International Journal of Design & Nature and Ecodynamics
Vol. 19, No. 3, June, 2024, pp. 753-759
Journal homepage: http://iieta.org/journals/ijdne

Vertical Position-Based Resistance of Teak Wood (*Tectona grandis* Linn.f.) Against Wood-Decay Fungi

Ariyanti Ariyanti, Yusran Yusran*, Aji Yusril, Erniwati Erniwati, Abdul Hapid, Hamzari Hamzari, Muthmainnah Muthmainnah, Rahmawati Rahmawati

Forestry Department, Forestry Faculty, Tadulako University, Palu 94118, Indonesia

Corresponding Author Email: yyusranyusran610@gmail.com

https://doi.org/10.18280/ijdne.190305

Received: 3 October 2023
Revised: 21 November 2023
Accepted: 4 December 2023
Available online: 25 June 2024

Keywords:
Tectona grandis, wood decay fungi, weight loss, Schizophyllum commune, Pycnoporus sanguineus, dactryopinax spathularia, resistance class, wood decay, tropical climate, Indonesian national standard

ABSTRACT

In the humid tropics of Indonesia, the durability of traditional wooden structures is challenged by pervasive fungal decay. This study investigated the decay resistance of teak wood (*Tectona grandis* Linn.f.) as influenced by the stem's vertical position against various wood-decay fungi. Employing a completely randomized factorial design, the research delineated two primary factors: vertical position within the log (bottom, middle, top) and fungal species (control, *Schizophyllum commune*, *Pycnoporus sanguineus*, *Dacryopinax spathularia*). These fungi were selected due to their dual significance as both decomposers and potential threats to wood-based materials. A total of 12 treatment combinations were tested, with each replicated thrice, culminating in 36 experimental wood samples. Results indicated a significant effect of both the log's vertical position and the species of fungus on teak wood weight reduction. A gradation in weight loss was observed vertically along the log, with the least at the bottom (1.84%), increasing at the middle (3%), and peaking at the top (5.38%). Among the fungi, the control exhibited negligible weight loss (0.07%), with *D. spathularia* (3.56%), *P. sanguineus* (4.99%), and S. commune (5.04%) contributing to progressive increments in decay. The interaction between the bottom log position and S. commune resulted in the most pronounced weight reduction (7.53%), while the top log position without fungal exposure exhibited the slightest change (0.02%). According to the Indonesian National Standard for wood resistance to rot fungi, teak wood demonstrated a resistance class II against *D. spathularia* and *P. sanguineus*, and a lower class III against S. commune. It is recommended that for construction purposes, teak sourced from lower stem positions should be prioritized and maintained under dry conditions with moisture content below the fiber saturation point to mitigate fungal degradation and extend the material's longevity.

1. INTRODUCTION

Indonesia's equatorial positioning bestows upon it a tropical climate typified by a dichotomous seasonal pattern: a dry season and a consequent rainy season, the latter persisting for approximately six months and characterized by substantial precipitation, with annual averages ranging from 2000 to 3000 mm. Such pluvial conditions not only foster prolific plant growth but also create an ideal milieu for fungal proliferation. Fungi, as multicellular eukaryotic organisms, exhibit remarkable diversity, with estimates of global species richness oscillating between 2.2 and 3.8 million, as predicated upon host associations [1].

It has been observed that fungi thrive in environments that offer shade, high humidity, adequate air currents, and diffuse sunlight, which collectively expedite their growth [2]. Additional factors contributing to this growth include cool temperatures, sufficient air circulation, and lowland habitats, which collectively create habitats highly conducive to fungal proliferation. Among the myriad of fungal species, those implicated in wood decay hold particular interest due to their heterotrophic nature, necessitating the colonization of a substrate such as wood for nutrient extraction, specifically lignin, hemicellulose, and cellulose [3].

Wood, constituted primarily of cellulose, possesses an inherent longevity; however, its integrity is susceptible to both biotic and abiotic degradative forces, which often operate in concert, thus obfuscating the primary cause of degradation. Notably, many cellulolytic fungi lack the capacity to degrade the lignin polymer that intricately associates with cellulose within the lignocellulosic matrix. Only select fungal species have evolved strategies to surmount the recalcitrant nature of lignin and harness the energy sequestered within lignocellulosic cell walls [4].

