptible to wood decay. Untreated posts of this wood average only 6 years of service before failing. Heartwood of ash species is considered easily penetrated with preservative solutions. The wood is subject to attack by powder post beetle (*Ptilinus basalis*) and is moderately susceptible to sapstain, mold, and iron stain.

Uses

Oregon ash is used for furniture, cabinets, paneling, veneer, tool handles, flooring, millwork, pallets, crates, boxes, and firewood.

Related Literature

FRENKEL, R.E., and E.F. HEINITZ. 1987. Composition and structure of Oregon ash (*Fraxinus latifolia*) forest in William L. Finley National Wildlife Refuge, Oregon. Northwest Science 61:203-212.

HIBBS, D.E., and G.R. AHRENS. Unpublished data. Forest Science Department, Oregon State University, Corvallis.

OWSTON, P.W. 1990. Oregon ash. P. 339-343 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

Oregon white oak
Quercus garryana

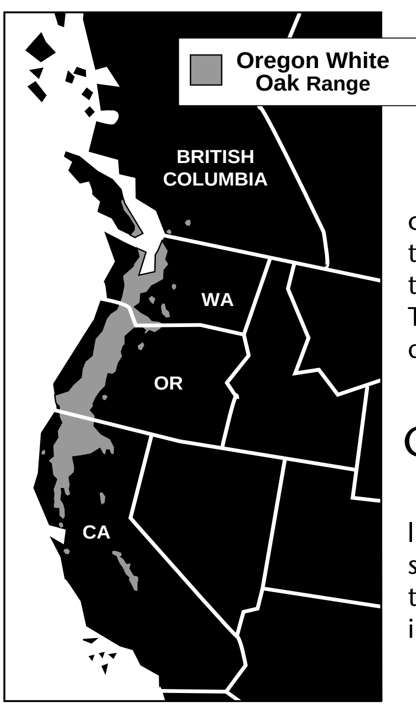
Garry oak

Oregon oak

Brewer oak

General Characteristics

Oregon white oak, a member of the beech family (Fagaceae), is one of only four deciduous oaks native to the West Coast. The massive, branching trunks and broad crowns of old white oaks are characteristic features of valley woodlands in the Pacific Northwest.



Size, Longevity, and Form

Mature Oregon white oaks are 50 to 90 ft tall (120 ft maximum) and 24 to 40 in. in DBH (97 in. maximum). Oregon white oaks may live 500 years. In forest stands on good sites, Oregon white oaks develop narrow crowns with small branches on straight, clear stems. In more open stands and on poor sites, boles are typically short and crooked; shrubby stands of stunted trees are common. Open-grown trees develop very broad, rounded crowns (crown width may equal total height) with massive, crooked branches on short, massive boles. The root system of this species is composed of a deep taproot and well-developed laterals.

Geographic Range

Oregon white oak has a wide latitudinal range from Vancouver Island (lat 49°N) to southern California (lat 34°N), although it takes on a shrub form toward the southern end of this range. It is well distributed throughout the valleys west of the Cascade Range and Sierra Nevada on inland slopes of the Coast ranges.

Timber Inventory

A substantial inventory of Oregon white oak (450 MMCF) is distributed throughout western Oregon and northwestern California. A much smaller volume (13 MMCF) occurs in western Washington (Appendix 1, Table 1).

Biology and Management

Tolerance, Crown Position

Oregon white oak is generally intolerant, although this depends on the environment and associated vegetation. Sparse development of branches in closed stands indicates intolerance to shade. Although it can reproduce in its own shade, Oregon white oak will die after overtopping by Douglas-fir.

Ecological Role

Oregon white oak is a persistent climax or sub-climax species on dry sites or under regimes of periodic fire. Large oaks have thick bark and are resistant to fire. Smaller trees are generally killed or badly injured by fire. Oregon white oak is an early successional species on better sites, where it is replaced by Douglas-fir and bigleaf maple in the absence of fire. Historically, periodic fires were a major factor maintaining Oregon white oak woodlands. After a century of fire exclusion, many acres have progressed from open Oregon white oak, to closed white oak, to Douglas-fir. Fire prevention is probably causing continued decline in the extent of Oregon white oak type forests. The white oak type will continue to diminish without periodic fire.

Associated Vegetation

Many distinct Oregon white oak associations are recognized. Common associate trees of Oregon white oak are Douglas-fir, grand fir, ponderosa pine, bigleaf maple, Pacific madrone, California black oak, Oregon ash, and cherry. Common shrubs include hazel, hawthorn, snowberry, serviceberry, poison-oak, wild rose, and oceanspray. Herbaceous associates include many different grasses, western swordfern, western bracken, wild strawberry, bedstraw, and sweetroot. A great variety of other plant species grow with Oregon white oak in other forest types.

Suitability and Productivity of Sites

Oregon white oak is particularly suited to exposed, droughty sites at the margins of more productive forest land. It is also well suited for areas near rivers that are very wet in winter but droughty in the summer. Oregon white oak will grow well on better sites, but requires management to persist among more competitive Douglas-fir and maple.

The capability of a site for growing Oregon white oak should be evaluated by examining growth and form of older trees. Good potential for growth of this species is indicated by the following site characteristics:

- Top height on mature trees of at least 60 ft
- Sustained height growth of 1 to 2 ft per year for trees 10 to 30 years old
- Continuing diameter growth on mature trees.

Climate

Oregon white oak grows across a diverse range of climates, most of which have moderate to extreme summer drought and annual precipitation of 10 to 100 in. Within its range, mean daily temperatures may vary from lows of 13 to 50 °F in January to highs of 60 to 84 °F in July.

Oregon white oaks are well adapted to hot, dry conditions. With adequate moisture early in the season, relatively large trees may develop on sites where severe summer drought limits other species. Extensive stands of small, shrubby white oak, often mixed with Pacific madrone, grow on sites that are often too dry to support any other tree species.

Of the western hardwoods, Oregon white oak is one of the most resistant to damage from ice and snow. Twigs and buds have moderate resistance to cold injury. Healthy Oregon white oak are not prone to windthrow or breakage.

Elevation

Oregon white oak is usually found at lower elevations in the interior valleys. It grows from sea level to 3800 ft in the north and at elevations of up to 7500 ft at the southern end of its range.

Soils

While common on droughty soils, Oregon white oak is also competitive on soils that are poorly drained during the wet season and droughty during the summer. This commonly occurs on heavy clays, coarse-textured flood plains, and river terraces in the interior valleys. Oregon ash is also common under these conditions.

Flowering and Fruiting

The age at which Oregon white oak first produces seed has not been determined. Oregon white oak flowers appear with new foliage in spring. Oregon white oak usually flowers later than common associates, in March in the south, and June in the north. Separate male and female flowers grow on the same tree. Male flowers (greenish-yellow catkins) emerge from existing buds and at the base of new shoots, expanding to a size of 1.2 to 3.9 in. when fully developed. Small, red female flowers appear in the axils of new leaves. The acorns ripen from August to November during the first season after flowering.

Seed

Oregon white oak has large acorns, which are about 1.2 in. long and half as wide, and average 85 seeds/lb. Acorns should be collected from September to November. They must be kept cool and moist until germination. Although germination usually occurs in spring, seeds will germinate soon after dispersal under warm, moist conditions; they also germinate prematurely in cool, moist storage. As with other Oregon white oaks, sowing seeds in the fall may be best. Limited tests indicate rates of viability that are greater than 75 percent. Seeds remain viable for only one season.

Regeneration from Seed

Natural regeneration from seed is often quite good where there has been soil disturbance, particularly in the absence of fire or grazing. Seedlings rapidly develop a deep taproot, which may account for their ability to establish in grass and in droughty soils. The shoot of natural seedlings often remains small and shrubby for many years, perhaps to accommodate development of deep roots. This is followed by a sapling stage with relatively rapid growth. Regeneration from seed is greatly improved when seeds are protected from rodents and other predators.

Regeneration from Vegetative Sprouts

Oregon white oak sprouts vigorously after cutting or fire. Sprouts arise from dormant buds at the root collar and along the trunk. Both the vigor and the abundance of sprouts increase as the size of the parent tree increases. Stumps should be cut low to the ground in order to produce well-formed sprouts of good quality.

Regeneration from Planting

Nursery culture of Oregon white oak is relatively easy. Experience with other white oaks indicates that with vigorous nursery stock, Oregon white oak has good potential for management in plantations. Performance of Oregon white oak has been poor to fair in limited outplanting trials, however. There are no known examples of operational forest plantations.

Site Preparation and Vegetation Management

Cultivated seedlings of Oregon white oak grow rapidly and do not display the prolonged shrub stage observed for many wild seedlings.

This suggests that site preparation and control of competition from grasses and shrubs could greatly improve growth of Oregon white oak seedlings in the field.

Stand Management

Oregon white oak has not been extensively managed for timber production. It shows good potential for management in closed, even-aged stands, as indicated by the relatively good stand growth and high stem quality in closed stands established after the exclusion of fire. Thinning in dense, sapling-sized stands can increase diameter growth.

Mixed-species Stands

Competitive associates such as Douglas-fir and bigleaf maple must be controlled to maintain Oregon white oak on better sites.

Growth and Yield

Growth of Oregon white oak is generally slow. Height growth is usually less than 1 ft per year and diameter growth is often 15 to 20 rings/in. Faster growth, particularly in diameter, is possible (3 to 10 rings/in.). Stump sprouts may grow as much as 3 ft per year during the first 3 years. Oregon white oak stands may achieve basal area of up to 265 ft^2 per acre and volume as high as 4500 ft^3 per acre.

Interactions with Wildlife

Oregon white oak trees and stands are very important for wildlife. Oak woodlands and forests provide food and habitat for many species. Two of note are the acorn woodpecker and Merriam's wild turkey. Diversity of bird species is often higher in oak forests than in adjacent conifer forests. Both acorns and foliage provide high-protein food for many animals.

Insects and Diseases

Filbertworm (*Melissopus latiferreanus*) and filbert weevils (*Curculio occidentalis*) attack acorns of Oregon white oak. Hundreds of other insect species live on Oregon white oaks, although few cause significant damage. The most damaging insect is the western oak looper (*Lambdina fiscellaria somniaria*), which can defoliate trees over large areas; tent caterpillars also have a preference for oak. Gall wasps are common on Oregon white oak. Noticeable damage is often inflicted on oak by *Bassettia ligni*, which girdles and kills branches.

Numerous pathogens attack Oregon white oak. The hairy mistletoe is widespread. Shoestring root rot, *Armillaria ostoyae* (*A. mellea*), and white pocket root and butt rot (*Polyporus dryophilus*) cause significant damage. One episode of anthracnose disease (*Gnomonia quericina*) appeared to cause significant damage in Washington in 1968.

Genetics

Oregon white oak hybridizes with four other oaks in California. There is relatively little genetic variation within the species, despite its wide latitudinal range.

Harvesting and Utilization

Cruising and Harvesting

Diameter at breast height and total height can be used with tables or equations to estimate total tree volume in cubic feet and sawlog volume. Log or tree grades are not used for Oregon white oak; however, recent studies have shown that there are differences in the value of lumber that can be recovered from each of the log grades. Log grades developed for eastern hardwoods may be a useful marketing tool in the future. Oregon white oak logs check easily during storage and should be end-coated to prevent splits.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 8 in., smaller logs are chipped for pulp. Rot, checks, and cross-grain have been problems in the lumber.

There is increasing interest in using Oregon white oak for cooperage for wine barrels, flooring, and chairs. It has been used for pulp and is frequently used for firewood.

Wood Properties

Characteristics

Oregon white oak is a hard, heavy wood that has distinct growth rings and very prominent rays. The sapwood is whitish to light brown; the heartwood is a pale, yellowish, grey-brown, often with a slight greenish cast. The dry wood is has no characteristic odor or taste. Oregon white oak is ring porous; the earlywood pores are large and distinct, forming a conspicuous band with each growth ring. The latewood pores are small and numerous, and require a hand lens to view. Rays are of two types, broad and narrow. The broad rays are readily visible to the naked eye and are separated by several to many narrow rays. When oaks are quartersawn, these rays appear as a pronounced fleck. The earlywood pores are plugged with a membranous growth known as tyloses, which makes the wood impenetrable to fluids. For commercial purposes, Oregon white oak is classed with the other white oaks in USDA Forest Service nomenclature.

Weight

Oregon white oak weighs about 69 lb/ft^3 when green and 50 lb/ft^3 at 12 percent moisture content (MC). The average specific gravity is 0.72 (green) or 0.75 (ovendry).

Mechanical Properties

The wood of Oregon white oak has exceptional strength properties and is noted for its hardness, toughness, resiliency, and resistance to abrasion. It holds nails well, but, because of its density and hardness, will split without preboring. See Appendix 1, Table 3 for average mechanical properties for small clear specimens.

