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Some Woods of Hawaii

Properties and Uses of 16 Commercial Species

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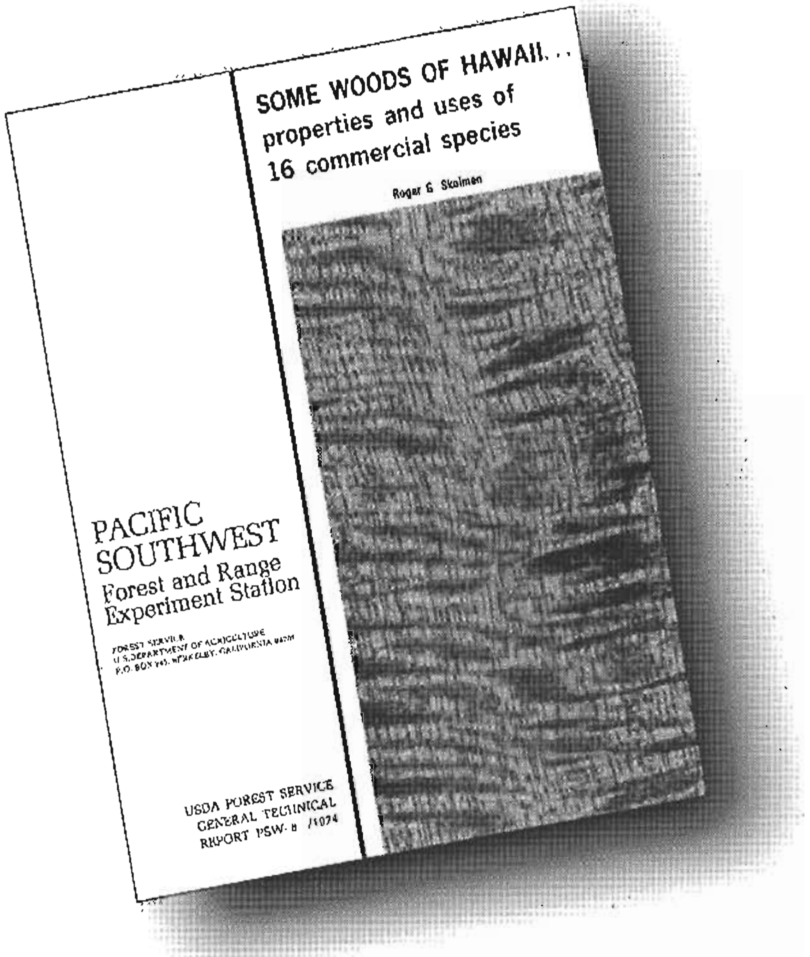

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Information is given for 16 Hawaii-grown species, both native and introduced, of present or potential commercial importance. Descriptive notes include tree characteristics, history, size, and growth rates; the timber volume available in Hawaii; and accessibility for logging. Wood properties, including appearance, weight, shrinkage, strength, workability, seasoning, durability, and finishing, are explained with reference to well-known woods, and present and potential uses are described. An appendix includes technical data. Each species is illustrated in color.

Retrieval Terms: Hawaii; commercial timbers information; silvical characteristics; distribution.

The Author

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Over the past several years, much information on the properties and uses of a number of Hawaii-grown woods has been gathered. Most of the data on physical and mechanical properties have been published in various reports by the U.S. Forest Products Laboratory. Several of these reports are now out of print or in short supply, and some available information has not yet been published. This material has been drawn together here and combined with information drawn from the world literature and with some new data gathered for this report.

Each species is covered from many points of view that might be of interest to a wide audience. Comments on the tree, its history, size, and growth rate, the timber volume available in Hawaii, and the accessibility of the timber for logging are given for the benefit of loggers, foresters, history buffs, and tree lovers. Properties of each species are explained in the text by means of general comparison to well-known woods.[1] To satisfy the needs of architects and engineers technical tables are included in the Appendix. Present and potential uses of the woods are described.

Hawaii has about 1 million acres of land with the soils and climate required to produce timber as a crop. This land is primarily in native forest in which the principal species is ohia *(Metrosideros collina)*. Koa *(Acacia koa)* is another widespread native species. There are some 30,000 acres in timber plantations of introduced species, and these constitute the bulk of the present timber resource. Altogether, more than 800 tree species grow in Hawaii; only 16 of those presently or potentially important commercially are described here.

Despite its rather heavily forested condition, Hawaii has only a small primary forest products industry. The annual cut of the three sawmills presently operating is less than 3 million board feet, of which well over half is koa. During the 1960's, the Hawaii Division of Forestry made a start toward providing an improved timber resource for the future by clearing about 8,000 acres of low-yield forest and planting fast-growing introduced species with desirable wood properties. Within 10 years, this timber will begin to reach harvestable size. If this program can be continued at an adequate level, a timber processing industry can become important in Hawaii's economy.

[1]These woods are referred to by their common names; the scientific name is given at the first mention of each species.

In the descriptions of the wood species, all tree and log volume figures are based on the International ¼-inch rule. Trees specified as sawtimber are those more than 11 inches in diameter breast height (d.b.h.). Logs, unless otherwise specified, are 16-foot lengths of the main stem. Hardwood lumber grades mentioned are those of the National Hardwood Lumber Association.

The specific gravity figures reported were calculated from the volume of the wood at 12 percent moisture content (air dry) and its weight when oven-dry. The density (pounds per cubic foot) figures were calculated for both volume and weight at 12 percent moisture content.

Wood characteristics naturally vary from one piece to another. The descriptions and numerical data in this report apply to the wood as it is usually observed. The information on durability—that is, resistance to decay and termite damage—and the need for preservative treatment applies only to wood use in Hawaii unless otherwise stated. Subterranean and drywood termites are more injurious pests in Hawaii than in most areas in the mainland United States. Decay is also severe in the more humid parts of the islands because of the year-round warm temperatures. Durability is usually described in standard terms: very resistant, resistant, moderately resistant, or nonresistant.

For those interested in a brief evaluation of the 16 wood species described in this report, the following broad observations are offered:

Most plentiful: ohia, robusta, koa

Most attractive in figure or grain: koa, mango, monkey-pod

Most dense: ohia, bluegum, brushbox

Least dense: Molucca albizzia, redwood, Australian toon

Most stable: Monkey-pod, redwood, mango

Strongest in mechanical properties: ohia, bluegum, brushbox

Most easily workable: redwood, Norfolk-Island-pine, sugi

Least susceptible to degrade in seasoning: redwood, sugi, monkey-pod

Most useful for . . .:

- flooring: ohia, blackbutt, brushbox
- cabinet work: koa, mango, tropical ash
- wood turning and carving: monkey-pod, koa, milo
- pallets and crating: robusta, saligna, bluegum
- wood chips and fiber products: bluegum, saligna.

KOA

Acacia koa Gray

Trees and Forests

Koa is Hawaii's finest native timber tree. Unfortunately, it grows best in areas that can be converted into good grazing land, and most of the best koa forests have been cleared to develop pasture. Consequently, not much koa is left. Koa seedlings are also palatable to grazing animals, so that the number of young, vigorous koa trees is small.

Koa sawtimber trees are typically 24 inches or larger in diameter and usually contain two 16-foot logs. They have fluted, often crooked main stems which break up into massive, widely spreading branches. Because the trees are old and decadent, butt and crotch rots are common (Burgan, *et al.* n/d). Deep fluting produces bark pockets which are the main cause of degrade in koa lumber.

The remaining koa forest that may be considered commercial is all on the island of Hawaii, primarily in rather inaccessible areas above 4,000 feet elevation on the slopes of Mauna Loa, Mauna Kea, and Hualalai. Timber volume in trees exceeding 11 inches d.b.h. is about 120 million board feet, (Nelson and Wheeler 1963), but less than a third of this is economically harvestable.

Wood Characteristics

Appearance—Koa has pale brown sapwood that changes abruptly into brown to reddish brown heartwood. Sapwood thickness is usually about 1 inch in old butt logs, but may be 2 inches or more in logs from young trees or branches. Heartwood varies in color from tree to tree, ranging from pale blond to deep chocolate brown. Reddish brown is the most common color.

The wood is usually figured by light and dark banding in the growth rings, sometimes prominently so. Grain is slightly to strongly interlocked and wavy. An attractive curly or fiddleback figure is often present. Fairly large vessel elements give the wood a moderately coarse texture.

Weight—Koa has a density of 38 pounds per cubic foot (specific gravity 0.55) when air dry (Gerry 1955; Harrar 1941, 1942[2]). This density is identical to that of black walnut *(Juglans nigra)*, with which wood koa compares quite closely in most technical properties (Skolmen 1968c).

Shrinkage and stability—The wood has a slight edge on walnut in shrinkage owing to greater uniformity of shrinkage in the radial and tangential directions (Harrar 1942). Once dried, koa remains stable and moves in place only slightly with changes in relative humidity.

Strength—Koa compares closely to black walnut in all its mechanical properties (Skolmen 1968). Like walnut, it has strength more than adequate for table and chair legs[2] (Gerry 1955). Like walnut, it has hardness not great enough for flooring, but more than adequate for scratch-resistant furniture (Harrar 1942).

Workability—Sharp saws, knives, and sandpaper are essential in machining koa because it is quickly burned by any dull rubbing action. The wood is somewhat harder to saw than its density would indicate, but does not have a pronounced dulling effect on tools. Straight-grained koa machines easily, but figured wood is difficult to shape or plane without tearouts because of irregular grain. Owing to its irregular grain, koa is best surfaced one side at a time with careful attention to grain direction. Lumber should be dried to 12 percent moisture content or less before planing to avoid grain lifting and fuzzy surfaces.

Seasoning—Koa is easily seasoned with little degrade. Some surface checking usually occurs in large cants when they are stored outdoors awaiting manufacture into carvings or veneer, but lumber of normal thicknesses gives no problem so long as good drying procedures are followed.

Durability—The wood is nonresistant to decay (Skolmen 1968a) and is highly susceptible to attack by both *Coptotermes formosanus*, the subterranean termite, and *Cryptotermes brevis*, the drywood termite. In normal use as a furniture and cabinet wood, koa is not subjected to decay or subterranean termite hazards, but in Hawaii it is open to attack by drywood termites. Permanent installations of koa woodwork and paneling should therefore be treated with a termite-repellent chemical.

Finishing—Koa takes a high polish and almost any type of natural finish. It will yellow quickly in the presence of bright sunlight even though well varnished, so is not well suited for exterior trim.

Wood Uses

Koa is primarily a furniture and cabinet wood. About 500,000 board feet are used each year in local furniture manufacture. Many homes and business establishments have some paneling, decorative wood

[2]Gerhards, C. C. *A limited evaluation of a few strength properties for Acacia koa, Metrosideros collina, and Eucalyptus robusta grown in Hawaii.* 1963. (Unpublished report on file at U.S. Forest Prod. Lab., Madison, Wis.)

work, and furniture of koa since it is the traditional Hawaiian cabinet wood.

The wood is also extensively used for carved bowls and turnery. Articles of koa generally command a premium in price over similar articles made of the more commonly used monkey-pod *(Pithecellobium saman).* Because of its nearly equal radial and tangential shrinkage in drying, koa can be worked into bowls while green and subsequently dried with only slight degrade.

Koa is a good wood for specialty gunstocks (Crane Creek Gun Stock Co. 1962). Selected gunstock blanks have been shipped to two manufacturers on the U.S. mainland for a number of years.

Koa is shipped to several mainland States as well as to Japan as cants and as logs for slicing and peeling into veneer. A local plywood company has also peeled koa for decorative paneling.

Because it is a valuable, scarce commodity with established market outlets, koa lumber is selected and graded to fit the requirements of particular uses. It is not uncommon for veneer manufacturers to visit Hawaii to select the logs and cants they want. Generally, the most colorful and highly figured koa goes into craftwork (carvings and turnery) and gunstocks. Veneer manufacturers use less highly figured but still colorful wood to avoid jointing problems. Low-grade lumber is used for upholstered furniture frames, pallets, and irrigation stakes.

Koa is an attractive, highly useful wood that commands a high price. It could probably fill a much greater and continuing market need if sustained supplies could be developed. Pressures for preservation of native forests—especially on public lands—and lack of programs to regenerate the resource on private lands make future supplies questionable.

MOLUCCA ALBIZZIA

Albizia falcataria Fosberg syn. *A. falcata* (L.) Back. *(A. moluccana* Miq.*)*

Trees and Forests

Molucca albizzia is the most common of several albizzias growing in Hawaii. Introduced to Hawaii by J. F. Rock in 1917 (Rock 1920), it has been planted on all the islands, both as an ornamental and as a forest tree. The largest plantings are on Kauai and contain 5.1 million board feet of sawtimber (Honda, *et al.* 1967). Until recently, there were about 1 million board feet on the island of Hawaii, but most of this has been cut (Nelson and Honda 1966). Other plantings of significance are on Lanai (525,000 board feet) and Oahu (367,000 board feet) (Wong, *et al.* 1967; Nelson, *et al.* 1968). The timber on Kauai is generally accessible to logging, but there is no industry there to use it.

Albizzia trees, when forest grown, usually produce a single stem that is generally erect but contains several crooks. The trees grow extremely fast on favorable sites (annual rainfall of 60 to 150 inches, less than 2,500 feet elevation), and can produce 48-foot merchantable stems, 27-inches in diameter, in as little as 13 years. Most of the available timber is in stands 40 to 45 years old, and typical trees in these stands are 24 inches in diameter with three 16-foot logs.

