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DURABILITY OF PLANTATION HINOKI.

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ABSTRACT: Hinoki (*Chamaecyparis obtusa* Endl) has been used in Japan for thousands of years owing to its excellent mechanical properties and resistance to biodegradation. There is an increasing volume of plantation Hinoki coming on the market. While old-growth Hinoki is known for its decay resistance, there are questions about the durability of the faster grown plantation material. There is increasing evidence that second-growth plantation heartwood of some species is less durable than old-growth material, but this has not been studied with Hinoki. The durability of second-growth Hinoki heartwood from four growing regions was assessed in laboratory tests against two brown rot fungi. An additional test was conducted to determine the amount of extractives present in the wood. Heartwood from these plantations was highly decay resistant and comparable to western redcedar (*Thuja plicata*). Hinoki from Shikoku and Kyushu had the least mass loss for *Gloeophyllum trabeum* (4.73%) and *Rhodonia placenta* (6.72%), respectively. These results, however, were poorly correlated with extractives content. While further tests are underway, the results support the continued use of this species in exterior applications.

KEYWORDS: biological durability, brown rot, heartwood, Hinoki, *Chamaecyparis obtusa*

1 – INTRODUCTION

The biological nature of wood, despite its sustainability and renewability, creates inherent risks of deterioration by biological organisms, which can potentially compromise the performance of the material in service.

Hinoki (*Chamaecyparis obtusa*) is a premier species in Japan and is often used for high-end applications. Commonly known as Hinoki Cypress, it is a highly prized wood in Japan, known for its pleasantly distinct aroma, aesthetic values, and arguably exceptional durability. Hinoki has been traditionally used in the construction of temples, shrines, and baths. The wood is also valued for its light colour, and fine, straight grain.

While Hinoki has traditionally been used in Japan, extensive plantation establishment has led to an over-abundance of this species and a desire to export excess supplies to the United States. A primary focus of this effort has been an extensive physical testing program to assign design values within the U.S. National Design Specification, but a secondary concern is whether this material retains the natural durability of the old growth material. The purpose of this project was to assess the decay resistance of Hinoki lumber in laboratory decay tests.

2 – BACKGROUND

Wood has exceptional properties, including renewability, high strength to weight ratio and valuable aesthetic properties. Despite its invaluable role in our world, its biological nature makes it susceptible to biodegradation [1], which potentially compromises its integrity by reducing its strength [2][3] . The natural durability of wood is its ability to withstand biodegradation without chemical treatment. This property is highly influenced by the presence and distribution of heartwood extractives [4][5]

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Hinoki (*Chamaecyparis obtusa*) is an indigenous species of cultural and economic significance in Japan accounting for about 25% of the country's plantation area [5]. Hinoki is a preferred construction material due to its mechanical properties, durability, and aesthetic attributes [6][7]. Hinoki wood has a long history of use in Japanese architecture; notably, the Horyuji Temple, one of the oldest wooden structures in the world, was constructed over 1,300 years ago, predominantly utilizing hinoki [8]. Durability and termite resistance have contributed to its sustained use in traditional and modern buildings [7][10][11][12][13]. Beyond its traditional role in architecture, hinoki is extensively utilized in modern interiors, including flooring, wall paneling, bathtubs, furniture, and kitchenware [14][15]. Despite its reputation for durability, there is substantial evidence that the heartwood resistance of many woods to fungal and insect attack diminishes in second-growth material of the same species. Though the reason for this is unclear, some have attributed it to a combination of both higher proportions of sapwood as well as reduced levels of heartwood extractives [16]. Second growth timber tends to be grown faster and this accelerated growth may impede the production of toxic extractives responsible for durability [17]. However, there is relatively little research on the natural durability of second growth hinoki especially using the US Standards. These data will be vital for ensuring that second growth hinoki is fit-for-purpose in the United States.

3 PROJECT DESCRIPTION

The decay resistance of Hinoki was assessed by cutting 25 mm cubes and 19 mm by 50 mm by 125 mm samples from boards from four growing regions across Japan. The cubes were weighed and sterilised prior to exposure to two brown rot fungi (*Gloeophyllum trabeum* and *Rhodonia placenta*) in a laboratory soil block test. The larger specimens were exposed to fungal attack in a Ground Proximity test in a sub-tropical environment near Hilo, Hawaii. The results from the Ground Proximity test are on-going and will be reported separately. Heartwood extractives content was also determined for all 120 parent boards used in this study. Some samples were ground and will be analysed later to determine specific extractives responsible for hinoki durability.