Drying and Shrinkage

Oregon white oak requires special care and attention to detail during an extended kiln schedule to properly reduce MC to a level suitable for interior products such as flooring, furniture, or millwork. Drying defects can cause serious downgrade. End- and surface-checking result from uncontrolled or overly rapid drying; honeycomb, collapse, and ring failure occur because of wetwood. Iron stains form when tannins contact certain metals, and grey sapwood staining will result if there is poor air circulation. Green MC of the wood is generally 67 to 72 percent (ovendry). Shrinkage values for green to ovendry (based on the original green size) average 4.2 percent radially and 9.0 percent tangentially. It is suggested that all the upper grades be air-dried to 20 percent MC and then kiln-dried according to a time schedule (See Table 7 for the appropriate kiln schedule).

Table 7. Kiln schedule—Oregon white oak 4/4, 5/4, 6/4, 8/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 35	110	107	19.1	90	43.5	41.5
2	35 to 30	110	106	17.6	87	43.5	41.0
3	30 to 25	120	114	15.5	83	49.0	45.0
4	25 to 20	130	120	12.2	74	54.5	49.0
5	20 to 15	140	115	6.8	46	60.0	46.0
6	15 to final	160	110	3.4	21	71.0	43.5

Equalize and condition as necessary.

Machining

Species in the white oak group, including Oregon white oak, generally machine well. They plane well (87 percent defect-free pieces), turn well (85 percent defect-free) and yield accurately sized, smooth-sided holes when bored and mortised. White oaks also bend exceptionally well after steaming. On white oak, sanding produces a smooth, relatively scratch-free surface with little or no fuzzing. The hardness, tannin content, and density of these woods cause considerable tool dulling and sandpaper wear. It is recommended that saws and other tools have hook angles of 15 to 20° and sharpness angles of 55° for optimum performance on white oaks. Care should be taken not to overfeed this wood or attempt to remove too much stock at once because machine burn or surface roughness may result.

Adhesives

Oregon white oak bonds satisfactorily, and there are no unusual problems when gluing conditions are well controlled. Careful curing/drying of glue joints is required to prevent sunken gluelines from subsequent machining.

Finishing

All white oaks finish well, although it may be necessary to fill the grain. White oaks color best with dyes or transparent stains, especially if dramatic color changes are sought. Heavily pigmented stains can also be used if care is taken to remove excess pigment from the wood.

Durability

Oregon white oak heartwood is classified as resistant to decay. In tests conducted by staff of the OSU Forest Products Department, untreated fence posts lasted an average of 18 years before failure. The sapwood has no decay resistance and will deteriorate rapidly. Iron stain and oxidative stain sometimes occur on Oregon white oak.

Uses

Oregon white oak is used for furniture, flooring, railroad ties, tight cooperage, turnings, veneer (sliced), millwork, fence posts, mine timbers, handles, boxes, crates, pallets, caskets, pulp chips, and fuelwood.

Related Literature

COBLENTZ, B.E. 1980. Production of Oregon white oak *Quercus garryana* acorns in the Willamette Valley, Oregon utilization by deer. Wildlife Society, Bulletin 8:348-350.

EVANS, D. 1972. Alternate generations of gall cynipids (Hymenoptera:Cynipidae) on Garry oak. Canadian Entomologist 104:1805-1818.

GUMTOW-FARRIOR, D.L., and C.M. GUMTOW-FARRIOR. 1992. Managing Oregon white oak communities for wildlife in Oregon's Willamette Valley: a problem analysis. Unpublished report prepared for the Oregon Department of Fish and Wildlife Nongame Program.

HIBBS, D.E., and B.J. YODER. 1993. Development of Oregon white oak seedlings. Northwest Science 67:30-36.

McDONALD, P.M., D. MINORE, and T. ATZET. 1983. Southwestern Oregon-northern California hardwoods. P. 29-32 *in* Silvicultural Systems for the Major Forest Types of the United States. R. Burns, tech compil. USDA Forest Service, Washington, DC. Agriculture Handbook 445.

PLUMB, T.R., and P.M. McDONALD. 1981. Oak management in California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-54. 12 p.

RIEGEL, G.M., B.G. SMITH, and J.F. FRANKLIN. 1992. Foothill oak woodlands of the interior valleys of southwestern Oregon. Northwest Science 66:66-76.

STEIN, W.I. 1990. Oregon white oak. P. 650-660 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, USDA Forest Service, Washington D.C. Agriculture Handbook 654.

PACIFIC MADRONE
ARBUTUS MENZIESII

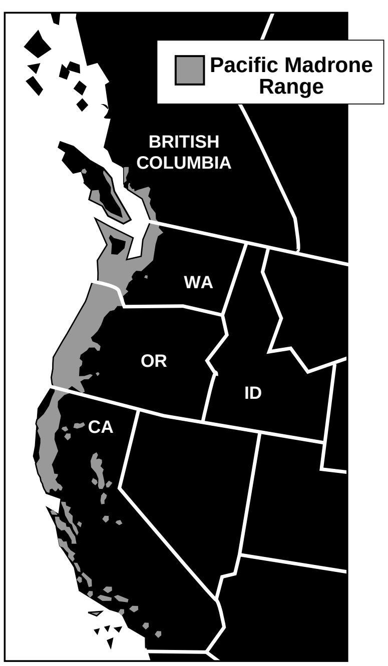
MADRONE

MADROÑA

MADROÑO

General Characteristics

Pacific madrone is one of the largest of about 14 species of *Arbutus* in the world, and one of the two *Arbutus* species in North America. Pacific madrone is a broadleaved evergreen tree and a member of the heath family (Ericaceae). It is distinguished by its smooth trunk, orange-red deciduous bark, white flowers, and red berries.



Size, Longevity, and Form

Pacific madrones attain heights of 80 to 125 ft and diameters of 24 to 48 in. The largest trees may be as much as 400 years old; ages of 200 to 250 years have been counted. Pacific madrone can develop a clear, straight bole under good conditions in forest stands, particularly in canyons and dense stands. Open-grown individuals and trees growing on lower quality sites often have multiple stems, which originate from sprouts or root burls that often are J-shaped and forked. The tree may become shrubby on poor sites. Pacific madrone generally develops a deep and spreading system of lateral roots, often in association with large root burls. Seedlings have a tap root.

Geographic Range

Pacific madrone is found from San Diego (lat 33°N) to eastern Vancouver Island (lat 51°N). In Oregon and Washington, it is restricted to the Coast Range and the west slopes of the Cascade ranges. In California, it is also found in the Coast Range, throughout much of the Klamath Mountains, and in some areas west of the Sierra Nevada.

Timber Inventory

Pacific madrone is the most abundant hardwood in the Siskiyou Mountains and interior coast ranges of the Southwest subregion of Oregon. This is the only subregion of Oregon that has a substantial inventory of Pacific madrone timber (Appendix 1, Table 1). Much of the Pacific madrone in Oregon is on federal lands, although volume estimates are not readily available. Pacific madrone is the second-most abundant hardwood in northern California. In Washington, it is common in the Puget Sound and Olympic subregions.

Biology and Management

Tolerance, Crown Position

Pacific madrone most commonly occurs as a codominant or intermediate tree in a canopy of mixed-hardwood species that often have some overstory of conifers. Pacific madrone is intermediate in tolerance. Tolerance appears to be lower for older trees and for trees at the northern end of the range. Seedlings establish best in partial shade, and young trees can survive in fairly dense shade. Top light is required for good growth; older trees may require top light to survive. Pacific madrone will grow toward openings, leaning as much as 15 to 20 degrees.

Ecological Role

Pacific madrone can be subclimax or climax in successional status; a substantial component of madrone is often maintained by periodic fires in the southern and central parts of its range. Although the thin-barked stems are easily killed by fire, Pacific madrone often dominates post-fire vegetation via vigorous regeneration of sprouts. It can also persist as a component of the mixed Douglas-fir/tanoak/Pacific madrone forest type.

Associated Vegetation

In the heart of its range, Pacific madrone is a major component of a widespread mixed-evergreen forest, which is characterized by an overstory of Douglas-fir and a secondary canopy of mixed hardwoods. Understory vegetation is often sparse under mature stands containing Pacific madrone. Pacific madrone is a common associate in a variety of other major cover types in the region.

Common tree species associated with Pacific madrone include Douglas-fir, ponderosa pine, sugar pine, white fir, western hemlock, tanoak, Oregon white oak, California black oak, giant chinkapin, bigleaf maple, bitter cherry, and California-laurel. Small trees commonly associated with Pacific madrone include vine maple, black hawthorn, red osier dogwood, willow, hazel, and red elderberry. Numerous shrub associates include manzanitas, Oregon-grape, ceanothus, salal, oceanspray, poison-oak, gooseberry, wood rose, snowberry, huckleberry, and thimbleberry.

Suitability and Productivity of Sites

Pacific madrone is particularly suited for warm, dry sites in the Northwest, especially on south and west aspects. Many of these sites may be marginal for production of other tree species, particularly in the absence of intensive vegetation management. On such sites, Pacific madrone's ability to maintain forest cover and produce usable wood becomes an important asset, one that may be improved with management. Relatively good growth and stem quality can be produced on better sites, although species such as Douglas-fir and tanoak are also more competitive on these sites. There are no established guides or site-index curves for estimating the productivity of a site for Pacific madrone. A site with good potential for growth of Pacific madrone is indicated by site trees with the following characteristics:

- Top height on mature trees of 80 to 100 ft
- Rapid juvenile height growth of 1 to 3 ft per year
- Sustained height growth from age 15 to 30 of 1 to 2 ft per year
- Continuing diameter growth on mature trees.

Climate

Pacific madrone prefers a climate characterized by mild, wet winters and dry, cool summers. Within its range, annual precipitation varies from 25 to 118 in. and average temperatures range from 36 °F in January to 77 °F in July.

Pacific madrone tolerates warm, dry conditions better than most tree species in the Northwest. It is one of the most drought-tolerant trees in the region and it has superior ability to extract water from soil or rock. Its roots can penetrate up to 12 ft in fractured bedrock, giving it access to substantial moisture unavailable to shallow-rooted species. Established and resprouting Pacific madrone are thus able to maintain relatively good growth on shallow, rocky soils where it may be difficult for seedlings of any species to establish and grow.

Pacific madrone is relatively sensitive to cold and snow. Its broad, evergreen leaves and brittle branches are vulnerable to breakage from heavy wet snow. Foliar damage and die-back are commonly observed after severe freezing or unseasonable frost. At the northern end of its range, Pacific madrone is one of the least frost-resistant tree species.

Pacific madrones are relatively windfirm because of their deep, spreading root systems.

Elevation

At the southern end of its range, Pacific madrone is found from 2000 to 4260 ft in elevation. In the north, it ranges from sea level to 3000 ft.

Soils

Towards the southern and middle part of its range, Pacific madrone grows on soils derived from a wide variety of parent materials. In the north, it is usually found on soils derived from glacial sands and gravels or hard glacial till. It is often found on rocky soils and on soils with low moisture retention. Pacific madrone is generally restricted to soils with good internal drainage; it will not tolerate poor soil drainage or flooding.

Flowering and Fruiting

Pacific madrone produces seed as early as 3 to 5 years of age. Trees begin flowering in early spring, from mid-March to May, depending on the elevation. The blossoms are dense, drooping clusters (terminal panicles) of small, white, urn-shaped flowers. The fruit is a berry (0.3 to 0.5 in.), which ripens in the fall, turning from yellow-green to bright red or reddish-orange.

Seed

Berries number from 630 to 1130/lb and contain an average of about 20 seeds per berry. Seeds are small, numbering from 197,000 to 320,000/lb. The berries are fleshy and relatively heavy; the seed are thus dispersed by gravity or by animals. The berries are eaten by many birds and mammals.

To obtain seeds, berries should be collected soon after they ripen in the fall. The following methods have been suggested for treatment of berries and seeds (Jane Smith, USDA Forest Service, PNW Station, Corvallis, Oregon). Berries can be dried at room temperature and stored at 34 °F (4 °C) for at least 2 years. Seeds should be separated from the pulp of fresh or dried berries. To extract seeds from dried berries, berries can be soaked in water (overnight) and blended in cold water in a blender at low speed for 3 to 10 minutes. Moist stratification for at least 4 to 6 weeks at 1 to 2 °C may improve germination.

Regeneration from Seed

In the northern parts of its range, Pacific madrone usually produces seed every year. Very good crops may occur as frequently as every 2 years, while very light seed crops may occur only once in 10 years. At the southern end of its range, good seed crops may occur as infrequently as once every 10 years. Seeds usually germinate in the first year after ripening. Natural rates of survival are often very low (0 to 10 percent) after seedling emergence because of drought, fungi, or predation.

Seedlings of Pacific madrone establish naturally in disturbed soils along roads, near uprooted trees, or in partially open forests. Bare mineral soil provides the best seedbed; very few seedlings establish in undisturbed litter. Seedlings also need partial shade to establish. Early growth of seedlings under natural conditions is slow (2 to 4 in. per year).