Wood Characteristics

Appearance—Sapwood is wide and white, and is not always distinguished from heartwood. Heartwood is pale yellowish-brown with a pinkish tinge. The grain is usually straight and shallowly interlocked. The wood is coarse in texture, with little or no figure. When green, it has a strong odor, somewhat like garlic, which disappears in dry wood.

Weight—Albizzia is a light wood—weighing 23 pounds per cubic foot (specific gravity 0.33) when air dry (Gerhards 1966a). This weight is comparable to that of black cottonwood *(Populus trichocarpa)* and Engelmann spruce *(Picea engelmannii).*

Shrinkage and stability—Shrinkage of the wood is small, and compares with that of Engelmann spruce and ponderosa pine *(Pinus ponderosa)* (Gerhards 1966a). In service, movement with humidity changes is also small.

Strength—Albizzia is generally comparable to ponderosa pine in strength properties (Gerhards 1966a). It is slightly stronger when green, but weaker when air dry. It is a little stronger than average for a wood of its density.

Workability—Logs usually contain some growth stress, which causes slight end-splitting and slight spring in sawing. Butt logs frequently contain a core of brittleheart, 4 to 6 inches in diameter, about the pith. Tension wood, which causes fuzzy surfaces after planing, is also common in the species.

Albizzia saws well, but has a slight dulling effect because of stress-caused saw-pinching. Dust from sawing or other machining operations of both green and air dry wood, is irritating to mucous membranes.

The machining properties of the wood have been evaluated at the Forest Products Laboratory (Peters and Lutz 1966). It planes nearly as well as red alder *(Alnus rubra),* behaving best with a cutting angle of 10°. It shapes well, but tension wood, when present, produces fuzzy end grain and both fuzzy grain and chipping on side grain. It is about equivalent to basswood *(Tilia americana)* in turning. It proved to be good in boring and mortising. Sharp tools are required to cut this soft wood cleanly.

Albizzia has been used for veneer in Hawaii and was excellent for this application. It can be rotary-cut cold and produces smooth veneer, as long as knives are sharp. It glues well. Abnormally large chucks are required to hold this soft wood and to extend beyond the brittleheart core; this results in larger cores than normal. End splits caused by growth stress are troublesome in peeling and often cause splitouts on the lathe.

Seasoning–Lumber stains rapidly if left close piled and should be quickly piled for drying after being sawn. It is an easy wood to season, drying rapidly with little degrade.

Durability–Albizzia is not resistant to decay or insects and should not be used in exposed situations unless treated with preservatives (Osborne 1970). It is relatively easy to treat.

Wood Uses

About 1 million board feet of albizzia timber has been cut in Hawaii. Most of this volume has been used for core stock veneer. The wood is excellent for this purpose, producing a high yield of low-density, clear veneer.

The lumber produced has had a variety of end uses, but the bulk of it has gone into light-weight pallets, crating, and shelving. One company in Hilo made several ladders of the wood and has used them successfully for several years.

The wood should be suitable for some internal furniture parts. It is well suited for use as filler, or core stock.

Albizzia should be a good species for board, paper, and other fiber products. Large volumes of light-colored, easily chippable wood can be grown rapidly.

"NORFOLK-ISLAND-PINE"

Araucaria columnaris (Forst.) Hook.

Trees and Forests

Although some true Norfolk-Island-pines *(Araucaria heterophylla)* grow in Hawaii, most of the trees called by this name are believed to be Cook- or columnar-pine *(A. columnaris)*, which they closely resemble. In this report, the probably incorrect but familiar common name is used.

"Norfolk-Island-pine" was introduced to Hawaii about 1860 and has been planted on all the islands, both as an ornamental and as a forest plantation tree. It is now being grown extensively for Christmas trees, which are marketed both locally and on the mainland. Most sawtimber stands are on Maui and Oahu at elevations below 2,000 feet and are generally readily accessible to logging. Many of these stands are too highly valued for recreation or scenic beauty, however, to allow logging.

The standing volume of sawtimber is 2.8 million board feet on Maui, 2 million on Oahu, and 1.5 million on Kauai (Wong, *et al.* 1969; Nelson, *et al.* 1968; Honda, *et al.* 1967). Most of the timber on the island of Hawaii has already been cut. The stands are predominantly 40 to 50 years old and contain trees typically about 18 inches d.b.h. and 90 feet tall. In these stands, the butt log is usually free of branches, but dead branches are retained on the second and third logs. The tree produces a whorl of branches about every foot up the trunk, so the wood is knotty. Little clear wood is produced except in the lower half of the butt log in old trees. Trees are easily logged because the branches usually break off cleanly when a tree hits the ground.

Wood Characteristics

Appearance–"Norfolk-Island-pine" has a pale blond, lustrous heartwood that is not differentiated from the sapwood. Frequent and evenly spaced knots in the wood are dark reddish brown to black. Most trees contain some compression wood, which produces lumber streaked with bands of pinkish-hued or darker brown wood. Occasional trees contain some heartwood streaked with dark brown discolorations. Growth rings can usually be discerned on end-grain surfaces, but rarely are distinct on radial or tangential faces. The wood is bland in figure and fine in texture. Strongly spiraled grain has been observed in some trees, and may be common in the species.

Weight–The air-dry weight of the wood is 31 pounds per cubic foot (specific gravity 0.44), placing the wood in the moderately heavy classification along with Douglas-fir *(Pseudotsuga menziesii)* (Gerhards 1967).

Shrinkage and stability–Shrinkage in drying is small, and the wood moves only slightly with changes in relative humidity (Gerhards 1967). It shrinks somewhat less than Douglas-fir and a little more than western redcedar *(Thuja plicata)*.

Strength–"Norfolk-Island-pine" is comparable in most strength properties to Douglas-fir of the "inland," or Intermediate type described in the U.S.

Department of Agriculture Wood Handbook of 1955 (Gerhards 1967). It is higher in shearing strength and hardness than Douglas-fir, but not quite as strong or stiff in bending. It is suitable for most general construction purposes so long as lumber containing severe diagonal grain (greater than 1 inch in 1 foot) is eliminated and so long as the weakening effect of its numerous knots is considered.

Workability—Clear wood saws and machines well in all operations, but clear wood is seldom encountered. The dense knots and irregular grain around knots cause some chipping and tearouts in planing dry lumber, but no particular difficulty is encountered in planing green lumber or in rotary peeling of green logs.

Seasoning—Blue stain develops rapidly in logs and also lumber if left close piled, so rapid conversion and drying is necessary. Compression wood that occurs in the trees has so far caused no problems of warping or excessive longitudinal shrinkage in lumber or plywood manufacture. Knots usually check minutely when the wood is dried and also bulge slightly when the surrounding wood shrinks—in lumber that has been planed while green, and in veneer.

Durability—"Norfolk-Island-pine" is highly susceptible to decay and insect damage and should not be used in exposed situations in Hawaii unless treated with preservatives. Because of its susceptibility to termites, it is desirable to treat the wood for any use where some permanence is desired. The wood is permeable to preservatives and easily treated (Skolmen 1971a).

Wood Uses

About 1 million board feet of "Norfolk-Island-pine" timber has so far been cut in Hawaii. About 150,000 feet of this volume was converted into veneer and plywood, the rest into lumber.

Most of the lumber has been used for residential framing and sheathing, the lowest grades going into pallets. Some "knotty pine"-type paneling has been produced and used quite effectively. "Norfolk-Island-pine" has an especially attractive luster, but for best appearance adjacent boards must be staggered lengthwise to avoid even rows of knots across a wall.

The wood is also used to a limited extent in the craft industry. Branch nodes are cut from trees of suitable size and turned into bowls and bracelets so that the knots form decorations around the piece.

The wood should be well suited for paper and fiber products. Its fiber tracheids are among the longest of any softwood, and the wood is essentially colorless.

BLUEGUM

Eucalyptus globulus Labill.

Trees and Forests

Bluegum was introduced to Hawaii about 1880 and has been planted on all the islands. Easy to propagate and adapted to many sites, it was planted widely for fuelwood and to satisfy certain Territorial leasing requirements before 1920. Below about 2,500 feet, it is usually poorly formed and spiral grained. At higher elevations it is well formed and spiral grain is much less common. In one 60-year-old stand on the island of Hawaii, a volume of 108,000 board-feet per acre was measured on a sample plot. And one tree in this plot contained 12 logs, each 16 feet long.[3] Bluegum is naturalized in Hawaii. It invades pasture lands both by root sprouting and through seeding.

Most of the bluegum is on Hawaii and Maui. Hawaii has 56 million board feet of sawtimber, almost all on land leased or owned by Kukaiau Ranch on the northeast slope of Mauna Kea.[3] Maui has an estimated 100 million board feet, a large portion of which is committed to a sawmill on the island.[3]

Bluegum was classed as a noncommercial species in forest resource inventories because it often has excessive and troublesome shrinkage in drying and excessive spiral grain. Apparently, this limitation is not universal, and the State has sold bluegum stumpage to private industry.

Wood Characteristics

Appearance—Bluegum has grayish-white sapwood about 1 inch thick which changes abruptly, but not too distinctly, into a pale yellow-brown heartwood similar in color to oak. It usually has interlocked grain, the degree of interlocking varying in localized areas. Localized areas of spiral and wavy grain may occur in otherwise straight-grained wood. The wood is moderately coarse in texture and has a faint figure imparted by light and darker banding in the growth rings.

The wood frequently contains gum veins, which are shakelike separations in the growth rings filled with a dark-reddish resinous material. These veins are a serious degrading feature.

Weight—Bluegum grown in Hawaii weighs 55 pounds per cubic foot (specific gravity 0.79) when air dry. It is a very heavy wood—generally comparable to

[3]Unpublished records on file at Hawaii Division of Forestry, Honolulu.

true hickories, such as shagbark hickory *(Carya ovata)* and to ohia *(Metrosideros collina)*.

Shrinkage and stability—Bluegum has a large shrinkage in drying, shrinking 8 percent radially and 12 percent tangentially in drying from green to oven-dry. It is unstable and changes dimensions appreciably with small changes in relative humidity.

Strength—The mechanical properties of Hawaii-grown bluegum have not been measured. Mechanical properties given for wood grown in Australia are for somewhat denser wood than that grown in Hawaii (Bolza and Kloot 1963). On the basis of wood density, the mechanical properties of Hawaii-grown bluegum are assumed to be comparable to those given for blackbutt *(E. pilularis)* and ohia. The wood is probably very strong in bending, very stiff, fairly high in shock resistance (if brittleheart and severe spiral grain are excluded), and very hard.

Workability—Bluegum trees contain little growth stress. End splitting and spring are much less troublesome than in other eucalypts, such as robusta and saligna. Brittleheart is common in the central core of logs, but is less extensive than in robusta or saligna eucalyptus. For a dense wood, it saws well. Spring is not a serious problem in making accurate cuts. Logs can be sawed for grade without excessive turning. Tearouts are common in planing in localized areas of severely interlocked or irregular grain. The wood rotary-peels well when heated.

Seasoning—Bluegum is a somewhat difficult wood to season. It is prone to checking on flat-sawn faces, and to deep end-checking, but if properly piled, it does not warp or collapse excessively. Quartersawn stock will season well, but should be sawed ¼-inch oversize per inch in thickness to overcome the large shrinkage. A small amount of 4/4-inch, flat-sawed stock has been successfully seasoned by slow air-drying in the humid Hilo area to equilibrium at 20 percent moisture content followed by mild kiln-drying. In much harsher air-drying conditions on Maui, straight, flat lumber is also being produced. It is possible to recover about one-third of the volume loss caused by shrinkage by steaming lumber when it has reached about 20 percent moisture content. Steaming (or reconditioning) is a normal practice used in Australia with this and other difficult species. In rotary-cut veneer manufacture, if 48-inch sheets are desired, green veneer should be clipped to at least 54-inch widths to allow for the large shrinkage in drying. Buckling in drying is a serious problem with bluegum veneer, but can be partially overcome by using screen-type driers.

Durability—The only tests of the durability of bluegum grown in Hawaii have been tests of fence posts. These tests indicate that the wood is moderately resistant to decay, but quite susceptible to subterranean termite attack—at least when sapwood is present as it was in the posts (Skolmen 1971). The wood is not suitable for use in exposed situations unless pressure treated with preservatives. No tests of pressure treating Hawaii-grown bluegum heartwood have been made, but the wood will probably be difficult to impregnate. Heartwood should be suitable for indoor use without treatment, but sapwood is known to be susceptible to powder-post beetle attack and probably to drywood termites as well.

Wood Uses

A small amount of rotary-cut bluegum veneer has been produced and laid up into sheathing-grade plywood. Except for its very heavy weight as compared with commonly used Douglas-fir plywood, it seems satisfactory.

About 20,000 board feet of bluegum lumber were produced by one sawmill. The bulk of this was used in pallets and was a complete failure. The pallets were made of green wood which collapsed, split at the nails, and warped to a remarkable degree. The rest of the lumber, of a higher grade, was carefully dried and run into flooring, which was satisfactory and was sold. The wood has also been used on a small scale for corral fences and gates, and for fence posts.

At another sawmill, some 150,000 board feet of lumber and timbers have been produced. Some of the lumber was used green as shed siding and in planter boxes and held up remarkably well. The rest was seasoned and for the most part performed satisfactorily. Occasional planks sawn from near the pith had extensive deep surface checking and honeycomb, but most of the lumber produced held its grade in drying. A large shipment of timbers was sent to Alaska for use as dock fenders. The customer is reportedly well satisfied.

