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Physical, mechanical, and anatomical properties of 12 *jabon* (*Neolamarckia cadamba*) provenances wood in Indonesia

NELLY ANNA[1,♥], ISKANDAR Z. SIREGAR[2], SUPRIYANTO[2], DEDE J. SUDRAJAT[3], LINA KARLINASARI[4]
[1]Faculty of Forestry, Universitas Sumatera Utara. Kampus 2 USU Bekala, Simalingkar A, Pancur Batu, Deli Serdang 20353, North Sumatera, Indonesia. Tel.: +62-618-220605, ♥email: nakoto@usu.ac.id, nacoto1006@gmail.com
[2]Department of Silviculture, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Lingkar Akademik, Dramaga, Bogor 16680, West Java, Indonesia. Tel.:+62-251-8626806, Fax.: +62-251-8621256,
[3]National Research and Innovation Agency. Gedung B.J. Habibie. Jl. MH Thamrin No. 8, Jakarta Pusat 10340, Jakarta, Indonesia
[4]Departement of Forest Product, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Lingkar Akademik, Dramaga, Bogor 16680, West Java, Indonesia

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Abstract. *Anna N, Siregar IZ, Supriyanto, Sudrajat DJ, Karlinasari L. 2023. Physical, mechanical, and anatomical properties of 12 jabon* (Neolamarckia cadamba) *provenances wood in Indonesia. Biodiversitas 24: 5895-5904. Jabon* is a raw wood material for paper industries and has a fast-growing ability. Comprehensive information on the fundamental qualities of wood from the 12 provenances of *jabon* (*Neolamarckia cadamba* (Roxb.) Bosser) is a critical aspect of understanding their superior properties. The age of the samples at the trial was 42 months old, and the number of trees tested was 12, representing one provenance. Wood samples for physical (disk samples), mechanical, and anatomical properties were sampled at a height and length of 1.3 m and 35 cm. The logs were divided into 5 cm and 30 cm for wood samples with anatomical and mechanical properties. The physical and mechanical properties were tested according to ASTM D 4442, ASTM D 2395, and ASTM D 143 standards. The physical (density, specific gravity, and moisture content), mechanical properties (MOE and MOR), and anatomical properties (fiber length and microfibril angle) were carried out on wood from 12 provenances. Physical and anatomical properties were tested, from the pith to the outer bark. The average green wood density was 0.94 gcm^{-3}, while the highest was obtained in the Rimbo Panti, Nusakambangan, Kapuas Tengah, and Batu Hijau provenances. The average specific gravity value from the 12 provenances of *jabon* was 0.46 in Batu Licin and Batu Hijau provenances; the average moisture content on oven-dry weight was 105.13%; and the highest value was in the Kuala Kencana provenance. The average MOE and MOR values were 51,039.93 $kgcm^{-2}$ and 488.37 $kgcm^{-2}$, with a dry air moisture content of 13.62%. The highest MOE and MOR values were in the Batu Licin and Gowa provenance, with MFA testing varied at 11.54°. The fiber length from the pith to the outer bark tended to increase, with an average of 1183.28 µm. Based on the value of physical, mechanical, and anatomical properties, 12 provenances of *jabon* can only be used as non-structural raw materials. The Batu Hijau provenances have the highest density and specific gravity. However, the highest fiber length was found in Gowa provenance.

Keywords: Anatomical, mechanical, *Neolamarckia cadamba*, physical, provenances

INTRODUCTION

Jabon (*Neolamarckia cadamba* (Roxb.) Bosser) is an Indonesian native species with many important values. *Jabon* is used traditionally in phytochemistry and pharmacology (Pandey and Negi 2016), the roots is used as antihyperglycemic and antilipidemic (Acharyya et al. 2013), the fruits and leaves be used as antioxidant (Chandel et al. 2013; Ganjewala et al. 2013), wood bark is extracted as a green inhibitor (Chaubey et al. 2015; Sutrisno et al. 2015). *Jabon* is used for community land rehabilitation (Irawan and Purwanto 2014) and carbon absorption (Bijalwan et al. 2014; Sandalayuk et al. 2020). The wood is easy to work with, soft and light, creamy white to reddish-brown in color, shiny, and slightly porous. Furthermore, it can be used for light construction, veneer, pulp, fiberboard, blockboard, particleboard, matches, wrapping crates, concrete molds, children's toys, and plywood. The wood has strength and durability grades of III-IV and V, with a specific gravity of 0.42 gcm^{-3} (Soerianegara and Lemmens 1993). It is known for its consistent quality and rapid development, with an average diameter increment of 1.2-11.6 cm at 5 years old (Krisnawati et al. 2011). *Jabon* is critical in developing community and plantation forests to ensure a steady supply of raw wood materials.

Growth and wood quality are strongly influenced by genetics, environment, and different geographic sources (You et al. 2021). This variation occurs between (interspecific) and within the species (intraspecific). Several studies have shown intraspecific variation in the wood quality of tree species, such as in *Picea glauca* (Moench) Voss (Lenz et al. 2013), *Acacia mangium* Willd. (Nurhasybi and Sudrajat 2019), and *Swietenia macrophylla* G.King (Sudrajat et al. 2021). Therefore, more comprehensive information on the basic properties of wood in the provenance level of *jabon* is critical to obtain superior provenances based on the quality of the wood. Basic physical and mechanical properties are important in assessing the suitability of wood for industrial processing and its quality requirements. The best and simplest way to determine the quality is through physical features, like density. Meanwhile, wood strength is classified according to its specific gravity with flexural and compressive strength parallel to the wood fibers under air-dry conditions (Lempang 2014). Anatomical properties such as fiber length are also crucial for their suitability as pulp and paper materials. Microfibril angle (MFA) is a technique used to determine wood stability. Therefore, understanding the nature and strength of the relationship between wood qualities is vital.

