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LUMBER POTENTIAL OF 12-YEAR-OLD SALIGNA EUCALYPTUS TREES IN HAWAII

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Abstract: The sawtimber potential of 12-year-old *Eucalyptus saligna* Sm. trees grown in Maui, Hawaii, was studied by using simple field techniques. Lumber manufactured from the trees was predominantly of low grade, but had lower average density than wood from older trees, and therefore was more desirable. Logs end-split badly, and sawed with the usually encountered amount of difficulty due to growth stress that averaged 1,350 psi per log. The wood shrank moderately in drying, but lumber degrade was not serious. Bending strength, except for modulus of elasticity, was high for the specific gravity. The wood nailed, machined, and glued reasonably well, but did not accept preservative when pressure treated.

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Saligna eucalyptus *(Eucalyptus saligna* Sm.*)* is one of the most widely planted species in Hawaii. But the wood of older trees has a number of utilization problems. It is heavy, varies widely in density, and shrinks excessively in drying. Logs spring in sawing and end-split when bucked because of growth stress. And they have a central core of brittleheart—brash wood that is unsuitable for most purposes.

Possibly, many of these problems could be overcome by using the lower density, less stressed wood of very young trees. To find out, I used simple field techniques to study the feasibility of manufacturing and using lumber from 12-year-old saligna eucalyptus trees. These characteristics were studied: volume and lumber grade yield, log end-splitting, growth stress, sawing characteristics, density, shrinkage, bending strength, lumber drying behavior, workability, gluability and treatability with preservatives. I compared data, whenever possible, with that for Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco*)* because I anticipated that the young saligna wood would probably be suitable for some of the same uses as that species.

The results suggest that lumber manufactured from young saligna trees grown in Hawaii is usable—perhaps even more so than that manufactured from older trees. The wood is generally low in grade, but is also of lower density. Although it cannot compete well with softwood in density and workability, it should be suitable for construction work. If its relatively large shrinkage can be tolerated, it should be usable in green moisture condition for house framing. Among normal hardwood uses, the wood is mostly of a grade, workability, and gluability well suited for upholstered furniture frames. And wood from close to the pith should be acceptable for pallet lumber.

PROCEDURE

Five trees were cut in each of two stands—one planted in 1960, the other in 1961— on the island of Maui. The trees were chosen for their accessibility and size, but were not the largest in the stands. They ranged in d.b.h. from 12.1 to 17 inches and in height from 94 to 132 feet, so were well into sawtimber size despite their young age. Merchantable lengths ranged from 42 to 73 feet, all but one of the trees containing three or more 16-foot logs. The log volume represented by the 10 trees was 2,111 board feet (Int. ¼ inch log rule).

Logs cut from the trees were 12 feet long and consisted of a butt log and a top log 8 inches diameter-inside-bark from each tree, and for five trees, a log from midway up the stem. This 25-log sample totaled 1,294 board feet. Logs were graded according to standard U.S. Forest Service hardwood log grading rules. Nine of the 10 butt logs graded number 2; the 16 other logs were number 3.

End splitting of logs was rated as to severity immediately after bucking and just before sawing—2 days after logging. The total linear inches of end splits across the log ends were also measured.

The logs were sawed through and through on a conventional circular headrig producing 4/4-inch boards from one side of the log and 8/4-inch boards from the other, but leaving as the dog board a flitch 6/4 to 8/4 inches thick containing the pith with the bark on either side. Except for the central flitches, which were used for growth stress measurements, the lumber manufactured was edged to leave the maximum wane for its grade potential.

To measure growth stress, each flitch was ripped down the pith soon after original sawing so that each side would crook as stress was relieved. The two half-flitches were placed back together so they touched at the center. I measured the width and thickness of each half-flitch at the central point of contact and at each end, and also the distance from the point of contact to each end and the separation of the two halves at each end. A knotfree 40-inch long section of one half-flitch was then sawed out and stored in a polyethylene wrapper so that it would still be green when used later for strength tests.