Bluegum is suitable for heavy construction and for flooring in areas with stable humidity. It would be a good wood for pulp and fiber products if this type of industry develops in Hawaii.

BLACKBUTT

Eucalyptus pilularis Sm.

Trees and Forests

Blackbutt was introduced to Hawaii about 1910. Small stands are found on all the islands, but the volume of standing sawtimber is negligible except on

Oahu, which has 2.5 million board feet (Nelson, *et al.* 1968). The tree is somewhat difficult to establish in plantations, so has not been favored in forestation work. Most plantations are in drier sites where annual rainfall ranges from 40 to 75 inches.

Blackbutt grows rapidly and on better sites, trees can exceed 20 inches d.b.h. and 160 feet tall in 35 to 40 years. Stems frequently are slightly crooked. Like most other eucalypts, blackbutt self-prunes early and produces a high proportion of clear wood.

Wood Characteristics

Appearance—Blackbutt has a white sapwood which changes abruptly into a pale brown, oak-colored heartwood. Grain is usually straight, but occasional trees produce wood abundantly marked with birdseye mottling. The normal straight-grained wood is unfigured except for slight color differentiation within growth rings. It is a medium-to-fine-textured wood, and though it lacks the broad ray structure of white oak *(Quercus alba),* bears such a close resemblance to oak that it has been used for door jambs in homes floored with that wood.

Weight—Average density of the wood when air dry is 46 pounds per cubic foot (specific gravity 0.66) and much more uniform than in robusta or saligna (Gerhards 1966b). Wood near the pith is usually brittleheart, particularly in butt logs. Such wood is lower in density than normal wood and often contains visible compression failures.

Shrinkage and stability—Blackbutt has a large shrinkage in drying, although somewhat less than robusta or saligna (Gerhards 1966b). It is reasonably similar to white oak and shagbark hickory in shrinkage and instability with relative humidity changes.

Strength—Blackbutt wood is exceptionally stiff and will deflect less under load than any commonly used mainland wood (Gerhards 1966b). It is stiffer in bending and stronger in compression parallel to the grain than robusta or saligna and has about the same shock resistance, hardness, and shear strength as saligna. It is comparable to the heavier hickories, such as shagbark hickory, in all strength properties except shock resistance. It is, however, quite high in shock resistance and approaches white ash *(Fraxinus americana)* in this property so long as the brash central core of brittleheart is excluded.

Workability—Blackbutt saws and machines well, but is more difficult to work than woods of lower density. Occasional pieces with interlocked grain tend to tear out in planing and molding.

Like logs of most other eucalypts in Hawaii, blackbutt logs contain growth stress which causes them to split on the ends and spring in sawing. Growth stresses do not seem to be as troublesome in this species as they are in saligna and robusta.

The principal degrading factors in blackbutt lumber and veneer are gum veins, which are in about one tree in five.

Seasoning—The wood is subject to collapse in drying and should be air-dried to below 30 percent moisture content before kiln drying. Flat-sawn boards check more in drying than do robusta and saligna, but this has not been a serious problem in drying the wood.

Durability—The wood is moderately resistant to decay and will provide good service in above-ground uses. It is not as resistant to decay as robusta and saligna, but appears to be more resistant to subterranean termites than either one. In a durability test lasting 9 years and 6 months, and including redwood *(Sequoia sempervirens),* western redcedar, and other durable species, blackbutt was the only wood that was not attacked by subterranean termites or other wood-boring insects (Skolmen 1968a). Attack by drywood termites has not been observed in blackbutt, but it is probably susceptible to them as are most other woods. The wood is difficult to impregnate with preservatives.

Wood Uses

Only a few hundred thousand board feet of blackbutt lumber have been produced in Hawaii, as the resource is limited, and little timber is found on the islands with sawmills—Hawaii and Maui.

The lumber that has been produced has been used for flooring, paneling, truck beds, refuse flumes, residential construction, heavy construction, irrigation stakes, and pallets. Thus it has been used for essentially the same products as robusta and saligna.

Blackbutt has been preferred among the local woods for flooring because of its color, resembling oak. The wood has performed well in the few flooring installations made. A few pieces of furniture have also been made of blackbutt on a trial basis and have stood up well in service.

The wood should be somewhat superior to robusta and saligna for pulp because of its light color, which permits easy bleaching.

ROBUSTA

Eucalyptus robusta Sm.

Trees and Forests

Robusta was introduced to Hawaii from Australia about 1885 and has been extensively planted on the six main islands. It grows well on a wide variety of sites and can be seen in its best form and size in numerous plantings above the sugarcane fields on the Hamakua Coast of the island of Hawaii. As most of the robusta was planted by the Civilian Conservation Corps during the 1930's, the plantations are still quite young.

Robusta trees have thick, soft, deeply furrowed bark somewhat similar to the bark of redwood trees. They usually have a single, straight main stem for about half their total height. At wet sites, trees in open stands often produce aerial roots from major branch crotches. Frequently, small buttresses are also produced.

The bulk of the robusta timber volume is on Hawaii and Maui and on these islands is generally accessible to logging. The volume of standing sawtimber on these two islands amounts to 150 million board feet (International ¼-inch rule) contained in trees 11 inches d.b.h. and larger (Nelson and Honda 1966; Wong, *et al.* 1969). Sawtimber trees are commonly 18 inches in diameter and contain three 16-foot logs. Much of this timber is now assigned by long-term contract to two lumber producers.

The yield of No. 1 Common and better lumber from mill-run logs averaged 44 percent in two studies (Malcolm 1961; Skolmen 1970).

Wood Characteristics

Appearance—Robusta has a pale brown sapwood which changes abruptly into a reddish-brown heartwood. The heartwood is pale red when fresh cut and darkens with continued exposure to light. Generally, wood near the pith is much lighter in color than later produced heartwood. Grain is interlocked, and occasionally produces a ribbon figure on quartersawn faces. Usually, the only figure present is caused by color variation in the heartwood. Texture is fairly coarse.

Weight—Robusta has an average density of 46 pounds per cubic foot (specific gravity 0.66) when air dry (Youngs 1960). Density is quite variable, however (Skolmen 1972a). Wood near the pith may be only 29 to 30 pounds per cubic foot; wood in the outer part of the stem—the wood that produces lumber of high grade—is often 52 or more pounds per cubic foot. As the heavier wood is in the greatest volume, for practical purposes robusta may be compared to the heavier hickories (*Carya* spp.) in density.

Shrinkage and stability—Robusta has a large shrinkage in drying and is subject to considerable dimensional change with changes in atmospheric humidity (Youngs 1960; Skolmen 1963). This condition is usually not a problem in Hawaii, where humidity is uniform the year round at any one location, but it can be troublesome on the mainland.

Strength—Robusta compares quite closely to Philippine apitong (*Dipterocarpus* spp.) in both green and air-dry strength properties (Skolmen 1963). Among mainland hardwoods, it compares fairly closely with white oak. It is stronger than white oak in all properties except shock resistance.

Robusta does not have an air-dry modulus of elasticity sufficiently higher than Douglas-fir to justify modifying the depth dimension of robusta structural members, as has been tried by some manufacturers. From the data for moduli of elasticity of Douglas-fir and robusta, it can be calculated that an air-dry robusta board 15/16-inch thick will deflect over a given span about as much as an air-dry Douglas-fir board 1-inch thick. It should therefore be possible to use 15/16-inch robusta in place of 1-inch Douglas-fir. In lumber manufacturing, however, it is impractical to be concerned with such a small dimensional difference. Shrinkage variation and sawmill inaccuracies negate initial sawing to such a close tolerance.

Centered around the pith of almost every log is a 4- to 6-inch core of brittleheart. Brittleheart is extremely weak in shock resistance, having only 29 percent of the toughness of normal robusta wood (Skolmen and Gerhards 1964). It is therefore unsuitable for most uses and is best discarded. An estimated 18.5 percent of the total volume of robusta sawtimber is brittleheart (Skolmen 1973).

Workability—Robusta saws easily for a dense wood, but gummy water-soluble extractives (kino) in wood build up quickly behind saw gullets when sawing both green and dry wood. This gumming can be reduced in the sawmill by lubricating saws with a water spray. The wood turns and bores well, but tearouts in planing and molding are frequent unless a low cutting angle (20° is recommended) and slow feed are used (Youngs 1960).

Growth stresses in logs are a serious problem in lumber and veneer manufacture. Log ends usually split badly soon after bucking. Logs and green lumber spring in sawing so that special sawing techniques and equipment are required for the species (Skolmen 1971b). Best results are achieved with a conventional sawmill by (a) sawing short logs, (b) plain sawing, (c) turning after every other cut, and (d) taper sawing to a boxed heart. Splits in log ends are enlarged when logs are heated for peeling or slicing (Skolmen 1967), and also by drying stresses if logs are held for long periods. This problem can be reduced by bucking logs after heating and by storing long logs.

Seasoning–If it is air-dried to below 30 percent moisture content before kiln-drying in carefully constructed lumber piles, robusta lumber can be dried without serious degrade. The most frequent causes of degrade in drying are the extension of pre-existing end splits, stain of sapwood, and ambrosia beetle attack of sapwood (Skolmen 1964). The low-grade central core of light-colored, low-density wood usually collapses in drying, but this wood is seldom used for products where this matters. Small pin knots that are found in almost all robusta lumber invariably check if the wood is dried below about 12 percent, but this has no effect on lumber grade, as knots are defects regardless of checking (Skolmen 1971b).

Durability–Robusta is resistant to decay, in fact, more resistant than western redcedar, but is not equal to redwood in tests made in Hawaii (Skolmen 1968a). It is not recommended for use in contact with the ground, but will give good service in somewhat less hazardous decay situations: boat frames, exterior construction, and picnic tables, for example. Laboratory and field tests have indicated it is slightly less resistant to the subterranean termite than redwood, but much more resistant than are Douglas-fir and western redcedar. Attacks by the drywood termite have been observed in this species, and it does not appear to be resistant to the insect. Robusta heartwood does not accept preservative treatment well. Round posts and poles with sapwood intact can be treated to American Wood Preservers' Association specifications fairly readily, however (Skolmen 1968b).

Finishing–A test of paintability that has been in progress for 7 years is showing that robusta holds conventional oil and water-base house paints better than Douglas-fir, but not as well as redwood and Australian toon *(Toona australis)* (Boone 1966; Skolmen 1972b).

Wood Uses

Robusta is presently the principal species produced by one sawmill in Hawaii. Annual lumber production has varied considerably in the past few years, but is presently at about 1 million board feet.

Most of the lumber produced has been used for pallets. The wood is being used increasingly for house siding, flooring, and paneling. Plywood formerly produced was of construction grades used for concrete forms, sheathing, and floor underlayment.

Robusta has also been used in furniture manufacture, mostly in upholstered frames. A set of 50 chairs made up for an airport restaurant gave excellent service over a 4-year period of hard usage. The wood is best suited for small-membered designs joined in ways that allow a small shrinkage and expansion with humidity changes. Tests of robusta for case-goods manufacture in Michigan suggested that the wood was too unstable for the extreme humidity changes prevalent there (Skolmen 1971b). In the stable climate of Hawaii, there has been no problem.

Robusta has found use in a variety of other products. It has proved well suited for sawn (not bent) boat frames. It is excellent for stakes used in irrigating sugarcane, and also finds considerable use by the sugar industry for refuse flume construction and conveyor-belt slats. Truck beds and stake sides for trucks are frequently made of robusta, as are corral fences and gates. The wood is also widely used for round and split fence posts.

In addition to the rotary-cut veneer that has been produced, robusta veneer has been sliced on a trial basis by several companies and made up into attractive plywood paneling and door skins. The wood is not ideal for pulp or fiber products because of its dark color and high density, but it may eventually find use in such products, as have other similar hardwoods.

SALIGNA

Eucalyptus saligna Sm.

Trees and Forests

Saligna was introduced to Hawaii in the late 1880's and has been widely planted for watershed protection and timber production, particularly since the early 1960's. Some foresters have questioned the identity of the trees called *Eucalyptus saligna* in Hawaii. Many of the trees are probably hybrids of *E. saligna* and *E. grandis* and some may in fact be *E. grandis.*

Whatever their genotype, the trees grow extremely rapidly on favorable sites, often attaining diameters over 20 inches and heights over 160 feet in only 30 years. Even at 10 years of age, trees are frequently over 10 inches in diameter and 100 feet tall.

Saligna stands are on all the major islands and are generally in areas of easy access. Hawaii and Oahu have the most saligna. Hawaii has 14 million board feet of sawtimber, mostly growing along the Hamakua Coast (Nelson and Honda 1966). Oahu has 8 million feet, mainly in the Ewa Forest Reserve (Nelson, *et al.* 1968). Typical trees in 40-year-old stands are 20 inches d.b.h. and contain five 16-foot logs.

Wood Characteristics

Appearance–Saligna has a pale brown sapwood about 1½-inches thick which changes abruptly into a pink to light reddish-brown heartwood. Grain varies from straight to strongly interlocked, the latter type producing a ribbon stripe figure on quartered faces. Otherwise the wood has a subdued or bland figure caused by slight color variation and concentrations of vessel elements in the growth rings. Texture is medium. The wood is generally paler in color and finer in texture than robusta.

