

Wood of Giant Sequoia: Properties and Unique Characteristics¹

Douglas D. Piirto²

Abstract: Wood properties of giant sequoia (*Sequoia gigantea* [Lindl.] Decne.) were compared with those for other coniferous tree species. Wood properties such as specific gravity, various mechanical properties, extractive content, and decay resistance of young-growth giant sequoia are comparable to or more favorable than those of coast redwood (*Sequoia sempervirens* [D. Don] Endl.). It is recommended that giant sequoia be considered for planting stock in managed production forests to increase future supplies of wood having the characteristics so highly valued in coast redwood and other decay-resistant species.

Giant sequoia (*Sequoia gigantea* [Lindl.] Decne.) is one of the oldest and certainly the largest living organism on earth. I have been studying giant sequoia and coast redwood (*Sequoia sempervirens* [D. Don] Endl.) since 1970. Although knowledge of both species is steadily improving, the focus has been on coast redwood, primarily because of its commercial importance. For this reason, correcting the many misleading generalizations about giant sequoia has been a slow and sometimes agonizing process. The wood from giant sequoia trees has had the reputation of being very brash (brittle) and of little use for lumber products. This belief fails to distinguish differences between old- and young-growth trees, and it fails to recognize the wide range of wood products obtainable from forest trees besides lumber, e.g., particleboard, plywood, and paper (Piirto and Wilcox 1981).

This paper has two objectives: First, to compare the wood properties of native grown giant sequoia to coast redwood, incense cedar (*Libocedrus decurrens* Torr), white fir (*Abies concolor* [Gord. and Glend.] Lindl. ex Hildebr.) and western redcedar (*Thuja plicata* Donn). And, second, to emphasize the value of giant sequoia in both National Parks and in production forestry (e.g., plantations containing giant sequoia). It also highlights key points in the following subject areas: (1) general characteristics and minute anatomy (2) physical and mechanical properties (3) chemical composition (4) natural decay resistance, and (5) utilization.

Several excellent studies on the wood properties of giant sequoia grown outside of its native range have been and are being conducted in several foreign countries (Finogeev and Kuznecov 1969, Liubimirescu and others 1972, Knigge 1983, Knigge and Wenzel 1982, Knigge and others 1983).

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²Associate professor, California Polytechnic State University, San Luis Obispo.

GENERAL CHARACTERISTICS AND MINUTE ANATOMY

The wood of giant sequoia closely resembles that of coast redwood (Panshin and deZeeuw 1970). The wood of both species is light in weight, rather soft, considered strong for its weight, and moderately coarse to coarse in texture (Mitchell 1935, 1936). Key points and differences between giant sequoia and coast redwood are these:

- The heartwood of both species is characteristically reddish-brown, but the wood of giant sequoia is darker and has a purplish cast (Panshin and deZeeuw 1970).
- On the average, the corresponding anatomical features of coast redwood are larger than those of giant sequoia (Mitchell 1935, 1936).
- Bands of latewood (one to four tracheids in width) are generally narrower in giant sequoia than in redwood (Panshin and deZeeuw 1970) (*fig. 1*).
- Giant sequoia has 75 percent more ray tissue than does coast redwood (Mitchell 1935, 1936). This is a key diagnostic feature used to separate the wood of the two species.
- Tracheid length (4 to 4.5 mm) for giant sequoia wood is slightly longer than the average length for conifers but significantly shorter than for coast redwood (Cockrell and others 1971, Barman 1966) (*fig. 2*).

Compression wood, wood formed on the lower side of branches and inclined trunks of softwoods, has been reported in young-growth giant sequoia (Cockrell 1974, Cockrell and Knudson).

