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*In Cooperation with the University of Wisconsin*

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# SOME STRENGTH AND RELATED PROPERTIES OF YAGRUMO HEMBRA

## ( *CECROPIA PELTATA* )

# FROM PUERTO RICO

# SOME STRENGTH AND RELATED PROPERTIES OF YAGRUMO HEMBRA (CECROPIA PELTATA) FROM PUERTO RICO

By

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## Summary

Evaluations of several mechanical and physical properties were conducted on specimens from five yagrumo hembra (Cecropia peltata) trees from Puerto Rico. With the exception of toughness and modulus of elasticity in both bending and compression parallel to grain, these specimens were lower in specific gravity and in strength properties than material reported previously. Although the specific gravity of the new material averaged about twice that of balsa, a wide range of specific gravity was evident and material at the lower part of the range could possibly be used as a substitute for balsa. Dense yagrumo hembra resembles North American black cottonwood in both specific gravity and mechanical properties. Total shrinkage from green to the ovendry condition was not excessive although the ratio of tangential to radial shrinkage appears about twice that characteristic of most species.

## Introduction

Yagrumo hembra (Cecropia peltata), as it is known locally in Puerto Rico, is one of many closely related species growing thoughout tropical America. It is a short lived deciduous tree, and characteristically grows rapidly in lowland flats, frequently forming nearly pure stands after clear cutting. It may grow to 60 feet in height, and 24 inches in diameter; however, it is more commonly 40 feet tall and 8 to 12 inches in diameter at maturity.

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[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

It is one of the lighter woods found in Puerto Rico. Apparently all sapwood, the wood is fairly lustrous, whitish when freshly sawn but turning pale brown upon exposure. It is generally straight grained and coarse in texture. Prior to 1958, it had not been considered for export purposes, and was limited in use to such products as match sticks, box boards, charcoal powder, and kindling.

Originally yagrumo hembra was considered just another prolific, fast-growing weed tree; however, perhaps because it grows somewhat faster than most other species of this classification, it now occupies a position near the top in terms of volume of timber in Puerto Rico.[2] With the approaching depletion of the valuable hardwoods that are traditionally cut, it became evident that this tree should be considered in forest utilization research programs.

The data on the mechanical and physical properties presented in this report are a part of a comprehensive cooperative project initiated in 1958 in which it was agreed the Institute of Tropical Forestry (formerly Tropical Forest Research Center) would supply material upon which the Forest Products Laboratory would conduct various phases of research. Several of these phases have been completed, including those on veneer cutting and drying properties, semichemical pulping, moisture content determinations by electrical moisture meter, development of kiln schedules, and strength properties of particle board. Results of that research, most of which have not previously been published, are summarized in the following paragraph.

R. H. McAlister found that, although excellent veneer may be cut from yagrumo hembra, it would have limited use due to certain drying defects associated with tension wood, to wet streaks, and to the wide range of specific gravity; it is not desirable for core and crossband stock due to its extreme compressibility under heat and pressure. Work by W. C. Lewis showed that several types of particle board produced from yagrumo hembra were generally superior, in modulus of elasticity and modulus of rupture in bending and in tensile strength perpendicular to grain, to both commercial and laboratory boards of similar density, resin content, and particle type. C. P. Pan concluded that the equilibrium moisture content of yagrumo hembra appears to be similar or perhaps slightly lower than that of North American species over the hygroscopic range although there is some doubt as to whether sufficient time was allowed for the specimen to equilibrate. He suggested moisture meter corrections of approximately -1.4 to 4.0 for resistance-type meters over the moisture range from 7.5 to 22.0 percent. McMillen[3] noted that yagrumo hembra is easy to dry in 1- and 2-inch flat lumber

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[2] Chalmers, W. S. Observations on some Caribbean forests. Carib. For. 19(1/2): 30-42. 1958.
[3] McMillen, J. M. Kiln schedules for Puerto Rican yagrumo hembra. Carib. For. 22(3/4): 84-90. 1961.

or small-to-moderate size dimension lumber. Shrinkage and warping were not excessive and significant collapse or seasoning degrade did not occur. No problems were encountered in achieving stress-free lumber. Kiln schedules for stock of various dimensions were recommended by McMillen. In an evaluation of the pulping potential of several tropical species, E. L. Keller et al[4] found that although the yield of pulp per cord was low, yagrumo hembra required an unusually short cooking time and produced unbleached pulp approaching the best northern deciduous neutral sulfite pulp in quality, Also, after centrifugal cleaning and a conventional three-stage bleach, the pulp was converted to bond paper of excellent brightness and quality.