Weight—Average density, air dry, is 46 pounds per cubic foot (specific gravity 0.66). But fast-grown wood near the pith has a much lower density than that of wood near the bark, which formed later (Gerhards 1965). Higher grades of lumber, being from the outer wood in a log, have a density of about 50 pounds per cubic foot when air dry. So, for most uses, the wood may be compared to shagbark hickory in density.

Shrinkage and stability—Saligna has a large shrinkage in drying and is subject to considerable movement in place with changes in relative humidity (Gerhards 1965).

Strength—Saligna is slightly stronger than robusta in most strength properties, probably because its grain is usually straighter (Gerhards 1965). It is superior to white oak in most properties and exceeds any commonly used mainland hardwood in stiffness.

Most logs contain a core 4 to 6 inches in diameter of brash wood, brittleheart, centered around the pith. Brittleheart is unsuitable for most uses, owing to its extreme weakness in shock resistance. Such wood can usually be recognized by its lower density, "fuzzy" sawn end-grain surfaces, and lighter color than sound heartwood.

Workability—Saligna saws and machines normally for a wood of its density. Wood with interlocked grain is subject to tearouts in planing and molding unless a low cutting angle (20°) and slow feed are used. Because of its straighter grain, the wood machines a little better than robusta.

Growth stress is a serious problem in logs. Logs split open on the ends soon after bucking, often quite deeply. Lumber and cants bow (spring) as they come off the saw, and logs spring on the carriage (Skolmen 1967). Stresses should be equalized by frequent turning of the log in sawing on a conventional carriage. Stress problems are generally more severe in saligna than in robusta. Suggested sawing procedures for stressed logs are covered in the discussion of robusta.

Seasoning—Saligna can be kiln dried without serious degrade if it is first air-dried to below 30 percent moisture content. Because of its large shrinkage in drying, it requires careful attention in drying to avoid warp, checking, collapse, and honeycombing. Low density wood will usually collapse in drying, but such wood is normally otherwise unmarketable so the problem is a minor one. If desired, the collapse and a considerable portion of total shrinkage can be recovered by steaming the wood for several hours when it is at about 20 percent moisture content.

Durability—The wood is resistant to decay, but not nearly so resistant as redwood. It is not recommended for use in contact with the ground. Its resistance to termites has not been specifically tested, but stake tests in the ground indicate that saligna is roughly as resistant to subterranean termites as robusta (Skolmen 1968a). This similarity would rank it superior to Douglas-fir and western redcedar, but less resistant than redwood. Attacks by drywood termites have not been observed in saligna, but it is probably susceptible to them. Saligna is difficult to impregnate with preservatives.

Wood Uses

Saligna has not been extensively cut or marketed in Hawaii as yet. The saligna that has been produced has been largely mixed with robusta and sold as pallet lumber and flooring. It is suitable for the same products as robusta and except for its paler color, resembles it quite closely.

Saligna is an important timber species in South Africa and Brazil. In South Africa, it is used for general construction, mine props, poles, furniture, and a multitude of other products, including paper, rayon, and hardboard. In Brazil, it is the mainstay of the steel industry, which, lacking coal, uses saligna charcoal for fuel. It is also manufactured into paper, hardboard, and particle board in Brazil. Saligna has good potential for such uses in Hawaii as well, because it grows so rapidly on a variety of sites.

TROPICAL ASH

Fraxinus uhdei (Wenzig) Lingelsheim

Trees and Forests

In the late 1800's, two trees of this Mexican species were planted on Oahu—one in Nuuanu Valley and one in Kalihi Valley. These two trees were the primary seed source for almost all the tropical ash planted in Hawaii. The Division of Forestry discovered about 1920 that the tree was easy to propagate in the nursery and hardy in field planting. It was therefore used for many small plantings in forest reserves on all the main islands.

In 1960, the Division of Forestry began planting the tree on a large scale in the Waiakea Forest Reserve near Hilo. These plantings were specifically aimed at timber production. This more extensive use of the tree continued for about 4 years, but was then greatly diminished in favor of other species. Tropical ash is not now being used in the tree planting program because it tends to produce poor form in plantations. If the tree form can be improved through research, its use may be resumed. Planting spacing studies indicate that improvement is possible.

Hawaii is the only island with a significant volume of sawtimber at present. The volume amounts to 1.3 million board feet in trees that are typically 18 inches d.b.h. and contain two 16-foot logs. Most of this timber is along the Maulua Trail at 4,500 feet elevation on the land of Laupahoehoe. The rest, about 400,000 feet, is mostly in scattered stands in the vicinity of Honokaa (Nelson and Honda 1966).

Merchantable tropical ash trees usually have small buttresses and a slightly fluted stem. Because of the early growth habit of the tree, the butt log, if branch free, is usually clear of knots to the pith. It saws out a high yield of high-grade lumber. Tiny bud knots are fairly common in otherwise clear wood, but are considered by local users to be an enhancement, rather than a defect. The trees usually contain growth stresses, which cause immediate splitting of log ends.

Wood Characteristics

Appearance–Tropical ash wood is blond without differentiation between sapwood and heartwood. It is a ring-porous wood, and is moderately fine in texture and straight grained. The growth rings and parenchyma tissue give it an attractive figure similar to that of white ash *(F. americana)*, but more subdued.

Weight–It weighs 35 pounds per cubic foot (specific gravity 0.50) when air dry, so is similar in density to black ash *(F. nigra)* (Youngs 1960). Density is fairly uniform throughout a cross section.

Shrinkage and stability–Shrinkage is appreciably less than most mainland ash species and is generally comparable to black cherry *(Prunus serotina)* (Youngs 1960). It is quite stable in place, moving little with changes in relative humidity.

Strength–Tropical ash is similar to black ash in most strength properties. It does not have the exceptional strength and toughness for which white ash is noted, but has adequate strength and hardness for use in furniture and cabinet work. It is not, however, suitable for high quality handle stock as wide-ringed white ash of similar appearance would be (Youngs 1960).

Workability–The wood is easy to saw. Logs and cants spring in the sawmill, but not to the extent that eucalypts do. Tropical ash machines well. It planes, shapes, turns, bores and mortises with little tearout, chip marking, fuzziness, or other problems.

Seasoning–Tropical ash seasons easily and with little degrade. End splits caused by growth stress extend in drying; this extension is the main cause of drying degrade. The wood is quite susceptible, however, to stain and insect damage, both in the log and immediately after conversion, and thus requires quick handling from the forest to the drying yard. It is desirable to dip-treat lumber directly off the mill to reduce later damage by ambrosia and powder-post beetles in the drying yard.

Durability–The wood is nonresistant to decay and insect attack. For any use in Hawaii where insect damage is a major problem, it should be treated with preservatives. It is easily pressure-treated and can generally be treated through and through with light-oil-borne preservatives.

Wood Uses

It is unfortunate that so little tropical ash is available in Hawaii because it is readily accepted in the market. It is primarily a furniture and cabinet wood and has been used for both furniture parts and finish furniture. It has also been used for paneling and molding.

Rotary-cut and sliced veneers have been produced on an experimental basis and made up into panels. The wood lacks sufficient figure to be outstanding as a face veneer, but with its high yield of defect-free material should be excellent for crossbanding.

In general, tropical ash may be considered a useful medium-density hardwood suitable for a wide range of applications–in the nature of yellow poplar *(Liriodendron tulipifera)* of the East Coast and red alder of the West Coast.

SILK-OAK

Grevillea robusta Sm.

Trees and Forests

Silk-oak was introduced about 1880 from Australia and planted on all the main Hawaiian Islands in both wet and dry sites. It has become naturalized widely and reproduction is often girdled or poisoned on ranches where it is considered a noxious weed (Nelson 1960).

The tree almost always produces a straight, erect stem–even when open grown. It grows well in plantations, achieving excellent growth on good soils with

60 to 80 inches of annual rainfall. It will also grow in areas with rainfall as low as 30 inches, but much more slowly.

Most of the silk-oak sawtimber resources are on Hawaii and Oahu. Hawaii has 3 million board feet, mainly in Kau and North Kona (Nelson and Honda 1966). Oahu has 2.5 million feet, mostly in the Honouliuli Forest Reserve (Nelson, *et al.* 1968). The stands are generally accessible for logging, but it is doubtful that much logging will be done on Oahu, where the trees are needed for watershed cover and scenic amenities. Merchantable trees are typically 16 to 18 inches d.b.h. and contain three 16-foot logs. Occasional trees contain numerous shake-like gum veins, but in general, lumber grade yield from logs is high.

Wood Characteristics

Appearance—Silk-oak has a cream-colored sapwood about 1 inch thick, which changes abruptly into a pale pinkish-brown heartwood. The heartwood becomes yellow brown on aging, losing its pink cast. The wood has large, prominent rays which give a pronounced ray fleck on quarter-sawn faces. While Australia's supplies lasted, silk-oak, along with the plane tree *(Platanus acerifolia)*, was the "lacewood" of world trade, owing to this attractive figure (Boas 1947). "Lacewood" is now supplied by *Cardwellia sublimis*, another Australian species with similar wood. In addition to the prominent ray figure, dark and light color banding in the growth rings provides figure on plain and quarter-sawn faces. The wood resembles sycamore *(Platanus* spp.*)* in figure, but is yellower. Grain is usually somewhat undulating, but not interlocked. Texture is medium.

Weight—Silk-oak weighs 40 pounds per cubic foot (specific gravity 0.57) when air dry, similar to paper birch *(Betula papyrifera)* (Youngs 1964). It is somewhat lighter than American beech *(Fagus grandifolia)*, yellow birch *(Betula alleghaniensis)*, and sugar maple *(Acer saccharum)*, and heavier than black cherry and sweet-gum *(Liquidambar stryaciflua)*.

Shrinkage and stability—Shrinkage in drying is relatively small and compares with that of black cherry, silver maple *(Acer saccharinum)*, and red lauan *(Shorea negrosensis)* of the Philippines (Youngs 1964). Movement in place with relative humidity changes is also relatively small, but as this wood shrinks almost three times as much in the tangential direction as in the radial, it stays in place best if quartersawn.

Strength—The only mechanical property of Hawaii-grown silk-oak that has been measured is hardness (Youngs 1964). Silk-oak has a side hardness when air dry that is similar to that of black cherry and paper birch. Its hardness is more than sufficient for mar-resistant furniture and paneling, but not for flooring.

Strength properties of silk-oak of similar density have been measured in Australia and South Africa. The wood from Australia had a breaking strength comparable to pecan hickory *(Carya illinoensis)* and some of the true oaks (Bolza and Kloot 1963); the wood grown in South Africa was weaker, more like silver maple (Scott 1953). The Hawaii-grown wood was harder than wood from either of these sources.

Workability—Silk-oak saws and machines with ease. It planes, shapes, bores, and mortises nicely and is one of the best woods in all-around machinability ever tested by the U.S. Forest Products Laboratory.[4] Ray tissue tends to lift with small moisture changes and the wood usually requires sanding immediately before finishing to obtain a smooth surface.

This wood has caused serious dermatitis in a number of people who have worked with it (Youngs 1964). Susceptibility varies, but appears to be most common in fair-skinned Caucasians. Green wood is more allergenic than dry wood, but sawdust of both green and dry wood has caused rashes. Silk-oak shavings and sawdust spread in a University of Wisconsin dairy caused a rash on cow udders. Furniture and other articles made of dry, finished wood are apparently safe to handle as no incidents have been reported.

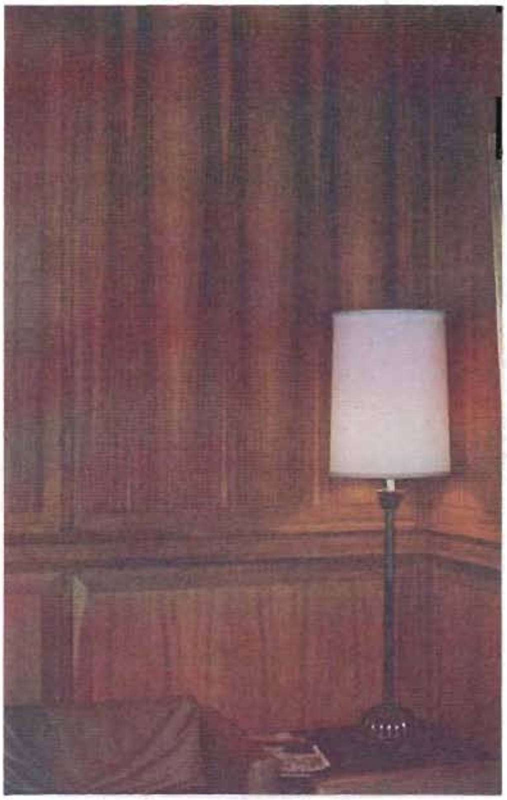
Seasoning—The wood seasons well in 1-inch-thick boards (Skolmen and Smith 1962). Thicker stock requires slow air-drying followed by a mild kiln schedule to avoid honeycombing. Sapwood is highly susceptible to ambrosia beetle and powder-post beetle attack; rapid conversion and preservative dipping of green lumber are recommended. Tiny pin knots are common and would be a serious degrading factor if classed as defects (Malcolm 1961).

Durability—Silk-oak is moderately resistant to decay and termites (Skolmen 1968a). It is not suitable for use in exposed situations unless treated with preservatives. Attack by drywood termites has been observed in this wood. The wood is readily treated with preservatives, can be readily stained, and finishes well. It tends to yellow with prolonged exposure to light.