The durability of wood, defined as its resistance to destructive organisms including rot fungi, becomes paramount when considering its utilitarian value [5]. Wood with inferior durability is particularly vulnerable to decay when exposed to the elements, especially when in contact with moist soil, given its inherent sensitivity to temperature fluctuations, air, moisture, and water [6]. Conversely, the utility of wood with high mechanical strength is negated if its durability is compromised, resulting in a reduced lifespan.

The pertinence of wood durability is underscored in the context of traditional house construction, wherein resistance to fungal assault emerges as a pivotal parameter in wood selection and processing. A paucity of data on native wood resistance often leads to indiscriminate use of varying wood qualities across industries such as woodworking, carpentry, and construction. Consequently, efficient wood use is compromised, as repair or renovation work necessitates the dismantling of structurally sound wood alongside the compromised sections, leading to a wanton depletion of natural resources. Notably, fungal damage to wood in public housing projects has been reported to reach a staggering 67.1% [7].

Against this backdrop, teak (*Tectona grandis* Linn.f.) emerges as a wood of interest, renowned for its high strength and durability, and thus posed as an ideal candidate for assessing resistance to fungal decay [8]. Despite the significant economic impact of fungal attack on timber, research quantifying such losses remains scant [9, 10].

The present study, therefore, endeavors to elucidate the physical properties and ascertain the decay resistance of teak wood to three distinct fungal species—*Schizophyllum commune*, *Pycnoporus sanguineus*, and *Dacryopinax spathularia*—based on the wood's vertical position within the trunk. These fungi were selected for their dual role as extensive wood degraders and, paradoxically, as nutritional sources for local communities. The hypothesis underpinning this investigation posits a variance in resistance to fungal attack across vertical sections of the trunk, with implications for both the selection of wood for construction and the sustainable management of teak resources.

2. MATERIAL AND METHODS

2.1 Time and study sites

This research was carried out in January to July 2023. Teak wood (*Tectona grandis* L.) sampling was carried out in the Community Forest, Watatu Village, South Banawa District, Donggala Regency, Central Sulawesi Province, Indonesia and analyzed the physical properties of the wood and tested the durability of the wood. carried out in the Forestry Science laboratory, Faculty of Forestry, Tadulako University, Palu, Central Sulawesi, Indonesia.

2.2 Research methods

This research uses a completely randomized design method with a factorial pattern consisting of two factors, namely: The first factor is the vertical of the wood part in the logs, namely: Bottom (K1), Middle (K2), Top (K3). The second factor is species of fungus, which consists of 4, namely without fungal application/control (J0), *Schizophyllum commune* (J1), *Pycnoporus sanguineus* (J2), *Dacryopinax spathularia* (J3). So, there were 12 treatment combinations and each treatment combination was repeated 3 times so that in total there were 36 wood sample units. The choice of factorial design is a design where in one situation two experimental factors are tried simultaneously, namely the location of wood on the stem and the species of wood decay fungi. In factorial experiments, in addition to being able to know the effect of each factor, it can also be known the combined effect (interaction) of the factors tried. factorial experiments are more efficient in using existing resources, the information obtained is more comprehensive because it studies several interactions between the treatments tried.

2.3 Research procedure

The research procedures in this study are divided into several stages, namely as follows:

2.3.1 Preparation of mushroom culture

The species of fungi used are *S. commune*, *P. sanguineus*, and *D. spathularia* collected from the field. The fruiting body of each decaying fungus was taken, then stored in plastic and stored in an ice box to keep it fresh and then brought to the laboratory to propagate the culture. Each fungal species was propagated using Potato Dextrose agar (PDA) media before being used in testing. Pure cultures of these fungi were kept as a collection of the Forestry Science Laboratory, Faculty of Forestry, Tadulako University.

Conditions for testing wood resistance to fungus must be made moist by first providing fungal culture in a sterile jar. Conditions that are not sterile will result in disturbed fungal growth, so that it cannot cause normal attack power on the wood. The test method uses PDA Media, the composition contained in the PDA media is potato juice, dextrose and agar-agar. PDA media is made by dissolving it in 1 liter of water.

Pure cultures of the *S. commune*, *P. sanguineus* and *D. spathularia* mushrooms were first made to produce fungal mycelium before being put into glass containers (jars) for testing. The PDA media is heated until boiling and then cooled. Next, around 40 ml of PDA media was put into a testing container (jar), then closed and sterilized in an autoclave for 2 hours. After sterilization, the container (jar) is placed flat and ready to be inserted into the test wood sample. Each mushroom mycelium that was 1 week old was then inoculated into a testing jar.