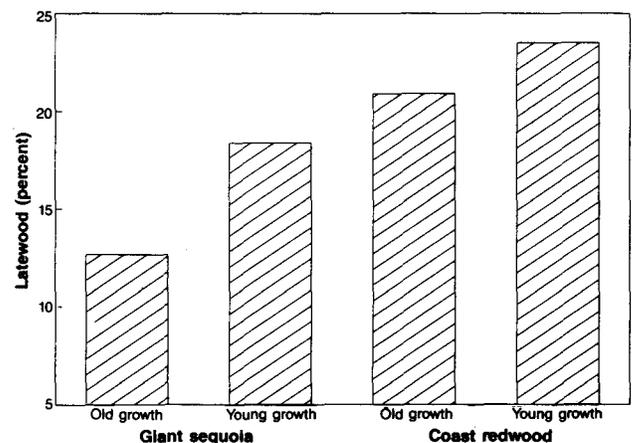


Figure 1-Percentage of latewood in giant sequoia and coast redwood. Values are from Cockrell and others (1971), Piirto and Wilcox (1981), and Resch and Arganbright (1968).

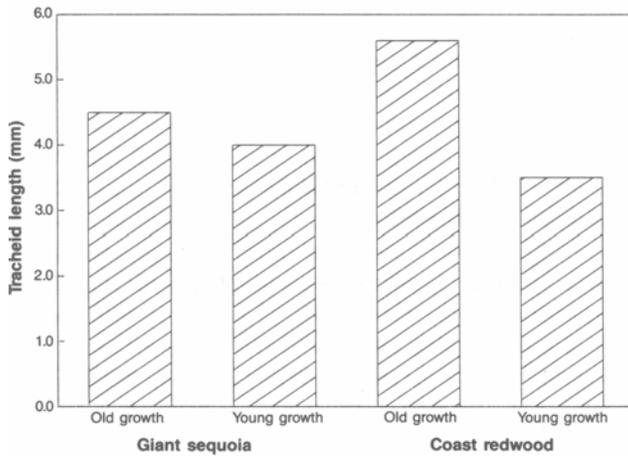


Figure 2-Anatomical characteristics of giant sequoia and coast redwood. Values are from Cockrell and others (1971), and Resch and Arganbright (1968).

PHYSICAL AND MECHANICAL PROPERTIES

The conclusions in the following paragraphs were reached by Piirto and Wilcox (1981) regarding the physical and mechanical properties of giant sequoia.

The average specific gravity (the ratio of the oven-dry weight sample to the weight of a volume of water equal to the volume of the sample at a specified moisture content-e.g., oven-dry weight/green volume) tends to be higher in young-growth (0.35) than in old-growth giant sequoia-0.30 (Cockrell and others 1971, Keylwerth 1954). Young-growth giant sequoia specific gravity is comparable to young-growth coast redwood (fig. 3).

Young-growth giant sequoia is heavier and stronger than old-growth giant sequoia (the reverse is true in coast redwood). Old-growth giant sequoia heartwood exhibits a characteristic brash-type failure in static bending and has very low toughness (resistance to sudden shock) values, thus it can be considered very

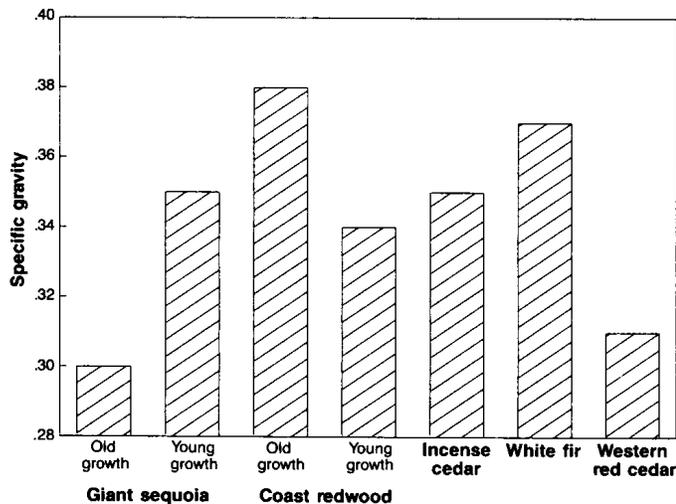


Figure 3-Specific gravity of several woods, based on oven-dry weight and green volume.

brittle. Koehler (1933) provided a good discussion of causes for brashness in wood; however, the mechanisms that cause wood to be brash are not completely understood (figs. 4 and 5).

Mechanical properties of young-growth giant sequoia are equal to, or somewhat superior to, white fir, incense cedar, western redcedar and young-growth coast redwood in most of its mechanical properties. Wood from young-growth giant sequoia is acceptable for dimension lumber in light construction (Cockrell and others 1971).