Previous evaluations of the mechanical properties of yagrumo hembra at the Forest Products Laboratory are limited to a few preliminary tests conducted by A. W. Dohr in 1943. The purpose of these tests was to determine whether yagrumo hembra had outstanding properties that might make it desirable for World War II use. He concluded that since it falls in the range of density and strength properties of some of the lightweight native North American species it could serve many wood uses. However, it did not appear to have especially outstanding mechanical or physical properties that would recommend it for special war uses. Specifically, it was decidedly heavier than balsawood, for which substitutes were needed. Dohr noted that yagrumo hembra was not especially tough for its light weight as indicated by Longwood,[5] although it is not known whether Longwood's remarks are based upon casual observations of the wood in use or upon experimental data. Dohr did find, however, that toughness was generally greater when the load was applied on the radial face than the tangential face. The average specific gravity was 0.32, comparable to native North American species such as cottonwood (0.35), balsam poplar (0.33), western redcedar (0.33), northern white-cedar (0.31), alpine fir (0.33), corkbark fir (0.30), and Engelmann spruce (0.33).

## Description of Materials

Materials used in this study came from the, Luquillo Experimental Forest in Puerto Rico. General ecological factors of the area of cutting are as follows: Average annual precipitation is 135 inches. Temperatures range from 55° to 98° F. with an annual mean temperature of 74° F. Relative humidity is classified

[4] Keller, E. L., Kingsbury, R. M., and Fahey, D. J. Neutral sulfite semichemical pulping of guaba (Inga vera), yagrumo hembra (Cecropia Peltata), and eucalyptus (Eucalyptus robusta) from Puerto Rico. U.S. Forest Products Lab. Rpt. 2127, 7 pp., illus. 1958.

[5] Longwood, F. R. Puerto Rican woods--their machining, seasoning, and related characteristics. U.S. Dept. Agr., Agr. Handb. 205, 98 pp., illus. 1961.

as high throughout the year with the prevailing wind direction east–northeast both winter and summer. Topography is described as mountainous with numerous permanent streams. Geological history is igneous. Soil type is clay loam and its condition is described as wet with medium–to–good drainage.

One 5–foot bolt was cut from each of five trees. These represented the e, d, f, c–d, and d bolts.[6] Selected trees ranged from 16 to 17 inches in diameter at breast height, from 35 to 45 feet in merchantable length, and from 50 to 60 feet in total height. Bolt diameters were 14 to 15 inches at the lower end.

The trees were cut in May 1959, and the bolts arrived at the Forest Products Laboratory in Madison in July 1959. They constituted part of the shipment (trees Nos. 1, 3, 5, 9, and 11) used by the Laboratory for the evaluation of properties in other phases as previously mentioned. Although the bolts were well protected by end coating and preservative treatment before shipment, considerable drying occurred during transit. Bolts were severely checked and split, particularly where bark was lost during shipment. They also appeared to be heavily blue stained, and some beetle infestation had occurred.

A cross section of each bolt and a flitch from one are shown in figures 1 and 2. They are characterized by the large hollow stems, by little evidence of tension wood despite considerable eccentric growth about the pith, by severe staining and possibly some deterioration by fungi, and by the septa in the hollow pith evident in the flitch (fig. 1).

## Procedures

The secondary method described in American Society for Testing and Materials D 143–52, “Standard Methods of Testing Small Clear Specimens of Timber,” was used as a guide for material selection and preparation because of the small tree diameter and the hollow pith. Further modification was also necessary since one bolt rather than two was sampled from each tree. This required that a system of matching air–dry and green material within a bolt be used, as opposed to the interchanged composite bolt system prescribed by D 143–52. This in turn limited the number of properties that could be evaluated, Static bending, compression parallel and perpendicular to grain, and hardness properties were evaluated on green and air–dry material, while evaluation of properties in shear parallel

[6] Even though the bolts were cut slightly longer than the standard 4-foot length, they represent approximately the same height in the tree as that normally indicated by the standard bolt designations.

to grain and toughness was limited to air-dry material. However, standard toughness specimens of both the old size (5/8 inch) and the new (2 centimeters) were evaluated. Radial and tangential shrinkage specimens were cut from the disks shown in figures 1 and 2, and longitudinal shrinkage specimens were also obtained from each tree.

## Presentation of Results

The data on mechanical properties, both green and air dry, together with average mechanical properties for black cottonwood, are presented in table 1. The average of these data, along with the species averages for yagrumbo hembra obtained by Dohr, for balsa obtained by Wiepking and Doyle,[7] and for black cottonwood (from U.S.D.A. Tech. Bul. 479[8] are also shown in table 2. The data from toughness tests are presented in table 3. Shrinkage data are presented in table 4.

## Discussion of Results

Considerable variation existed in the manner in which specimens failed. In bending, compression failures varied from barely perceptible to very deep, sometimes causing a reduction in load after maximum load prior to any indication of tension failures. Tension failures varied from simple brash tension to splintering tension, high loads being associated with the splintering tension. A similar range of tension failures was also evident in the toughness specimens as indicated in figure 3.