The wood properties and usages of *jabon* have been known based on research conducted on the physical characteristics of the wood. Rahayu et al. (2014) and Darmawan et al. (2013) related to the point of differentiation (demarcation) between juvenile and mature wood in *sengon* and *jabon*; Fajriani et al. (2013) about variations in the properties of the wood in the radial direction, Widiyanto and Siarudin (2016) related to the shaving properties of the wood as raw material for frames; and Nugroho et al. (2011) about the physical and mechanical properties of the wood. Chemical modification and impregnation on the *jabon* wood could improve quality and resistance to termite attacks (Hadi et al. 2013, 2015; Komariah et al. 2015; Hadiyane et al. 2018; Lestari et al. 2018; Arsyad et al. 2019; Hadi et al. 2019; Malik and Ozarska. 2019; Prihartini et al. 2020; Hadi et al. 2021; Malik et al. 2022). Log boiling could minimize the number of lathe checks in manufacturing 1 and 2 mm rotary cut veneer from juvenile wood (Kabe et al. 2013). The lamination process using different adhesives was also carried out on *jabon* wood (Hadi et al. 2021; Lestari et al. 2018). The fundamental qualities of wood from the breeding program were still limited, such as the anatomy cell wall of *jabon merah* provenance (Mompewa et al. 2019). This information is important in ensuring the quantity and quality of seeds produced in the future. Therefore, to obtain a superior provenance based on wood quality, it is necessary to conduct a study examining the physical, mechanical, and anatomical qualities of 12 *jabon* wood provenances in a 42-month-old progeny test in Parungpanjang, Indonesia.

MATERIALS AND METHODS

The properties tested were derived from 12 *jabon* provenances of the same age and planted in the same location. The provenance trial of *jabon* was established at Parungpanjang Forest Research Station, West Java, Indonesia (06°20'42"; 106°06'15", 52 m-asl (meters above sea level)). The 12 *jabon* provenances have an average diameter of 8.74-13.30 cm. The 12 *jabon* provenances came from different regions (Figure 1 and Table 1). Growth characteristics were evaluated before the *jabon* provenance was logged, and the height of the trees in the sample ranged from 7.00-12.70 m. Furthermore, the diameter ranged from 8.74-13.30 cm.

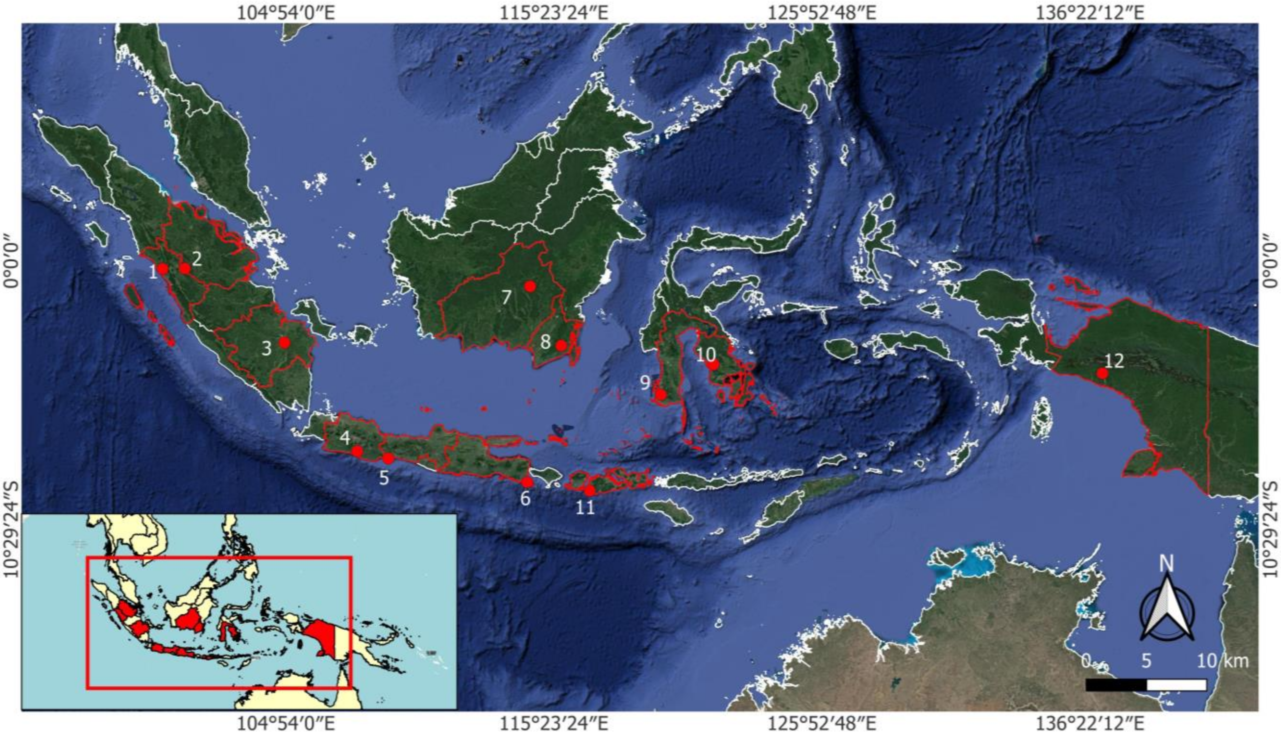

Figure 1. Source of 12 *jabon* provenances distribution in Indonesia. Notes: 1. Rimbo Panti; 2. Kampar; 3. Ogan Komering Ilir; 4. Garut Selatan; 5. Nusakambangan; 6. Alas Purwo; 7. Kapuas Tengah; 8. Batu Licin; 9. Gowa; 10. Pomalaa; 11. Batu Hijau; 12. Kuala Kencana