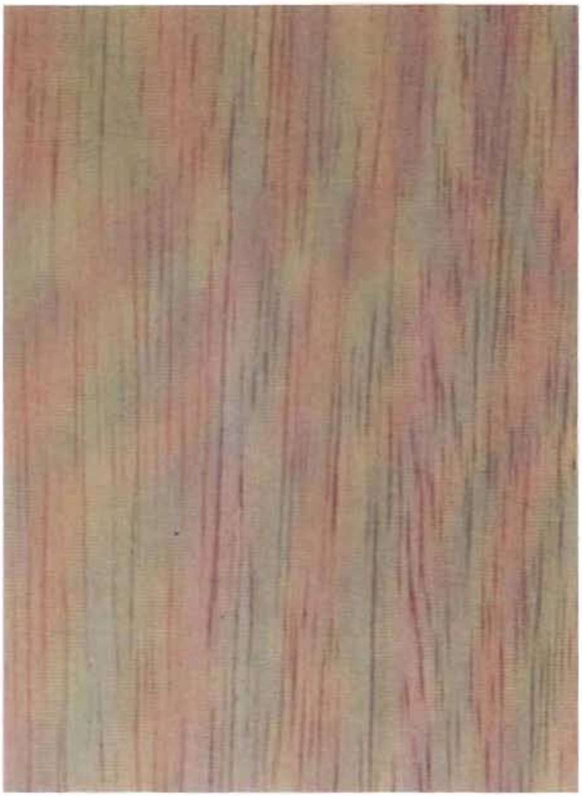
Wood Uses

The supply of silk-oak lumber has been sporadic.

[4]Unpublished report on file at U.S. Forest Products Lab., Madison, Wis. 1961.



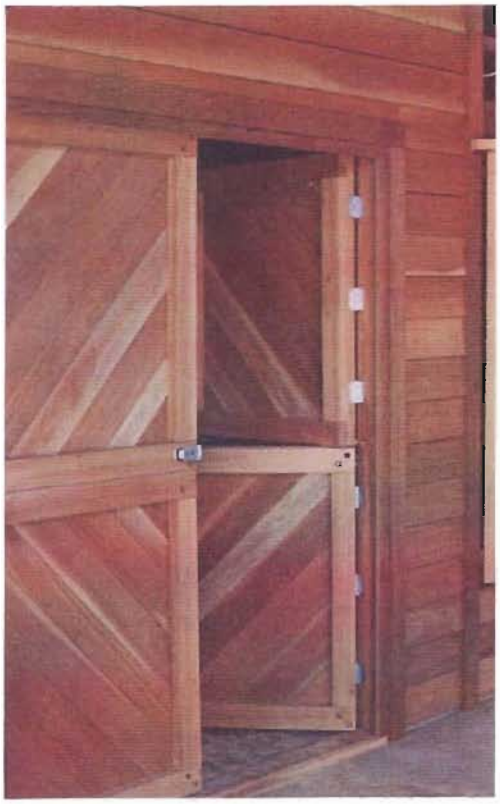
Koa



Molucca albizzia

Bluegum eucalyptus

Norfolk-Island-pine



Robusta eucalyptus

Blackbutt eucalyptus

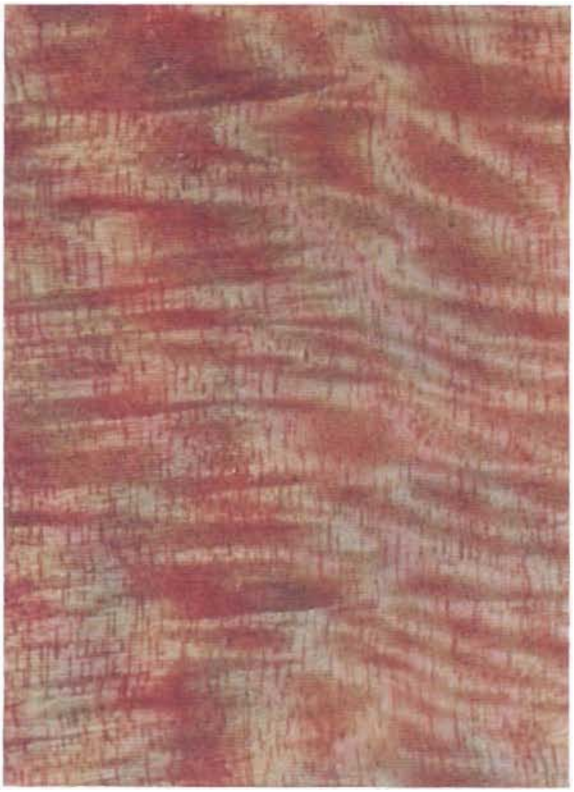
Saligna eucalyptus

Tropical ash

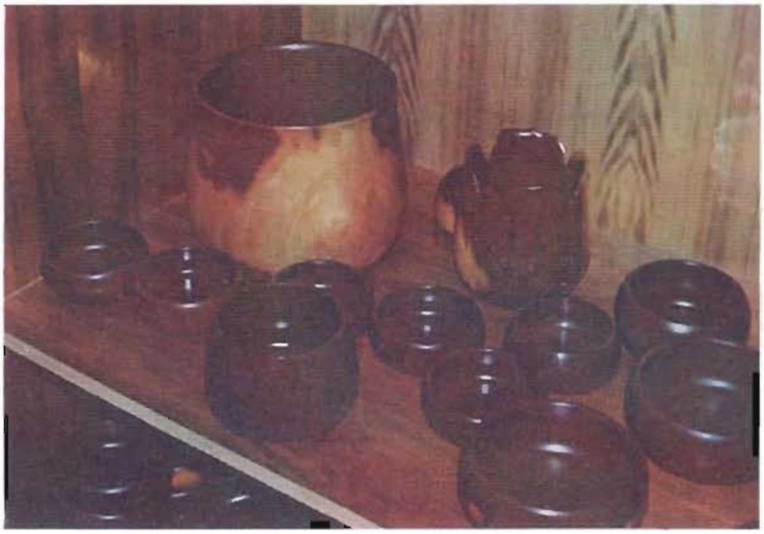
Silk-oak

Ohia

Monkey-pod



Mango



Milo

Redwood

Australian toon

Brushbox

Because of the limited resource, it has not been possible to offer the continuing supply required to develop a broad use pattern. In all, about 500,000 board feet of timber have been cut since the late 1950's.

The wood has been used for the exposed parts of furniture, upholstery frames, drawer sides and backs, turnery, paneling, bin pallets, standard pallets, and many other items. A house on the island of Hawaii was built entirely with silk-oak framing, flooring, and siding in 1967.

A small furniture company some years ago made several sets of natural-finish bedroom furniture from silk-oak, but despite advertising pointing out the unique wood, consumer acceptance was disappointing. The wood was apparently too similar in appearance to natural-finish oak, which had been out of style for many years.

Other furniture companies have since used the wood successfully for stained or painted furniture parts, interior parts, and upholstery frames. These companies would continue to use the wood if supply could be assured.

Because of its relatively light weight, the wood was found acceptable for pallets used in handling air cargo, and a considerable volume has been used for this purpose.

Silk-oak is, of course, a well-known face veneer species under the name of lacewood, and is well suited for this use. It is readily peeled and produces excellent core stock and crossbanding when rotary cut. Face veneer is always sliced on the quarter to obtain the lacelike ray-fleck figure. So far, however, use of Hawaii-grown silk-oak as veneer has been only on an experimental scale.

For a hardwood, the wood has long fibers—average 1.75 mm. This, coupled with the pale color of the wood and its moderate density, should make silk-oak well suited for pulp and fiber products.

MANGO

Mangifera indica L.

Trees and Forests

Mango was introduced to Hawaii sometime before 1825 from at least three different countries—Chile, the Philippines, and China—and was taken to all the islands as a desirable fruit tree (Hamilton and Yee 1962). Though now naturalized, it is a large-seeded plant and spreads very slowly. One of the easiest methods of finding old dwelling sites in Hawaii is to locate huge old mango trees. Usually near the trees will be the stonework of old foundations and walls. These trees are the so-called common mango and are variable in both tree form and fruit type. Other, better flavored fruiting varieties were introduced in more recent times, the most important of these introductions being the Pirie in 1899 and the Haden in 1930.

Mango trees in the forest generally occur singly or in small groups, usually in drainage bottoms. Access to the trees is quite variable, but usually difficult. Some of the oldest trees reach diameters of 8 to 10 feet and heights of 80 to 100 feet. The trees usually have a short, deeply fluted main stem and massive branches. Occasionally, the trees have a surprisingly good form with a straight cylindrical stem containing one or two 16-foot logs. There are estimated to be about 4 million board feet of mango sawtimber in the State.

Wood Characteristics

Appearance—Mango is a lustrous, blond wood without distinct sapwood. Old trees sometimes contain a small central core of dark brown or gray streaked wood, which is probably the true heartwood. Mango wood is moderately coarse in texture, often with irregular, strongly interlocked grain. Wood that reaches the market place is usually stained, particularly in the vessel elements. This staining is easily prevented during processing, but is generally preferred by customers. In typical stained wood, the pores (vessels) are black and the surrounding wood is marbled with blue-gray, green, yellow, and sometimes pink discoloration.

The wood is commonly figured by grain irregularities. Figuring may take the form of mottling, dimples, swirls, ripples, or a pronounced fiddleback.

Weight—Mango grown in Hawaii weighs 40 pounds per cubic foot (specific gravity 0.57) when air dry. This is the same as mango grown in Puerto Rico (Longwood 1961) and within the range of mango grown in India (Ghosh 1963). It is thus a little heavier than black walnut, and a little lighter than white ash (U.S. Forest Products Laboratory 1955).

Shrinkage and stability—Mango has a small lateral shrinkage in drying and remains stable in service where relative humidity changes are large (Crane Creek Gun Stock Co. 1962). Longitudinal shrinkage of highly figured wood sometimes exceeds 0.5 percent, which is quite large compared to most woods, but this has not caused any seasoning problems in Hawaii.

Strength—Wood of specific gravity similar to Hawaii-grown wood has been tested in India (Ghosh 1963) and was found to be similar to black ash and black cherry in bending strength, stiffness, and crushing strength, but more on the order of butternut *(Juglans cinerea)* or silver maple in shock resistance. Its hardness is similar to that of black walnut—it can be just barely dented with a fingernail.

These properties indicate that the wood should serve well if used for finish furniture of moderately small-membered design. The wood does not have a sufficiently high shock resistance for use in extremely thin-membered designs.

Workability—Mango saws easily, but its machining properties vary with grain irregularities. Grain tear-outs are common in wavy-grained wood when planed, turned, or shaped. The wood bores and mortises well, however (Longwood 1961). It shows scratches from sanding unless a fine grit is used for final finish.

Highly figured wood has been tried as a sliced face veneer. Such wood is highly fragile as veneer due to its intensely wavy grain. It is easily broken in handling and chipped in jointing. It glues well, however.[5]

Seasoning—Mango seasons easily—thick lumber can be kiln-dried from the green state by a fairly harsh schedule without degrade. In the wet climate of Hilo, where most mango lumber has been produced, the wood will invariably stain if set out for normal air-drying. Stain can be avoided by immediate kiln drying of freshly sawed lumber. Mango is also highly susceptible to stain and insect attack when in log form and requires rapid processing.

Durability—The wood is not resistant to decay and is highly susceptible to insect damage in Hawaii even when used indoors as furniture. The wood should be pressure-treated with preservatives for any use—indoors or out. Excellent penetration and retention of preservatives are easily achieved.

Wood Uses

Mango has been used in Hawaii on a small scale for craftwood products, furniture, paneling, and gunstocks. As a craftwood, it is used primarily for turned plates and bowls, though some carved bowls have been made of the wood. For this purpose highly figured wood is used and varicolored, stained wood is preferred. Furniture has consisted of chairs, occasional tables, and cabinets, which have all been quite attractive and have given good service. Paneling used in one home and in a church has likewise been highly successful.

Mango is of an unusual color for gunstocks, but has performed well in this use. It is a much more stable wood than walnut, the standard wood for stocks, so holds sight alignment better. It is more difficult to finish, especially in checkering of the grips, but the beauty of the mango stock is said to be worth the extra effort required (Crane Creek Gun Stock Co. 1962).

Besides having these special ornamental uses, mango is a good general utility hardwood suitable for pallets, crates, and upholstery framing.

[5]Unpublished results of tests at U.S. Forest Products Laboratory, Madison, Wis.

OHIA

Metrosideros collina (Forst.) Gray
subspecies *polymorpha* (Gaud.) Rock.

Trees and Forests

Ohia, a native species, is the most abundant tree in Hawaii, but commercially operable stands occur only on the island of Hawaii. The island has about 360 million board feet in trees over 11 inches d.b.h. (Nelson and Wheeler 1963). Trees in the better stands are commonly 18 to 24 inches in diameter and contain two 16-foot logs. Low per-acre yields are common. The better stands yield from 5,000 to 6,000 board feet per acre. Roads into the ohia rain forest are few; therefore the timber is relatively inaccessible to logging.

The stems are commonly deeply fluted and often contain over-grown tree stems of other species and treefern trunks. Despite these defects, yield of No. 1 Common and better lumber usually exceeds 50 percent of log volume for logs over 16 inches in diameter. Severe spiral grain is often present in logs. Although this condition does not affect standard hardwood grades, it results in diagonal grain that weakens the wood for construction purposes.

Wood Characteristics

Appearance—Ohia has a pale brown sapwood that grades gradually into a reddish to purplish-brown heartwood. Occasional trees contain heartwood with a color similar to black walnut. Grain is usually interlocked, and together with color banding in the growth rings, gives the wood an attractive subdued figure. Texture is medium.