With the exception of modulus of elasticity in bending and in compression parallel to grain and toughness, all mechanical properties evaluated (air dry) were considerably below those obtained by Dohr. However, Dohr sampled one tree only, and it was considerably higher in specific gravity than the average of the five trees evaluated in this research. A comparison of Dohr's data to that of tree 5 (approximately the same specific gravity) shows little difference between the various mechanical properties. No explanation can be offered, however, for the higher modulus of elasticity obtained in the present evaluation. The difference appears significant, however, since modulus of elasticity of Dohr's material in both compression parallel to grain and in static bending approximates that of two trees of this study with the lowest specific gravity (0.08 lower than Dohr's).

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[7] Wiepking, C. A., and Doyle, D. V. Strength and related properties of balsa and quipo woods. U.S. Forest Products Lab. Rpt. 1511, 9 pp., illus. 1943.

[8] Markwardt. L. J., and Wilson, T. R. C. Strength and related properties of woods grown in the United States. U.S. Dept. Agr. Tech. Bul. 479, 99 pp., illus. 1935.

Dohr, using the old standard toughness specimen (5/8 by 5/8 by 10 inches), concluded that toughness was somewhat greater when the load was applied on the radial face than on the tangential face. However, the data from this research for both the old and new standard toughness specimens (0.79 by 0.79 by 11 inches) indicates that toughness is greater when the load is applied on a tangential face, which is normally expected for many species.

The mechanical properties generally do not appear to differ substantially from those of balsa, other than that which might be expected because of the difference in specific gravity. Yagrumo hembra is about twice as high in specific gravity as balsa and from 2 to 3 times stronger in most strength properties. A notable exception to this is toughness where yagrumo hembra is only about one-third that of balsa. This is surprising because casual observations were that yagrumo hembra was exceedingly tough for its density.

No North American hardwood of commercial importance has as low a specific gravity as yagrumo hembra. However, black cottonwood presents a reasonable opportunity for a comparison of mechanical properties since it is comparable in specific gravity to that of tree 5. When comparing the properties (green) of tree 5 to those of cottonwood, yagrumo hembra is slightly stronger in modulus of rupture, work to maximum load in bending, maximum crushing strength, stress at the proportional limit in compression perpendicular to grain, and in hardness; cottonwood is stronger in stress at the proportional limit and modulus of elasticity in bending. Of those properties evaluated, air-dry yagrumo hembra (tree 5) was stronger in work to maximum load in bending, stress at proportional limit in compression perpendicular to grain, in end and side hardness, and in shear parallel to grain.

Total shrinkage did not appear excessive although the ratio of tangential to radial shrinkage was unusually high at 4.3:l compared to the 2:1 ratio considered a general average of most species. Tangential shrinkage averaged 7.5 percent from the green to ovendry condition, and radial shrinkage averaged 1.7 percent over the same range. Longitudinal shrinkage, although averaging only slightly greater than normal at 0.33 percent, was quite erratic, ranging from 0.15 to 0.65 percent. Even though the presence of reaction wood was not particularly evident, growth about the pith was quite eccentric, and the erratic longitudinal shrinkage was probably due to tension wood.

## Conclusions

Yagrumo hembra is lower in specific gravity and is not as strong as previously reported except in toughness and in modulus of elasticity in both bending and compression parallel to grain. It averages approximately twice as dense as balsa and also appears to be stronger in proportion to the usual specific gravity–strength relationships. However, the specific gravity is quite variable and, where specific gravity tolerances are not critical, yagrumo hembra of low density could be used as a substitute for balsa. Dense yagrumo hembra resembles North American black cottonwood in both specific gravity and mechanical properties, Total shrinkage is not excessive but the tangential–radial shrinkage ratio, at 4.3:1, appears about twice that characteristic of most species.

Table 1.--Mechanical properties of yagrumo hembra (*Cecropia peltata*) from Puerto Rico