Heartwood of old- and young-growth giant sequoia and old- and young-growth coast redwood shows appreciably lower tangential, radial, and volumetric shrinkage than sapwood (old-growth heartwood decidedly lower than young-growth). Old-growth and young-growth giant sequoia have comparable shrinkage properties to similar categories of coast redwood (Cockrell and others 1971). Tarkow and Krueger (1961) attributed the relatively low shrinkage properties of coast redwood heartwood to the presence of extractives in the cell wall. This basic principle applies equally as well to the heartwood of giant sequoia. Deposition of extractives within the cell walls makes wood more resistant to decay and the compounds more resistant to leaching (Scheffer and Cowling 1966).

CHEMICAL COMPOSITION OF EXTRACTIVES

In addition to its principle cell-wall components (cellulose, hemicellulose, and lignin), wood may contain a great variety of chemical compounds extractable with water and neutral organic solvents such as alcohol, benzene, and ethyl ether. These compounds are called extractives and are not an integral part of the cell wall structure. Color, decay, and insect resistance (Anderson 1961), density and modulus of elasticity (Arganbright 1971), pulping properties (Institute of Paper Chemistry 1945, Hillis 1962, Martin and others 1960), and dimensional stability (Tarkow and Krueger 1961) as well as other wood properties of giant sequoia and coast redwood are specifically related to the quantity and nature of the extractives present. Most of the research on extractive chemistry has focused on coast redwood. However, it is reasonable to assume that giant sequoia would share many of the following key points:

- Amounts of extractives range from 15 to 30 percent of the wood's original oven-dry weight (Anderson and others 1962).
- Extractive compounds vary depending upon their location within the tree and age of the wood (Sherrard and Kurth 1933a). Extractive content of old-growth coast redwood decreases with height in the tree and towards the center of the lower trunk, with extractive content being highest in the outer heartwood of the butt log (Sherrard and Kurth 1933a, Isenberg 1951, Institute of Paper Chemistry 1945, Anderson 1961, Resch and Arganbright 1968). Contrary to this gradient pattern of extractive content in old-growth coast redwood, young-growth shows a tendency for a more uniform distribution of extractives throughout the heartwood (Anderson 1961, Resch and Arganbright 1968). Extractive concentration is significantly greater in the center of young-growth coast redwood than in old-growth. This difference suggests that the extractive gradient pattern in old-growth coast

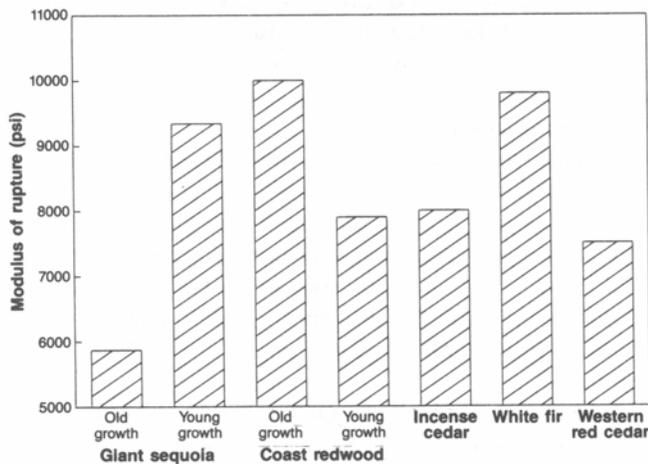
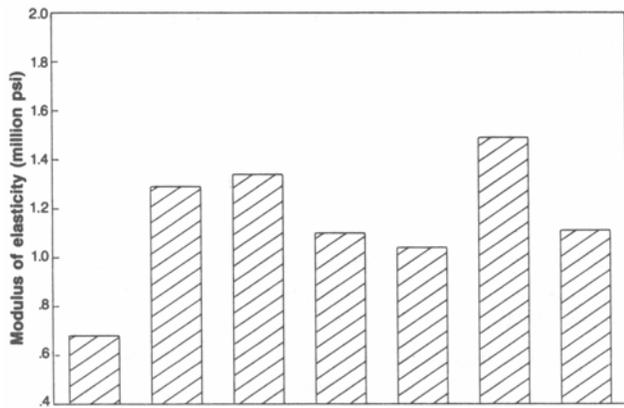


Figure 4-Modulus of rupture and of elasticity for several woods (air-dry condition). Values are based on data from Cockrell and others (1971), and USDA (1974).

redwood may be the result of decomposition, change in solubility, or change in extractive distribution with age (Resch and Arganbright 1968).