Weight—Ohia weighs 57 pounds per cubic foot (specific gravity 0.81) when air dry (Youngs 1960). It is heavier than any wood commonly used in the United States.

Shrinkage and stability—Shrinkage in drying is large and movement in place with humidity changes is also large (Youngs 1960). In Hawaii, where the climate is very uniform throughout the year, ohia stays in place well. In other areas with large variations in relative humidity, shrinking and swelling of ohia might cause problems.

Strength—Ohia is generally comparable to shagbark hickory in its strength properties, though it is substantially weaker in toughness, impact bending strength, and strength in compression perpendicular to the grain (Youngs 1960). It exceeds white oak in almost all strength properties. A very hard wood, it exceeds sugar maple in this property.

Workability—Ohia was previously reported to have a pronounced dulling effect on tools (Youngs 1960). This effect has not shown up in more extensive work with the wood. It saws and machines with difficulty, but no more so than would be expected for a wood of its density.

Inserted saw teeth and tooth holders designed for sawing frozen hardwood perform well with ohia, as also do carbide tipped sawteeth. The wood is better than many commonly used mainland woods in shaping and boring, but poorer in planing and turning. A cutting angle of 20° works best in planing (Youngs 1960).

Seasoning—Because of its large shrinkage and interlocked grain, ohia is prone to warping during seasoning unless carefully piled. Sticker spacing should be no more than 2 feet. The wood is not prone to surface checking. Ohia should be air-dried to a moisture content below 30 percent before kiln-drying.

Durability—Ohia is nonresistant or moderately resistant to decay and is not recommended for use in contact with the ground unless treated with preservatives (Skolmen 1968a). It is less resistant than Douglas-fir to decay. It has shown considerable resistance to the subterranean termite in laboratory tests. Though not immune to attack by this insect, it was much less severely attacked than redwood or western redcedar. The wood does not seem to be preferred by the drywood termite, but damage by this insect is common in old installations of ohia. Ohia is somewhat variable in its acceptance of preservatives, but in all commercial pressure-treating done with the wood, penetration and retention of both oil- and waterborne preservatives have met or exceeded American Wood Preservers Association standards.

Wood Uses

Ohia is an excellent wood for strip flooring and this is its main use in Hawaii. Its next most common use is for ship blocking in the drydocks at Pearl Harbor. Another important use of the wood has been for stakes used to brace water barriers in irrigation ditches in sugarcane culture. It has been used fairly extensively as wharf fenders and other marine construction, both pressure-treated and untreated. It is also used in pallets and conveyor belt slats. In general, it is well suited to any use requiring great strength, hardness, and abrasion resistance in which its heavy weight is not a disadvantage. For example, ohia has proved excellent for pile-driver cushions—circular blocks of wood placed between the hammer and concrete piles to prevent shattering.

Ohia has been sliced and rotary-peeled into veneer. It makes up into attractive plywood paneling, but is not preferred as a veneer species due to its tendency to buckle in drying. With a screen-type drier designed to hold the veneer flat, excellent veneer can be produced from the wood.

Ohia is also used in Hawaii for decorative poles in residential construction and business establishments. With bark removed and given a clear finish the poles have an attractive rustic appearance. Poles used are generally in the 5 to 8 inch diameter range and 8 to 10 feet long.

Hardboard has been produced experimentally from ohia groundwood and found to meet Federal specifications (Swartz 1960). Medium-density particleboard has also been produced experimentally from ohia. Though the wood is not ideal for fiber products because it has short fibers, high density, and dark color, it should be usable for some pulping processes and products.

MONKEY-POD

Pithecellobium saman (Jacq.) Benth.;
syn. *Samanea saman* (Jacq.) Merr.

Trees and Forests

Monkey-pod seed was brought to Hawaii from Mexico in 1847 (Anon. 1938). One seedling raised was planted at Koloa, Kauai, and another on the site now occupied by the Alexander Young Building in Honolulu. The tree was early recognized as a desirable shade tree and was soon planted on all the islands. It is primarily a roadside and garden tree, but is also found near old home sites along streams out in the forest. It has become naturalized in several pasture areas and is spreading. A few forest plantations have also been made with monkey-pod.

The tree usually has a short main stem which breaks up into massive, wide spreading branches. When forest-grown, the stem will sometimes be limbfree for 24 feet or more, but such growth is rare. Typical older monkey-pod trees are over 30 inches d.b.h. and have an 8- to 12-foot butt log. The branches contain a large volume of wood and are usually used as well as the main stem.

It is difficult to estimate accurately the volume of monkey-pod present in the islands because of the sparse, irregular occurrence of the tree, its use as a yard and street tree, and the difficulty of estimating branch-wood volume. Garden trees and roadside trees are cut as urbanization intensifies. These cuttings form the main source of monkey-pod wood processed in Hawaii. At least 6 million board feet of monkey-pod sawtimber are present in Hawaii. The heaviest concentrations are on the island of Hawaii, in a belt along the Kona coast, in Kau, and in Waipio Valley; and on the west side of Kaneohe Bay on Oahu. Logs are generally sold to mills by tree-trimming companies that are paid to remove unwanted or dangerously decadent trees from yards and roadways. The resource is not plentiful.

Though Hawaii is famous for carved monkey-pod bowls, the tree is found in the tropics all over the world. Originally from northern South America, primarily Venezuela, it goes by many names in the countries to which it has been introduced. In most English-speaking countries it is called raintree, while in the Philippines it is called acacia. Today, most of the wood seen in carved bowls, even in Hawaii, is wood that was grown in the Philippines and Indonesia. As in Hawaii, yard and street trees are the principal source of logs in the Philippines, and this resource is becoming increasingly scarce.

Wood Characteristics

Appearance—Monkey-pod has a cream-colored sapwood 1 to 2 inches thick that changes abruptly into a golden-brown to dark-brown heartwood. The wood is coarse textured and usually prominently figured with light and dark bands of color in the growth rings and by varying degrees of interlocking in the grain. Occasionally, the wood is marked with wavy or rippled figure and ribbon striping is common in quarter-sawn faces. Color and figure vary from tree to tree.

Weight—Monkey-pod grown in Hawaii weighs 36 pounds per cubic foot (specific gravity 0.52) when air dry. This is a little heavier than monkey-pod grown in Venezuela (Wangaard, Koehler, and Muschler 1954) or Puerto Rico (Longwood 1961) and probably results from the tendency in Hawaii to use wood from branches as well as from the main stem. Branch wood is generally of higher density than wood in the stem. The wood is comparable in density to sweetgum and black cherry.

Shrinkage and stability—Monkey-pod has a very low shrinkage in drying and is stable once dried. This low shrinkage gives monkey-pod its high rank as a craftwood species. It can be worked into shape while green and dried afterwards. With most woods, such a practice would result in badly misshapen and checked articles, but with monkey-pod there is hardly any spoilage from degrade resulting from drying.

Strength—The mechanical properties of Hawaii-grown monkey-pod have not been tested, but properties of the same wood grown in Venezuela and of similar specific gravity indicate what can be expected of it (Wangaard, Koehler, and Muschler 1954). It compares with sweetgum and bigleaf maple *(Acer macrophylla)* in hardness and with silver maple in bending strength and stiffness. The wood is strong and hard enough to use in furniture.

Workability—Monkey-pod saws easily and well, but is not as good in other types of machining as its uses would indicate. Machining tests of wood grown in Puerto Rico, which was considerably lower in density than Hawaii-grown wood, indicated that its irregular grain frequently resulted in torn grain and fuzziness in machining (Longwood 1961). This problem has not been observed as a serious one in Hawaii, but small tearouts in planing are not uncommon. When dry, the wood is poor in turning, but when green it turns and carves exceptionally well. It sands and takes finishes well.

Seasoning—Monkey-pod wood seasons easily. Owing to its low and uniform shrinkage it dries with very little degrade from checks, splits, or warp. When bowls that have been turned or carved while green are dried, about 10 percent are reduced in value owing to effects of drying, usually minute end checks. This proportion of loss is remarkably low for wood handled so harshly. Free-form tabletops sawn to shape from green wood occasionally split at the ends in drying, but the problem is not considered serious by manufacturers.

Durability—The wood is resistant to decay and insects. This, of course, applies only to heartwood. In its usual indoor uses about the only hazard to which monkey-pod is exposed in Hawaii is the drywood termite. Tests of the wood in Puerto Rico indicate that it is resistant to this insect (Wolcott 1946).

Wood Uses

The use of monkey-pod for decorative carved and turned articles probably originated in Hawaii. This use of the wood began on a commercial scale about 1946 and became so important an industry that 10 years later Hawaii was importing large quantities of the wood from other islands in the Pacific. Today, high labor costs in Hawaii and intense competition from Southeast Asia have greatly reduced the size of the local craftwood industry, but it is still important. To compete, the local industry is gradually changing its emphasis from monkey-pod to other more uniquely Hawaiian woods, such as koa and milo *(Thespesia populnea)*.

The main products made of monkey-pod in Hawaii are craftwood articles (mostly carved bowls), free-form coffee tables, and furniture. At least one company still specializes in coffee tables made of local wood, but for the most part the tables are now simply finished in Hawaii, the wood being imported already cut to size and sanded. Many homes in Hawaii have dining room and living room furniture sets made of monkey-pod, but most of these pieces were made about 15 years ago when the wood was "in style."

The wood has also been used for paneling, cabinetry, boatbuilding, and even flooring. It is too soft for flooring, but has performed well in the other uses. In boats, it has been used as a substitute for teak in trim, butt-blocks in planking, and heavy framing members.

Monkey-pod is an excellent ornamental wood that commands a high price. It will probably have continued wide use if supplies are grown, but few land owners or industry agents are interested in this aspect of resource supply. The industry is now mining a resource that is in short supply.

REDWOOD

Sequoia sempervirens (D. Don) Endl.

Trees and Forests

Redwood plantings have been successful on restricted sites in Hawaii, but slow early growth makes it difficult to establish the tree in plantations. Sites where it will grow well are quite limited. But the tree grows on the island of Maui in fairly substantial volume, and on Kauai and Hawaii in lesser volume.

Maui has 280 acres of planted redwood containing 6.2 million board feet of sawtimber—all in the Kula Forest Reserve (Wong, *et al.* 1969). The trees there grow rapidly and with a form generally comparable to second-growth redwood in coastal California. Most of this timber is 35 to 45 years old and still retains dead branches right to the ground, so only low grade lumber would be obtainable from the trees. The Maui redwood is not now easily accessible. Kauai has 230,000 board feet of sawtimber (Honda, *et al.* 1967) and Hawaii has 94,000 (Nelson and Honda 1966). The trees on these islands are not as well formed as those on Maui.

Typical sawtimber trees on Maui are 25 inches d.b.h. and contain four 16-foot logs. Many of the largest trees (36 to 40 inches d.b.h.) have fungus fruiting bodies on the butt log, suggesting that butt rot might be severe. Early development of deterioration has also been noted in a small stand growing at Honaunau on Hawaii. This condition may indicate that stands grown for timber should be logged while relatively young.

Wood Characteristics

Appearance—Hawaii-grown redwood is quite similar in appearance to open-grown second-growth redwood from California. It is wide ringed (two to four rings per inch), and has a wide band of cream-colored sapwood that changes abruptly into pale reddish-brown heartwood. The summerwood portion of each growth ring is smaller than in California-grown wood.

Weight—The wood weighs 25 pounds per cubic foot (specific gravity 0.36) when air dry (Youngs 1960). This weight is similar to that of close-grown rather than open-grown second growth of California. The wood is not quite as dense as that of old-growth redwood.

Shrinkage and stability—Shrinkage of the wood is small, and is generally comparable to that of close-grown second growth of California. Longitudinal shrinkage is quite low in the Hawaii-grown wood, but volumetric shrinkage is somewhat higher than in any type of California-grown redwood. This difference suggests that the wood may be somewhat more prone to collapse in drying (Youngs 1960). The wood is stable in service, as is California redwood.

Strength—The wood is more shock resistant than any type of California redwood, and compares closely to old-growth redwood in hardness. It is comparable to close-grown second growth in bending strength, but is not as stiff in bending as this type of redwood. It does, however, exceed open-grown second growth considerably in both bending strength and stiffness (Youngs 1960).

Workability—So little Hawaii-grown redwood has been cut that any special sawing and machining peculiarities it may have, have not yet shown up. The wood seems to be like California second-growth redwood in sawing and machining characteristics.

Seasoning—The wood is somewhat wetter when green than most California redwood and may be slightly more prone to collapse. Therefore, air-drying before kiln-drying is probably advisable.

Durability—Hawaii-grown redwood has a larger proportion of sapwood than California-grown redwood. Sapwood is, of course, not resistant to decay and insect damage. Until more information on durability of Hawaii-grown redwood is available, it should be assumed to be similar to second-growth Douglas-fir in lack of resistance to decay and termites. The wood should be pressure-treated with preservatives for most uses in Hawaii, but this may be difficult. Exploratory tests at the U.S. Forest Products Laboratory indicated that Hawaii-grown redwood is similar to California redwood in being difficult to treat. Preservative penetration is nonuniform in both sapwood and heartwood (Youngs 1960).

Finishing—Because the trees are generally much smaller than redwood cut in California, most of the lumber that will be produced from them will be flat-sawn, rather than quartersawn. For this reason, the Hawaii material will probably not hold paint as well as California redwood. Flat-sawn California redwood does not have good paint-holding properties either.