2.3.2 Preparation of wood test samples

The selected teak tree (*Tectona grandis* Linn.f.) was 18 years old with a circumference of 69 cm, a height of 20 meters and a diameter of 22 cm. This tree was chosen because it had enough heartwood for testing for decay fungi attack to determine its durability. The tree is cut down and divided equally into 3 parts based on the height of the trunk (base, middle and tip) as treatment. The test example taken was the terrace, which was made with dimensions of 5cm × 2.5cm × 1.5cm. Each treatment was repeated 3 times. Meanwhile, for testing water content and specific gravity, wood samples are made with dimensions of 2cm × 2cm × 2cm based on the DIN 51283-77 standard.

2.3.3 Testing of the wood samples

Test media for decaying-fungi were MEA (malt-extract agar), which consisted of malt-extract (3%), bacto-agar (2%), and distilled water. The medium used for Chaetomium globosum fungus comprised PDA (potato-dextrose-agar) 39 g/l in distilled water, similarly as performed by Suprapti et al. [7, 10]. All the media after being inoculated with fungus-culture were stored in the incubation chamber until the growth of fungus mycelium became evenly spread and thickened, following Indonesia's National Standard [11].

The decay and corroding-wood properties test was performed using the Kolle-flask method, which is referred to Indonesia's National Standard (SNI 7207:2014). Test wood samples that are sterile and have had their weight calculated are placed in a test container (jar) that has been inoculated with the pure culture of each fungus. Contaminated fungal cultures should be replaced. The test wood samples were placed in a jar containing each fungal culture, namely *S. commune*, *P. sanguineus*, and *D. spathularia*. The test wood samples were put into a culture jar (flask), based on different fungal cultures. The container (jar) containing the test wood samples is stored indoors at room temperature. This testing was carried out for 12 weeks.

2.3.4 Observation and calculation of weight loss percentage

After three months of incubation, the test samples are removed from the container (jar). The surface of the test wood samples was cleaned from the mycelium attached to the surroundings, then dried in an oven. After the test sample is dried in the oven, it is then stored in a desiccator and weighed to determine the dry weight in the oven. The amount of weight loss due to fungal attack is calculated using the formula, namely:

$$P = \frac{W1-W2}{W1} \times 100\% \quad (1)$$

where, P is the percentage reduction in wood weight, $W1$ is the weight of the wood sample before testing, and $W2$ is the weight of the wood sample after testing.

Calculation of the weight reduction percentage is carried out after the wood sample is dried in the oven until it reaches a constant weight, then weighed to obtain the final weight. Wood resistance classes against wood rot fungi can be seen in Table 1.

Table 1. Classification of wood resistance to destroying fungus based on its weight loss

Class	Resistance	Average Weight Loss (%)
I	Very resistant	<0.5
II	Resistant	0.5-4.9
III	Moderately Resistant	5.0-9.9
IV	Non-Resistant	10.0-30.0
V	Perishable	> 30.0

Indonesian National Standard [11]

2.3.5 Testing the wood physical properties

1. Moisture content

Moisture content (MC) of wood is defined as the ratio between the weight of water in wood and the oven-dried weight of wood. The water content value is calculated using a formula based on Ruiz-Villanueva et al. [12], namely:

$$MC (\%) = (m_{water} * m_{dry\text{-}wood}^{-1}).(100\%) \quad (2)$$

2. Wood density

Density (ρ_{log}) is defined as the mass or weight (m_{wood}) per unit volume (V_{wood}), usually expressed in grams per cubic centimeter or kilogram per cubic meter ($g.cm^{-3}$ or $kg.m^{-3}$). Nothing is universal the procedure for calculating the specific gravity of wood, so it is important to detail it whether density is expressed in terms of green and green weight volume or weight and volume dried in an oven [12]. Density is an important factor to determine the physical and mechanical properties of wood. Therefore, density can be calculated for each water content as:

$$\rho_{log} = m_{wood} * v_{wood}^{-1} \quad (3)$$

2.4 Data analysis

Treatment levels were calculated using analysis of variance (Anova). The average reduction in weight of wood samples between various treatments was further tested using the Least Significant Difference Test (LSD 0.05% confidence). Analysis of variance used the SPSS software package (IBM SPSS Statistics 25, Armonk, NY, USA). The average weight loss of wood is grouped using the value or class scale of wood resistance to rot fungi according to Indonesian National Standards [11].