Lumber was tallied and graded according to the National Hardwood Lumber Association's standard rules and rules for hardwood construction and utility boards. The flitches used for growth stress measurements were included in the tally, but were not graded. Grading was done just after sawing and after air-drying. Causes of degrade occurring during drying were recorded.

Six 1-inch and six 2-inch thick boards were randomly selected from the lumber and used to determine planing, sawing, and nailing characteristics. Surfaced 1 by 6s and 2 by 4s were made from halves of each board when green and from the other halves when air-dry. The boards and 2 by 4s were each cut into three equal lengths. Each set of three matched boards was then joined together with 8d common nails to each set of 2 by 4s to simulate rough wall construction. Two similar test units were made of air-dry Douglas-fir lumber when the test panels were manufactured. This comparison provided a rough guide of nailing difficulty on which to base the nailing characteristics of the green and air-dry saligna. The test panels made of green wood were stored outdoors in the shade, and their condition was observed after 4 months of weathering.

I measured specific gravity, and lateral and volumetric shrinkage in 75 samples. They consisted of 1-inch square, 4-inch long pieces obtained from each flitch and from two board-ends from each log. Basic specific gravity was also determined for wood near the pith and wood near the bark on each strength test sample and for wood from each treatability sample. Some shrinkage samples were used for a trial of steam reconditioning.

Strength in bending was tested by loading ½- by 1-inch test sticks as cantilever beams over a 12-inch span—a procedure Kauman and Kloot[1] had suggested. The test sticks were taken from close to the pith and close to the bark of each flitch section. A test stick was held in a vice and loaded by filling a 10-gallon bucket with water from a hose. The bucket was filled at a constant rate that caused an approximate deflection of 0.1 inch per minute within the proportional limit. Deflection was recorded at 5-pound load intervals. After failure occurred, the load was weighed.

Machining tests consisted of planing the panel boards and 2 by 4s and the strength-test sticks to size when green and when air-dry. An ogee mold was run across one end and a side of some of the left-over strength test material when it was air-dry. Planing and shaping were compared with trials done at the same time with silk-oak *(Grevillea robusta)* and lauan *(Shorea* spp.*)* boards that were on hand.

Gluability was tested by gluing three matched ½- by 1-inch pieces that had been conditioned to 12 percent moisture content. The pieces overlapped in such a way as to provide two 1-inch square glue lines per sample. These pieces were loaded to failure in shear in a vice. Gluability was rated as the percent of wood showing per failed glue line. Urea formaldehyde and phenol-resorcinol glues were used, and Douglas-fir served as the comparison species.

Treatability was measured by pressure-treating 10 saligna and two Douglas-fir 4-foot 2 by 4s with chromated copper arsenate-type C. They were included in a regular commercial run of Douglas-fir framing material. Retention was measured by before-and-after-weighing, and penetration was measured at saw cuts made at the center of each piece soon after treatment. The Douglas-fir 2 by 4s were used for comparison.

RESULTS

End-Splitting of Logs

All logs had some growth stress-caused end splits on at least one end immediately after bucking. The end splitting became worse during the 2 days the logs were held before sawing. The logs with the largest amount of splitting had some splits that were felling or bucking damage. Splitting was most severe in butt logs, less in middle logs, and least in top logs. End splits across the log ends averaged 21 inches per log measured just after bucking and 31 inches per log after 2 days' storage. Total inches per log decreased as height of log in the tree decreased and this reduction was statistically significant—even when the differing diameters of the logs were adjusted for. The sawmill operator and I judged these logs to be worse than average splitters, but still acceptable for manufacture into lumber.

Volume and Grade Recovery

A total of 1,520 board-feet of lumber were recovered from the 1,290 board-feet of logs. Of the total, 997 board-feet were in the lumber cut from either side of the central flitch and were graded when green. I did not grade the flitches because they were not representative of good manufacturing practice. All contained pith full length, thereby placing them in a grade no higher than 2 Common. Most flitches were miscut, with thickness variation exceeding ¼-inch. Stress relief caused by sawing down the center produced excessive crook greatly reducing the width of cuttings. After green grading, 147 board-feet were kept separate for use in other tests. The rest of the lumber (850 board-feet), was piled and air-dried for 4 months.