Table 1. Source and altitude of 12 *jabon* provenances

Provenance	Altitude and height (m-asl)
Rimbopanti-West Sumatra	00°19' S; 100°05' E; 294
Kampar-Sumatra	00°18' S; 100°57' E; 50
Ogan Komering Ilir-South Sumatra	03°12' S; 104°51' E; 23
Garut-West Java	07°26' S; 107°42' E; 628
Nusa Kambangan Island	07°43' S; 108°55' E; 40
Alas Purwo-East Java	08°38' S; 114°21' E; 33
Kapuas-Central Kalimantan	01°00' S; 114°28' E; 147
Batulicin-South Kalimantan	03°19' S; 115°41' E; 47
Gowa-South Sulawesi	05°14' S; 119°35' E; 119
Pomalaa-Southeast Sulawesi	04°03' S; 121°39' E; 210
Batu Hijau-Sumbawa island	08°58' S; 116°48' E; 53
Kuala Kencana-Papua	04°24' S; 136°52' E; 107

Additionally, the age of the samples at the trial was 42 months old, and the number of trees tested was 12, representing one provenance. Wood samples for physical (disk samples), mechanical, and anatomical properties were taken at a height and length of 1.3 m and 35 cm. The logs were divided into 5 cm and 30 cm for wood samples with anatomical and mechanical properties.

Procedures

Physical properties of wood

The physical properties of the wood tested were green density (WD), specific gravity (SG), and moisture content (MC). The samples were taken from the pith to the outer bark (1×1×2 cm), and the standards were referred to as ASTM D 4442 and ASTM D 2395. The equations used to calculate each of the tested properties are presented in the following:

$$MC\ \% = \frac{(W1 - Wo)}{Wo} X\ 100\%$$

$$WD\ (g/cm^3) = \frac{W1}{V1}$$

$$SG = \frac{\frac{Wo}{V1}}{\rho\ water}$$

Where:
MC : moisture content (%)
WD : wood density (g/cm^3)
SG : specific gravity
W1 : weight of sample test in fresh condition (g)
Wo : oven-dry weight (g)
V1 : volume of test sample in fresh condition (cm^3)

Flexural mechanical properties

Mechanical properties in static bending strength were tested based on the ASTM D 143 standard with a Universal Testing Machine (UTM). Samples measuring 2×2×30 cm were tested in air-dry conditions. From the static flexural strength test, the stiffness (MOE) and fracture toughness (MOR) values will be obtained and calculated using the equation:

$$MOE = \frac{PL^3}{4ybh^3}$$

$$MOR = \frac{3BL}{2bh^2}$$

Where:
MOE : modulus of elasticity (kg/cm^2)
MOR : modulus of rupture (kg/cm^2)
P : load below proportion limit (kgf)
L : support distance (cm)
B : maximum load when the wood is broken (kg)
Y : bending at load P (cm)

Anatomical properties

Observation of the cross-section of *jabon* provenance wood being carried out using the Scanning Electron Microscope (SEM) test. The samples tested were 3 *jabon* provenances from Kampar, Nusakambangan, and Alas Purwo, representing the small, medium, and largest diameters.

The Schlutz technique was used for maceration, and a 4× magnification optical microscope was used to determine the fiber length. MFA was selected through X-ray Diffraction (XRD). Measurement of fiber length and MFA was carried out in 12 provenances. Each provenance was tested, starting from the pith to the outer bark with a size of 1×1×2 cm^3.

RESULTS AND DISCUSSION

ANOVA results on MOE, MOR, and MFA showed significant differences (Table 2). The research results of Mahmud et al. (2017) also showed significant differences in the MOE test for 7-year-old *jabon* wood. The MOE values in 1, 2, 3, and 12 provenances were almost identical but different from 4, 5, 6, 7, 8, 9, 10, and 11 provenances. The 5, 10, and 11 provenances were almost identical but different from 1, 2, 3, 4, 6, 7, 8, 9, and 12 provenances. The MOR value at the 12 provenances differed from 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 provenances. The 1, 2, 3, 5, 6, and 10 provenances were almost identical but different from those of the 4, 7, 8, 9, 11, and 12. The MFA values in 1, 2, 3, 4, 5, 6, 7, 10, and 11 were the same but different from 8, 9, 12 provenances. The 2, 5, 8, 9, and 12 provenances were the same but different from 1, 3, 4, 6, 7, 10, and 11 provenances (Table 3).

Physical properties of wood

The samples used for testing physical properties in each provenance were different because the diameter in each provenance was different. Samples were taken from the pith to bark (per 1 cm). The different colors on the graph indicate different segments (sky blue, orange, grey, yellow, dark blue, light green, dark green). The moisture content of wood describes the amount of water expressed as a percentage of the dry weight of the kiln. The 12 provenances of *jabon* had different moisture content, which decreased from the pith to bark. Meanwhile, the segment near the pith had the highest moisture content, according to Figure 2.

Wood density is the ratio of the mass or weight to its volume among 12 *jabon* provenances. In each provenance, the green density from the pith to bark also varied in the range of 0.92-0.97 gcm^{-3} (Figure 3).

Specific gravity is the ratio of wood density to a standard object based on oven-dry weight. The gravity of the 12 provenances differed, as was each segment from pith to bark. The specific gravity increased from the pith to bark around 0.35-0.55 (Figure 4).

Flexural mechanical properties

The flexural stiffness MOE is the ratio between stress and strain under the proportional limit. The 12 *jabon* provenances had varying average MOE, and the highest was found in the Kapuas Tengah provenance, followed by the Batu Licin and Garut Selatan. In contrast, the lowest was in the Kuala Kencana provenance, around 3,700 $kgcm^{-2}$ (Figure 5).

MOR measures the ability to withstand loads calculated in the flexural strength test. Batu Licin's provenance had the highest MOR value of 639 $kgcm^{-2}$, followed by Kapuas Tengah's and Garut Selatan's provenances. Meanwhile, the lowest MOR value was the provenance of Kuala Kencana, which was around 360 $kgcm^{-2}$ (Figure 6).