- Early reports indicated that these extractives were largely found in the cell lumina of ray and longitudinal parenchymal cells (Institute of Paper Chemistry 1945). However, more recent studies (Kuo 1977) have shown that 77 percent of the total extractive content is present within the cell wall.

- The greatest portion of coast redwood extractives are hot-water soluble (Anderson 1961) and include tannin, cyclitols, polyphenolics, polysaccharides, free sugars, color matter, and other unknown compounds (*fig. 6*). Cyclitols have been reported as having some taxonomic significance (Anderson and others 1968a,b).

- The water insoluble extractives of coast redwood heartwood include phlobaphenes, polymerized tannin, native lignin, phenols, fatty acids, wax, and other compounds (Anderson 1961) (*fig. 7*). These are soluble in hot ethanol.

- There is little ether-soluble material (less than 1 percent) in coast redwood indicating the absence of fats, waxes, oils, and resinous substances. However, terpenoids (e.g., alpha pinene and various resin acids) have been reported (Anderson and others

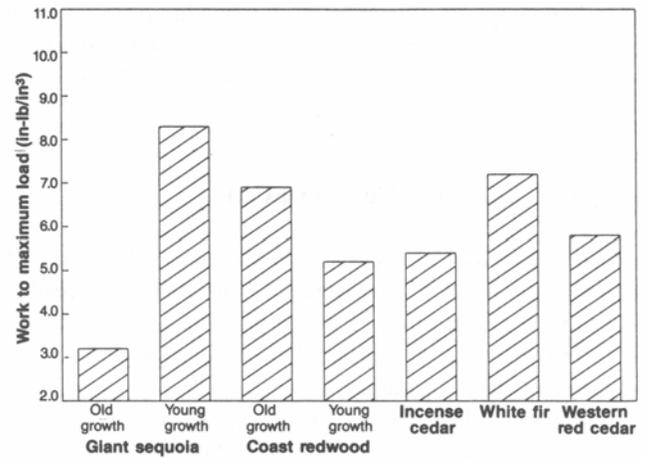


Figure 5-Work to maximum load for several woods (air-dry condition). Values are from Cockrell and others (1971) and USDA (1974).

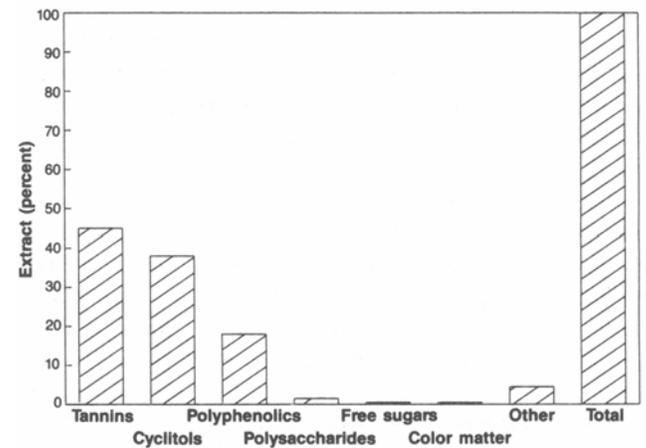


Figure 6-Water-soluble extractives of coast redwood heartwood. Values are from Anderson (1961).