Regeneration from Vegetative Sprouts

Most reproduction of Pacific madrone arises from sprouts after fire or cutting. Death of the main stem stimulates profuse sprouting (up to 300 sprouts per parent), which originate from dormant buds near the root collar. These sprouts provide reliable regeneration and have rapid growth potential, which is due to carbohydrate reserves and soil access provided by pre-existing roots. Sprouts may grow as much as 5 ft in height the first year and attain an average height of 10 ft after 3 years. To produce vigorous, high-quality sprouts, stumps should be cut low to the ground (<8 in.), with a slight angle to the stump surface. Pacific madrone sprouts in partial or shelterwood cuttings have relatively poor growth and quality. Moderate to large clearings with little competitive vegetation produce the best growth of sprouts.

Plantation Regeneration

Little effort has been made to regenerate Pacific madrone from planted seedlings. Commercial seedling production methods have not been developed, although good quality seedlings have been produced for some research applications. Mortality rates have been high in field transplantings to date.

Site Preparation and Vegetation Management

Little site preparation is necessary for establishing stands of sprout origin. Regeneration and growth may be enhanced by burning or mechanically removing slash that shades Pacific madrone stumps. Rapid growth of sprout clumps makes Pacific madrone a superior competitor in the new stand. Control of competing herbs and shrubs can greatly improve the growth of young sprouts.

Site-preparation treatments that produce bare mineral soil while leaving some partial shade (debris, vegetation) may be best for promoting establishment and growth of Pacific madrone seedlings.

Stand Management

The growth and quality of Pacific madrone stands may be greatly improved through management. Diameter growth of madrone is responsive to increased growing space within or between sprout clumps.

Sprouts should be thinned after dominant stems have emerged, at 5 to 10 years. Thinning should select well-formed, dominant stems that originate near the ground and are evenly distributed around the stump. One early thinning is probably adequate for production of firewood, which may be done in 15- to 20-year rotations. A second thinning (yielding firewood) may be beneficial if sawtimber production is desired.

Thinning in older existing stands can increase diameter growth on residual trees by 2 to 5 times. Pacific madrone stands (pure or mixed) are often quite dense, and sometimes stagnant, with little or no diameter growth. Periodic thinning may be necessary to avoid stagnation and maintain stand growth.

Selective harvesting or dense shelterwoods are not recommended for management of Pacific madrone sprouts. Uneven-aged management may be feasible over a large area, with clearing in patches larger than 0.2 acres. Thinning will be necessary within patches or sprout clumps.

Mixed-species Stands

Pacific madrone typically occurs as a component or patch within mixed stands. Management of mixed stands is complex, and may require periodic treatments to maintain growth of diverse components. Pacific madrone stump sprouts may need to be controlled or thinned to avoid early suppression of associated conifer seedlings. Later treatments may be needed to maintain growth of Pacific madrone, particularly on better sites where conifer species are superior competitors.

Growth and Yield

Most natural Pacific madrone stands originate from sprouts. Dense sprout regeneration grows rapidly under open conditions. By age 10, the average height of sprouts may reach 15 to 22 ft and stand basal area may reach 100 ft^2 per acre on a good site. Typical mature trees (50 to 70 years old) are 50 to 80 ft tall and 10 to 20 in. in diameter. Diameter growth in natural stands is relatively slow, averaging 12 to 15 rings per in.

Mature stands or patches may attain basal areas of 140 to 200 ft^2 per acre. The best stands of Pacific madrone may exceed 4000 ft^3 per acre over several acres. Average stand volume of Pacific madrone forest types in California is 1705 ft^3 per acre.

There are few examples of growth and yield from managed stands. One test with 45-year-old Pacific madrone on a poor site suggested that thinning in dense, stagnant stands can greatly increase diameter growth (as much as 5 times) while maintaining or even increasing total annual volume growth per acre (33 to 37 ft) after removal of up to 65 percent of the stand basal area. Another study of Pacific madrone in mixed hardwood stands in northern California showed annual growth rates of 85 ft^3 per acre among all species combined, after removal of 40 to 50 percent of the original stand basal area.

Interactions with Wildlife

Pacific madrone berries are an important food for many birds and mammals. The berries are a particularly significant component in the diet of doves and pigeons during the fall. Deer eat the berries and also browse young shoots. Damage caused by animals is relatively minor on Pacific madrone. Live trees with rotten heartwood provide excellent habitat for cavity-nesting birds. Pacific madrones in mixed-conifer forests provide a middle canopy story, an important element in forest structural diversity.

Insects and Diseases

Significant mortality and damage is caused by a fungus commonly known as "madrone canker" (asexual stage, *Fusicoccum aesculi*; sexual stage *Botryosphaeria dothidea*). The canker causes a dieback of branches from the tip, and cankers may spread to the bole and kill the tree. The bark of dead branches becomes blackened, somewhat resembling fire damage. The disease reproduces from spores in the outer bark, which are spread by insects and, possibly, rain and wind.

A basal canker, *Phytophthora cactorum*, also has significant impact. The annosus root rot, *Heterobasidium annosum*, has potential to cause serious damage.

Insects such as defoliators, wood borers, and bark beetles are common but cause only minor damage.

Genetics

No natural varieties or hybrids of Pacific madrone are recognized, although there may be some horticultural cultivars.

Harvesting and Utilization

Cruising and harvesting

Diameter at breast height and total height of Pacific madrone can be used in tables or equations to estimate total tree volume in cubic feet and sawlog volume. Tests of the eastern hardwood grades have found no difference in value between log grades for this species, but have found a significant relation between log diameter and value. Stump burls offer an additional harvesting and management option for Pacific madrone.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 10 in.; smaller logs are chipped for pulp. The percentage of No. 1 Common and Better green lumber recovered from Pacific madrone logs compares favorably with the grade recovery from eastern oaks (Appendix 1, Table 2). Pacific madrone burls are highly prized and valued for their appearance, and are used in novelty items such as tables and clocks.

Wood Properties

Characteristics

Pacific madrone is a hard, heavy wood with a fine grain and little texture. The sapwood is white or cream-colored with a pinkish tinge;

the heartwood is a light reddish-brown. The wood is without any characteristic odor or taste. Pacific madrone wood is diffuse porous; the pores are nearly uniform, numerous, and minute. With a hand lens, the growth rings are barely visible. The rays range from barely visible to readily visible.

Weight

Pacific madrone weighs about 60 lb/ft^3 when green and 45 lb/ft^3 at 12 percent MC. The average specific gravity is 0.58 for green volume and 0.69 for ovendry.

Mechanical Properties

Pacific madrone wood has good strength properties. For most of its common applications (e.g., flooring or furniture), its resistance to indentation and abrasion is a plus. Pacific madrone has exceptional resistance to breakage, making it suitable for joinery. Because of its hardness, nailing is difficult and splitting is likely unless the wood is prebored. See Appendix 1, Table 3 for average mechanical properties for small, clear specimens.

Drying and Shrinkage

Pacific madrone requires special care during drying because of its wetwood, which can contribute to collapse. Green MC for this wood ranges from 68 to 93 percent. Its shrinkage values are considerably higher than for most other woods, which may result in increased drying degrade from warp. The radial shrinkage (green to ovendry) is 5.4 percent and the tangential shrinkage is 11.9 percent. For comparison, the respective values for alder are 4.4 percent and 7.3 percent, and for white oak are 4.2 percent and 9.0 percent. Lumber cut in a quartersawn pattern will minimize some of the high shrink/warp potential; otherwise, careful design consideration is a must. Because the tree does not always grow straight, tension wood sometimes forms, which will contribute to nonuniform shrinkage. Presteaming the kiln charge and stickering at a closer interval has been used successfully to control warp. (See Tables 8a and 8b for the appropriate kiln schedules).

Prior to kiln drying, Pacific madrone can develop a chemical oxidative stain that appears as blue or purple streaking in the wood. It does not show on rough-sawn surfaces of the wood and is apparent only after planing. To minimize staining, madrone should be dried as soon as possible after sawmilling, and tight stacking of wet lumber should be avoided.

Machining

Of all the hardwoods of the Pacific Northwest, Pacific madrone ranks highest (fewest machining defects) for planing, shaping, boring, and turning. Because of its high density, it should not be processed too fast

Table 8a. Kiln schedule—Pacific madrone 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 35	110	106	17.6	87	43.5	41.0
2	35 to 30	110	105	16.3	84	43.5	40.5
3	30 to 25	120	112	13.5	77	49.0	44.5
4	25 to 20	130	116	10.1	65	54.5	46.5
5	20 to 15	140	110	5.8	38	60.0	43.5
6	15 to final	180	130	3.5	26	82.0	54.5

Equalize and condition as necessary.

Table 8b. Kiln schedule—Pacific madrone 8/4.

Step	Moisture content (%)	Temperature °F Dry-bulb	Temperature °F Wet-bulb	Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C Dry-bulb	Temperature °C Wet-bulb
1	Above 35	110	107	19.1	90	43.5	41.5
2	35 to 30	110	106	17.6	87	43.5	41.0
3	30 to 25	120	114	15.5	83	49.0	45.0
4	25 to 20	130	120	12.2	74	54.5	49.0
5	20 to 15	140	115	6.8	46	60.0	46.0
6	15 to final	160	110	3.4	21	71.0	43.5

Equalize and condition as necessary.

(overfeed). It is recommended that saws and other tooling have a hook angle of 20° and a sharpness angle of 55° for optimum performance. As with other fine-grain, hard woods such as birch or maple, surface scratching (cross-grain or swirls) during sanding can be a problem with Pacific madrone.

Adhesives

Pacific madrone bonds well; there are no unusual problems with this wood when gluing conditions are moderately well controlled. Careful curing/drying of glue joints is required to prevent sunken gluelines from subsequent machining.

Finishing

Pacific madrone finishes well, without the need to fill the grain; it colors best with dyes or transparent stains. Heavily pigmented stains tend to be muddy in appearance. Pacific madrone can be successfully ebonized.

Durability

Pacific madrone is a nondurable species that is susceptible to wood decay. Untreated wood posts in ground contact have an average service life of 6 years. Mold and oxidative staining are moderate problems.

Uses

Pacific madrone is used for furniture, flooring, turnings, paneling, veneer for hardwood plywood faces and core stock, pulpwood, and firewood.

Related Literature

DICKINSON, F.E., D.R. PRESTEMON, and W.A. DOST. 1965. Pacific madrone log grades and lumber yield. California Agriculture Experiment Station, Berkeley, California. California Forestry and Forest Products No. 43.

McDONALD, P.M. 1983. Local volume tables for Pacific madrone, tanoak, and California black oak in north-central California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-362. 6 p.

McDONALD, P.M. 1992. Estimating seed crops of conifer and hardwood species. Canadian Journal of Forest Research 22:832-838.

McDONALD, P.M., D. MINORE, and T. ATZET. 1983. Southwestern Oregon-northern California hardwoods. P. 29-32 *in* Silvicultural Systems for the Major Forest Types of the United States. R. Burns, tech compil. USDA Forest Service, Washington, DC. Agriculture Handbook 445.

McDONALD, P.M., and J.C. TAPPEINER II. 1990. Pacific madrone. P. 124-132 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

RAPHAEL, M.G. 1987. Use of Pacific madrone by cavity-nesting birds. P. 198-202 *in* Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources. T.R. Plumb and N.H. Pillsbury, tech. coords. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-100.

TAPPEINER, J.C., II, P.M. McDONALD, and T.F. HUGHES. 1986. Survival of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*) seedlings in forests of southwestern Oregon. New Forests 1:43-55.

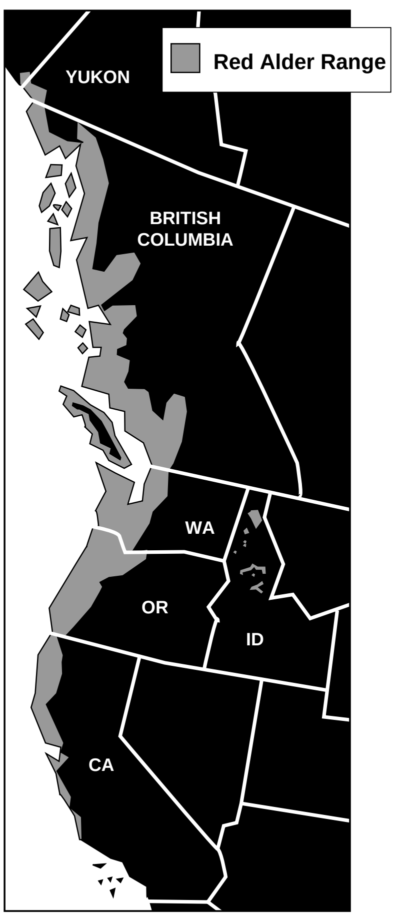
TINNIN, R.O., and L.A. KIRKPATRICK. 1985. The allelopathic influence of broadleaf trees and shrubs on seedlings of Douglas-fir. Forest Science 31:945-952.