4 – EXPERIMENTAL SETUP

4.1 SAMPLE PREPARATION.

One hundred twenty sawn boards of hinoki (*C. obtusa*) were obtained from four different sources in Japan. This species does not produce a visible heartwood, but boards were selected with growth rings suggesting that they originated closer to the pith to increase the probability of using heartwood. The boards were segregated by source and six cubes (25 mm) were cut . One of the 6 cubes from each parent board was allocated to be exposed to one of the two test fungi following the AWPA standard E10 [9]. Additional material from each board was retained for later extractive content determination. Additional blocks of *Thuja plicata* and *Pinus* spp. were also cut and processed to serve as decay resistant and decay susceptible controls, respectively.

The samples were oven-dried at 50 °C for a minimum of 24 hours and weighed to determine initial dry mass. The test blocks were vacuum impregnated in distilled water to approximately 60 % moisture content, placed into plastic bags and sterilized by exposure to 2.5 mrads of ionizing radiation from a cobalt 60 source.

The final cube from each board was ground to pass a 4mm mesh screen for determination of heartwood extractives content.

4.2 ACCELERATED LABORATORY TEST.

Decay resistance was evaluated following procedures described in the American Wood Protection Association Standard (AWPA) E10 with modifications [18]. French square bottles (454 ml) with screw caps were half-filled with a blend containing equal parts of Willamette River Sandy Loam Soil and compost. The soil contained 40% sand, 40% silt, and 20% clay. Large particles (>3.36 mm) were sieved from the mix which had a final pH of approximately 6.4. Western hemlock (*Tsuga heterophylla* (Raf) Sarg) feeder strips (3 x 28 x 34 mm; Transverse by Radial by Tangential) were placed on the top of the soil. Distilled water was added to increase the moisture soil moisture content to 50% of the water-holding capacity. The bottles were loosely capped and autoclaved for 120 minutes at 121 °C and then allowed to cool. The bottles were inoculated by placing a small disc (3 mm diameter) of agar cut from the actively growing edges of cultures of *Rhodonia placenta (*Fr.) Niemalá, Larss & Schigel (MAD 538) or *Gloeophyllum trabeum* (Pers. Ex Fr.) Murr. (MAD 617) on the edge of the feeder strips. The bottles were incubated for 14 days at room temperature until the fungus colonized the entire feeder strip. Two sterile blocks were placed, cross section down, on the fungal mat in each bottle. In addition, 20 blocks of each species were exposed in sterile bottles with no fungus. Blocks were exposed to the brown rot fungi for 16 weeks at 28 °C. Pine sapwood

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controls exposed to the same test fungi were periodically sampled beginning at 10 weeks to assess mass loss and the other blocks exposed to the same fungus were sampled when mass losses on the pine sapwood controls reached 40 %. These samples also served to demonstrate that test conditions were suitable for aggressive fungal decay. After exposure, blocks were removed from the bottles, the mycelium was scraped off and blocks were oven-dried at 50℃ for at least 48 hours before being reweighed. A total of 240 blocks were assessed for hinoki, while 60 and 18 blocks were assessed for western redcedar and pine, respectively. Mass loss was calculated using the initial and final oven dry masses.

Figure 1. Soil block jars in an incubator.

4.3 EXTRACTIVE CONTENT DETERMINATION.

Total extractives content was determined using a method described by [19] whereby the blocks from each board were ground to pass a 4mm mesh screen. A measured amount (~0.5 g) of ground wood was placed in a plastic mesh bag that was sealed and weighed. The bags were immersed in an excess of hexane that was boiled for 6 hours with stirring. The bags were removed, drained of excess solvent and dried at 60 °C until they reached constant mass. The bags were weighed to determine hexane extractives, then immersed in an excess of 95 % ethanol and boiled for an additional 6 hours. The bags were removed and allowed to drain before being dried at 60 °C until they reached constant mass. Finally, the bags were immersed in an excess of dionized water and boiled for 6 hours. The bags were allowed to drain and then oven dried to a constant mass at 60 °C. The differences between initial and final mass after each extraction were used to estimate extractives content. It is important to note that this procedure does not necessarily remove all extractives, but it provides a more rapid method for assessing differences between large numbers of samples.

5 – RESULTS

5.1 SOIL BLOCK TEST

The pine blocks experienced mass losses of over 40%, with both brown rots indicating that the test setup was suitable for aggressive fungal attack. Average mass losses varied slightly between the four different growing regions for both test fungi. Blocks from Chugoku exposed to *R. placenta* had the highest mass loss (12.46%) while those from Kyushu recorded the least (6.72%) (Table 1). Blocks from Chubu exposed to *G. trabeum* experienced the highest mass losses (8.91%), while those from Shikoku recorded the least (4.73%) (Table 1). Mass losses for western redcedar were 15.00 % and 10.70% for *R. placenta* and *G. trabeum,* respectively (Table 1). Some hinoki blocks had higher mass losses (<20%) (Fig 3). We suspect these blocks contained some decay-susceptible sapwood, which does not differ in colour from the heartwood. The results for hinoki exposed to both brown rot fungi would place this material in the highly decay resistant category indicating that second growth material retained its decay resistance.