3. RESULTS AND DISCUSSIONS

3.1 Physical properties of teak wood (*Tectona grandis* Linn.f.)

The physical properties of wood samples measured in this research include water content and density. The teak wood samples had an average water content of 73.39%. This result is almost the same as the research results of Wibowo [13] who reported that the average water content of teak wood samples was 70.79%. The water content obtained is the equilibrium water content which shows that the wood is in balance with the surrounding temperature and humidity. The water content of the wood in this condition will not bind and release water vapor around it unless there is a change in the surrounding humidity and temperature.

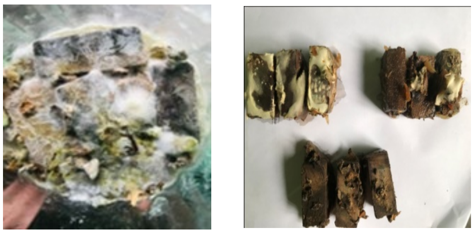
The density of the teak wood samples in this study had an average of 0.72 g/cm^3 and was also almost the same as the research results of Wibowo [13], namely 0.72 g/cm^3. Wood with a density value like this is classified into strength class I.

3.2 Symptoms of fungal attack on test wood samples

Based on observations, it appears that in the second week after the wood was fed, rotting fungi began to attack the wood, characterized by the growth of mycelium on the surface of the wood. Mycelium appeared to grow on the surface of the test wood samples after the second week, this is thought to be due to the need for adjustment or adaptation to the newly inserted wood substrate and the wood itself, with its hygroscopic nature, slowly absorbs water from the media through a diffusion process so that it becomes moist. The initial moisture content of wood when fed is in the range of 8.79-10.03%. In wood with this moisture content, fungi cannot grow. This is in line with Carll and Highley [14] who stated that rot fungi do not attack wood when the wood moisture content is below the fiber saturation point. During this two-week period, the wood absorbs water from the media so that the water content of the wood increases and the wood becomes damp so that fungus can grow.

Some signs of damage or weathering of wood by fungi are that the wood looks brittle and has a blackish color and loses the weight of the test sample which can be measured quantitatively using gravimetry. Dinwoodie [15] stated that weight loss of wood test samples is a characteristic marker of wood weathering. Baldwin and Streisel [16] also stated that in advanced weathering, weight loss is an indicator used to state the level of wood damage. The loss of wood weight during the weathering process reflects cell wall damage due to fungal metabolic processes. This weight loss is caused by the degradation process of wood chemical components, especially cellulose and lignin [15, 17, 18].

Symptoms of attack by the three fungi on teak wood can be seen in Figures 1-3 below:



a b

Figure 1. Teak wood samples before testing (a) and after testing (b) with *S. commune* fungus

a b

Figure 2. Teak wood samples before testing (a) and after testing (b) with *P. sanguineus* fungus

a b

Figure 3. Teak wood samples before testing (a) and after testing (b) with *D. spathularia* fungus

3.3 Percentage reduction in weight of wood samples

The test parameters for wood resistance to several wood rot fungi are seen from the percentage value of the weight loss of the test samples. The weight reduction percentage is the value of the reduction in wood test samples against wood rot fungi carried out for 3 months so that there is a reduction in the weight of the test wood samples. The percentage reduction in weight of wood test samples due to attack by wood rot fungi is used as a standard for wood durability.

The results of the analysis of various species of fungal attack by three wood rotting fungi on teak wood showed that the single factor, the vertical of the wood part in the logs, the species of fungus and the interaction between the two, had a significant influence on the weight reduction of teak wood aged 3 months after testing. Therefore, it is necessary to carry out further tests using the least significant difference test (LSD), which is presented in Figures 4-6.

The research results in Figure 4 show that the average weight loss of teak wood samples due to attack by wood rot fungi was greater at the top of the wood, amounting to (5.38%) followed by (3%) in the middle and the lowest at the bottom (1.84%). Statistically, the three treatments are significantly different. According to Suprapti and Krisdianto [7] that the bottom of the stem is the part that is formed first and has a larger heartwood position than the middle and ends so that fungal hyphae do not enter the pores of the wood because its durability is very high. This is thought to be due to the higher content of extractive substances at the base of the stem which can inhibit fungal growth compared to the top of the stem. Furthermore, the wood at the middle and end of the stem is still soft and has more active cells which are a source of food for fungi so that in this section the fungus is easier and faster to grow and develop. The content of extractive substances in wood is thought to have antifungal activity, which is shown by the growth of thin mycelium on the surface of the test sample. The teak wood samples in this study were also relatively young (18 years), so the weight loss of this wood experienced a drastic decrease from its original level of durability.