The green grade recovery for such young trees was good *(table 1).* Graded by the standard NHLA rules, although no FAS boards were found, the yield of 1 Common and better amounted to 35 percent of the tally. Most knots were quite small. Knots were infrequent in the outer wood of the logs so that almost one-fourth of the boards had one face clear enough to make the NHLA construction and utility grade of "B" Finish—essentially low grade paneling. The rather large volume of 2 Construction was caused primarily by wane restrictions of the higher finish and utility grades.

Degrade in Drying

The lumber grade yield was reduced somewhat by drying, but drying degrade was less than had been anticipated *(table 1).* Altogether, 124 board-feet, or 14.6 percent of the 850 board-foot total, were degraded in drying. One board containing 16 board-feet dropped down two grades, from select to 2 Common. Other boards changed only one grade, most commonly from 1 Common to 2 Common.

Degrade was caused chiefly by cupping severe enough to reduce the number of cuttings of standard thickness after surfacing. Two boards were reduced in grade because end splitting reduced the cuttings. Four boards were reduced in grade because of deep side checking. The checks occurred in boards having severe diagonal grain. They were similar in nature to end splits. Collapse and surface checking—often serious degrading factors in drying of eucalypts—were not a problem.

During grading, each air-dried board was measured with an electrical moisture meter. The average moisture content after 4 months' drying outdoors was 19 percent; 1-inch thick lumber averaged 18 percent and 2-inch lumber was 19.5 percent.

When the boards were still green, I marked the length of the end splits. The extension of these splits

Table 1—*Yield of graded lumber from 12-year-old saligna eucalyptus logs before and after air drying, Maui, Hawaii, by two grading systems*

NHLS grades[1]	Lumber yield[2]			
	Green		Air-dry	
	Board-feet	*Percent*	*Board-feet*	*Percent*
Standard:				
Sel	42	4.9	19	2.2
1C	252	29.6	191	22.5
2C	404	47.6	468	55.1
3C	152	17.9	172	20.2
Finish and utility:				
B	167	19.6	111	13.1
1	405	47.7	420	49.4
2	257	30.2	298	35.0
3	21	2.5	21	2.5

[1]National Hardwood Lumber Association rules for standard grades and for hardwood construction and utility boards: Standard grades—FAS, Select, 1, 2, and 3 Common; Finish and Utility grades—A and B Finish, and 1, 2, and 3 Construction.

[2]Total yield of lumber (ignoring flitches) was 997 board-feet; 147 board-feet were withdrawn for other tests.

Table 2–*Averages of calculated growth stresses per log in 12-year-old saligna eucalyptus, Maui, Hawaii, by tree and stand*

Item	Stand 1[1]					Stand 2[1]					Means
	Tree numbers										
	1	2	3	4	5	6	7	8	9	10	
	Pounds per square inch										
Butt log	2,600	1,500	900	1,000	2,500	2,400	2,000	2,000	1,900	700	1,800
Middle log	1,700				2,100	1,500	1,000	1,100			1,500
Top log	800	1,200	600	700	1,000	1,000	900	900	1,300	800	900
Tree mean[2]	1,700	1,300	700	800	1,800	1,700	1,500	1,500	1,600	700	1,350

[1]Mean for Stand 1: 1,300; for Stand 2: 1,400 lbs./sq. inch.
[2]Butt and top logs only.

was measured on the air-dry boards. It averaged 11 inches per board. This figure includes all splits on both ends and both sides formed after green grading. Split extension ranged from 0 in six boards to 65 inches in one board. Serious split extension varied independently of which stand, which tree, or what height in the trees the lumber came from.