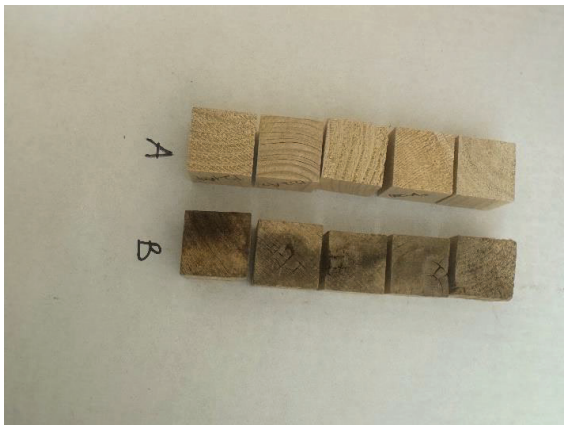

Figure 2. hinoki blocks from Kyushu before (A) and after (B) exposure to R. placenta.

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5.2 Extractives content

Total extractives levels varied slightly among the four timber sources, but the differences within individual sources also varied widely, reflecting the natural variability of wood (Table 2). The extraction series went from non-polar to polar solvents. Hexane and ethanol extractives were slightly more abundant than those removed with hot water (Fig 4).

Table 1. Mass losses of hinoki blocks exposed to selected brown rot fungi in an AWPA E10 soil block test.

Source	Reps/ Fungus	Mass Loss (%)			
		R. placenta		*G. trabeum*	
		Range	Mean[a]	Range	Mean[a]
Kyushu	10	3.11-17.39	6.72 (4.79)	3.71-7.65	4.82 (1.17)
Shikoku	22	3.61-21.39	9.42 (6.89)	3.65-5.62	4.73 (0.56)
Chugoku	25	3.31-46.01	12.46 (11.90)	3.14-26.81	7.02 (6.00)
Chubu	14	3.59-27.70	8.09 (6.50)	4.28-36.11	8.91 (9.78)
Pine sapwood	9	38.67-45.99	42.17 (2.98)	37.78-43.47	39.79 (3.48)
Western redcedar	30	5.42-27.00	14.99 (7.09)	4.46-24.48	10.68 (7.21)

[a]Values represent means while figures in parentheses represent one standard deviation.

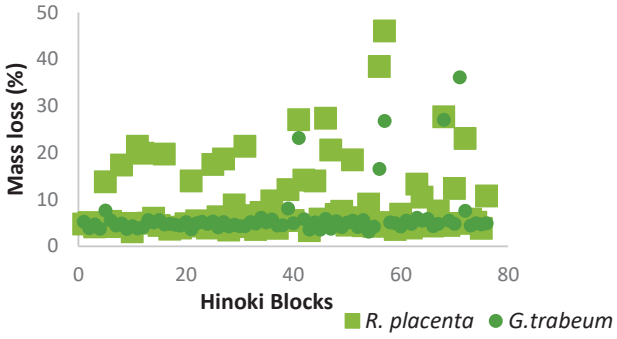

Figure 3. Mass loss distribution of hinoki blocks exposed to selected fungi in an AWPA E10 soil block test.

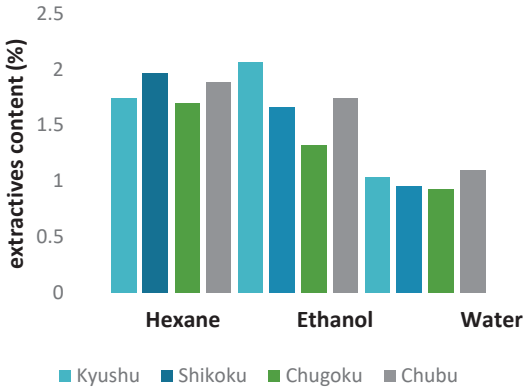

Figure 4. Extractives content of hinoki by timber source and extraction solvent.

Table 2. Extractives levels removed by sequential boiling in hexane, 95 % ethanol, and water.[a]

Source	Reps	Extractives Content by Solvent (%)			Total (%)
		Hexane	Ethanol	Water	
Kyushu	10	1.74 (0.60)	2.06 (0.59)	1.03 (0.68)	3.09 (1.87)
Shikoku	22	1.97 (1.04)	1.66 (0.65)	0.95 (0.38)	4.58 (2.07)
Chugoku	25	1.70 (0.99)	1.32 (0.75)	0.93 (0.41)	3.95 (2.15)

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Chubu	14	1.89 (0.83)	1.74 (0.88)	1.10 (0.43)	4.73 (2.14)
Avg		1.83 (0.93)	1.61 (0.76)	0.98 (0.38)	4.43 (1.27)

[a]Values represent means while figures in parentheses represent one standard deviation.