ZUMRAWI, A.A., and D.W. HANN. 1989. Equations for predicting the height to crown base of six tree species in the central western Willamette Valley of Oregon. Forest Research Laboratory, Oregon State University, Corvallis. Research Paper 52. 12 p.

Red alder
Alnus rubra

Oregon alder
Western alder
Pacific coast alder

General Characteristics



Alders are members of the birch family (Betulaceae). Of the ten species of *Alnus* native to the United States, red alder is the only one that reaches commercial size and abundance. It is also the most common and important of the hardwoods in the Pacific Northwest.

Size, Longevity, and Form

Mature red alder trees are typically 70 to 120 ft in height (130 ft maximum) and 10 to 34 in. in diameter (70 in. maximum). Red alder are mature at 60 to 70 years; they seldom survive beyond 100 years. In forest stands, red alder develops a clear (60 to 70 percent of total height), slightly tapered bole with a narrow, domelike crown. Open-grown trees form broadly conical crowns and highly tapered boles, often with large forks and branches. The root system of red alder is shallow and spreading where limited by poor drainage; a deep-root system develops on soils with better drainage.

Geographic Range

The range of red alder extends from southeastern Alaska (lat 60°N) to southern California (lat 34°N), generally within 125 miles of the ocean. Red alder is common at low elevations throughout the Coast and north Cascade ranges but is restricted to riparian areas or moist microsites farther south.

Timber Inventory

Historical inventories indicate that the abundance of red alder has increased about 20-fold since the 1920s, though this trend may be reversed by modern forest practices, which favor conifers. The current inventory of about 7.4 billion cubic feet of red alder comprises 60 percent of the total hardwood volume in the Northwest (Appendix 1, Table 1). The greatest volume occurs in the Puget Sound and Northwest Oregon subregions. A significant portion of the red alder resource is not available for harvest; forest practices rules constrain timber management in riparian areas where red alder is most abundant. Also, very little red alder is sold from public lands, although substantial inventory occurs there.

Biology and Management

Tolerance, Crown Position

Red alder is intolerant of shade, and it must maintain a dominant or codominant canopy position. Trees of intermediate or suppressed-crown classes do not survive long. Both pure and mixed-species stands are predominantly even-aged. In mixed stands, red alder are usually grouped.

Ecological Role

Red alder is a pioneer species that establishes rapidly in openings created by forest disturbance; it commonly invades newly bared soils after landslides, logging, or fire. Red alder can maintain or improve soils via rapid input of organic matter and nitrogen. Its roots fix atmospheric nitrogen via symbiosis with the actinomycete, *Frankia*. Red alder does not reproduce in the absence of soil disturbance.

Associated Vegetation

Red alder often occurs in mixture with other tree species. Common associates include Douglas-fir, western redcedar, western hemlock, grand fir, Sitka spruce, bigleaf maple, vine maple, black cottonwood, Pacific willow, and bitter cherry. Common shrubs and herbs associated with red alder are salmonberry, thimbleberry, red elderberry, devil's-club, whortleberry, osoberry, evergreen blackberry, western swordfern, and hedge nettle.

Suitability and Productivity of Sites

The suitability of specific sites should be carefully assessed before red alder management is planned. Although red alder colonizes a wide variety of sites, many of those sites present high risks of tree mortality, persistent damage, or poor growth and are thus unsuitable for timber management. Good sites for red alder are generally found along streams, in moist bottomlands, and on lower slopes. Growth of red alder can also be quite good on upland sites (below 2000 ft) with adequate soil moisture and a favorable climate.

When representative red alder trees are present, site index should be estimated with either the 20-year base age (Harrington and Curtis 1985) or the 50-year base age (Worthington *et al*. 1960). Harrington's 1986 study, "A method of site quality evaluation for red alder," should be used for evaluating a site when there are no representative red alder present.

Climate

The typical climate in the range of red alder is mild and humid. Most precipitation occurs as rain in the winter; summers are generally cool and dry. Better red alder sites receive occasional rain and frequent morning fog during the summer. Annual precipitation ranges from 16 to 220 in. (405 to 5600 mm) and temperatures range from -22 to 115 °F (-30 to 46.1 °C).

For red alder, risks of excessive mortality and damage from sunscald, heat, or drought are high on southerly aspects, particularly inland on steep slopes. Planted red alder seedlings are particularly susceptible. Near the coast, higher humidity and soil moisture provide more favorable conditions on any aspect.

Good development of trees occurs where annual precipitation exceeds 40 in. or where roots have access to ground water. Red alder do poorly under droughty conditions, which may result from inadequate annual or seasonal precipitation, low moisture-holding capacity of the soil, or high evapotranspiration, together or singly.

Severe freezing or unseasonable frost hazards can greatly limit management of red alder. Local frost pockets and flat areas that accumulate cold air from large, cold-air drainages are poor sites for red alder. Both late spring and early fall frost can be disastrous to young plantations. Cumulative effects of periodic frosts produce poor quality stands.

Periodic exposure to high winds can greatly reduce stem quality and height growth of red alder. Areas exposed to periodic high winds (>50 mph) and coastal sites that are not protected from prevailing winds should be avoided.

Elevation

Management of red alder should generally be restricted to elevations below 3000 ft at the southern end and 1000 ft at the northern end of red alder's range.

Soils

Although red alder is found on a wide range of soils, the most productive stands occur on deep, well-drained loams and sandy loams derived from marine sediments or alluvium. There are also good red alder sites on soils of volcanic origin. Plentiful soil moisture during the growing season is necessary for good development of red alder. Excessive drought is produced by soils with low water-holding capacity including coarse-textured soils (sandy loams or sands) or soils with high rock fragment contents (>40 percent by volume). Coarse soils with consistent subsurface moisture (flood plains, riparian areas) are acceptable, although drought hazards are still high during stand establishment, particularly if competing vegetation is present.

Red alder tolerates poor drainage and occasional flooding during the growing season. Sites with very poor drainage or sites subject to prolonged flooding during any season are not suitable for management of red alder plantations.

Soils low in available phosphorus (P) greatly limit establishment and growth of red alder, although specific criteria for determining deficiency of P in soils have not been developed for red alder. Deficiency of P in red alder is indicated by foliar concentrations of less than 0.16 percent. Deficiency of soil nitrogen (N) is of lesser concern for red alder. Nitrogen fixation via red alder's symbiotic association with *Frankia* can compensate for deficiencies in soil N.

Flowering and Fruiting

Trees reach sexual maturity as early as 3 to 4 years of age. Dominant trees in a stand usually begin to produce seed at 6 to 8 years of age. Red alder is monoecious, having separate male and female flowers on the same individual. Male catkins develop in clumps that hang down. In late winter, they elongate from 1 to 3 in. and turn from green to reddish-brown, releasing their pollen in late winter and early spring. Female flowers are borne in clumps of upright catkins, which later develop into cone-like strobiles that bear the seed. The "cones" begin to ripen in September or October, changing from green to yellow-green or brownish-green to brown.

Seed

The seeds are small, winged nutlets borne in pairs at the base of bracts within the strobiles. Seeds are very light (350,000 to 1,400,000 seeds/lb) and they can be carried long distances by the wind. Seed dispersal may begin in late September; most seeds are released from late fall through winter. Seed should be collected from a local source to ensure that seedlings are adapted to conditions on the outplanting site. Cones should be collected from numerous trees of good growth and form that are well distributed within a stand. The quality and quantity of the cone crop should be assessed in July or August. Collection of cones may begin when the color of a cone has changed to about 50 percent yellow. Another test for crop maturity is to twist cones along the long axis. Seeds are ripe if the cone twists easily and the bracts separate.

After collection, cones should be airdried in paper or cloth bags. Care must be taken to provide adequate ventilation and prevent molding. When cones have dried, seed should be extracted via thrashing in a tumbler or by hand (for small lots). Yield may be increased by repeated wetting, redrying, and extracting. Extracted seeds are screened to remove large debris. Air column machines can be used to remove small trash and empty seed. For short-term storage, dry seed can be stored in sealed containers in the refrigerator with no loss in viability. Red alder seed may be stored for 5 to 10 years with little loss in viability when dried to less than 10 percent moisture content (MC) and stored in sealed containers in the freezer.

Regeneration from Seed

Dissemination of light red alder seed by the wind commonly produces widespread colonization on disturbed soils under a variety of conditions. Very little work has been done to develop methods of intentional regeneration of red alder from seed, however. Establishment from seed generally requires open conditions and bare mineral soil; red alder seedlings become established on organic substrates only under very moist conditions. Excessive heating or drying of the soil surface at any time greatly limits establishment of red alder from seed.

High humidity and soil moisture near the coast or at the north end of red alder's range provide favorable conditions on almost any aspect. In the interior Coast Range or Cascade foothills, establishment from seed is practically zero on southern aspects, and it may be limited to wet microsites and lower slopes on northern aspects.

Adequate distribution of seeds can be provided by well-distributed seed trees or a seed "wall" adjacent to the selected unit. Smaller clearings (<20 acres) with a seed source on at least two sides can regenerate well. Isolated seed trees left after harvest may not stand very long. Seed trees on the north side of a unit are preferable, since dispersal is accomplished primarily by drying north winds in the late fall and winter.

Conditions favorable for natural regeneration of red alder often produce an overabundance of seedlings (exceeding 100,000 stems per acre), and early precommercial thinning may be necessary to prevent stagnation or poor growth.

Regeneration from Vegetative Sprouts

Young red alder will sprout vigorously after cutting (coppicing). Coppices with rotations of 4 to 6 years have been managed successfully for a few rotations. Red alders more than 10 years old do not sprout well after cutting; regenerating red alder by coppicing older stands is not feasible.

Red alder are not easily established from unrooted cuttings. Cuttings of greenwood from young trees can be rooted by dipping in indole-3-butyric acid and culturing in a warm, well-aerated medium. Tests of operational regeneration from rooted cuttings have been minimal.

Regeneration from Planting

Planting of seedlings allows greater flexibility in site selection and provides greater control over spacing and seed source compared to regeneration from seed. Vigorous, planted red alder seedlings will have an advantage over competing vegetation. Seedlings of good quality, planted on well-prepared sites can reach heights of 4 to 7 ft after the first growing season.

Plantations of red alder can be successfully established with a variety of seedling stocktypes, but many efforts have failed because of poor quality seedlings, extreme weather, and other hazards. Consistent success requires a careful evaluation of regeneration hazards, along with adequate seedling quality, and good site-preparation and planting practices. Red alder seedlings that will have the best survival rate, growth rate, and resistance to damage over a range of conditions are characterized as follows:

- Height of 12 to 36 in. and basal diameter (caliper) of at least 0.16 in. (4 mm)
- Stocky, rather than tall and thin
- Healthy buds or branches along the entire length of the stem, particularly the basal portion
- Full, undamaged fibrous root systems
- Free of disease.

Site Preparation and Vegetation Management

Vigorous red alder seedlings can compete successfully with little or no site preparation when levels of competing vegetation are low to moderate. Moderate amounts of slash, debris, and vegetation shelter new seedlings and may also improve establishment. With high levels of competing vegetation, site preparation is required to achieve adequate stocking and good performance. Growth of red alder seedlings may be lower if the cover of competing vegetation exceeds 90 percent during the first year. Survival may be reduced by competition from 125 to 150 percent cover with overtopping in the first year.

Broadcast burning often provides adequate site preparation where levels of slash and/or shrub cover are high. Chemical site preparation may be most cost-effective for controlling both shrubby and herbaceous competitors. When a site has been heavily invaded by herbs, herbicide treatments just before planting can make the difference between success and failure of hardwoods.

When regeneration is directly from seed, site preparation should produce an even distribution of bare mineral soil. Mechanical scarification, broadcast burning, or piling and burning will do this in most situations. To prevent overabundant regeneration, one method is to minimize soil disturbance during harvest and then mechanically scalp evenly spaced spots throughout the unit. Closely spaced red alder seedlings (<9 ft) can effectively dominate a site within 2 to 4 years, thereafter, site-preparation treatments are unnecessary. Red alder at wider spacings (10 to 20 ft) are vulnerable to the prolonged effects of vegetative competition. At these wider spacings, maintenance of weed-free conditions after establishment can double to quadruple seedlings' growth in comparison to unweeded trees.

Stand Management

Natural stands of red alder generally establish at high densities (10,000 to 100,000 stems per acre); intense competition causes rapid self-thinning and slow diameter growth. Management of lower initial densities (300 to 600 stems per acre) can increase diameter growth rates on crop trees 15 to 20 percent compared to unmanaged stands during the first 15 years. Continued thinning (pulpwood, fuelwood, precommercial thinning) can maintain diameter growth rates up to 30 percent higher than those in unmanaged stands, at least until age 25. Managed stands are expected to attain an average diameter of 12 in. by age 30 or before; the average natural stand would take 45 years (SI_{50} = 100 ft).