Growth Stress

In calculating growth stress, I assumed that a uniformly distributed load was causing each flitch-half to bend. This is a gross oversimplification of the loading condition needed to hold the half-flitches in their in-tree configuration. And it does not account for unrelieved stresses retained in the half-flitches. However, it provided a convenient measure for comparing the stress between the logs.

The stress was calculated as the normal, uniform load that would be required to deflect a beam of the average green elasticity found by strength tests of each flitch and average dimensions of the two half-flitches to the average crook of the two half-flitches. The growth stress per log calculated this way averaged 1,350 pounds per square inch *(table 2).* This stress is in the same range as other workers using more precise techniques have found in the outer wood of highly stressed logs. Kubler[2] found stress of 1,420 psi in large diameter beech. Jacobs[3] determined the average tensile stress in the outer wood of *Eucalyptus delegatensis* of various diameters to be in the order of 1,200 psi, and Boyd[4] confirmed this value. Nicholson[5] found tensile stresses along the surface of *Eucalyptus regnans* logs of 300 to 4,000 psi.

Growth stresses resembled end splits in pattern; they were greatest in butt logs and least in top logs *(table 2).* This relationship is not surprising because Boyd[4] has shown that longitudinal growth stresses result in lateral growth stresses that are probably the primary cause of end splitting. However, the correlation coefficient between inches of end splits per log divided by log diameter and growth stress per log was only 0.75. This correlation is rather low, probably because the end splits measured included those caused by felling and bucking as well as those caused by growth stress.

The sawyer, who had 4 years of experience sawing

Table 3–*Specific gravity and shrinkage of wood from saligna eucalyptus*

Sample	Specific gravity		Shrinkage from green to . . .					
			Air-dry[1]			Ovendry		
	Green volume ovendry weight	Air-dry volume[1] ovendry weight	Radial	Tangential	Volumetric	Radial	Tangential	Volumetric
			Percent					
12-year-old saligna	0.56	0.62	3.7	6.6	10.2	6.0	9.6	15.7
55-year-old saligna[2]	.63	.70	4.0	9.0	[3]12.7	7.3	12.7	[3]19.3
27-year-old saligna[2]	.55	.62	3.5	8.5	[3]10.8	5.7	11.6	[3]16.8

[1]Test values adjusted to 12 percent moisture content.

[2]Source: Gerhards, C. C. *Physical and mechanical properties of saligna eucalyptus grown in Hawaii.* U.S. Forest Serv. Res. Paper FPL 23, Forest Prod. Lab., Madison, Wis. 12 p., illus. 1965.

[3]Based on radial, tangential, and longitudinal shrinkages.

Table 4–*Specific gravity of 12-year-old saligna eucalyptus wood, Maui, Hawaii, by position in tree*

Log position	Wood near pith			Wood near bark		
	Specific gravity[1]	Samples	Standard deviation	Specific gravity[1]	Samples	Standard deviation
Butt	0.42	10	0.047	0.58	10	0.047
Mid-height	.48	5	.057	.62	5	.061
Merchantable top	.48	11	.049	.63	11	.073

[1]Green volume, ovendry weight.

eucalypts, rated each log according to sawing difficulty. His notes indicated he considered the spring in these logs to be average or normal as compared with logs of other *Eucalyptus* species.

During strength testing, I found only one butt log with partially brash wood near the pith. One macroscopic compression failure was found in the inner wood from this log, indicating that some longitudinal stress relief–or brittleheart development–had already occurred. The half-flitches from this log indicated that it still retained a large stress of 2,600 psi–the largest of any of the logs.

Specific Gravity and Shrinkage

The specific gravity of the wood of the young trees was in the range of that from older trees previously sampled *(table 3)*. Density at 12 percent moisture content was 43.4 pounds per cubic foot. The wood was similar in weight to yellow birch *(Betula alleghaniensis)*, and therefore rather dense for use as a construction material.

Basic specific gravity obtained from the strength test samples was a little lower than that from the shrinkage samples because more wood from near the pith was represented. Average specific gravity (green volume, oven dry weight) was 0.53. That for wood near the pith was 0.46 and that for wood near the bark 0.61. Specific gravity increased as distance from the pith increased and as height of wood in the trees increased *(table 4)*.