| Tree No. | Bolt No. | No. of tests[1] | Moisture content | Specific gravity[2] | Static bending[3]: 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 | Compression parallel to grain[3]: Stress at proportional limit | Compression parallel to grain: Modulus of elasticity | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain: Stress at proportional limit | Hardness[4]: End | Hardness: Side | Shear parallel to grain: Maximum shearing strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pct. | | P.s.i. | P.s.i. | 1,000 p.s.i. | In.-lb. per cu. in. | In.-lb. per cu. in. | P.s.i. | 1,000 p.s.i. | P.s.i. | P.s.i. | Lb. | Lb. | P.s.i. |
| YAGRUMO HEMBRA (GREEN) | | | | | | | | | | | | | | | | |
| 1 | e | 12 | 180 | 0.24 | 1,810 | 3,240 | 680 | 0.29 | 2.9 | 1,110 | 930 | 1,600 | 160 | 230 | 180 | (5) |
| 3 | d | 10 | 111 | .27 | 2,000 | 4,400 | 1,060 | .21 | 4.3 | 1,450 | 1,230 | 2,090 | 220 | 360 | 290 | (5) |
| 5 | f | 12 | 108 | .33 | 2,760 | 5,140 | 1,000 | .48 | 6.4 | 1,620 | 1,070 | 2,320 | 270 | 330 | 270 | (5) |
| 9 | c-d | 14 | 123 | .23 | 2,040 | 3,970 | 810 | .30 | 4.0 | 1,570 | 880 | 1,800 | 150 | 210 | 170 | (5) |
| 11 | c | 10 | 148 | .22 | 1,710 | 3,470 | 770 | .22 | 4.3 | 1,190 | 900 | 1,540 | 170 | 270 | 200 | (5) |
| Average........ | | | 134 | .26 | 2,060 | 4,040 | 860 | .30 | 4.4 | 1,430 | 1,000 | 1,870 | 190 | 280 | 220 | (5) |
| YAGRUMO HEMBRA (AIR DRY) | | | | | | | | | | | | | | | | |
| 1 | e | 12 | 12.5 | .26 | 3,420 | 5,650 | 960 | .73 | 4.7 | 1,660 | 1,130 | 3,090 | 210 | 390 | 230 | 650 |
| 3 | d | 10 | 12.6 | .30 | 4,340 | 7,300 | 1,310 | .84 | 7.6 | 2,710 | 1,460 | 3,850 | 290 | 560 | 390 | 840 |
| 5 | f | 12 | 12.8 | .33 | 4,290 | 7,920 | 1,180 | .92 | 8.5 | 2,140 | 1,350 | 3,880 | 380 | 600 | 420 | 1,070 |
| 9 | c-d | 14 | 12.4 | .24 | 3,090 | 5,710 | 950 | .59 | 4.9 | 2,060 | 1,020 | 3,040 | 210 | 360 | 200 | 710 |
| 11 | c | 10 | 12.5 | .25 | 3,130 | 5,530 | 1,010 | .57 | 4.9 | 2,000 | 1,070 | 3,110 | 240 | 480 | 310 | 860 |
| Average........ | | | 12.6 | .28 | 3,650 | 6,420 | 1,080 | .73 | 6.1 | 2,110 | 1,210 | 3,390 | 270 | 480 | 310 | 830 |
| Adjusted to.... | | | 12.0 | .28 | 3,700 | 6,490 | 1,090 | .75 | 6.2 | 2,150 | 1,220 | 3,490 | 270 | 500 | 320 | .......... |
| BLACK COTTONWOOD (GREEN)[6] | | | | | | | | | | | | | | | | |
| .... | ....... | ....... | 132 | .32 | 2,900 | 4,800 | 1,070 | .44 | 5.0 | 1,760 | ....... | 2,160 | 200 | 280 | 250 | 600 |
| BLACK COTTONWOOD (AIR DRY)[6] | | | | | | | | | | | | | | | | |
| .... | ....... | ....... | 12.0 | .35 | 5,300 | 8,300 | 1,260 | 1.25 | 6.7 | 3,270 | ....... | 4,420 | 370 | 540 | 350 | 1,020 |

[1] Indicates the number of static bending and compression parallel tests; others ranged from 3 to 8 per tree.

[2] Specific gravity based on volume at test and weight when ovendry.

[3] Specimen 1 by 1 inch in cross section.

[4] Load required to embed a 0.444-inch ball to one-half its diameter.

[5] No tests conducted.

[6] U.S. Dept. Agr. Tech. Bul. 479.

Table 2.--Mechanical properties of yagrumo hembra (*Cecropia peltata*) compared to previous data on yagrumo hembra, balsa, and black cottonwood