Guidelines for management of stand density are provided by the density management diagram (Puettmann *et al*. 1993). Thinning must favor trees with good growth potential (dominant or codominant trees less than 15 to 20 years old). It is not worthwhile to thin older stands or to leave suppressed trees because the remaining trees will not have adequate capacity for growth response.

Some crowding is necessary to maintain dominance of red alder and to reduce branching, forking, and stem taper. The goal is to manage spacings that optimize growth while maintaining the benefits of crowding. Moderate crowding will induce lower branch mortality with minimal reductions in diameter growth. Relatively uniform spacing in managed stands will also improve stem form by producing straighter stems. Red alder grow towards the light; clumpy spacing and large holes in the stand increase lean and sweep.

Initial spacings of 9 to 10 ft between trees should shade out lower branches 30 to 40 ft up the bole by ages 8 to 15 years. A subsequent thinning, combined with pruning of dead branches (many are broken off during thinning) will maintain diameter growth on a high-quality bole. Pruning of live branches may also increase wood quality, although little work has been done on this.

Mixed-species Stands

Because of red alder's ability to improve soils via N-fixation and addition of organic matter, there is particular interest in managing red alder in mixture with conifers in order to maintain or improve site productivity. Management of mixtures can be difficult because of red alder's rapid height growth and great sensitivity to competition. Under favorable moisture conditions, red alder will overtop and suppress conifers established at the same time. Low proportions of red alder may be difficult to maintain over the long term, because red alder must maintain codominance in order to thrive.

Strategies for managing mixtures include (1) delaying the establishment of red alder for at least 3 to 6 years, (2) maintaining a low proportion of red alder in the stand (10 to 20 percent by stem count) and, (3) managing mixtures in small patches of single species, similar to most natural mixtures.

Growth and Yield

On good sites, height growth may exceed 6 ft/year for the first five years, and trees may attain heights of 60 to 80 ft in 20 years. Mean annual production rates in young stands have been estimated at 6.8 dry tons per acre. Growth slows substantially after the juvenile stage, particularly on poor sites. Site index ranges from 33 to 82 ft for base age 20 years and 60 to 120 ft for base age 50.

Yield tables based on site index and stand basal area (Chambers 1983) are available for estimating volumes of red alder in natural stands. Maximum volume per acre for red alder typically occurs at age 50 to 70, ranging from 5000 to 7000 ft^3 per acre. On very good sites, annual volume growth rates may average 300 ft^3 per acre for the first 10 years and 200 ft^3 per acre over 30 years.

Relatively little information is available on growth and yield in managed stands of red alder. Major gains in average stem diameter and stand basal area appear to be possible with management of spacing in young stands. Optimistic projections anticipate sawlog rotations of 30 to 35 years for managed stands compared to 45 to 50 years for natural stands.

Interactions with Wildlife

For wildlife, red alder provides an important deciduous component in the predominantly coniferous forests of the Northwest. Typically, shrub and herb vegetation under red alder is quite different from that of conifer-dominated areas. A variety of animals seem to prefer or depend on red alder for food or habitat. Maintenance of a red alder component can provide greater habitat diversity within or between conifer stands.

Browsing, antler rubbing, and trampling by deer and elk can cause serious problems in young plantations. Red alder are very sensitive to this damage; effects on young trees include decreased growth, multiple stems, and poor stem form. Rapid growth and close spacings generally ensure that an adequate number of crop trees will escape serious damage. Risks of permanent damage are highest with plantations established at wide spacings (>12 ft). Areas of concentrated use by elk or deer should not be managed for red alder.

Both mountain beaver and fur beaver can cause substantial damage to seedlings. Planted seedlings may be the major food source for mountain beaver during the first years after burning or chemical site preparation. Preventative measures such as trapping should be considered if there is evidence of a significant mountain beaver population. Fur beaver can cause extensive mortality of saplings and trees up to 150 ft from streams.

Voles, mice, and other rodents often severely damage seedlings, particularly in grassy or marshy areas. Basal netting or tubing can protect seedlings from rodents.

Insects and Diseases

Young, undamaged red alder stands are fairly free of problems from insects and disease. Stem cankers are common in some young stands, although they seldom have significant impact except under stressful environments. Although red alder has long been perceived as highly susceptible to decay, some recent work shows that healthy, living trees are exceptionally resistant to decay after typical stem injuries.

Occasionally, serious outbreaks of defoliating insects can cause growth reductions in healthy stands and mortality in stressed stands. Tent caterpillars (*Malacosoma disstria*, *M. californicum*), red alder flea beetle (*Altica ambiens*), red alder woolly sawfly (*Eriocampa ovata*), striped red alder sawfly (*Hemichroa crocea*), and a leaf beetle (*Pyrrhalta punctipennis*) have all caused damage.

Genetics

Major gains in growth and quality may be possible with selective breeding of red alder. This is because red alder has a large amount of genetic variation, early sexual maturity, frequent seed production, rapid growth, and the capability of vegetative propagation. Little effort has been made to establish breeding programs.

Harvest and Utilization

Cruising and Harvesting

Both cubic-foot and board-foot volume tables have been developed to estimate volume in standing trees from DBH and total height. Standard log grades, adapted from eastern hardwood log grades, have been developed for red alder. Most pricing decisions, however, are based on log diameter, length, and grade specifications developed by the specific log buyer.

Harvesting and transport costs for red alder are often higher than those for softwoods, although no special logging equipment is required. Red alder typically has lower volumes per acre and smaller, shorter trees. Red alder has a high green-weight-to-volume ratio, and natural stands produce a high percentage of logs with sweep and crook, which reduces the amount of logs that can be loaded on a truck. Most logging takes place in the dryer months; harvest volume declines in the rainy winter months because of road and site conditions.

Logs are generally scaled with Scribner log scale rules. Logs are also sold by weight or by the truckload. To prevent staining, red alder logs must be removed from the woods and processed within 6 to 8 weeks in the summer and 8 to 12 weeks in the winter.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 6 in.; smaller logs are chipped for pulp. Lumber is graded under special National Hardwood Lumber Association (NHLA) rules for red alder; grades include Selects and Better, No. 1 Shop, No. 2 Shop, No. 3 Shop, and Frame. Unlike the standard NHLA grading rules, these grades are generally based on the best face of the piece, whereas the other NHLA rules are based on the poorer face. Grades can be applied to rough, surfaced, green, or dry lumber; in practice, lumber is usually dried and surfaced before grading. A considerable volume of the low-grade material is sawn into 1 X 4, 1 X 6, and 2 X 4 for making pallets.

Recent studies show that the cubic volume of red alder that is recoverable as lumber ranges from 30 percent in small diameter logs to 50 percent in larger logs. Grade recovery also varies by log size or log grade; e.g., 85 percent of the surface-dried lumber produced from 7-in. logs was pallet material, but 75 percent of the surface-dried lumber from 20-in. logs was No. 1 Shop and Select. An earlier study conducted with NHLA standard grades (rather than the modified red alder and maple grades) showed that the average green lumber grade recovery from alder logs was lower than that of other eastern and western hardwoods for a given log grade (Appendix 1, Table 2). For a given log diameter, grade recovery from butt logs is much higher than that for logs higher in the tree.

Most of the high-grade lumber is used for furniture, cabinets, and turned products. Lumber prices have remained high and are competitive with prices for eastern hardwoods. Red alder lumber is marketed internationally, with strong markets in the Pacific Rim countries and in Europe, especially Italy and Germany.

Red alder is peeled into veneer for both low-grade core stock and high-grade face material. Veneer logs are an increasingly important market that is competitive with sawlogs. Red alder is also widely used for pulp, both domestically and overseas, but staining and fiber deterioration are a problem in storing pulp chips for more than a few months. An evaluation of red alder as a raw material for structural panels, such as oriented strand board, found no problems in producing flakes, bonding with resins, or meeting structural design values.

Wood Properties

Characteristics

The wood of red alder is evenly textured with a subdued grain pattern, and is of moderate weight and hardness. Red alder is a light-colored or white wood when it is freshly sawn, but with exposure to air, the wood darkens and changes to a light brown hue with a reddish tint. There is no color distinction between heartwood and sapwood.

The growth rings are distinct, delineated by either a whitish or brownish line at the outer margin. The pores are uniformly distributed within a growth ring (diffuse porous). Rays are present and of two types, narrow (simple) and broad (aggregate). Both the pores and the rays are indistinct to the naked eye. The wood is without any characteristic taste or odor.

Weight

Red alder weighs about 46 lb/ft^3 when green and 28 lb/ft^3 when dried to 12 percent MC. The average specific gravity is 0.37 for green and 0.43 for ovendry.

Mechanical Properties

Because of its moderate specific gravity, red alder is not an exceptionally strong wood. In many applications this will be apparent as indentations on the surface of the wood. In furniture applications, it may be necessary to redesign joints and the sizes of structural parts to compensate for the often slightly lower strength values of red alder. Red alder holds nails well and does not readily split when nails are driven into it. Lower grades of red alder perform adequately as pallet material. See Appendix 1, Table 3 for average mechanical properties for small, clear specimens.

Drying and Shrinkage

Red alder lumber 5/4 and thinner is one of the easiest North American wood species to dry. Establishing and maintaining uniform color requires special handling and storage of logs and freshly cut lumber, and specially developed dry-kiln schedules. Variable coloration is due to the oxidation of extractives present in the wood. Colors may range from yellow to deep red and may be mottled.

Kiln-drying the lumber as soon as possible after sawing prevents mottling. Steaming the kiln charge at different temperatures for different lengths of time will result in different colored wood (from white to dark red); this technique allows the kiln operator to select the desired final color. See Table 9 for a standard kiln schedule. Other schedules are available for either lighter or darker final coloring of the wood.

Shrinkage values for green to ovendry wood based on original green sizes are low and average 4.4 percent in the radial direction and 7.3 percent tangentially. The green MC of the wood averaged 98 percent (ovendry basis).

Table 9. Kiln schedule—Red alder (standard color) 4/4, 5/4, 6/4.

Step	Moisture content (%)	Temperature °F		Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C	
		Dry-bulb	Wet-bulb			Dry-bulb	Wet-bulb
1	Above 50	140	133	14.2	82	60.0	56.0
2	50 to 40	140	130	12.0	75	60.0	54.5
3	40 to 35	140	125	9.6	64	60.0	51.5
4	35 to 30	140	115	6.8	46	60.0	46.0
5	30 to 25	150	110	4.4	28	65.5	43.5
6	25 to 20	160	110	3.4	21	71.0	43.5
7	20 to 15	170	120	3.5	24	76.5	49.0
8	15 to final	180	130	3.5	26	82.0	54.5

Equalize and condition as necessary.

Machining

Red alder has an excellent reputation for machining. Due to the moderate specific gravity and the even texture of the wood, high throughput of material is possible. Quality surfaces can be obtained if sharp cutting edges are used. Some tear-out is possible during planing and shaping if tooling becomes dull or if feed rates are excessive. Red alder sands well without scratching and with a minimum of fuzzing. Its turning characteristics are similar to those of black cherry.

Adhesives

The ease of gluing red alder is well known in the industry. It bonds well and there are no unusual problems when conditions are moderately well controlled.

Finishing

Because of its uniform, small pore structure and the consistency of color, red alder is a preferred wood for finishing. It accepts a variety of stain types and has been successfully substituted for other woods when properly colored stains are applied.

Durability

Red alder is a non-durable wood when subjected to conditions that are favorable to decay. We recommend that it be rapidly processed into lumber after harvest to prevent staining and decay. A reddish-purple stain develops in solid-piled lumber that has not been dried or treated with anti-stain chemicals. In-ground tests indicate that untreated, peeled round posts will decay and fail in 3 years on average, while split posts will last only 5 years.

Uses

Uses for red alder include face veneer, furniture, cabinets, paneling, edge-glued panels, core-stock and cross-bands in plywood, millwork, doors, pallets, woodenware and novelties, chips for waferboard, pulpwood, and firewood.

Related Literature

AGER, A.A., P.E. HEILMAN, and R.F. STETTLER. 1993. Genetic variation in red alder (*Alnus rubra*) in relation to native climate and geography. Canadian Journal of Forest Research 23:1930-1939.

AHRENS, G.R., A. DOBKOWSKI, and D.E. HIBBS. 1992. Red alder: guidelines for successful regeneration. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 24. 11 p.

ATTERBURY, T. 1978. Alder characteristics as they affect utilization. P. 71-81 *in* Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, compils. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-70.

BRIGGS, D.G., D.S. DeBELL, and W.A. ATKINSON, compilers. 1978. Utilization and management of alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-70. 379 p.