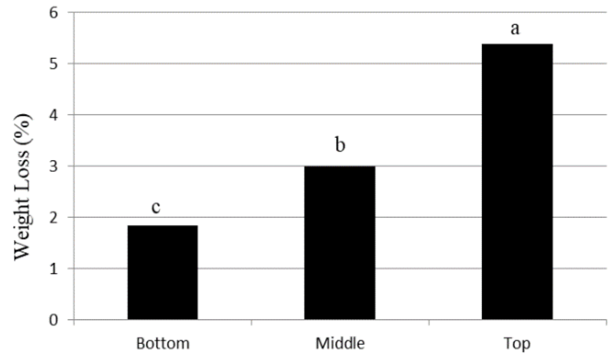


Figure 4. Average reduction in weight of wood samples based on the vertical of the wood part in the logs

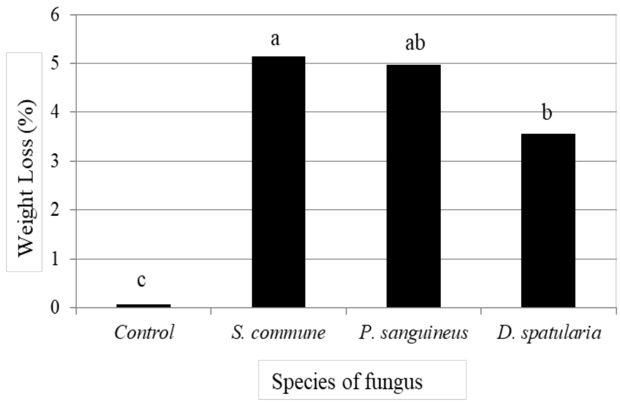


Figure 5. Average weight loss of wood samples based on fungal species

Each species of fungus has the ability to rot or damage each type of wood which can be influenced by the type of wood and the species of organism. The ability of fungi to rot wood varies according to the species of wood used and the species of fungus that attacks it, which is indicated by variations in the amount of weight loss. The research results in Figure 5 show that the largest average weight reduction for teak wood samples was obtained in the *S. commune* fungus treatment with a wood weight reduction of 5.04%, followed by the *P.*

Sanguineus fungus treatment with a wood sample weight reduction of 4.98%. and the lowest was treated with *D.spathularia* fungus at 3.56%. The decrease in the weight of the teak wood samples was due to these three species of fungi attacking the parts of the wood that contain lots of chemical components and being less vicious on the parts of the wood that are more durable, such as the base of the heartwood. The results of the least significant difference test showed that the *P.sanguineus* and *S.commune* fungi had almost the same level of malignancy in reducing the weight of teak wood, while the *D.spathularia* fungus had a less malignant level. The same thing was also reported by Suprapti et al. [10] that the fungi *S. commune* and *P. Sanguineus* also have a very high ability to rot and reduce the weight of *Parashorea* spp wood. The *S. commune* fungus has a very wide distribution in the world [19]. And in Indonesia, this is confirmed by the results of research by Yusran et al. [20], where they found that the *S. commune* fungus has a very large growing substrate, namely 92 types of rotted wood which can grow from the lowlands to the highlands, more than 1000 m above sea level.

The results of the analysis of variance show that the interaction of the stem location and mushroom type factors has a real influence, so it is necessary to carry out further tests using the Least Significant Difference Test (LSD), for the mushroom type factor which is presented in Figure 6.