| Moisture content | Specific gravity[1] | Static bending[2]: Stress at proportional limit | Static bending[2]: Modulus of rupture | Static bending[2]: Modulus of elasticity | Static bending[2]: Work to--Proportional limit | Static bending[2]: Work to--Maximum load | Compression parallel to grain[2]: Stress at proportional limit | Compression parallel to grain[2]: Modulus of elasticity | Compression parallel to grain[2]: Maximum crushing strength | Compression perpendicular to grain: Stress at proportional limit | Hardness[3]: End | Hardness[3]: Side | Shear parallel to grain: Maximum shearing strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pct. | | P.s.i. | P.s.i. | 1,000 p.s.i. | In.-lb. per cu. in. | In.-lb. per cu. in. | P.s.i. | 1,000 p.s.i. | P.s.i. | P.s.i. | Lb. | Lb. | P.s.i. |
| YAGRUMO HEMBRA (GREEN) | | | | | | | | | | | | | |
| 134 | 0.26 | 2,060 | 4,040 | 860 | 0.30 | 4.4 | 1,430 | 1,000 | 1,870 | 190 | 280 | 220 | .......... |
| YAGRUMO HEMBRA (AIR DRY) | | | | | | | | | | | | | |
| 12.6 | .28 | 3,650 | 6,420 | 1,080 | .73 | 6.1 | 2,110 | 1,210 | 3,390 | 270 | 480 | 310 | 830 |
| YAGRUMO HEMBRA (AIR DRY)[4] | | | | | | | | | | | | | |
| 11.5 | .32 | 4,430 | 7,820 | 1,020 | 1.08 | 8.1 | 2,700 | 1,080 | 4,060 | 390 | 520 | 370 | 940 |
| BALSA (AIR DRY)[5] | | | | | | | | | | | | | |
| 10.7 | .13 | 1,430 | 2,440 | 480 | .24 | 1.5 | 950 | 490 | 1,380 | 100 | ..... | 80 | 250 |
| BLACK COTTONWOOD (GREEN)[6] | | | | | | | | | | | | | |
| 132 | .32 | 2,900 | 4,800 | 1,070 | .44 | 5.0 | 1,760 | ....... | 2,160 | 200 | 280 | 250 | 600 |
| BLACK COTTONWOOD (AIR DRY)[6] | | | | | | | | | | | | | |
| 12.0 | .35 | 5,300 | 8,300 | 1,260 | 1.25 | 6.7 | 3,270 | ....... | 4,420 | 370 | 540 | 350 | 1,020 |

[1] Based on volume at test and weight when ovendry.

[2] Specimen 1 by 1 inch in cross section.

[3] Load required to embed a 0.444-inch ball to one-half its diameter.

[4] From work by A. W. Dohr at the Forest Products Laboratory in 1943.

[5] U.S. Forest Products Lab. Rpt. 1511.

[6] U.S. Dept. Agr. Tech. Bul. 479.

Table 3.--Toughness tests[1] of yagrumo hembra (*Cecropia peltata*), from Puerto Rico (air dry)

| Tree No. | Bolt No. | Radial: No. of tests | Radial: Moisture content | Radial: Specific gravity[2] | Radial: Toughness | Tangential: No. of tests | Tangential: Moisture content | Tangential: Specific gravity[2] | Tangential: Toughness |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pct. | | In.-lb. | | Pct. | | In.-lb. |
| OLD STANDARD SIZE[3] | | | | | | | | | |
| 1 | e | 3 | 11.7 | 0.23 | 39 | 3 | 11.6 | 0.24 | 59 |
| 3 | d | 3 | 12.3 | .35 | 81 | 3 | 12.2 | .34 | 70 |
| 5 | f | 2 | 12.0 | .30 | 62 | 4 | 12.1 | .34 | 89 |
| 9 | c-d | 4 | 11.5 | .23 | 38 | 4 | 11.4 | .24 | 42 |
| 11 | c | 3 | 11.8 | .28 | 68 | 3 | 11.7 | .28 | 50 |
| Average.......... | | | 11.9 | .28 | 58 | ....... | 11.8 | .29 | 62 |
| NEW STANDARD SIZE[4] | | | | | | | | | |
| 1 | e | 3 | 11.8 | .24 | 65 | 3 | 11.7 | .26 | 88 |
| 3 | d | 3 | 12.0 | .30 | 109 | 3 | 12.2 | .31 | 126 |
| 5 | f | 3 | 12.0 | .29 | 89 | 4 | 12.1 | .30 | 107 |
| 9 | c-d | 4 | 11.4 | .22 | 66 | 4 | 11.6 | .22 | 64 |
| 11 | c | 3 | 12.3 | .27 | 106 | 3 | 12.1 | .28 | 97 |
| Average.......... | | | 11.9 | .26 | 87 | ....... | 11.9 | .27 | 96 |
| AVERAGE OF PREVIOUS TESTS ON YAGRUMO HEMBRA[5] | | | | | | | | | |
| ...... | ..... | 6 | [6]11.5 | [6].32 | 54 | 6 | [6]11.5 | [6].32 | 47 |

[1]Total toughness (inch-pounds per specimen) when loaded on face indicated.

[2]Specific gravity based on volume at test and weight when ovendry.

[3]5/8 by 5/8 by 10 inches, 8-inch span.

[4]0.79 by 0.79 by 11 inches, 9.47-inch span.

[5]From work by A. W. Dohr at the Forest Products Laboratory in 1943.

[6]Moisture content and specific gravity taken from data on compression parallel.