CHAMBERS, C.J. 1983. Empirical yield tables for predominantly alder stands in western Washington. Washington Department of Natural Resources, Olympia, Washington. DNR Report N. 31. 70 p.

CLEAVES, D.A. 1992. Marketing alder and other hardwoods. Oregon State University Extension Service, Corvallis, Oregon. Extension Circular 1377. 8 p.

CURTIS, R.O, D. BRUCE, and C. VanCOEVERING. 1968. Volume and taper tables for red alder. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-56. 35 p.

DeBELL, D.E. Unpublished data. USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington.

FEDDERN, E.T. 1978. Harvesting of red alder. P. 61-70 *in* Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, compils. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-70.

GEDNEY, D.R. 1990. Red alder harvesting opportunities in western Oregon. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Resource Bulletin PNW-RB-173. 22 p.

HAEUSSLER, S., and J.C. TAPPEINER II. 1993. Effect of the light environment on seed germination of red alder (*Alnus rubra*). Canadian Journal of Forest Research 23:1487-1491.

HARRINGTON, C.A. 1986. A method of site quality evaluation for red alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-192. 22 p.

HARRINGTON, C.A. 1990. Red alder. P. 116-123 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington, D.C. Agriculture Handbook 654.

HARRINGTON, C.A., and R.O. CURTIS. 1985. Height growth and site index curves for red alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-358. 12 p.

HIBBS, D.E., and A.A. AGER. 1989. Red alder: guidelines for seed collection, storage, and handling. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Special Publication 18. 6 p.

HIBBS, D.E., D.S. DeBELL, and R. TARRANT, editors. 1994. The Biology and Management of Red Alder. Oregon State University Press, Corvallis. 256 p.

HIBBS, D.E., W.H. EMMINGHAM, and M.C. BONDI. 1989. Thinning red alder: effects of method and spacing. Forest Science 35:16-35.

JOHNSON, H.M., E.J. HANZLIK, and W.H GIBBONS. 1926. Red alder of the Pacific Northwest: its utilization, with notes on growth and management. USDA, Washington, D.C. Department Bulletin 1437.

KOZLIK, C.J. 1987. Presteaming to minimize mottling in partially air-dried red alder lumber. Forest Research Laboratory, Oregon State University, Corvallis. Research Note 80. 6 p.

LENEY, L., A. JACKSON, and H.D. ERICKSON. 1978. Properties of red alder (*Alnus rubra* Bong.) and its comparison to other hardwoods. P. 25-33 *in* Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, compils. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-70.

LOWELL, E.C., and R.L. KRAHMER. 1993. Effects of lean in red alder trees on wood shrinkage and density. Wood and Fiber Science 25:2-7.

MACKIE, D.M, and G.J. Williams. 1984. Growth and utilization of alder within the Pacific coastal region. Pulp & Paper Canada 85(8):71-76.

PLANK, M.E., T.A. SNELGROVE, and S. WILLITS. 1990. Product values dispel "weed species" myth of red alder. Forest Products Journal 40(2):23-28.

PUETTMANN, K.J., D.E. DeBELL, and D.E. HIBBS. 1993. Density management guide for red alder. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 2. 6 p.

RAETTIG, T., G.R. AHRENS, and K. CONNAUGHTON. Hardwood supply in the Pacific Northwest: a policy perspective. USDA Forest Service, Pacific Northwest Research Station, Portland. In preparation.

RESCH, H. 1980. Utilization of red alder in the Pacific Northwest. Forest Products Journal 30(4):21-26.

RESCH, H. 1988. Red alder: opportunities for better utilization of a resource. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 16. 13 p.

RHOADES, C.C., and D. Binkley. 1992. Spatial extent of impact of red alder on soil chemistry of adjacent conifer stands. Canadian Journal of Forest Research 22:1434-1437.

WORTHINGTON, N.P, F.A. JOHNSON, G.R. STAEBLER, and W.J. LLOYD. 1960. Normal yield tables for red alder. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 36.

TANOAK
LITHOCARPUS DENSIFLORUS
TANBARK-OAK

General Characteristics

Tanoak is a unique evergreen hardwood that belongs to the beech family (Fagaceae). It has characteristics similar to both oak and chestnut. All other 100 to 200 species of *Lithocarpus* are native to southeast Asia or Malaysia. In southwestern Oregon, tanoak is second to Pacific madrone as the most abundant hardwood.

Size, Longevity, and Form

Mature tanoak trees typically attain heights of 50 to 150 ft (208 ft maximum) and diameters of 6 to 48 in. (109 in. maximum). Tanoaks may live at least 250 years, although age can be difficult to determine. In dense forest stands, tanoaks develop narrow crowns with ascending branches on single, straight stems that are clear for 30 to 80 ft. In open stands, tanoaks often have broad crowns with large horizontal branches on short, forked boles. The root system of tanoak is composed of both deep and extensive lateral roots.

Geographic Range

Tanoak is native to a relatively narrow range on the West Coast from Santa Barbara, California, to Reedsport, Oregon (lat 34 to 43°N). It is most common in the Coast ranges and Siskiyou Mountains in California and southwestern Oregon, and can also be found in the Sierra Nevada.

Timber Inventory

Growing stock volume in southwestern Oregon is about 350 MMCF (Appendix 1, Table 1), much of it on federal lands (269 MMCF). The inventory in California is 1938 MMCF; this considerably larger volume has supported better market development in California than in Oregon.

Biology and Management

Tolerance, Crown Position

Tanoak is very tolerant, and it commonly occurs in any crown position. Seedlings and saplings are quite common in the understory of hardwood or conifer stands. Understory tanoak can grow rapidly in response to death or removal of overstory trees. Tanoak of any age seem to prefer some shading from codominant stems within clumps. Sudden, excessive exposure of stems or crowns is detrimental. Tanoak typically occurs as a codominant tree with other hardwoods, often with an overstory of conifers. Pure stands of tanoak are also common during early stages of succession after fire or logging, however.

Ecological Role

Tanoak is a persistent, versatile species capable of maintaining a substantial component at any successional stage in many forest types. While tanoak is considered to be a climax species capable of reproducing in undisturbed forests, it is also well-adapted to disturbance. It sprouts vigorously after fire or cutting and often dominates large areas.

Fire is the most important factor determining the fate of individual tanoaks and the abundance of the species in general. Fire often kills tanoak stems, although non-fatal injury may be more common. Stands with a substantial component of tanoak may be less flammable than stands of pure conifers.

Associated Vegetation

Tanoak is the most important hardwood species in the Mixed-Evergreen Zone of vegetation. The most common associate trees are Douglas-fir, Pacific madrone, and redwood. Other common associates are giant chinkapin, canyon live oak, California black oak, California-laurel, white fir, ponderosa pine, western hemlock, and Sitka spruce.

Shrubs commonly associated with tanoak include blueblossom, hazel, evergreen huckleberry, salal, Pacific rhododendron, Oregon-grape, western poison-oak, red-flowered currant, and thimbleberry. Important herbaceous associates include western bracken, western swordfern, New Zealand fireweed, bull thistle, western whipplea, California brome, California fescue, and California sweetgrass.

Suitability and Productivity of Sites

A high proportion of tanoak in the canopy often indicates high site productivity in general. The proportions of associated Pacific madrone, California black oak, and canyon live oak tend to increase on warmer, drier sites, which are less productive for tanoak. Rapid early growth of tanoak stump sprouts occurs regardless of site quality. The capability of a site for growing tanoak should be evaluated by examining growth and form of older trees. Good growth potential for tanoak on a site is indicated by the following:

- Top height on mature trees of at least 80 ft, up to 150 ft on the best tanoak sites
- Sustained height growth of 1 to 2 ft per year from age 5 to 20 years
- Continuing diameter growth on mature trees.

Climate

Tanoak thrives in a mild, humid climate characterized by dry summers and wet winters, where snow is infrequent and ephemeral. In this climate, annual precipitation ranges from 40 to 140 in., typically with less than 5 percent falling from June through September. Mean daily temperatures range from a minimum of 36 to 42 °F in January to a maximum of 60 to 74 °F in July.

Tanoak's large, deep root system and sclerophylous leaves impart some resistance to heat and drought. Compared to other sclerophylls (plants with thick, shiny blue-green leaves), however, tanoak requires more moderate temperatures and high levels of moisture; it shows little control over stomatal water loss. Tanoak grows best close to the coast where rain and fog, high humidity, and low clouds are plentiful. It prefers shade and dense foliage, which indicates a relatively high sensitivity to heat or sunlight. Mature tanoaks often decline in vigor when codominant neighbors are removed, causing sudden increases in exposure.

Severe cold is rare in the natural range of tanoak. Significant dieback of foliage has been observed after a hard freeze. Heavy snow or ice may bend saplings to the ground and cause sprouts to break at their connection to the stump. Sound, undamaged tanoaks are windfirm.

Elevation

At the southern limit of its range, tanoak grows at 2400 to 4700 ft elevation on the coast and up to 6500 feet in the Sierra Nevada. It is most abundant from 500 to 3000 ft in the central and northern part of its range.

Soils

Tanoak grows best on deep, well-drained, sandy, or gravelly loams, which may be derived from a variety of parent materials. The most productive soils for Douglas-fir or redwood are also some of the best soils for tanoak. It seldom thrives on heavy clay soils. Tanoak is also common on shallow, stony soils, usually on north slopes. It will not tolerate poor soil drainage or flooding.

Flowering and Fruiting

Sprouts as young as 5 years old may produce seed. Abundant seed production generally begins after 30 to 40 years. Most tanoaks bloom during the summer months, although some flowering may occur in the spring or fall. Separate male and female flowers are borne on the same plant. Most flowers of both sexes grow from the axils of new leaves on the current year's shoot. The flowers are borne in dense, yellowish blossoms composed of clusters of female flowers at the base of erect male catkins (2 to 4 in. long). Seed ripens in the second autumn after pollination.

Seed

A tanoak seed is similar to an oak acorn, about 0.75 in. long with a shallow, hairy cup. There are about 110 acorns/lb. Tanoak seed may be collected from late September to mid-November. Early acorns are often infested with insects; later acorns are generally sound, especially in a mast (high seed production) year. Acorns should be collected soon after they fall to reduce losses in viability from exposure to heat or drying. Germination and seedling emergence usually occur in spring. Acorns should be planted immediately or stored under cool, moist conditions (33 to 34 °F) until spring planting. Estimates of germination rate vary from 19 to 80 percent. Acorns should be planted with the pointed end up.

Natural Regeneration from Seed

Natural reproduction of tanoak from seed is often quite abundant. The best conditions for seedling establishment occur in undisturbed duff and litter under partial to full forest cover. There, regeneration occurs as a steady accumulation over long periods of time. Although acorns germinate under other conditions, their survival is poor in clearcuts and heavily disturbed environments.

Even under good conditions, only a small percentage of seeds become established seedlings. Regeneration is successful because tanoaks produce large amounts of seed. Mature trees may produce as many as 110,000 seeds per year. Tanoaks generally produce some seeds every year and usually bear heavy crops of acorns every two years.

The low percentage of acorns that become established seedlings is primarily due to predation by insects, birds, rodents, deer, bears, and raccoons. Predation is particularly high in clearcuts and exposed areas.

Regeneration from Vegetative Sprouts

Tanoak produces vigorous basal sprouts under a variety of conditions. Sprouting is most vigorous after fire or cutting. Sprouts usually originate from belowground burls, which are characteristic of tanoak of any size. To promote development of better quality sprouts, stumps should be cut low to the ground.

Regeneration from Planting

Very little effort has been made to regenerate tanoak with planted seedlings. Seedlings established from broadcast seeds have performed poorly, particularly in well-prepared sites under open conditions that are successful for plantations of other hardwoods. Better results may be possible with the outplanting of vigorous nursery stock, as demonstrated for some true oaks. In comparison to sprout regeneration, however, seedlings have lower rates of survival and growth.

Site Preparation and Vegetation Management

Little site preparation is necessary for establishing stands of sprout origin. Regeneration and growth are enhanced by burning or mechanically removing slash that shades tanoak stumps. Pre-established roots and rapid growth of sprout clumps make tanoak a superior competitor in the new stand. With high densities of parent stumps, rapid development of tanoak cover will inhibit establishment and growth of competing species. At lower densities of tanoak, control of competing herbs and shrubs can improve the growth of young tanoak sprouts.

Site-preparation treatments that leave intact litter and partial protection (debris, vegetation) may be best for promoting establishment and growth of tanoak seedlings.

Stand Management

Tanoak sprouts initiate at very high densities (up to 500 per parent), after which self-thinning and expression of dominance proceed rapidly. Thinning young sprout clumps at 3 to 10 years is not effective because of the abundant resprouts.

Thinning may improve growth and quality in older stands of tanoak. Density should not be reduced below about 100 ft^2 per acre of basal area. To avoid excessive exposure of residuals, thinning should be done in small steps of about 25 ft^2/acre at 3-to-5-year intervals, if necessary. Thinning should leave well-formed, dominant stems that originate from the ground. Companion sprouts with "V"-type connections should be left intact or cut as a unit.