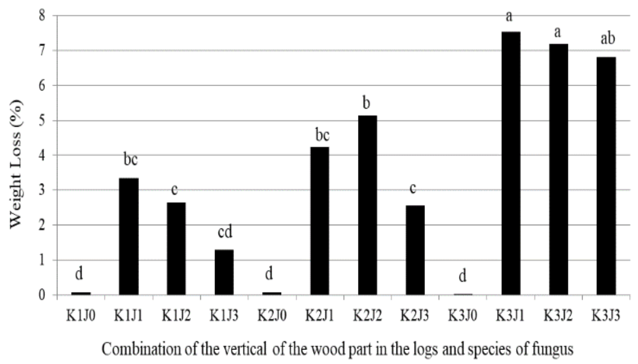


Figure 6. Average reduction in weight of wood samples due to attack by several types of fungi based on the vertical of the wood part in the logs

The research results in Figure 6 show that the highest average reduction in wood weight occurs in the upper part of the teak wood. The interaction between the wood at the base of the teak trunk and the fungus *S. commune* (K3J1) resulted in the highest reduction in wood weight, namely 7.53%, and the lowest in the treatment of the position of the test sample at the tip of the trunk without the application of fungal culture (K3J0), namely 0, 02%. Attacks by the three types of fungus on the top of the finished wood showed a trend of higher weight loss compared to the middle and bottom of the teak wood, and the lightest weight loss on all parts tested without fungus or control. This is because the lower part of the teak wood is dominated by the heartwood, while the upper part of the heartwood has not yet fully formed and the cells are still active. In the heartwood there are extractive substances that are toxic to wood-destroying organisms such as fungi, so they have the effect of weakening the decay activity of the fungi tested.

The data above also shows a decrease in the weight of teak wood based on the location of the wood samples on the trunk and the three types of fungus tested. From the results of the research, the tip of the teak wood core experienced a significant decrease in weight when tested against the fungi *S. commune*, *P. sanguineus* and *D. spathularia*. The *S. commune* fungus is a white rot fungus that is vicious in destroying wood. This fungus breaks down lignin and some cellulose. Weathering of wood by this fungus can be divided into two stages, namely the initial stage and the advanced stage. In the early stages of weathering, color changes occur on the surface of the wood. The hyphae threads will spread in all directions, especially longitudinally. Hyphae can also develop on the surface of wood to form mycelium, which absorbs nutrients. Sometimes changes in wood color are not easy to see. At the advanced level, wood appears to increasingly change both its color and physical properties [21]. Ramirez [22] stated that it is a fungus that destroys forest products and can attack all forest products such as wood, bamboo, rattan, fruit and seeds.

Masitoh [23] explained that the macroscopic characteristics of the mycelium of the grigit fungus (*S. commune*) have white colonies like cotton, circular colony shape, smooth colony surface like cotton, filamentous edges (like threads), raised type elevation (convex), and thick mycelium colonies. The fungus *P. sanguineus* is a white rot fungus that has been studied extensively [24], and has a high ability to biodegrade, composite fragments, natural polymers such as lignin, water pollutants and other heavy compounds [3, 25, 26]. Brown rot fungi differ from white rot fungi in terms of the presence of lignolytic enzymes, brown rot fungi do not have this type of enzyme so that in the weathering process the fungus does not degrade lignin [27].

The tests that have been carried out have obtained an average value of weight loss from teak wood test samples by several types of wood decay fungi. The percentage of wood weight reduction caused by wood rot fungus attacks appears to vary. Wood rotting fungi have the ability to break down chemical components of wood such as cellulose and lignin from complex compounds into simple compounds so that they can be absorbed and metabolized by the fungus as food. This can reduce the weight of the wood from its initial weight. The magnitude of the reduction in the weight of the test samples due to attack by wood rotting fungi within 3 months shows the level of attack by the type of wood rotting fungus on the part of the wood used.

The *S. commune* fungus was able to reduce the weight of the teak wood test samples by (5.04%), respectively the position of the teak trunk at the Base (3.35%), Middle (4.24%) and Tip (7.53%). The weight reduction value is included in the durability class II-III range, however based on SNI 01-7207-2006, the weight reduction value for teak wood is included in durability class II, which means that teak wood is in the durability class.

From this research, teak wood can be used as a substitute for buildings because the damage is >5% and falls into class 2 based on the wood resistance table against fungi, however it is recommended that teak wood for building construction must be older so that its useful life can last longer.

In accordance with what was suggested by Martawijaya and Barly [28], woods that belong to class I-II could be used for construction materials. However, if the woods belong to class III-IV, they should be treated or preserved prior to their uses to increase their resistance against attacking-organisms.