Table 2. ANOVA of wood properties in 12 *jabon* provenances

Parameter	ANOVA
MC	0.909^{ns}
WD	0.605^{ns}
SG	0.880^{ns}
MOE	0.000**
MOR	0.000**
FL	0.424^{ns}
MFA	0.007**

Notes: ** difference, ^{ns} not significant

Table 3. Duncan test results of wood properties in 12 *jabon* provenances

Provenances	MOE	MOR	MFA
1	43672.19^{ab}	449.12^{bc}	10.07^{abc}
2	44869.12^{abc}	440.15^{b}	12.20^{abcd}
3	45995.23^{abc}	432.05^{b}	8.51^{ab}
4	57812.78^{de}	524.01^{de}	9.72^{abc}
5	50533.87^{bcd}	466.09^{bcd}	12.93^{abcd}
6	47273.13^{bc}	465.56^{bcd}	7.06^{a}
7	67751.04^{f}	572.54^{e}	7.28^{a}
8	64383.33^{ef}	639.87^{f}	18.84^{d}
9	53664.24^{cd}	525.92^{de}	15.81^{cd}
10	49151.75^{bcd}	466.12^{bcd}	10.49^{ac}
11	49525.45^{bcd}	517.85^{cde}	10.73^{abc}
12	37847.07^{a}	361.15^{a}	14.87^{bcd}

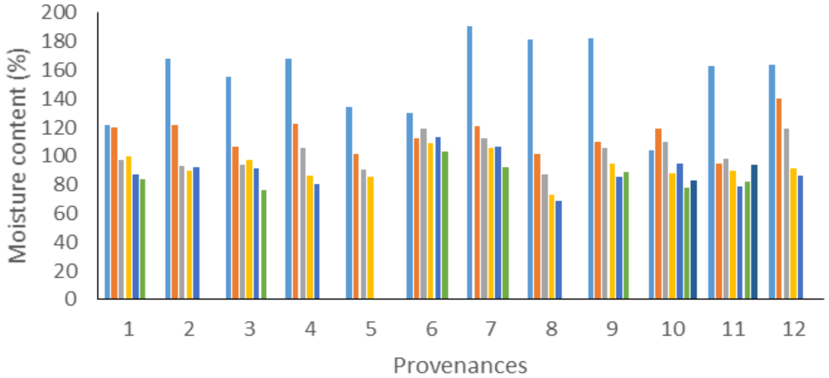

Figure 2. The green moisture content of 12 provenances of *jabon* from the pith to bark. Notes: 1. Rimbo Panti; 2. Kampar; 3. Ogan Komering Ilir; 4. Garut Selatan; 5. Nusakambangan; 6. Alas Purwo; 7. Kapuas Tengah; 8. Batu Licin; 9. Gowa; 10. Pomalaa; 11. Batu Hijau; 12. Kuala Kencana

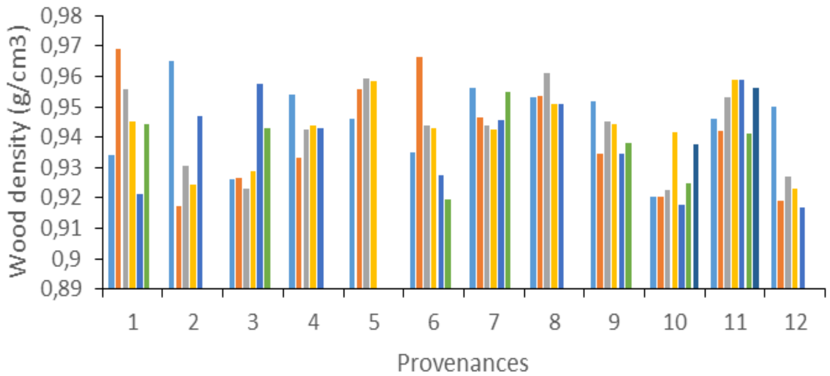

Figure 3. The green wood density in 12 provenances of *jabon* from the pith to bark. Notes: 1. Rimbo Panti, 2. Kampar, 3. Ogan Komering Ilir, 4. Garut Selatan, 5. Nusakambangan, 6. Alas Purwo, 7. Kapuas Tengah, 8. Batu Licin, 9. Gowa, 10. Pomalaa, 11. Batu Hijau, 12. Kuala Kencana

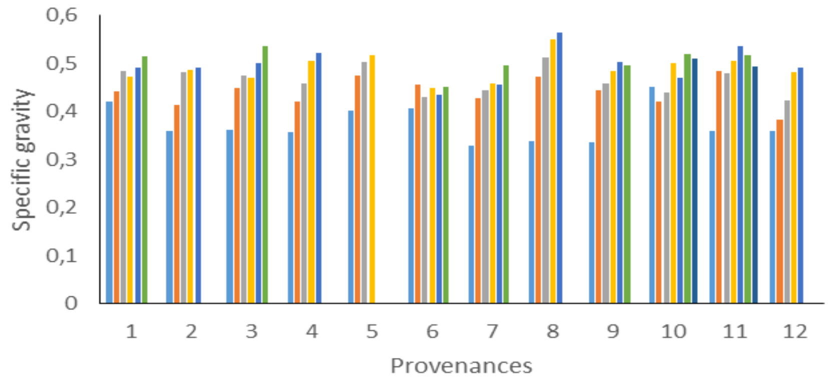

Figure 4. The specific gravity of 12 provenances of *jabon* from pith to bark. Notes: 1. Rimbo Panti; 2. Kampar; 3. Ogan Komering Ilir; 4. Garut Selatan; 5. Nusakambangan; 6. Alas Purwo; 7. Kapuas Tengah; 8. Batu Licin; 9. Gowa; 10. Pomalaa; 11. Batu Hijau; 12. Kuala Kencana