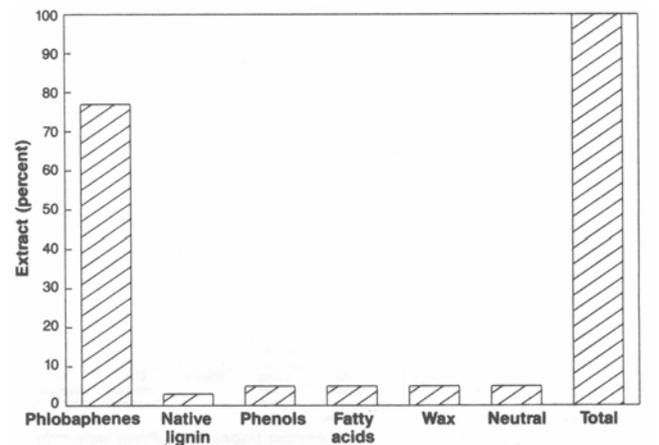


Figure 7-Ethanol-soluble extractives of coast redwood heartwood. Values are from Anderson (1961).

1968a,b) within a sticky viscous resin found in open pockets of coast redwood. Similarly, a resinous, sticky material has been observed on the fire scars of giant sequoia (Piiro 1977).

NATURAL RESISTANCE TO DECAY

Natural resistance to decay can be defined as the ability of wood to resist attack by decay fungi. The sapwood is readily decayed by fungi, but the heartwood of some species is highly resistant to decay. Key points on natural decay resistance of coast redwood and giant sequoia are these:

- The wood of both old- and young-growth giant sequoia is classified as resistant to *Poria monticola* and highly resistant to *Lenzites trabea*. However, giant sequoia shows lower decay resistance than does coast redwood, a highly decay-resistant species (fig. 8).

- Extractives have been reported as the principal contributors to decay resistance. The variation in extractive content within individual coast redwood trees has been found to be directly related to the variation in decay resistance within these same trees (Sherrard and Kurth 1933a, Anderson 1961). The durability of coast redwood and giant sequoia would therefore be highest in the butt log heartwood nearest the sapwood, and the susceptibility to decay would increase towards the pith of the tree and towards the top.

- The unstable labile nature of coast redwood and giant sequoia extractives makes it difficult to determine which component is responsible for the decay resistance. Tannins have been reported as being weak fungicides in laboratory tests. Phlobaphenes have been reported as being nontoxic (Anderson 1961).

Possible explanations for the high decay resistance of coast redwood and giant sequoia are these three: (1) several extractive components (water- and alcohol-soluble) may work together to produce fungi toxicity; (2) extractives may be basically nontoxic and merely operate as bulking agents preventing fungal enzymes from penetrating and subsequently decomposing cell walls; or,

(3) some very toxic components may exist but have not been documented.

UTILIZATION

Old-growth coast redwood is valued for its durability, low shrinkage and texture. It is commonly used for these purposes (USDA 1974):

- Building, particularly in areas of modest decay hazard.
- Siding, sashes, doors, blinds, and finish, and similar products.
- Cooling towers, wood stove pipe, tanks, silos, and outdoor furniture where decay hazard may exist.
- Split products such as fence posts and fence material.
- Decorative plywood.
- Paper manufacture.

Presumably giant sequoia could occupy these same markets, but the use of old-growth giant sequoia is limited by the brittle nature of the wood and the very small supply because the majority of giant sequoia groves have been incorporated into National Parks. Old-growth giant sequoia has been used for fence posts, vineyard stakes, shakes, shingles, and occasionally lumber where decay hazard is high (Panshin and deZeeuw 1970, Meyer 1952).

Young-growth giant sequoia, on the other hand, has favorable wood properties in comparison to white fir and young-growth coast redwood. It is acceptable for use as dimension lumber in light construction (Cockrell and others 1971). Young-growth giant sequoia has veneer properties comparable to coast redwood, which was rated as excellent for decorative siding and intermediate where strength is the primary concern to the plywood consumer (Lutz 1972). Finogeev and Kuznecov (1969) reported similar veneer quality of Russian-grown giant sequoia trees.

I suspected for sometime, and Knigge and others (1983) confirmed that heartwood formation begins early in young-growth giant sequoia and continues steadily following the shape of the stem. Knottiness is one of the biggest problems for all types of utilization of young-growth giant sequoia. As such, early pruning is recommended to produce any appreciable volume of clear lumber within short to medium rotation periods. A more cylindrical stem results from pruning.

Fiber studies by Cockrell and others (1971) and Barman (1966) indicated that giant sequoia promises to make acceptable pulp.