4. CONCLUSIONS

The results showed that based on the vertical of the wood part in the logs, the species of fungus and their interactions had a significant effect on the reduction in teak wood weight. The decrease in teak wood weight was based on the vertical of the wood part in the logs, sequentially from the lowest, namely at the bottom of the trunk (1.84%), the middle of the trunk (3%) and at the top of the trunk (5.38%). The reduction in teak wood weight was based on the species of fungus tested in sequence from the lowest, namely without the application of fungal culture (0.07%), *D. spathularia* fungus (3.56%), *P. sanguineus* (4.99%) and *S. commune* (5.04%). The interaction between the position of the test sample at the base of the teak trunk with S. commune fungus (K3J1) resulted in the highest wood weight loss of 7.53%, and the lowest in the treatment of the position of the test sample at the end of the trunk without the application of fungal culture (K3J0) of 0.02%. Based on the classification of wood resistance to wood rot fungi (Indonesian National Standard), teak wood resistance is classified as class II resistant in tests with *D. spathularia* (3.56%) and *P. sanguineus* (4.99%) and class III resistant in tests with *S. commune* (5.04%). Therefore, it is recommended to use teak wood at the base of the trunk for building wood, in addition to keeping it dry with a moisture content below the fiber saturation point to get a longer service life.

REFERENCES

[1] Hyde, K. (2022). The numbers of fungi. Fungal Diversity, 249224534. https://doi.org/10.1007/s13225-022-00507-y

[2] Fitriani, L., Krisnawati, Y., Anorda, M.O., Lanjarini, K. (2018). Jenis-jenis dan potensi jamur makroskopis yang terdapat di pt perkebunan hasil musi lestari dan pt djuanda sawit kabupaten musi rawas. Jurnal Biosilampari: Jurnal Biologi, 1(1): 21-28. https://doi.org/10.31540/biosilampari.v1i1.49

[3] Kartal, S.N., Aysal, S., Terzi, E., Yılgör, N., Yoshimura, T., Tsunoda, K. (2013). Wood and bamboo-PP composites: Fungal and termite resistance, water absorption, and FT-IR analyses. BioResources, 8(1): 1222-1244.

[4] Goodell, B., Winandy, J.E., Morrell, J.J. (2020). Fungal degradation of wood: Emerging data, newinsights and changing perceptions. Coatings, 10(2): 1210. https://doi.org/10.3390/coatings10121210

[5] Suprapti, S., Djarwanto, D., Hudiansyah, H. (2007). Ketahanan lima jenis kayu terhadap tigabelas jamur perusak kayu. Jurnal Penelitian Hasil Hutan, 25(1): 75-83. https://doi.org/10.20886/jphh.2007.25.1.75-83

[6] Hutabarat, F.V., Diba, F., Sisillia, L. (2019). Daya hambat ekstrak kulit jati (Tectona grandis Linn F) terhadap pertumbuhan jamur pelapuk kayu schizophyllum commune fries. Jurnal Hutan Lestari, 7(3). https://doi.org/10.26418/jhl.v7i3.36433

[7] Suprapti, S., Krisdianto, K. (2006). Ketahanan empat jenis kayu hutan tanaman terhadap beberapa jamur perusak kayu. Jurnal Penelitian Hasil Hutan, 24(4): 267-274. https://doi.org/10.20886/jphh.2006.24.4.267-274

[8] Martias, A.T., Naemah, D., Susilawati, S. (2021). Identifikasi kerusakan tegakan jabon putih (Anthocephalus cadamba) di miniatur hutan hujan tropis balai pembenihan tanaman hutan kalimantan selatan. Jurnal Sylva Scienteae, 4(4): 741-750. https://doi.org/10.20527/jss.v4i4.3952

[9] Iswanto, A.H. (2009). Identifikasi jamur perusak kayu. Departemen Kehutanan Fakultas Pertanian, Universitas Sumatera Utara, Medan.

[10] Suprapti, S., Djarwanto, Dewi, L.M. (2020). Determining the wood (*Parashorea* spp.) decaying and metal corroding abilities of eight fungi. Journal of the Korean Wood Science and Technology, 48(1): 50-60. https://doi.org/10.5658/WOOD.2020.48.1.50

[11] SNI (Indonesian National Standard). https://pesta.bsn.go.id/produk/detail/9766-sni72072014, accessed on Dec. 23, 2023.