Table 4.--Shrinkage of yagrumo hembra (*Cecropia peltata*) from Puerto Rico

| Tree No. | Bolt No. | No. of pieces | Green moisture content | Air dry: Moisture content | Air dry: Shrinkage | Ovendry: Moisture content | Ovendry: Shrinkage | Ovendry: Minimum shrinkage | Ovendry: Maximum shrinkage |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| LONGITUDINAL SHRINKAGE | | | | | | | | | |
| 1 | e | 4 | 255 | 13.6 | 0.145 | 0 | 0.445 | 0.290 | 0.650 |
| 3 | d | 4 | 88 | 13.5 | .078 | 0 | .272 | .230 | .330 |
| 5 | f | 4 | 92 | 13.7 | .110 | 0 | .242 | .230 | .260 |
| 9 | c-d | 5 | 114 | 13.5 | .222 | 0 | .498 | .380 | .640 |
| 11 | c | 4 | 120 | 13.7 | .052 | 0 | .185 | .150 | .210 |
| Average........... | | | 134 | 13.6 | .121 | 0 | .328 | .150 | .650 |
| RADIAL SHRINKAGE | | | | | | | | | |
| 1 | e | 2 | 277 | 13.6 | .94 | 0 | 1.84 | 1.50 | 2.19 |
| 3 | d | 2 | 171 | 13.4 | .76 | 0 | 1.99 | 1.89 | 2.09 |
| 5 | f | 2 | 146 | 13.6 | .68 | 0 | 1.70 | 1.60 | 1.80 |
| 9 | c-d | 2 | 202 | 13.5 | .58 | 0 | 1.56 | 1.52 | 1.60 |
| 11 | c | 2 | 295 | 14.0 | .64 | 0 | 1.56 | 1.42 | 1.70 |
| Average........... | | | 218 | 13.6 | .72 | 0 | 1.73 | 1.42 | 2.19 |
| TANGENTIAL SHRINKAGE | | | | | | | | | |
| 1 | e | 3 | 290 | 13.3 | 4.49 | 0 | 8.23 | 6.93 | 8.95 |
| 3 | d | 4 | 154 | 13.5 | 4.32 | 0 | 8.47 | 7.48 | 9.08 |
| 5 | f | 3 | 172 | 13.6 | 3.00 | 0 | 6.07 | 5.67 | 6.42 |
| 9 | c-d | 3 | 244 | 13.5 | 3.81 | 0 | 7.07 | 5.77 | 7.83 |
| 11 | c | 3 | 266 | 13.7 | 4.27 | 0 | 7.71 | 6.18 | 9.13 |
| Average........... | | | 225 | 13.5 | 3.98 | 0 | 7.51 | 5.67 | 6.42 |