Tangential shrinkage of the young wood was appreciably lower than that of wood from older trees *(table 3)*. Nevertheless, some collapse and considerable warping were evident among the shrinkage samples. The samples had been brought to constant weight under 12 percent equilibrium moisture content conditions and then oven-dried. Shrinkage, like weight, was similar to that of yellow birch.

To demonstrate that some of the collapse that occurred in drying could be recovered, I steamed 12 radial and 11 tangential shrinkage samples for 5 hours at atmospheric pressure and then allowed them to dry to constant weight at 12 percent equilibrium moisture content conditions. Such reconditioning is most effective if done on air-dried wood, or wood at about 20 percent moisture content.[6] The wood used for this demonstration had been ovendried and allowed to recover to about 12 percent moisture content. Despite this, steaming reduced the volumetric shrinkage from green to 12 percent moisture content for the samples from an average of 11.6 percent to 10.2 percent. Almost 12 percent of the volumetric shrinkage that had occurred in air drying was recovered, and distortion of the samples from drying stresses was greatly reduced.

Strength in Bending

Though the wood of the young trees was somewhat lower in specific gravity than wood of older trees, its fiber stress and modulus of rupture in bending when green were similar to those of wood from older trees *(table 5)*. Its modulus of elasticity was much lower, however. The fiber stress and modulus of rupture increased more in air-dry wood of young trees than in wood from older trees. Modulus of elasticity remained considerably below that of older trees in the air-dry wood.

In the tests of green wood, one of the 25 samples failed rather suddenly with a partially brash type fracture. This piece contained a visible compression failure before testing. During the air-dry tests, four samples failed suddenly with a brash or partially brash fracture. All these samples were from wood near the pith. These results indicate that brittleheart had already started to form in the 12-year-old trees, but not in an amount sufficient to be serious.

The wood near the pith had a breaking strength similar to that of Douglas-fir. Wood near the bark had a higher breaking strength than Douglas-fir. However, the wood was not as stiff as Douglas-fir. Its stiffness was similar to that of Western hemlock–still well within the strength range accepted for construction in Hawaii.

Table 5–*Strength in bending of saligna wood from 12-year-old trees and from older trees, by location and number of samples*

Location and No. samples	Moisture content	Specific gravity	Fiber stress at prop. limit	Modulus of rupture	Modulus of elasticity
	Percent		*1,000 psi*	*1,000 psi*	*1,000 psi*
Young trees:					
Near pith					
25	115	0.46	5.4	9.6	970
25	13	.51	8.2	11.5	1,040
Near bark					
25	80	.61	8.8	13.2	1,660
25	13	.67	12.5	18.3	1,840
Average					
50	98	.53	7.1	11.4	1,310
50	73	.59	10.3	14.7	1,440
Older trees:[1]					
5[2]	77	.59	7.1	11.5	1,980
5[3]	12	.66	9.9	16.4	2,390

[1]Source: Gerhards, C. C. *Physical and mechanical properties of saligna eucalyptus grown in Hawaii.* U.S. Forest Serv. Res. Paper FPL 23, Forest Prod. Lab., Madison, Wis. 12 p., illus. 1965.

[2]55-year-old trees–five trees.

[3]27-year-old trees–five trees.

Nailing

Nails were almost as easy to drive into the wood when green as into dry Douglas-fir. However, nails driven within 1-inch of the board ends often caused splits. About one-fourth of all nails driven near the board ends of green wood caused splits.

Nailing air-dry wood was much more difficult than nailing green wood. The 8d nails were fairly readily driven through the boards, but were quite difficult to drive into the 2 by 4s. In one panel, the 2 by 4s were from a very dense upper log. These were almost impossible to nail into without bending the nails. This dense wood had a specific gravity (air-dry volume, oven-dry weight) of 0.71 and a moisture content of 17 percent. Typical easier-to-nail air-dry wood had a specific gravity of 0.60. The air-dry wood did not split as badly as green wood in nailing. Only one-fifth of all nails near the ends caused splits.