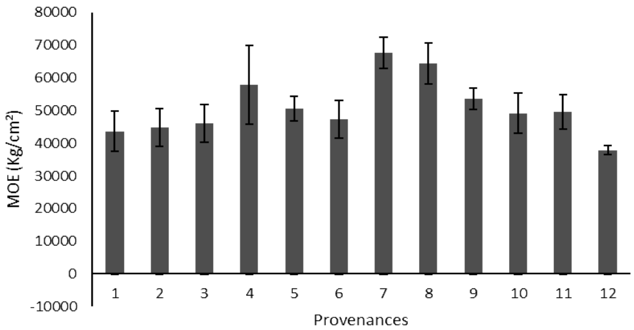

Figure 5. MOE values of 12 provenances of *jabon*. Notes: 1. Rimbo Panti; 2. Kampar; 3. Ogan Komering Ilir; 4. Garut Selatan; 5. Nusakambangan; 6. Alas Purwo; 7. Kapuas Tengah; 8. Batu Licin; 9. Gowa; 10. Pomalaa; 11. Batu Hijau; 12. Kuala Kencana

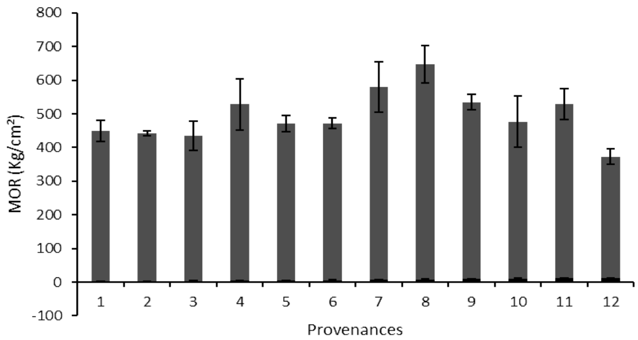

Figure 6. MOR values of 12 provenances of *jabon*. Notes: 1. Rimbo Panti; 2. Kampar; 3. Ogan Komering Ilir; 4. Garut Selatan; 5. Nusakambangan; 6. Alas Purwo; 7. Kapuas Tengah; 8. Batu Licin; 9. Gowa; 10. Pomalaa; 11. Batu Hijau; 12. Kuala Kencana

Anatomical properties

Observations on the cross-section of Kampar, Nusakambangan, and Alas Purwo indicated that the 3 *jabon* provenances had the same vascular (porous) characteristics. They had scattered or diffuse vessels without an actual pattern in the cross-section. The pore arrangement was almost entirely radial, and circular vessels were small (100-200) to relatively large (200-300). Some are isolated, although 2-3 others can be found close (4), and the perforation plane was simple, without tylosis in the pore cavity. Cell wall thickness included thin to thick, with narrow wood radii, and the pores in the Alas Purwo provenance were larger than the others (Figure 7). Environmental, genetic, and interaction factors influence growth. The growth of the Alas Purwo provenance is faster than that of other provenances and is influenced by many factors, including the environment or the availability of nutrients around the tree. Faster growth will form thinner cell walls.

Fiber length and MFA samples were different in each provenance, according to diameter. The samples tested ranged from the pith to bark (per 1 cm). The fiber length was measured using a light microscope, with 50 random measurements repeated in each segment. The fiber length from the pith to the bark was getting longer (Figure 8). Meanwhile, the results of the MFA measurement did not show a specific trend from the pith to bark (Figure 9). The MFA in each *jabon* provenance did not show a trend. This is thought to be because it is still juvenile wood (42 months old). Rahayu et al. (2014) explained that the MFA value had shown a trend for *jabon* (6 years old and 48 cm in diameter).

Discussion

Physical properties of wood

The wood density test did not show a trend from pith to bark, this may be due to the young age of the tree or the wood was still juvenile, and this result was different from the previous study. Miranda et al. (2011) and Blohm et al. (2016) reported the average value of increasing green density from the direction of the pith to the bark. In addition, Bowyer et al. (2007) reported the density of wood increases from the pith to the bark. According to Tsoumis (2013), wood quality in the growth circle around the pith has the lowest wood density, short constituent cells, thin cell walls, large S2 layer microfibril angle, and low cellulose percentage. The average, lowest, and highest density value of 12 *jabon* provenances aged 42 months (Figure 3) was 0.94 gcm^{-3}, 0.92 gcm^{-3} (Pomalaa provenance), and 0.95 gcm^{-3} (Rimbo Panti, Nusakambangan, Kapuas Tengah, and Batu Hijau provenances). This result differs from Nugroho et al. (2011) and Mahmud et al. (2017), who tested 7-year-old *jabon* to obtain 0.57 gcm^{-3} and 0.63 gcm^{-3}. Furthermore, the density of wood is the best predictor of its strength. The high wood density explains the large proportion of cells with thick walls.

The wood's strength can be estimated from the characteristics of its specific gravity. In general, the specific gravity of the wood is directly proportional to its strength. It depends on the substance in the wood, the extractive content, the moisture content, and the size of the wood cells. The specific gravity of the 12 provenances of *jabon* tended to increase from pith to bark. The low value near the pith is thought to be caused by juvenile wood. Similar results were also obtained in Widiyanto and Siarudin (2016) research on *jabon* aged 7 years. The average specific gravity was 0.46, with a range of 0.44 (Kuala Kencana provenance) - 0.49 (Batu Licin and Batu Hijau provenance). The study revealed the value acquired was higher than the results by Rahmayanti et al. (2016) in *jabon* aged 6 years (0.34) which were not derived from the breeding program. Nugroho et al. (2011), and Widiyanto and Siarudin (2016) in *jabon* aged 7 years, namely 0.32 and 0.33. Based on the specific gravity, it can be concluded that *jabon* provenance wood is stronger than the result of a breeding program. Differences in the value of specific gravity can also be caused by the tree's age, location, position of the wood in the trunk, and speed of growth. Based on the value of the wood generated, 12 provenances of *jabon* are classified as strong class III (Martawijaya et al. 1989).