6 – CONCLUSION

Hinoki exhibited excellent resistance to the two brown rot fungi. Extractive content and decay resistance were poorly correlated across all four growing regions. Future research will focus on specific sesquiterpenes in second-growth hinoki responsible for its high durability.

7 – REFERENCES

[1] Brischke, C., & Alfredsen, G. (2020). Wood-water relationships and their role for wood susceptibility to fungal decay. *Applied Microbiology and Biotechnology*, *104*(9), 3781–3795.

[2] Winandy, J. E., & Morrell, J. J. (1993). Relationship Between Incipient Decay, Strength, and Chemical Composition of Douglas-Fir Heartwood. *Wood and Fiber Science*, 278–288.

[3] Zhang, J., Hu, D., Orr, G., & Schilling, J. (2019). Fluorescence in situ mRNA hybridization for gene expression detection in a wood decay fungus. *International Biodeterioration & Biodegradation*, *143*, 104731.

[4] Verbist, M., Nunes, L., Jones, D., & Branco, J. M. (2019). Service life design of timber structures. In Long-term Performance and Durability of Masonry Structures (pp. 311–336). Elsevier.

[5]Findlay, W. P. K. (Ed.). (1985). Preservation of timber in the tropics (Vol. 17). Springer Netherlands.

[6] Japan Forestry agency (2011) Annual report on trends in forests and forestry fiscal year 2011. Tokyo, Japan, pp 55–56

[7] Kinjo, K., & Yaga, S. (1988). Termiticidal substances from the wood of *Chamaecyparis obtusa* Endl. 34(5), 451–455.

[8] Kijidani, Y., Fujii, Y., Kimura, K., Fujisawa, Y., Hiraoka, Y., & Kitahara, R. (2012). Microfibril angle and density of hinoki *(Chamaecyparis obtusa)* trees in 15 half-sib families in a progeny test stand in Kyushu, Japan. Journal of Wood Science, 58(3), Article 3.

[9] Matsushima, N., Kang, H., Sameshima, K., & Takamura, N. (1990). The complexity of termiticidal activity in hinoki (Chamaecyparis obtusa) wood. Journal of the Japan Wood Research Society.

[10] Kondo, R., & Imamura, H. (1986). Antifungal compounds in heartwood extractives of hinoki (Chamaecyparis obtusa Endl.). Journal of the Japan Wood Research Society.

[11] Kimura, J., & Fujimoto, T. (2014). Modeling the effects of growth rate on the intra-tree variation in basic density in hinoki cypress (*Chamaecyparis obtusa*). Journal of Wood Science, 60(5), 305–312.

[12] Fujihira, M., Nakamura, Y., Isoda, N., & Hikita, Y. (1997). Relationship between decay resistance and changes of bending strength of structural lumber of wood-framing construction by fungal attack. Mokuzai gakkaishi, 43(7), 589–594.

[13] Sakai, H., Kakutani, T., Sugai, Y., Tezuka, D., Shigeyama, T., Shintani, T., & Yamaguchi, A. (2020). Decay resistance of wood and treated wood to 12 strains of fungi. 46(4).

[14] Bae, D., Seol, H., Yoon, H.-G., Na, J.-R., Oh, K., Choi, C. Y., Lee, D., Jun, W., Youl Lee, K., Lee, J., Hwang, K., Lee, Y.-H., & Kim, S. (2012). Inhaled essential oil from *Chamaecyparis obtusa* ameliorates the impairments of cognitive function induced by injection of β-amyloid in rats. Pharmaceutical Biology, 50(7), 900–910.

[15] Park, M.-J., Choi, W.-S., Kang, H.-Y., Gwak, K.-S., Lee, G.-S., Jeung, E.-B., & Choi, I.-G. (2010). Inhibitory effect of the essential oil from *Chamaecyparis obtusa* on the growth of food-borne pathogens. The Journal of Microbiology, 48(4), 496–501.

[16] Cabrera Orozco, Y. (2008). Improving the durability of second growth timbers of naturally durable species. Dissertation, Oregon State University.

[17] Freitag, C. M., & Morrell, J. J. (2001). Durability of a Changing Western Redcedar Resource[1]. Wood and Fiber Science, 69–75.

https://doi.org/10.52202/080513-0195

[18] American Wood Protection Association. 2023. Standard E10. Laboratory method for evaluating the decay resistance of wood-based materials against pure Basidiomycete cultures: soil/block test. In: AWPA Book of Standards, AWPA, Birmingham, Alabama. Pages 421-432

[19] Ajuong, E., C. Freitag, and J.J. Morrell 2014. Decay resistance and extractive content of second growth Port Orford cedar (*Chamaecyparis lawsoniana*) wood. Wood and Fiber Science 46(4):502-509.