Panels were nailed together when green, stored for 4 months, and then examined. Shrinkage of 1- by 6-inch boards was such that seams opened 3/8- to 5/8-inch. Additional splitting at the nails usually occurred, and most boards showed slight cupping and collapse. The 2 by 4 framing material was satisfactory, however. It did not split, warp, or collapse. This suggests that young saligna wood might be suitable for framing lumber if used green.

Machining

The saligna had slightly to moderately interlocked grain that caused occasional slight tearouts in planing. These tearouts were more frequent in the denser wood. I judged air-dry wood to be inferior to silk-oak and slightly inferior to lauan in machine planing on a jointer.

Except for a slight tendency to burn, the young saligna wood molded perfectly on both sides and ends. The lowest density wood worked as easily as that from silk-oak and lauan, but even the densest wood shaped perfectly.

Gluing

Results of the test on gluability were indecisive. The urea-formaldehyde glue joints all failed in shear, with 100 percent of the glue line surface showing wood. The urea-formaldehyde therefore provided perfect joints. On the other hand, joints glued with phenol-resorcinol were not as good. These glue lines generally failed, with 46 percent of the surface as wood. Two of eleven samples had 100 percent wood, but one had only 10 percent. The phenol-resorcinol glue also gave incomplete adhesion on two Douglas-fir samples used for comparison; perhaps the glue used may have been at fault–not the gluability of the wood.

Treatability

Saligna wood from young trees is non-resistant to moderately resistant to decay and non-resistant to termites.[7] For use in Hawaii in locations and situations where termites are a hazard, it should be treated with preservatives.

Tests by the Honolulu Wood Treating Company[8] showed that the young saligna wood does not pressure-treat well. The treatment was with a 2 percent oxide solution of chromated copper arsenate Type C with a 1 hour vacuum of 27 inches mercury followed by 8 hours of 135 psi pressure. These conditions usually give 0.23 pounds of dry chemical per cubic foot in Douglas-fir, and gave 0.28 to the Douglas-fir in this test. But the saligna retained only 0.08 pounds and penetration was almost nil. In the Douglas-fir, penetration varied from 1/8 to 1/4 inch.

CONCLUSIONS

This study suggests that it is feasible to manufacture and use lumber from 12-year-old saligna trees. And to do so may be sound forestry practice because if trees are left until they are 30 to 40 years old, most of the wood formed in later years will be of high density, and most formed in early years will become unusable brittleheart. Lumber from the young trees will be of low grade, but because of its lower density and easier working characteristics will have a use potential in general construction which wood from older trees does not have. For ease of nailing, the wood should be used green. For certain purposes, house framing, for example, shrinkage and distortion of green wood in drying should not cause serious problems. If used in a dry condition, the wood should be pre-drilled for fastenings. Young saligna machines and glues well enough to satisfy the requirements for upholstery frame material. And because little brittleheart has formed, wood near the pith is suitable for pallets. The wood of young trees does not treat well with preservatives which will prove a problem in Hawaii where decay and termites are serious hazards. Methods for improving treatability, such as incising, require development.

The variations in calculated growth stress among the trees studied suggest the possibility for improving the utilization potential of future saligna plantings: Select and breed trees having low growth stress.

NOTES

[1]Kauman, W. G., and N. H. Kloot. *Technological appraisal of little-known or unused timber species.* C.S.I.R.O. Div. Forest Prod. Reprint 720, 5 p., illus. 1968.

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[6]Anonymous. *Collapse and the reconditioning of collapsed timber.* C.S.I.R.O. Div. Forest Prod. Trade Circ. 20, 23 p., illus. 1942.

[7]Skolmen, R. G. *A durability test of wood posts in Hawaii . . . third progress report.* USDA Forest Serv. Res. Note PSW-260. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 4 p., illus. 1971.

[8]Trade names and commercial products or enterprises are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

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