Another physical property tested was the green moisture content, which was used to determine the water weight. The moisture content from the pith to the skin decreased, and the inner wood (near the pith) had a higher moisture content. Young wood has a high lignin content, thin fiber walls, and a large lumen that can hold water compared to matured parts. According to Uar (2014), the wood near the pith has thin cell walls and lower density, which increases the amount of water in this area. The results are similar to Bal et al. (2011) in that the average moisture content value decreases from the pith to the bark. The average moisture content value was 105.13%, with the lowest and highest at 96.62% (Batu Hijau provenance) and 115.71% (Kuala Kencana provenance). In contrast to the research by Widiyanto and Siarudin (2016), *jabon* aged 7 years was 120.88%, while the research by Nugroho et al. (2011) and Mahmud et al. (2017) was lower at 66.92% and 80.01%. The different moisture content values are related to the condition of the pores, which causes the free water content to be high.

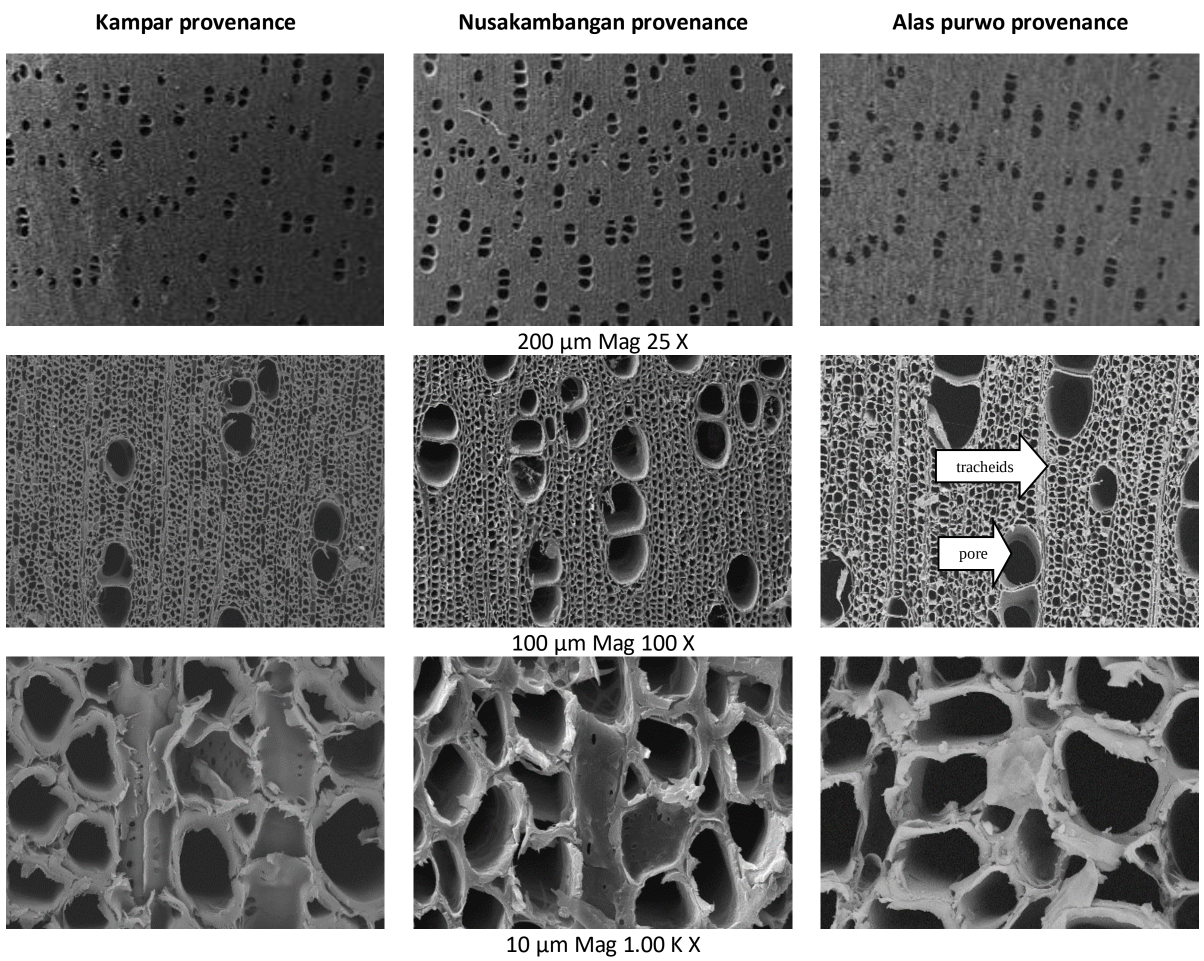

Figure 7. Axial cross-section of three provenances of *jabon*

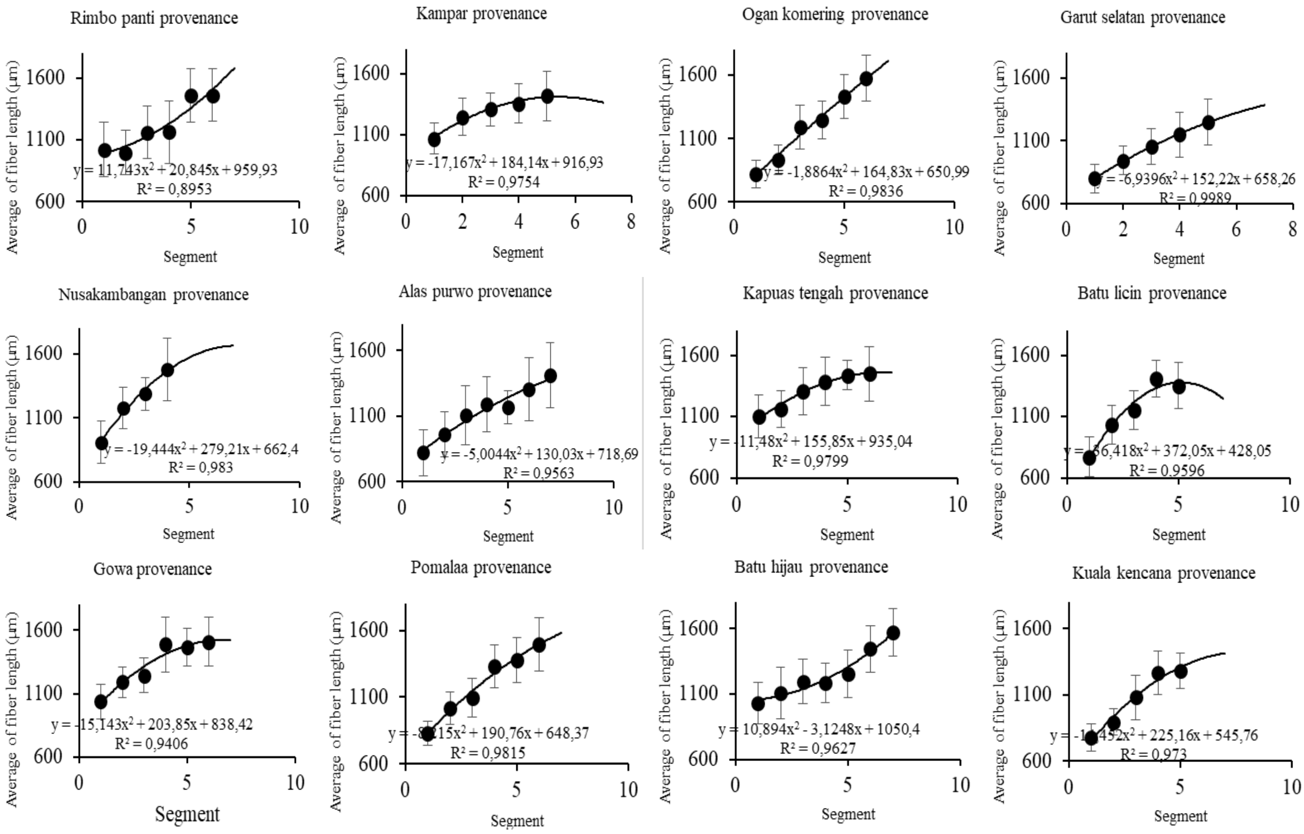

Figure 8. Fiber length in each *jabon* provenance from pith to bark

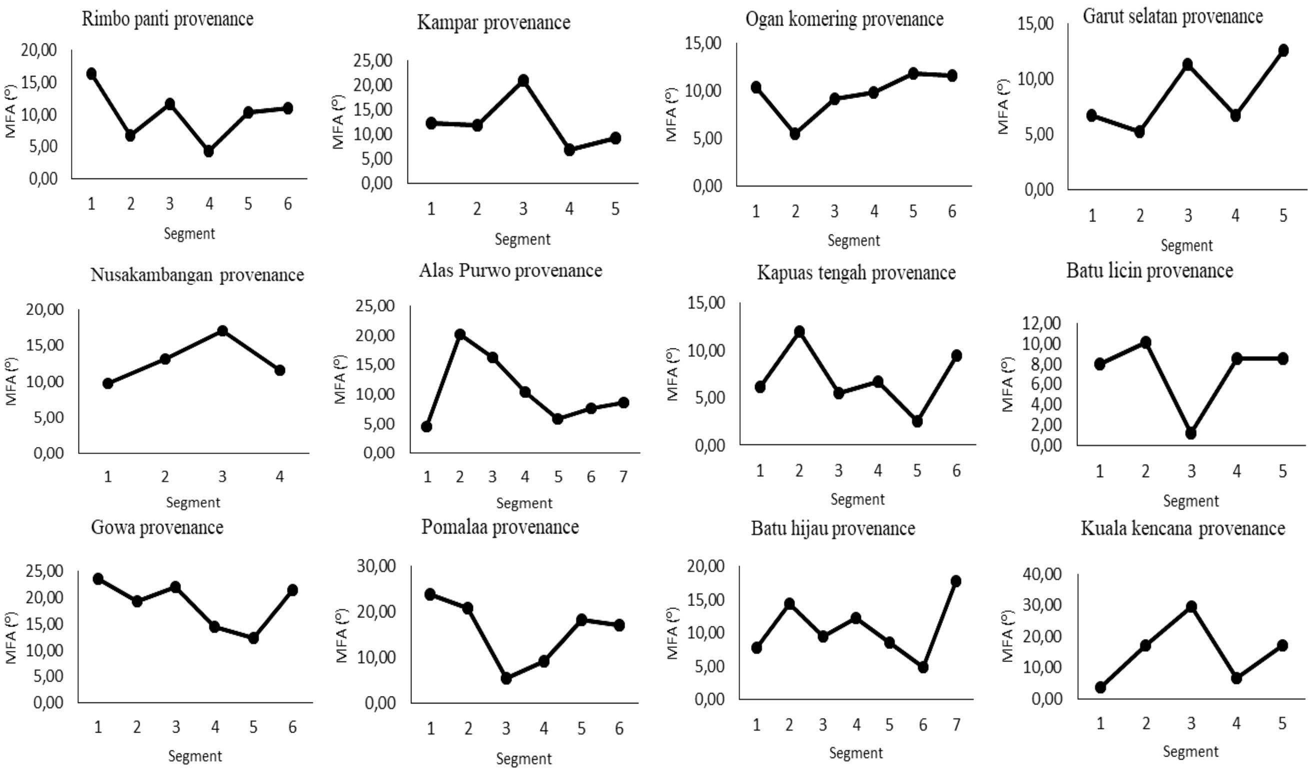

Figure 9. MFA of each *jabon* provenance starting from the pith to bark

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Mechanical properties

Wood's mechanical properties are essential for its function as a structural raw material. The important mechanical properties are MOE and MOR, which are tested under conditions of air-dry moisture content. Determination of moisture content in air-dry conditions is the most desirable in a wood application. There are no essential changes in shape (bent, broken, split), and the determination of dry air moisture content depends on the surrounding climate. The moisture content of the 12 *jabon* provenances varied, and the average, lowest, and highest dry air moisture content was 13.62%, 12.48% (Nusakambangan provenance), and 14.73% (Pomalaa provenance). The average MOE and MOR value was 51039.93 $kgcm^{-2}$ and 488.37 $kgcm^{-2}$ with such moisture content. The research by Nugroho et al. (2011) explained that the average values in *jabon* aged 7 years were 651 x 10^2 $kgcm^{-2}$ and 601 $kgcm^{-2}$. Meanwhile, the values for *A. mangium* aged 10 years were 89814.4 $kgcm^{-2}$ and 651.97 $kgcm^{-2}$ (Nurhasybi and Sudrajat 2019). This study's MOE and MOR values were lower than those of *jabon* and *A. mangium*, aged 7 and 10 years. In contrast to the research of Rahayu et al. (2014) in *jabon* aged 60 and 72 months, the MOR value was lower than that of provenance *jabon* aged 42 months with 454 kg cm^{-2} and 464 kg cm^{-2}, respectively. Wood tends to get stronger and harder as the tree ages. In the fast-growing species, the tree's cell walls are still thin; hence, the strength or elasticity is very low compared to the slow-growing plants. MOE and MOR in this study did not show a trend from pith to bark. The result of this study was different from the previous study. Darmawan et al. (2013) reported the MOE and MOR of 7-year-old *sengon* (*F. mollucana*) and *jabon* (*A. cadamba*) also increased from pith to the bark.

Anatomical properties

The anatomical properties tested were fiber length and MFA. Fiber length is one indicator of quality used to determine the raw material for pulp and paper production (Figure 9). It affects physical qualities, such as strength and stiffness. The strength properties influenced by the length of the fiber are tensile, folding, and tear resistance. Fiber length was measured using a light microscope, with 50 replicates for each segment. In 12 provenances of *jabon*, the length from the pith to the outer bark tended to increase, indicating a juvenile wood. Bowyer et al. (2007), Palermo et al. (2015), and Mansfield et al. (2016) reported that the fiber length continues to increase up until a certain segment and then remains constant closer to the bark. The formation of mature wood is characterized by the fiber length becoming constant between each segment. Rahayu et al. (2014) also obtained the same result, which reported that *jabon* aged 60 and 72 months were still juvenile wood. The average length in the 12 *jabon* provenances was 1,183.28 μm, ranging from 1,041.64 μm (Garut Selatan provenance) to 1,341.10 μm (Gowa provenance). However, different results were obtained by Rahayu et al. (2014) in *jabon* aged 60 and 72 months (1,190 and 1,245 μm) and 7 years (1,288 μm) (Fajriani et al. 2013). Therefore, the difference in fiber length can be caused by the tree's age, trunk diameter, location, and cell maturity.

MFA affects wood's physical and mechanical properties, including density, tensile strength, stiffness, and shrinkage. A smaller value indicates a more stable wood, which is profitable to process. The minimal value required to utilize wood as a construction material does not yet exist. Furthermore, MFA value with XRD on 12 *jabon* provenances varied from pith to bark. This finding contrasts with the previous study. Darmawan et