Wood Uses

The yield of clear wood from young Hawaii-grown redwood will be extremely low and practically all of the clear boards that are produced will be sapwood. The wood will not have the natural durability for which redwood is noted, either. Therefore Hawaii-grown redwood lumber will not substitute for top-grade redwood lumber imported from California. It will not be suitable for single-wall house siding, sills, plates, and water tanks as is the clear, vertical-grained, imported material.

Rather, Hawaii-grown redwood should be considered a general construction and utility softwood similar in use potential to Douglas-fir of "Standard" grade. It should be well suited for house framing and similar uses.

MILO

Thespesia populnea (L.) Sol.

Trees and Forests

Milo may be native to Hawaii, or the species may have been introduced by the Hawaiians. It is widely, although not plentifully distributed throughout the tropics, occurring most commonly along sheltered seashores. It was formerly widely used as a shade tree in coastal areas of Hawaii and was much more common than it is today. In Florida, where it grows naturally, and in California, where it has been planted, it is known as the portiatree.

Milo is a small tree, rarely reaching a height of more than 30 feet, or a trunk diameter of more than 12 inches. It has a low, spreading crown and a short main stem. Trees large enough to contain one 8-foot saw log are quite rare, but this is not a particular problem to utilization since the wood is used in small pieces for turnery and carvings. Branches as small as 2 inches in diameter are utilized. The milo resource has not been inventoried, but is probably less than 200,000 board feet for the entire State. Milo is usually sold to carvers by the cord or piece, rather than by log scale. The trees, though not common, are usually in easily accessible areas.

Wood Characteristics

Appearance—Milo from the main stem of a tree has a pale brown sapwood sometimes streaked with red, which changes abruptly into a dark reddish-brown to chocolate-brown heartwood. Heartwood from small branches is usually pale reddish-brown. The wood is moderately fine textured with a subdued growth-ring figure consisting of dark streaks. A faint ribbon-stripe figure due to mildly interlocked grain is also common on quartersawn faces.

Weight—Milo is a heavy wood, weighing 43 pounds per cubic foot (specific gravity 0.61) when air dry. It is somewhat variable in density, and usually a little heavier than other common craftwoods such as monkey-pod, koa, and mango. It is comparable in density to such common mainland woods as yellow birch and some of the red oaks (*Quercus* spp.).

Shrinkage and stability—The wood has a small shrinkage in drying and is stable in conditions of changing humidity. Milo is usually worked into bowls and carvings while green, as is monkey-pod. Degrade during subsequent drying is small owing to the low shrinkage of the wood.

Strength—The mechanical properties of milo grown in Hawaii have not been tested, and except for hardness, are unimportant to its sole use here—in craftwork. Wood of somewhat higher density (48 lb./cu. ft., air dry) grown near Bombay, India had a bending strength and stiffness comparable to white oak and some of the pecan hickories (Chowdhury and Ghosh 1958).

Workability—Milo saws and machines easily and well. It is an easily worked wood and carves well either by hand or machine. It turns well, both green and dry. It is considered the best and most easily worked wood of any commonly used for craftwork in Hawaii.

Seasoning—The wood seasons well. It is not prone to warping or checking and can withstand quite harsh drying treatment.

Durability—Milo is reputed to be quite resistant to decay and to drywood termites, though these characteristics have not been tested. Durability is not a particularly important concern, since practically all the wood is used in turnings and carvings.

Finishing—It can be finished to a high polish, but contains a natural oil that greatly retards the drying of varnish finishes. Normal oil-base varnishes will eventually dry on milo, but require days rather than hours to lose their tack. Lacquers are not affected.

Wood Uses

About 5,000 board feet of milo are used each year in Hawaii by the craftwood industry. Most of the articles made are quite small because the wood is generally available only in small sizes. The more common items are small carved tikis (idols), sculptured faces, turned and carved bowls, and bracelets. Tree stumps with roots still in place are sometimes used for larger sculptured faces.

The wood is also used occasionally in furniture, when larger pieces can be obtained. It has been used in yachts for block (pulley) cheeks and interior trim and also on occasion for gun stocks.

Strips of milo bark are sometimes used as a substitute for twine, but are inferior for this purpose to the more commonly used bark of the related hau tree *(Hibiscus tiliaceus)*.

AUSTRALIAN TOON

Toona australis Harms syn. *T. ciliata v. australis* (Roxb.) M. Roem.

Trees and Forests

Australian toon was introduced to Hawaii in 1914 (Judd 1920) and was planted in small, scattered stands on all the islands. In 1961, it was selected as a principal species for plantings for timber production by the Hawaii Division of Forestry in the Waiakea Forest Reserve on Hawaii. This reserve now has about 4,000 acres of young Australian toon.

The tree is in the botanical family *Meliaceae*, which includes *Swietenia, Khaya, Cedrela,* and other genera noted for their superior wood.

No island has even 100,000 board feet of Australian toon sawtimber at present. Stands on Hawaii hold only about 90,000 board feet (Nelson and Honda 1966). Lanai stands hold the next greatest volume with 40,000 board feet (Wong, *et al.* 1967). Better trees in 40-year-old stands are typically 18 to 20 inches d.b.h. and contain two 16-foot logs. Older trees tend to have buttresses and frequently have upper stems that are badly forked or leaning. What little timber is available is generally accessible to logging.

Wood Characteristics

Appearance—Australian toon has cream-colored sapwood which changes abruptly into pale reddish-brown heartwood. The heartwood is pale when first cut, and darkens with age. The wood is ring porous, each growth ring being defined at its beginning by a multiple row of closely spaced vessel elements. The wood is usually straight-grained and has a faint growth-ring figure. Occasional trees produce wood with slightly interlocked grain that produces a ribbon-stripe figure when quartersawn. The figure and general appearance are similar to that of Honduras mahogany *(Swietenia macrophylla)*. Texture is moderately coarse and the wood has a cedarlike odor.

Weight—The wood is light, weighing 28 pounds per cubic foot (specific gravity 0.40) when air dry (Youngs 1960). This density is comparable to that of old-growth redwood and red alder. Like the eucalypts, Australian toon has considerable variation in density between wood near the pith and wood farther out in the stem.

Shrinkage and stability—Shrinkage in drying is much higher than the density value of the wood indicates (Youngs 1960). Australian toon more closely resembles such heavy woods as sugar maple and white oak in shrinkage. Movement in place with humidity changes is correspondingly fairly large.

Strength—Australian toon is similar to red alder in most strength properties (Youngs 1960). It is rather soft for use in finish furniture and is easily marred, but can be used in some applications where softness is not a problem. It should be suitable for paneling and some construction uses, such as single-wall house siding.

Workability—The wood is generally easy to saw and machine. Growth stress causes end-splitting and spring in logs, and brittleheart is sometimes present near the pith. There is slight spring in sawing logs, but it is not as pronounced as in the eucalypts. Normal wood finishes well. Occasional tension wood causes fuzzy surfaces in planing; these are difficult to sand smooth unless held with a size.

Seasoning—The wood seasons fairly well despite its large shrinkage. It has some tendency toward end-splitting and warp, but these problems can be reduced by end-sealing and careful piling.

Durability—Australian toon grown in Hawaii is not resistant to decay and should not be used in exposed conditions (Skolmen 1968a). In limited laboratory tests, the wood showed resistance to subterranean termites, exceeding redwood and almost equaling ohia in this characteristic. It has not been observed under attack by drywood termites, but is probably susceptible to them. Preservative treatment of the wood has not been tried.

Paintability—A test of paintability has shown that the wood holds conventional oil- and water-base paints better than do Douglas-fir and robusta eucalyptus. After 7 years of exposure, the wood showed paint-holding ability equal to that of redwood, and did not bleed extractives as does redwood (Skolmen 1972b).

Wood Uses

So little timber of this species has been cut in Hawaii that no important use patterns have emerged. It has been used for kitchen cabinets and paneling in one instance and found to be too soft for facing on the cabinets. It is fine for paneling, however. One office desk of Australian toon has been made and is holding up very well after several years of use. Although considerable care is required to avoid denting and scratching the wood, a few other furniture pieces have been made of the wood and performance was completely satisfactory. Two furniture manufacturers have used the wood for interior parts—drawer sides and backs and upholstery frames—and were quite pleased with it. Two workmen in one of these plants developed dermatitis from the sawdust, however. Although this is the only instance on record, irritating properties may become a problem.

Veneer was produced by one firm and used for plywood door skins in a State of Hawaii office building. The manufacturer recommended that the wood not be considered a veneer species.[6] From the plywood produced it was apparent that the logs had not been of sufficiently high grade to produce defect-free face veneer.

Lower grades of Australian toon lumber have been used successfully for pallets and crating.

All in all, it would appear that the wood grown in Hawaii will be an excellent general utility hardwood owing to its easy workability and termite resistance. It may have special applications in home construction as single-wall house siding and interior paneling. It is an attractive wood that might find some use as a cabinet wood, but its softness limits it for this use.

BRUSHBOX

Tristania conferta R. Br.

Trees and Forests

Brushbox was introduced to Hawaii in the late 1800's, when many eucalypts were also brought in. It grows well in plantations, though usually at a somewhat slower rate than many of the eucalypts. It has been planted in forests on all the islands and is often used as an ornamental yard or street tree.

The main resource of brushbox is on the islands of Hawaii and Oahu. Hawaii has 1.3 million board feet of sawtimber (Nelson and Honda 1966) and Oahu has 1.1 million (Nelson, *et al.* 1968). Only a small volume is present on the other islands. Most stands are 30 to 40 years old, with typical trees about 16 inches d.b.h., containing three 16-foot logs. Stems are usually straight and in closed stands are free of branches for two or more log lengths. Most commonly, the tree is found interplanted with various eucalypts, particularly *E. saligna,* and has been harvested only as a secondary species in such stands. The brushbox on Hawaii is generally accessible for logging. Stands on Oahu will probably be maintained for watershed protection and scenic beauty with only limited logging for stand improvement.

Wood Characteristics

Appearance—Brushbox has a pale brown sapwood which changes abruptly into a pinkish-brown or greyish-brown heartwood. Texture is medium to fine, and grain is mildly interlocked and sometimes wavy. The wood is usually lacking in prominent figure.

Weight—Brushbox grown in Hawaii weighs 47 pounds per cubic foot (specific gravity 0.67) when air dry. It is similar in weight to white oak, and also to robusta eucalyptus.

Shrinkage and stability—It has a fairly large shrinkkage in drying and is unstable in conditions of varying humidity. Its shrinkage is a little less than that of robusta and saligna eucalyptus.

Strength—The mechanical properties of Hawaii-grown brushbox have not been measured. Brushbox grown in Australia is usually more dense (55 lb./cu. ft., air dry) (Bolza and Kloot 1963), and is slightly stronger than robusta in most properties and slightly weaker than ohia. The less dense Hawaii-grown wood should be equivalent in strength properties to robusta, or to white oak. The central portion of butt logs may occasionally be brittleheart.

Workability—As brushbox logs contain little growth stress, they do not end-split badly or spring badly in sawing. Lumber can be sawed without any particular difficulty other than that caused by the somewhat high density of the wood. Brushbox in Australia is reputed to be highly abrasive to saws, but this characteristic has not been noted in Hawaii. The wood planes well, provided a low-knife angle is used to reduce tearouts in the interlocked grain on quar-

[6]Personal correspondence with R. C. Stadelman, Nickey Brothers, Inc., Memphis, Tenn., May 30, 1961.

tered faces. Results in Australia indicate that it does not steam-bend well (Boas 1947).

Seasoning–Brushbox is difficult to season. It tends to warp in drying and will also collapse. If rapidly air-dried, flat-sawn faces check badly, but in the humid climate of Hilo, surface checking is not a problem. The wood can be successfully dried in well-made piles, but should be air-dried to below 30 percent moisture content before kiln-drying.

Durability–Wood grown in Australia is reported to be resistant to decay and termites (Boas 1947). Results with the wood in Hawaii are variable: in one instance a number of small-diameter poles have given excellent service for more than 40 years in an area of extremely high decay and subterranean termite hazard. Near this location, brushbox fence posts of similar size have failed in only a year or two (Skolmen 1971). Hawaii-grown brushbox should be considered moderately resistant to decay and termites until more information is gathered. It is a difficult wood to pressure treat with preservatives.

Wood Uses

The only use so far made of brushbox lumber in Hawaii has been for pallets. In these pallets the wood was used green in mixture with robusta, and was apparently satisfactory.

Brushbox should be suitable for the same uses as other dense hardwoods grown in Hawaii, such as robusta, saligna, and ohia. It should be particularly well suited for use as flooring. Other uses include truck beds, conveyor slats, and irrigation stakes.