[12] Ruiz-Villanueva, V., Piégay, H., Gaertner, V., Perret, F., Stoffel, M. (2016). Wood density and moisture sorption and its influence on large wood mobility in rivers. Catena, 140: 182-194. https://doi.org/10.1016/j.catena.2016.02.001

[13] Wibowo, A. (2013). Uji Coba Tebangan Kayu JPP Asal Stek Pucuk (Studi kasus petak 61a, BKPH Kedunggalar, KPH Ngawi). Laporan Pengamatan. Cepu.

[14] Carll, C.G., Highley, T.L. (1999). Decay of wood and wood-based products above ground in buildings. Journal of Testing and Evaluation, 27(2): 150-158.

[15] Dinwoodie, J.M. (2000). Timber: Its Nature and Behaviour. CRC Press.

[16] Baldwin, R.C., Streisel, R.C. (1985). Detection of fungal degradation at low weight loss by differential scanning calorimetry. Wood and Fiber Science, 17(3): 315-326.

[17] Antai, S.P., Crawford, D.L. (1982). Degradation of extractive-free lignocelluloses by Coriolus versicolor and Poria placenta. European Journal of Applied Microbiology and Biotechnology, 14: 165-168.

[18] Fortin, Y., Poliquin, J. (1976). Natural Durability and Preservation of One Hundred Tropical African Woods. IDRC, Ottawa.

[19] Krause, K., Jung, A., Lindner, J., Hardiman, I., Poetschner, J., Madhavan, S., Mattha, C., Kai, M., Menezes, R.C., Popp, J., Svatoš, A., Kothe, E. (2020). Response of the wood-decay fungus *Schizophyllum commune* to co-occurring microorganisms. PLoS ONE, 15(4): e0232145. https://doi.org/10.1371/journal.pone.0232145

[20] Yusran, Y., Erniwati, E., Khumaidi, A., Pitopang, R., Jati, I.R. (2023). Diversity of substrate type, ethnomycology, mineral composition, proximate, and phytochemical compounds of the *Schizopyllum commune* Fr. in the area along Palu-Koro Fault, Central Sulawesi, Indonesia. Saudi Journal of Biological Sciences, 30(4): 103593.

[21] Sudarmadi, B., Diba, F., Yanti, H. (2013). Uji aktivitas anti jamur ekstrak minyak kayu sindur (Sindora wallichi Benth) terhadap pertumbuhan jamur schizophyllum commune fries. Jurnal Hutan Lestari, 1(2). https://doi.org/10.26418/jhl.v1i2.2768

[22] Ramirez, I. (1939). Schizophyllum commune Fr. A forest-products rotting fungus. The Philippine Journal of Foresty, 2: 121-144.

[23] Masitoh, S. (2021). Karakterisasi dan uji potensi jamur grigit (Schizophyllum commune Fr.) secara in vitro sebagai pengayaan bahan ajar praktikum mikologi. Doctoral dissertation. Universitas Jambi.

[24] Kim, J.S., Gao, J., Daniel, G. (2015). Cytochemical and immunocytochemical characterization of wood decayed

by the white rot fungus *Pycnoporus sanguineus* I. preferential lignin degradation prior to hemicelluloses in Norway spruce wood. International Biodeterioration & Biodegradation, 105: 30-40. https://doi.org/10.1016/j.ibiod.2015.08.008

[25] Brijwani, K., Rigdon, A., Vadlani, P.V. (2010). Fungal laccases: Production, function, and applications in food processing. Enzyme Research, 2010: 149748. https://doi.org/10.4061/2010/149748

[26] Rodríguez-Delgado, M., Orona-Navar, C., García-Morales, R., Hernandez-Luna, C., Parra, R., Mahlknecht, J., Ornelas-Soto, N. (2016). Biotransformation kinetics of pharmaceutical and industrial micropollutants in groundwaters by a laccase cocktail from *Pycnoporus sanguineus* CS43 fungi. International Biodeterioration & Biodegradation, 108: 34-41. https://doi.org/10.1016/j.ibiod.2015.12.003

[27] Hasyiati, R. (2019). Keanekaragaman jenis jamur kayu di kawasan pucok krueng alue seulaseh sebagai media ajar dalam pembelajaran biologi di SMA Negeri 3 aceh barat daya. Doctoral dissertation, UIN Ar-Raniry Banda Aceh.

[28] Martawijaya, A., Barly. (2010). Pedoman Pengawetan Kayu Untuk Mengatasi Jamur dan Rayap Pada Bangunan Rumah dan Gedung. IPB Press, Bogor.