Mixed-species Stands

Tanoak can grow in any crown position in stands with mixed species or age classes. Management of mixed stands is complex, however, and will require aggressive control of tanoak to maintain diverse components of hardwoods and conifers, which are generally less tolerant of shade. Tanoaks grow very slowly in dense shade, but understory saplings respond quickly to increased light. Larger, codominant trees may decline if stands are opened too much.

Growth and Yield

Seedlings grow slowly, generally averaging 2 to 8 in. in annual height growth during the first 5 years. Sprouts may grow up to 5 ft in the first year, and average 2 ft per year for the first 15 to 20 years.

Fully stocked tanoak stands of sprout origin rapidly accumulate basal area. On one good site, sprout basal area reached 100 ft^2 per acre after

9 years. After 50 years or more, typical basal areas can range from 160 to 260 ft^2 per acre.

Typical stand volumes range from 2000 to 4000 ft^3 per acre, with volumes as high as 7000 ft^3 per acre occurring in small productive patches of up to several acres. The net annual growth of tanoak in California averages 3.5 percent of standing inventory, the highest rate of any hardwood in California.

There has been very little management of tanoak stands. Average annual growth rates of 85 ft^3 per acre were measured in 50-to-60-year-old tanoak stands after they were thinned to a basal area of 102 to 125 ft^2 per acre on a high site in northern California. Unthinned stands on the same site had growth rates of 198 ft^2 per acre.

Interactions with Wildlife

Tanoak acorns are an important food source for many animals, including birds, rodents, deer, bears, and raccoons. A component of tanoak provides thermal cover, refuge, and nesting habitat for wildlife. Northern flying squirrels, Allens' chipmunks, and dusky-footed woodrats are closely associated with tanoak. Combined with an overstory of large conifers, a component of tanoak may improve habitat for northern spotted owls by providing canopy structure and habitat for prey such as woodrats and northern flying squirrels.

Insects and Diseases

Fungi commonly enter tanoak trunks that have been injured by fire. The combination of fire injury followed by fungal decay is frequent, producing a high incidence of defect in older trees. Common fungi that decay living trees include a brown cubical rot (the beefsteak fungus, *Fistula hepatica*), a white root rot, weeping conk (*Inonotus dryadeus*), and a sap rot (*Schizophyllum commune*).

Genetics

There are no known hybrids of tanoak. A shrub form of tanoak (*Lithocarpus densiflorus* var. *echinoides*) grows on moist sites at elevations higher than the tree form.

Harvest and Utilization

Cruising and Harvesting

Diameter at breast height and total height can be used with tables or equations to estimate total tree volume in cubic feet and sawlog volume. A recent study of tanoak lumber recovery found that, even though eastern hardwood grades will separate logs into distinct value classes, the impact of log diameter on lumber value is more important. Shifts in lumber values and competition with eastern hardwood species may make the use of log grades more important in the future.

Product Recovery

Sawlogs usually have a minimum small-end diameter of 6 to 10 in., smaller logs are generally chipped for pulp. If tanoak logs are not processed shortly after their removal from the woods, the lumber commonly end-splits. One study showed that the percentage recovery of No. 1 Common or Better green lumber from grade 1 tanoak logs is slightly lower than the recovery from eastern oaks. The lumber grade recovery from grade 2 and 3 logs compares favorably with the lumber grade recovery from eastern oaks and is higher than from the other hardwoods (Appendix 1, Table 2). Even high grade tanoak logs yielded a comparatively low percentage (29 percent) of Select or Better lumber, however.

Tanoak has also been found to yield good quality veneer for furniture production. Heat treatment of the blocks to 160 °F improved the smoothness, tightness, and quality of the veneer without increasing the amount of end splitting. Defects included surface checking and associated staining, and knots greater than 2 in. The interior cores produced veneer that was rough and buckled, so the cores should be left larger than normal. There were no problems drying the veneer.

Wood Properties

Characteristics

Tanoak is a hard, heavy wood that in many ways resembles the true oaks; thus, tanoak is often included in discussions about lumber from western oak species. The wood is a light, reddish-brown when freshly cut, but it ages to a tannish, reddish-brown. The sapwood is very wide; it is difficult to distinguish the heartwood from the sapwood. There is some opinion that true heartwood does not exist in this species. The growth rings are difficult to distinguish and are delineated only by a faint narrow line of darker, denser tissue at the outer margin. The infrequent pores are barely visible to the naked eye, are unevenly distributed, and are inserted in light-colored tissue in streamlike clusters that extend across several or many growth rings. As a result, the wood is evenly textured, with little apparent grain. There are broad rays, however, which are conspicuous and especially prominent on quartersawn surfaces. Narrow rays are also present, but require magnification to view. When dry, the wood has no characteristic odor or taste.

Weight

Tanoak weighs about 62 lb/ft^3 when green and 41 lb/ft^3 at 11 percent moisture content (MC). The average specific gravity is 0.54 (green) or 0.66 (ovendry).

Mechanical Properties

The wood of tanoak is highly rated for its strength properties. It is noted for hardness, resistance to abrasion, stiffness, and bending strengths. It holds fasteners well, but requires preboring before nailing to prevent splitting. See Appendix 1, Table 3 for average mechanical properties for small clear specimens.

Drying and Shrinkage

Tanoak lumber requires special care and well-controlled conditions during drying to properly lower MC without causing excessive degrade. It is no more difficult to dry than some eastern or other West Coast oak species, however, unless it has mineral streak. Poor or uncontrolled drying will cause defects such as end and surface checking in the lumber. In addition, tanoak lumber can be degraded with honeycomb and collapse if the drying rate is too rapid. These problems increase when lumber with mineral streak is dried; in many cases, it is not worth the effort to dry mineral streak material.

Tanoak can stain if certain metals contact the wet wood; contact with iron can produce a pronounced blue-black discoloration. Molds and bacterial stains will develop if air circulation around the wet lumber is inadequate. Proper air-drying of tanoak requires very mild conditions, with moderate temperatures and high humidities, to avoid developing molds and bacterial stains. Poor handling of green wood can also produce sap staining. Air-drying will minimize much of the drying degrade and will reduce the total kiln times as well.

The green MC of tanoak is reported to be 115 percent (ovendry basis). Shrinkage values for green to ovendry lumber (based on the original green size) average 5.5 percent radially and 10 percent tangentially. See Table 10 for the appropriate kiln schedule. For information about schedules for thicker material or wood that is partially air-dried, contact the Forest Products Department at OSU.

Table 10. Kiln schedule—Tanoak 4/4, 5/4, 6/4, 8/4.

Step	Moisture content (%)	Temperature °F		Equilibrium moisture content (%)	Relative humidity (%)	Temperature °C	
		Dry-bulb	Wet-bulb			Dry-bulb	Wet-bulb
1	Above 35	110	107	19.1	90	43.5	41.5
2	35 to 30	110	106	17.6	87	43.5	41.0
3	30 to 25	120	114	15.5	83	49.0	45.0
4	25 to 20	130	120	12.2	74	54.5	49.0
5	20 to 15	140	115	6.8	46	60.0	46.0
8	15 to final	160	110	3.4	21	71.0	43.5

Equalize and condition as necessary.

Machining

Tanoak's machinability is comparable to or better than that of the oaks with regard to planing, shaping, boring, and mortising. As with the oaks, tanoak sands well with a minimum or scratching or fuzzing. Both tooling and sandpaper dull moderately quickly because of the hardness of the wood. For optimum planing results, the recommended hook angle is 15°. Machine burn is possible if feed speeds are too slow.

Adhesives

If conditions are well controlled, tanoak produces glue joints of good strength.

Finishing

Tanoak finishes well because of its uniform color (between sapwood and heartwood) and evenly textured, fine-grained appearance. Transparent stains and dyes are better than pigmented stains in retaining more readable finishes on tanoak. Clear-coated flooring products made from tanoak have a warm, pleasant appearance.

Durability

Tanoak is a non-durable species when subjected to conditions favorable to wood decay organisms. On average, round, unpeeled posts decay within 4 years of being placed in the ground. Tanoak can be effectively treated with wood preservatives.

Uses

Tanoak is used for flooring, furniture, truck bedding, pallets, veneer, paneling, ties and mine timbers, pulpwood, and firewood.

Related Literature

DICKINSON, F.E., and D.R. PRESTEMON. 1965. Tanoak log grades and lumber yield. California Agriculture Experiment Station, Berkeley, California. California Forestry and Forest Products No. 41.

ESPENAS, L.D. 1953. The seasoning of one-inch tanoak lumber. Oregon Forest Products Laboratory, State Board of Forestry and School of Forestry, Corvallis, Oregon. Bulletin 3. 46 p.

HARRINGTON, T.B., R.J. PABST, and J.C. TAPPEINER II. 1994. Seasonal physiology of Douglas-fir saplings: response to microclimate in stands of tanoak or Pacific madrone. Forest Science 40:59-82.

HARRINGTON, T.B., J.C. TAPPEINER II, and R. WARBINGTON. 1992. Predicting crown sizes and diameter distributions of tanoak, Pacific madrone, and giant chinkapin sprout clumps. Western Journal of Applied Forestry 7:103-108.

McDONALD, P.M. 1983. Local volume tables for Pacific madrone, tanoak, and California black oak in north-central California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-362. 6 p.

McDONALD, P.M. 1992. Estimating seed crops of conifer and hardwood species. Canadian Journal of Forest Research 22:832-838.

McDONALD, P.M., D. MINORE, and T. ATZET. 1983. Southwestern Oregon-northern California hardwoods. P. 29-32 *in* Silvicultural Systems for the Major Forest Types of the United States. R. Burns, tech compil. USDA Forest Service, Washington, D.C. Agriculture Handbook 445.

McDONALD, P.M., and J.C. TAPPEINER. 1987. Silviculture, ecology, and management of tanoak in northern California. P. 62-70 *in* Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources. T.R. Plumb and N.H. Pillsbury, tech. coords. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-100.

RAPHAEL, M.G. 1987. Wildlife-tanoak associations in Douglas-fir forest of northwestern California. P. 183-189 *in* Proceedings of the symposium on Multiple-Use Management of California's Hardwood Resources. T.R. Plumb and N.H. Pillsbury, tech. coords. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-100.

SCHOWALTER, W.E. 1949. The suitability of tanoak (*Lithocarpus densiflora*) for the production of veneer. USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. Administrative report. 7 p. On file with: Timber Quality Research Team, Forestry Sciences Laboratory, Pacific Northwest Research Station, P.O. Box 3890, Portland, Oregon 97208-3890.

TAPPEINER, J.C., II, P.M. McDONALD. 1984. Development of tanoak understories in conifer stands. Canadian Journal of Forest Research 14:271-277.

TAPPEINER, J.C., II, P.M. McDONALD, and T.F. HUGHES. 1986. Survival of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*) seedlings in forests of southwestern Oregon. New Forests 1:43-55.

TAPPEINER, J.C., II, P.M. McDONALD, and D.F. ROY. 1990. Tanoak. P. 417-425 *in* Silvics of North America. Volume 2, Hardwoods. R.M. Burns and B.H. Honkala, coords. USDA Forest Service, Washington D.C. Agriculture Handbook 654.

APPENDIX 1

Comprehensive tables

Table 1. Volume of hardwood growing stock in subregions of northern California, Oregon, and Washington.

	Volume of growing stock in million cubic feet (MMCF)									
	California	Oregon				Washington				Region Total
Species	North-west	South-west	West-Central	North-west	Total	South-west	Puget Sound	Olympic Peninsula	Total	
Bigleaf maple*	72	118	345	446	909	321	587	281	1189	2170
Black cottonwood*	2	1	10	50	61	66	277	52	395	458
California black oak*	345	110	21	—	131	—	—	—	—	476
California-laurel*	204	93	—	—	93	—	—	—	—	297
Giant chinkapin*	50	45	40	1	86	—	—	—	—	136
Oregon ash*	—	20	23	38	81	46	30	27	103	184
Oregon white oak*	148	60	128	114	302	4	1	8	13	463
Pacific madrone*	716	274	13	4	291	—	45	15	60	1067
Red alder	121	814	871	1404	3089	1248	1626	1352	4226	7436
Tanoak	1438	350	—	—	350	—	—	—	—	1788

*Inventory not available for these species on federal lands in SW Oregon.
Total combined volume of these species on federal land in SW Oregon was 449 MMCF in 1976.

Sources: NW California, all ownerships, 1981-1984 inventory, Resource Bulletin PNW-131, June 1986. Oregon non-federal land, 1985-86 survey: Resource Bulletin PNW-RB-138, September 1986; Resource Bulletin PNW-RB-140, September 1986; Resource Bulletin PNW-RB-143, March 1987. Oregon federal land, 1976 survey: Resource Bulletin PNW-72, March 1979; Resource Bulletin PNW-76, 1978; Resource Bulletin PNW-82, March 1979. Washington, all ownerships, 1988-89 survey: Resource Bulletin PNW-RB-191.