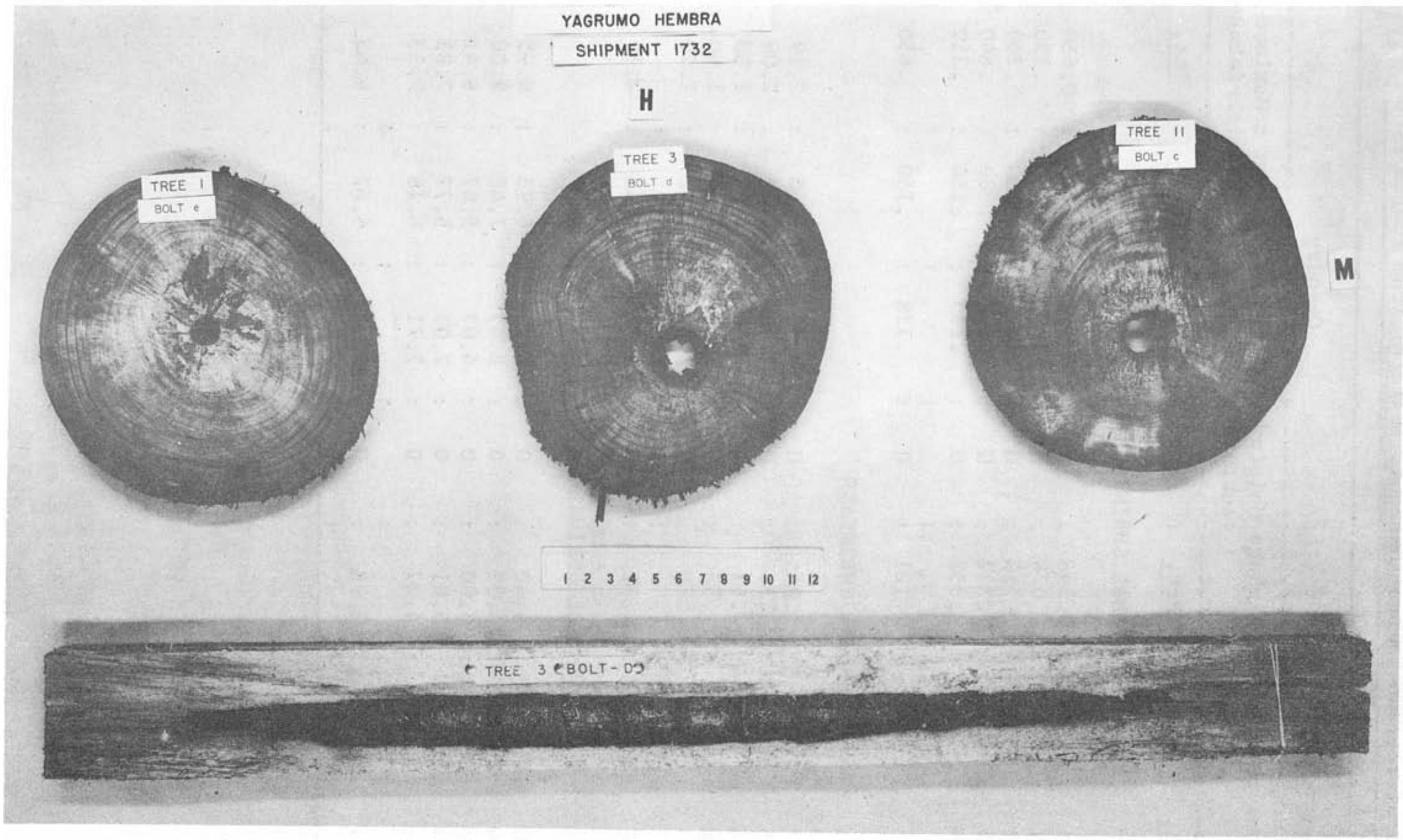


Figure 1.--Cross sections of trees 1, 3, and11 and a flitch from tree 3 showing the large hollow stem, eccentric growth, severe staining and some evidence of fungal deterioration, and the septa in the hollow pith.

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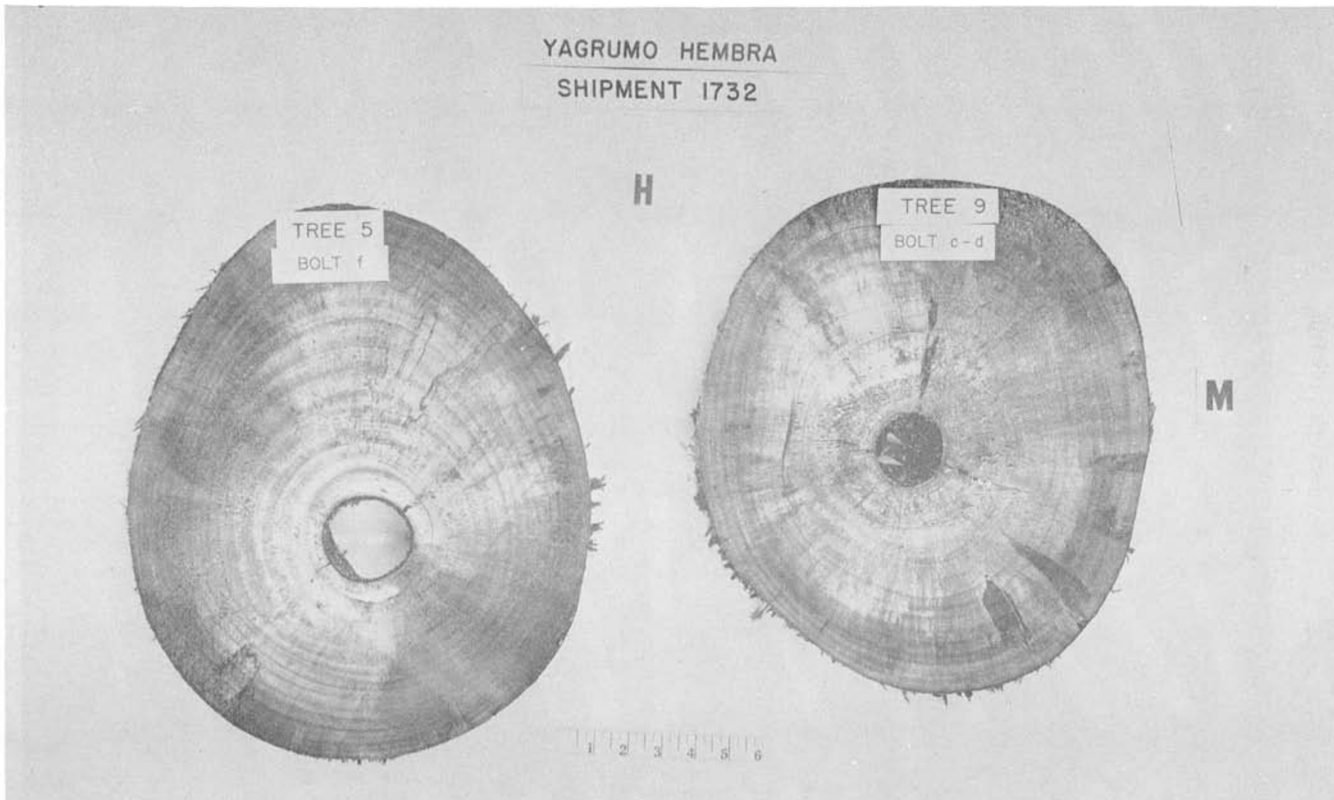