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APPENDIX

Table 1—*Moisture content, specific gravity, and shrinkage of 16 Hawaii-grown woods*

Species	Trees tested	Moisture content	Specific gravity[1]	Shrinkage from green to . . . air-dry[2] Radial	air-dry[2] Tangential	oven-dry Radial	oven-dry Tangential	Sources
	No.	*Percent*		*Percent*				
Acacia koa	3	([3])	0.53	–	–	5.5	6.2	Gerhards 1963; Harrar 1941-42
Koa	3	12	.55					
Albizia falcataria	5	57	.32	1.6	3.7	3.2	6.2	Gerhards 1966a
Molucca albizzia	5	12	.33					
Araucaria columnaris	5	91	.42	1.5	2.6	3.5	5.3	Gerhards 1967
"Norfolk-Island-pine"	5	12	.44					
Eucalyptus globulus	7	60	.67	5.3	9.1	8.0	12.3	([4])
Bluegum	7	12	.79					
Eucalyptus pilularis	5	82	.59	2.8	5.8	5.9	10.0	Gerhards 1966b
Blackbutt	5	12	.66					
Eucalyptus robusta	8	88	.60	2.9	6.7	6.1	10.7	Dohr[5]; Youngs 1960
Robusta	8	12	.66					
Eucalyptus saligna	10	77	.59	3.8	8.8	6.5	12.1	Gerhards 1965
Saligna	10	12	.66					
Fraxinus uhdei	5	46	.47	–	–	3.5	7.4	Youngs 1960
Tropical ash	5	12	.50					
Grevillea robusta	8	110	.51	1.2	4.2	2.7	7.7	Youngs 1964
Silk-oak	8	12	.57					
Mangifera indica	2	72	.55	1.1	2.6	2.9	5.9	([4])
Mango	2	12	.57					
Metrosideros collina	11	67	.70	–	–	6.9	12.1	Youngs 1960
Ohia	11	12	.81					
Pithecellobium saman	4	132	.49	.8	1.4	2.3	4.4	([4])
Monkey-pod	4	12	.52					
Sequoia sempervirens	5	156	.35	–	–	2.3	5.3	Youngs 1960
Redwood	5	12	.36					
Thespesia populnea	2	74	.58	–	–	–	–	([4])
Milo	2	12	.61					
Toona australis	4	109	.35	–	–	4.3	9.8	Youngs 1960
Australian toon	4	12	.40					
Tristania conferta	4	89	.61	2.6	6.1	5.0	9.5	([4])
Brushbox	4	12	.67	–	–	–	–	

[1] Based on volume at test and ovendry weight.
[2] "Air-dry" is about 12 percent moisture content.
[3] Green.
[4] Data published herein for the first time.
[5] Dohr, A. W. Results of limited tests of *Eucalyptus robusta* from Hawaii. 1959. (Unpublished report on file at U.S. Forest Products Lab., Madison, Wisc.)

Table 2—*Moisture content, specific gravity, and static bending properties of small clear specimens of wood from 16 Hawaii timber species and six imported woods used in Hawaii*

Species and source of wood	Trees tested	Moisture content	Specific[1] gravity	Stress at proportional limit	Static bending: Modulus of . . . Rupture	Static bending: Modulus of . . . Elasticity	Static bending: Work to . . . Proportional limit	Static bending: Work to . . . Maximum load	Sources
	No.	*Pct.*		*Psi*	*Psi*	*1,000 Psi*	*In-lb per cu-in*	*In-lb per cu-in*	
Acacia koa	3	([2])	0.53	5,500	9,000	1,520	1.18	12.9	Gerhards 1963;
Koa (Hawaii)	–	12	.46	10,100	13,300	1,570	3.58	9.1	Gerry 1955
Albizia falcataria	5	57	.32	3,400	5,300	1,080	.63	5.5	Gerhards 1966a
Molucca albizzia (Hawaii)	5	12	.33	4,800	8,400	1,280	1.04	8.7	
Araucaria columnaris	5	91	.42	4,100	7,100	1,410	.70	8.1	Gerhards 1967
"Norfolk-Island-pine" (Hawaii)	5	12	.44	6,000	11,000	1,560	1.31	8.8	
Eucalyptus globulus[3]	18	([2])	.73	7,590	12,200	2,160	–	–	Bolza and
Bluegum (Australia)	18	12	.87	13,400	21,200	2,950	–	–	Kloot 1963
Eucalyptus pilularis	5	82	.59	7,000	11,700	2,200	1.28	12.5	Gerhards 1966b
Blackbutt (Hawaii)	5	12	.66	10,600	18,000	2,700	2.41	17.3	
Eucalyptus robusta	8	88	.60	6,500	10,400	1,780	1.38	9.2	Youngs 1960
Robusta (Hawaii)	8	12	.66	8,200	15,600	2,200	1.77	14.5	
Eucalyptus saligna	10	77	.59	7,100	11,500	1,980	1.50	12.5	Gerhards 1965
Saligna (Hawaii)	10	12	.66	9,900	16,400	2,390	2.33	17.4	
Fraxinus uhdei	5	46	.47	4,600	8,500	1,410	.87	11.0	Youngs 1960
Tropical ash (Hawaii)	5	12	.50	6,800	12,800	1,660	1.62	12.0	
Grevillea robusta	8	110	.51	–	–	–	–	–	Youngs 1964
Silk-oak (Hawaii)	8	12	.57	–	–	–	–	–	
Mangifera indica	–	([2])	.59	–	8,700	1,300	–	–	Ghosh,
Mango (India)	–	([4])	.61	–	12,800	1,600	–	–	*et al.* 1963
Metrosideros collina	11	67	.70	6,000	10,100	1,800	1.18	10.6	Youngs 1960
Ohia (Hawaii)	11	12	.81	10,700	18,300	2,370	2.75	16.7	
Pithecellobium saman	2	([2])	.48	4,880	8,100	910	1.51	10.4	Wangaard 1954
Monkey-pod (Venezuela)	2	12	.50	6,080	8,860	1,100	1.97	7.8	
Sequoia sempervirens	5	156	.35	3,500	6,100	770	.91	7.5	Youngs 1960
Redwood (Hawaii)	5	12	.36	4,600	8,700	980	1.22	8.3	
Thespesia populnea	–	([2])	.65	–	13,400	1,500	–	–	Chowdhury &
Milo (India)	–	([4])	.69	–	17,100	1,700	–	–	Ghosh 1958
Toona australis	4	109	.35	3,400	5,700	1,010	.67	7.2	Youngs 1960
Australian toon (Hawaii)	4	12	.40	6,000	10,600	1,300	1.61	9.5	
Tristania conferta	19	([2])	.69	6,530	11,400	1,700	–	–	Bolza and
Brushbox (Australia)	19	12	.79	10,500	17,600	2,220	–	–	Kloot 1963
Pseudotsuga menziesii	–	38	.45	4,500	7,600	1,570	.75	7.6	USFPL 1955;[5]
Douglas-fir (W. Coast)	–	12	.48	7,800	12,200	1,950	1.77	9.8	Youngs 1960
Sequoia sempervirens	16	112	.38	4,800	7,500	1,180	1.18	7.4	USFPL 1955;
Redwood (old-growth) (Calif.)	16	12	.40	6,900	10,000	1,340	2.04	6.9	Youngs 1960
Thuja plicata	15	37	.31	3,200	5,100	920	.63	5.0	USFPL 1955
Western red cedar (W. Coast)	15	12	.33	5,300	7,700	1,120	1.44	5.8	
Shorea negrosensis	5	([2])	.46	4,890	7,770	1,440	–	–	Lauricio and
Red lauan (Philippines)	5	12	.49	7,080	11,500	1,700	–	–	Bellosillo 1963
Dipterocarpus grandiflorus	5	([2])	.62	4,780	8,480	1,750	–	–	Lauricio and
Apitong (Philippines)	4	12	.72	10,200	16,700	2,500	–	–	Bellosillo 1963
Quercus alba	20	68	.60	4,700	8,300	1,250	1.08	11.6	USFPL 1955
White oak (Central states)	20	12	.68	8,200	15,200	1,780	2.27	14.8	

[1] Based on ovendry weight and volume at test.
[2] Green.
[3] Includes *E. bicostata* and *E. St. Johnii.*
[4] Air-dry.
[5] USFPL = U.S. Forest Products Laboratory.

Table 3—*Hardness, toughness, and compression properties of small clear specimens of wood from 16 Hawaii timber species and six imported woods used in Hawaii*

Species and source of wood	Trees tested	Compression parallel to grain: Stress at proportional limit	Compression parallel to grain: Maximum crushing strength	Compression perpendicular to grain stress at proportional limit	Maximum shear strength	Hardness: End	Hardness: Side	Toughness: Radial	Toughness: Tangential	Sources
	No.	*Psi*	*Psi*	*Psi*	*Psi*	*Lb*	*Lb*	*In-lb*	*In-lb*	
Acacia koa	3	2,600	3,900	–	–	950	870	–	–	Gerhards 1963; Gerry 1955; Harrar 1941-42
Koa (Hawaii)	–	–	7,300	1,364	1,780	1,340	1,110	–	–	
Albizia falcataria	5	1,880	2,610	230	800	410	360	250	250	Gerhards 1966a
Molucca albizzia (Hawaii)	5	2,420	4,490	400	1,130	580	450	190	180	
Araucaria heterophylla	5	2,500	3,170	–	1,010	600	500	170	180	Gerhards 1967
"Norfolk-Island pine" (Hawaii)	5	3,570	5,840	–	1,510	1,030	650	120	130	
Eucalyptus globulus[1]	18	5,000	6,180	760	1,500	1,580	1,650	–	–	Bolza and Kloot 1963
Bluegum (Australia)	18	8,190	12,000	1,410	2,370	2,560	2,580	–	–	
Eucalyptus pilularis	5	4,500	5,720	–	1,460	1,120	1,100	350	340	Gerhards 1966b
Blackbutt (Hawaii)	5	5,670	9,760	–	2,240	1,530	1,380	390	370	
Eucalyptus robusta	8	3,560	5,260	–	–	1,100	970	260	260	Youngs 1960
Robusta (Hawaii)	8	4,150	8,200	–	–	1,670	1,330	270	280	
Eucalyptus saligna	10	3,960	5,560	–	1,470	1,130	1,120	370	380	Gerhards 1965
Saligna (Hawaii)	10	5,180	8,920	–	1,860	1,600	1,360	390	370	
Fraxinus uhdei	5	–	–	–	–	790	700	260	290	Youngs 1960
Tropical ash (Hawaii)	5	–	–	–	–	1,270	860	200	230	
Grevillea robusta	8	–	–	–	–	710	850	–	–	Youngs 1964
Silk-oak (Hawaii)	8	–	–	–	–	900	930	–	–	
Mangifera indica	–	–	4,200	–	–	–	–	–	–	Ghosh *et al.* 1963
Mango (India)	–	–	6,400	–	–	–	–	–	–	
Metrosideros collina	11	3,090	4,720	640	1,680	1,340	1,270	410	410	Youngs 1960
Ohia (Hawaii)	11	5,270	8,900	1,400	2,360	2,390	2,090	380	390	
Pithecellobium saman	2	2,720	3,760	600	1,100	800	750	–	–	Wangaard 1954
Monkey-pod (Venezuela)	2	3,920	5,070	830	1,280	900	850	–	–	
Sequoia sempervirens	5	–	–	–	–	580	440	(150)[2]	(170)[2]	Youngs 1960
Redwood (Hawaii)	5	–	–	–	–	740	500	(90)	(130)	
Thespesia populnea	–	–	6,400	–	–	–	–	–	–	Chowdhury and Ghosh 1958
Milo (India)	–	–	8,200	–	–	–	–	–	–	
Toona australis	4	2,060	2,790	–	–	510	430	160	170	Youngs 1960
Australian toon (Hawaii)	4	2,930	5,480	–	–	870	550	140	140	

(See footnotes at end of table.)

(Continued)

Table 3—*Hardness, toughness, and compression properties of small clear specimens of wood from 16 Hawaii timber species and six imported woods used in Hawaii,* continued

Species and source of wood	Trees tested	Compression parallel to grain		Compression perpendicular to grain stress at proportional limit	Maximum shear strength	Hardness		Toughness		Sources
		Stress at proportional limit	Maximum crushing strength			End	Side	Radial	Tangential	
	No.	*Psi*	*Psi*	*Psi*	*Psi*	*Lb*	*Lb*	*In-lb*	*In-lb*	
Tristania conferta	19	4,410	5,650	960	1,650	1,580	1,760	–	–	Bolza and Kloot 1963
Brushbox (Australia)	19	5,130	9,270	1,270	2,480	1,970	2,040	–	–	
Pseudotsuga menziesii	–	3,130	3,860	440	930	510	500	150	200	USFPL 1955[3]; Youngs 1960
Douglas-fir (W. Coast)	–	5,850	7,430	870	1,160	900	710	140	200	
Sequoia sempervirens	16	3,700	4,200	520	800	570	410	(60)[2]	(110)[2]	USFPL 1955; Youngs 1960
Redwood (old-growth) (Calif.)	16	4,560	6,150	860	940	790	480	(50)	(80)	
Thuja plicata	15	2,470	2,750	340	710	430	270	–	–	USFPL 1955
Western red cedar (W. Coast)	15	4,360	5,020	610	860	660	350	(40)[2]	(70)[2]	
Shorea negrosensis	5	2,500	3,880	510	970	590	630	– 290 –		Lauricio and Bellosillo 1963
Red lauan (Philippines)	5	3,410	6,020	680	1,330	790	740	– 240 –		
Dipterocarpus grandiflorus	5	2,560	4,050	650	1,070	820	870	– 240 –		Lauricio and Bellosillo 1963
Apitong (Philippines)	4	4,820	8,730	1,130	1,760	1,660	1,500	– 280 –		
Quercus alba	20	3,090	3,560	830	1,250	1,120	1,060	–	–	USFPL 1955
White oak (Central states)	20	4,760	7,440	1,320	2,000	1,520	1,360	–	–	

[1] Includes *E. bicostata* and *E. St. Johnii.*
[2] Specimen size of figures in parentheses 5/8 by 5/8 inches tested over 8-inch span.
[3] USFPL = U.S. Forest Products Laboratory.