CONCLUSIONS

Wood properties of young-growth giant sequoia are comparable to or more favorable than those of coast redwood. It seems reasonable, therefore, to consider giant sequoia for planting stock in managed production forests to increase future supplies of wood having the same characteristics that are so highly valued in redwood.

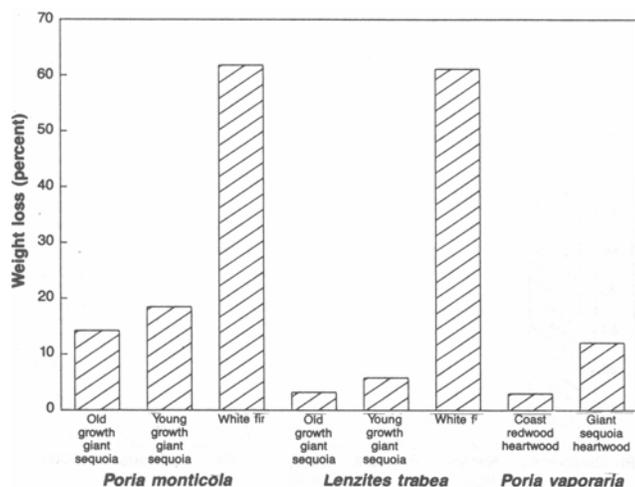


Figure 8-Decay resistance of several woods exposed to various decay fungi. Values are from Piiro and Wilcox (1981) and Rennerfeldt (1956).