Table 2. Green lumber recovery percentages for some northwestern and eastern hardwood species.

Species	Log grade	Average diameter (in.)	Select and Better (%)	No. 1 Common or Better (%)
Northwestern				
Bigleaf maple[1,3]	1	23	41	80
	2	19		58
	3	18		31
California black oak[6]	1	24	27	60
	2	21		35
	3	15		19
Giant chinkapin[7]	1		18	63
	2			45
	3			30
Pacific madrone[5]	1	21	33	69
	2	18		52
	3	14		36
Red alder[1,2]	1	19	26	69
	2	19		36
	3	17		31
Tanoak[4]	1	25	29	65
	2	21		52
	3	19		43
Eastern				
Hard maple	1	19	46	73
	2	16		48
	3	14		17
Red oak	1	22	46	73
	2	17		51
	3	16		21
Yellow birch	1	18	48	73
	2	17		49
	3	13		13
White oak	1	19	41	67
	2	19		45
	3	17		23

[1]Grade recovery is based on standard NHLA grades based on the poor face, not modified grades for red alder and bigleaf maple.

[2]Pfeiffer, J.R., and A.C. Wollin. 1954. Red alder log and lumber grading. Oregon Forest Products Laboratory, Corvallis, Oregon. Report No. G-3. 21 p.

[3]Wollin, A.C., and J.R. Pfeiffer. 1955. Oregon maple log and lumber grading. Oregon Forest Products Laboratory, Corvallis, Oregon. Report No. G-4. 21 p.

[4]Dickinson, F.E., and D.R. Prestemon. 1965. Tanoak log grades and lumber yield. California Agriculture Experiment Station, Berkeley, California. California Forestry and Forest Products No. 41.

[5]Dickinson, F.E., D.R. Prestemon, and W.A. Dost. 1965. Pacific madrone log grades and lumber yield. California Agriculture Experiment Station, Berkeley, California. California Forestry and Forest Products No. 43.

[6]Malcolm, F.B. 1962. California black oak—a utilization study. USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. Report No. 2237. 10 p.

[7]Prestemon, D.R., F.E. Dickinson, and W.A. Dost. 1965. Chinkapin log grades and lumber yield. California Agriculture Experiment Station, Berkeley, California. California Forestry and Forest Products No. 42.

[8]Vaughn, C.L., A.C. Wollin, K.A. McDonald, and E.H. Bulgrin. 1966. Hardwood log grades for standard lumber. USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. Research Paper FPL-63. 52 p.

Table 3. Average mechanical properties for northwestern (bold-face) and some eastern hardwood species.

Species	MOR (lb/in.^{2})	MOE (lb/in.^{2})	COMP (lb/in.^{2})	Side hardness (lb)	Impact bending	Shear (lb/in.^{2})	SP. GR. 12% MC
Black cottonwood	8300	1.26 X 10^6	370	350	22	1020	0.35
Aspen	8400	1.18 X 10^6	370	350	21	850	0.38
Red alder	9800	1.38 X 10^6	540	590	20	1080	0.41
Yellow-poplar	10100	1.58 X 10^6	500	540	24	1190	0.42
American chestnut	8600	1.23 X 10^6	620	540	19	1080	0.43
Silver maple	8900	1.14 X 10^6	740	700	25	1480	0.47
Bigleaf maple	10700	1.45 X 10^6	930	850	28	1730	0.48
Giant chinkapin	10700	1.24 X 10^6	680	730	30	1260	0.48
Black ash	12600	1.60 X 10^6	760	850	35	1570	0.49
Cherry	12300	1.49 X 10^6	690	950	29	1700	0.50
Black walnut	14600	1.68 X 10^6	1010	1010	34	1370	0.55
California-laurel	8000	0.94 X 10^6	1400	1270	31	1860	0.55
Oregon ash	12700	1.36 X 10^6	1540	1160	33	1790	0.55
California black oak	8700	0.99 X 10^6	1440	1100	16	1470	0.57
Southern red oak	10900	1.49 X 10^6	870	1060	26	1390	0.59
Northern red oak	14300	1.82 X 10^6	1010	1290	43	1780	0.63
Sugar maple	15800	1.83 X 10^6	1470	1450	39	2330	0.63
Eastern white oak[1]	10300	1.03 X 10^6	1200	1370	29	1810	0.65
Pacific madrone	10400	1.23 X 10^6	1620	1460	23	1810	0.65
Tanoak	16300	1.80 X 10^6	1080	1410	NA	2180	0.66
Oregon white oak	10300	1.10 X 10^6	2110	1660	29	2020	0.72

MOR—modulus of rupture: strength measurement of the load required to break a test sample.

MOE—modulus of elasticity: stiffness measurement.

COMP—compression perpendicular to grain.

Impact Bending—drop distance in in. for a 50-lb hammer to break sample.

SP. GR.—specific gravity.

[1]Burr oak figures from Wood Handbook (USDA Ag. Handbook #72).

APPENDIX 2

Common and scientific names of tree species

Bigleaf maple	*Acer macrophyllum* Pursh
Bitter cherry	*Prunus emarginata* (Dougl. ex Eaton)
Black cottonwood	*Populus trichocarpa* Torr. & Gray
Black hawthorn	*Crataegus douglasii* Lindl.
California black oak	*Quercus kelloggii* Newb.
California-laurel	*Umbellularia californica* (Hook. & Arn.) Nutt.
California sycamore	*Platanus racemosa* Nutt.
Canyon live oak	*Quercus chrysolepis* Liebm.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Giant chinkapin	*Castanopsis chrysophylla* (Dougl.) A. DC.
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Knobcone pine	*Pinus attenuata* Lemm.
Northwest willow	*Salix sessilifolia* Nutt.
Oregon ash	*Fraxinus latifolia* Benth.
Oregon white oak	*Quercus garryana* Dougl. ex Hook.
Pacific dogwood	*Cornus nuttallii* Aud.
Pacific madrone	*Arbutus menziesii* Pursh
Pacific willow	*Salix lasiandra* Benth.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Port-Orford-cedar	*Chamaecyparis lawsoniana* (A. Murr.) Parl.
Red alder	*Alnus rubra* Bong.
Redwood	*Sequoia sempervirens* (D. Don) Endl.
River willow	*Salix fluviatilis* Nutt.
Scouler willow	*Salix scoulerana* Barratt ex Hook.
Sitka spruce	*Picea sitchensis* (Bong.) Carr.
Sugar pine	*Pinus lambertiana* Dougl.
Tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western redcedar	*Thuja plicata* Donn ex D. Don
Western white pine	*Pinus monticola* Dougl. ex D. Don
White fir	*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.

APPENDIX 3

Common and scientific names of shrub species

Bearclover	*Chamaebatia foliolosa* Benth.
Bearberry	*Arctostaphylos uva-ursi* (L.) Spreng.
Blue elderberry	*Sambucus caerulea* Raf.
Blueblossom	*Ceanothus thyrsiflorus* Eschsch.
Buckbrush	*Ceanothus cuneatus* (Hook.) Nutt. ex Torr. & A. Gray
Ceanothus	*Ceanothus* spp.
Common snowberry	*Symphoricarpos albus* (L.) S.F. Blake
Creeping snowberry	*Gaultheria hispidula* (L.) Muhl.
Deerbrush	*Ceanothus integerrimus* Hook. & Arn.
Devil's-club	*Oplopanax horridum* (Sm.) Miq.
Evergreen blackberry	*Rubus laciniatus* Willd.
Evergreen huckleberry	*Vaccinium ovatum* Pursh.
Greenleaf manzanita	*Arctostaphylos patula* Greene
Hairy manzanita	*Arctostaphylos columbiana* Piper
Hazel	*Corylus cornuta* Marsh.
Himalaya blackberry	*Rubus procerus* P.J. Mull.
Mountain-lover	*Pachistima canbyi* Gray
Oceanspray	*Holodiscus discolor* (Pursh.) Maxim.
Oregon crab apple	*Malus fusca* (Raf.) C.K. Schneid.
Oregon-grape	*Berberis aquifolium* Pursh
Osoberry	*Oemleria cerasiformus* (Hook. & Arn.) J.W. Landon
Pacific dewberry	*Rubus ursinus* Cham. & Schlechtend.
Pacific rhododendron	*Rhododendron macropyllum* D. Don ex G. Don
Red elderberry	*Sambucus callicarpa* Greene
Red-flowered currant	*Ribes sanguineum* Pursh.
Red huckleberry	*Vaccinium parvifolium* Sm.
Red osier dogwood	*Cornus sericea* L.
Salal	*Galtheria shallon* Pursh.
Salmonberry	*Rubus spectabilis* Pursh.
Snowbrush	*Ceanothus velutinus* Dougl. ex Hook.
Sweet mock-orange	*Philadelphus coronarius* L.
Thimbleberry	*Rubus parviflorus* Nutt.
Vine maple	*Acer circinatum* Pursh
Wax myrtle	*Myrica cerifera* L.
Western poison-oak	*Rhus diversiloba* Torr. & A. Gray
Western raspberry	*Rubus leucodermis* Dougl. ex Torr. & A. Gray
Western serviceberry	*Amelanchier alnifolia* (Nutt.) Nutt.

Western whipplea	*Whipplea modesta* Torr.
Whiteleaf manzanita	*Arctostaphylos viscida* Parry
Whortleberry	*Vaccinium corymbosum* L.
Wood rose	*Rosa gymnocarpa* Nutt.

APPENDIX 4

Common and scientific names of herb species

Angelica	*Angelica* spp.
Bedstraw	*Galium* spp.
Bittercress	*Cardamine* spp.
Bull thistle	*Cirsium vulgare* (Savi) Ten.
Buttercup	*Ranunculus* spp.
California brome	*Bromus carinatus* Hook. & Arn.
California fescue	*Festuca californica* Vasey
California sweetgrass	*Hierochloe occidentalis* Buckley
Canada violet	*Viola canadensis* L.
Enchanter's-nightshade	*Circaea alpina* L.
False lily-of-the-valley	*Maianthemum canadense* Desf.
False Solomon's-seal	*Smilacina stellata* (L.) Desf.
Golden-saxifrage	*Chrysosplenium* L.
Hedge nettle	*Stachys* L.
Honeysuckle	*Lonicera* L.
Horsetail	*Equisetum* spp.
Iris	*Iris* spp.
Ladyfern	*Athyrium felix-femina* (L.) Roth
Maidenhair fern	*Adiantum pedatum* L.
New Zealand fireweed	*Erechtites arguta* DC.
Prince's-pine	*Chimaphila umbellata* (L.) Bart.
Red woodsorrel	*Oxalis oregana* Nutt.
Sedges	*Carex* spp.
Skunkcabbage	*Lysichiton americanum* Hult & St. John
Spiraea	*Spiraea* spp.
Spreading sweetroot	*Osmorhiza chilensis* (Molina) Hook. & Arn.
Stinging nettle	*Urtica dioica* L.
Twinflower	*Linnaea borealis* L.
Water celery	*Oenanthe sarmentosa* K. Presl. ex DC.
Wild strawberry	*Fragaria virginiana* Duchesne
Western swordfern	*Polystichum munitum* (Kaulf.) K. Presl.
Western bracken	*Pteridium aquilinum* L.
Western springbeauty	*Montia sibirica* (L.) J.T. Howell
Youth-on-age	*Tolmiea menziesii* (Pursh) Torr. & A. Gray

Niemiec, S.S., G.R. Ahrens, S. Willits, and D.E. Hibbs. 1995. HARDWOODS OF THE PACIFIC NORTHWEST. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 8. 115 p.

This publication brings together in one place information on the general characteristics, biology and management, harvesting and utilization, wood characteristics, and related literature of Pacific Northwest hardwoods. Species included are bigleaf maple, black cottonwood, California black oak, California-laurel, giant chinkapin, Oregon ash, Oregon white oak, Pacific madrone, red alder, and tanoak.

Niemiec, S.S., G.R. Ahrens, S. Willits, and D.E. Hibbs. 1995. HARDWOODS OF THE PACIFIC NORTHWEST. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 8. 115 p.

This publication brings together in one place information on the general characteristics, biology and management, harvesting and utilization, wood characteristics, and related literature of Pacific Northwest hardwoods. Species included are bigleaf maple, black cottonwood, California black oak, California-laurel, giant chinkapin, Oregon ash, Oregon white oak, Pacific madrone, red alder, and tanoak.

Forestry Publications Office
Oregon State University
Forest Research Laboratory 227
Corvallis, OR 97331-7401

Address Correction Requested

Non-Profit Org.
U.S. Postage
PAID
Corvallis, OR
Permit No. 200