Figure 2.--Cross sections of trees 5 and 9 showing the large hollow stem, eccentric growth, severe staining and some evidence of fungal deterioration.

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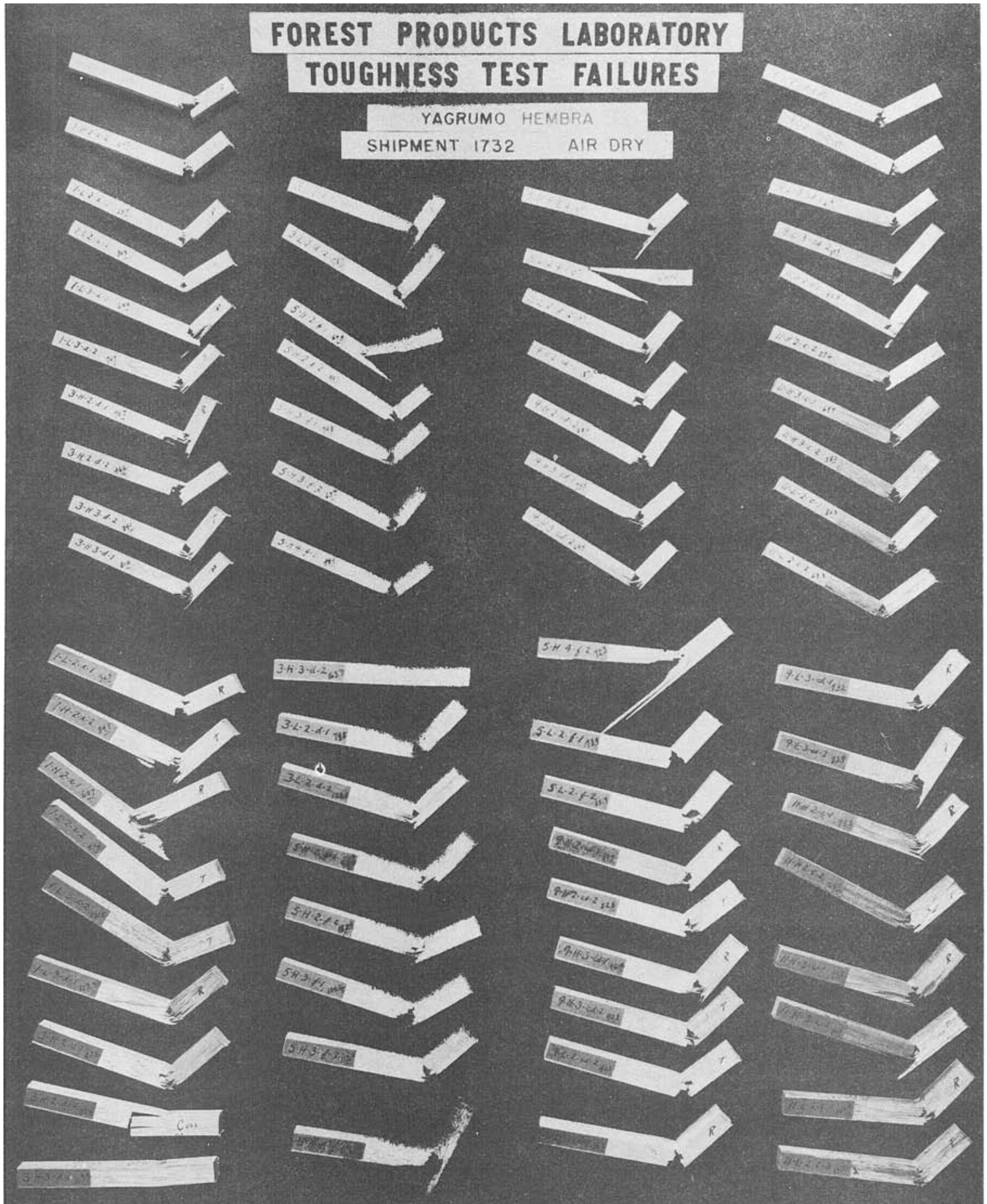


Figure 3.--Toughness specimens showing typical failures from splintering tension to brashy simple tension.

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