REFERENCES

- Anderson, A. B. The influence of extractives on tree properties. Pt. 1. California redwood. *J. Inst. Wood Sci.* 8: 14-34; 1961.
- Anderson, A. B.; Duncan, C. G.; Scheffer, T. C. Effect of drying conditions on durability of California redwood. *Forest Prod. J.* 12(7): 311-312; 1962.
- Anderson, A. B.; Riffer, R.; Wong, A. Chemistry of the genus *Sequoia*-V Cylitolis from the heartwood of *Sequoia gigantea*. *Phytochemistry* 7(8): 1367-1371; 1968a.
- Anderson, A. B.; Riffer, R.; Wong, A. Chemistry of the genus *Sequoia*-VI. On the cyclitolis present in heartwood of *Sequoia sempervirens*. *Phytochemistry* 7(10): 1867-1870; 1968b.
- Arganbright, D. G. Influence of extractives on bending strength of redwood (*Sequoia sempervirens*). *Wood and Fiber* 2(4): 367-372; 1971.
- Barman, M. W. Cell length and rate of anticlinal division in the cambium of the sequoias. *Can. J. Bot.* 44(2): 209-218; 1966.
- Cockrell, R. A.; Knudson, R. M.; Stangenberger, A. G. Mechanical properties of southern Sierra old- and second-growth giant sequoia. Bull. 854. Berkeley: University of California, Agriculture Experiment Station; 1971.
- Cockrell, R. A.; Knudson, R. M. A comparison of static bending, compression and tension parallel to grain and toughness properties of compression wood and normal wood of a giant sequoia. *Wood Sci. and Technol.* 7(4): 241-250; 1973.
- Cockrell, R. A. A comparison of latewood pits, fibril orientation and shrinkage of normal and compression wood of giant sequoia. *Wood Sci. and Technol.* 8(3): 197-206; 1974.
- Finogeev, B. L.; Kuznecov, S. I. Industrial properties of the wood of *Cedrus atlantica*, *C. deodara* and *Sequoia gigantea*. *Bjull. Gos. Nikit. Bot. Sada.* 2: 11-13; 1969.
- Hillis, W. E., ed. 1962. Wood extractives. New York: Academic Press; 1969. Institute of Paper Chemistry. Redwood--a report of fundamental investigations and related application studies for the Pacific Lumber Company. Res. Bull. 12(2). Appleton, WI; 1945.
- Isenberg, I. H. Pulpwoods of United States and Canada. 2d ed. Appleton, WI: Inst. Paper Chem.; 1951.
- Keylwerth, R. Das Holz der *Sequoia gigantea*. *Holz als Roh- und Werkstoff* 12(3): 105-107; 1954.
- Knigge, Von W.; Wenzel, B. Variability of fiberlength within a tree of *Sequoiadendron giganteum* (Lindl.) Buchholz. *Forstarchiv* 53(3): 94-99; 1982.
- Knigge, Von W.; Pellinen, P.; Schilling, T. Investigations on growth, branch-formation, heartwood-formation and bark-diameter of giant sequoia trees (*Sequoiadendron giganteum* [Lindl.] Buchholz). *Forstarchiv* 54(2): 54-61; 1983.
- Knigge, Von W. Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz), a fast growing wood of the future. *Forstarchiv*. In press.
- Koehler, A. Causes of brashness in wood. *Tech. Bull.* 342. Washington, DC: U.S. Department of Agriculture; 1933.
- Kuo, M. L. Cellular distribution of extractives in redwood (*Sequoia sempervirens*) and incense cedar (*Libocedrus decurrens*) wood. Berkeley: Univ. of California; 1977. Dissertation.
- Liubimirescu, A.; Guriianu, M.; Lonescu, R. Physical and mechanical properties of the wood of *Sequoia gigantea*. *Revista Padurilor* 87(12): 613-616; 1972.
- Lutz, J. E. Veneer species that grow in the United States. Res. Paper FPL- 167. Madison, WI: Forest Products Laboratory, Forest Service, U.S. Department of Agriculture; 1972.
- Martin, J. S.; Simmonds, F. A.; Fahey, D. J. Pulping and papermaking experiments on redwood. Mimeo Rep. 2181. Madison, WI: Forest Products Laboratory, Forest Service, U.S. Department of Agriculture; 1960.
- Meyer, F. A. The status of *Sequoia gigantea* in the Sierra Nevada. Report pursuant to Senate Concurrent Resolution 44, 1951 General Session. Sacramento: State of Calif.; 1952. 75 p.
- Mitchell, J. N. The comparative histology of the secondary xylem of *Sequoia gigantea* and *Sequoia sempervirens*. Berkeley: Univ. of California; 1935. Dissertation.
- Mitchell, J. N. The detailed structure of stem wood of the two sequoias. *J. For.* 34(11): 988-993; 1936.
- Panshin, A. J.; deZeeuw, C. Textbook of wood technology. Vol. 1, 3d ed. McGraw-Hill Book Company; 1970.
- Piirto, D. D. Factors associated with tree failure of giant sequoia. Berkeley: Univ. of California; 1977. Dissertation.
- Piirto, D. D.; Wilcox, W. Wayne. Comparative properties of old- and young-growth giant sequoia of potential significance to wood utilization. Bull. 1901. Berkeley: University of California, Division of Agricultural Sciences; 1981.
- Piirto, D. D.; Wilcox, W. Wayne; Parmeter, J. R.; Wood, D. L. Causes of uprooting and breakage of specimen giant sequoia trees. Bull. 1909. Berkeley: University of California, Division of Agriculture and Natural Resources; 1984.
- Rennerfelt, E. The natural resistance of decay of certain conifers. *Friesia* 5(3-5): 361-365; 1956.
- Resch, H.; Arganbright, D. G. Variation of specific gravity, extractive content and tracheid length in redwood trees. *Forest Sci.* 14(2): 148-155; 1968.
- Scheffer, T. C.; Cowling, E. B. Natural resistance of wood to microbial deterioration. *Ann. Rev. Phytopathology* 4: 147-170; 1966.
- Sherrard, E. C.; Kurth, E. F. Distribution of extractive in redwood: its relation to durability. *Ind. Eng. Chem.* 23(3): 300-302; 1933a.
- Sherrard, E. C.; Kurth, E. E. The crystalline colouring compounds in redwood extract. *J. Amer. Chem. Soc.* 55: 1728-1732; 1933b.
- Tarkow, H.; Krueger, J. Distribution of hot-water soluble material in cell walls and cavities of redwood. *For. Prod. J.* 11(5): 228-229; 1961.
- United States Department of Agriculture. Wood handbook: wood as an engineering material. Agric. Handb. 72. Washington, DC: U.S. Department of Agriculture; 1974.
- Wilcox, W. W.; Piirto, D. D. Decay resistance in redwood (*Sequoia sempervirens*) heartwood as related to color variation. *Wood and Fiber* 7(4): 240-245; 1976.

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