al. (2013, 2015) and Cahyono et al. (2015) reported that one of the characteristics of juvenile wood transition to adult wood is the MFA decreasing from the part close to the pith toward that near the bark. In addition, this finding contrasts with Rahayu et al. (2014) study, which examined *jabon* aged 60 and 72 months using a different method involving iodine and measurements with a light microscope. The 12 *jabon* provenances had an average MFA value of 11.54°. This result differs from *jabon* aged 60 and 72 months at 24° and 22° (Rahayu et al. 2014). The MFA value of provenance *jabon* aged 42 months was smaller than those aged 60 and 72. The variations might be caused by the adaptability of plants related to differences in growing conditions and environment, geographical location, and the testing methods used.

In conclusion, the physical, mechanical, and anatomical properties of *jabon* wood from 12 provenances at 42 months had varied growth characteristics. The highest wood density values were in the Rimbo Panti, Nusakambangan, Kapuas Tengah, and Batu Hijau provenances. The highest specific gravity values were in Batu Licin and Batu Hijau. The highest water content value was obtained in the Kuala Kencana provenance. The highest MOE and MOR values were obtained in the Batu Licin and Gowa provenance. The fiber length from the pith to the outer bark increased while the MFA fluctuated. Based on the value of the 12 *jabon* provenance's physical, mechanical, and anatomical properties, they can only be used as non-structural raw materials for furniture, children's wooden toys, and matches or in combination with other wood as pulp and paper materials. The *jabon* Batu Hijau provenances have the highest density and specific gravity. In addition, *jabon* Batu Hijau provenances have the lowest moisture content. However, the highest fiber length was found in Gowa provenance.

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REFERENCES

Acharyya S, Dash GK, Abdullah MS. 2014. Antihyperglycemic and antilipidemic activity of *Anthocephalus cadamba* (Roxb.) Miq. Roots. Euro J Exp Bio 3 (3): 116-120.

Arsyad WOM, Basri E, Hendra D, Trisatya DR. 2019. Termite resistance of impregnated *jabon* wood (*Anthocephalus cadamba* Miq.) with combined impregnant agents. J Korean Wood Sci Technol 47 (4): 451-458. DOI: 10.5658/WOOD.2019.47.4.451.

Bal BC, Bektas I, Tutus A, Kaymakci A. 2011. The within-tree variation in some physical properties in *Eucalyptus* wood (*Eucalyptus grandis* W. Hill ex Maiden) grown in Karabucak Region. Düzce Üniversitesi Orman Fakültesi Ormancılık Dergisi 7 (2): 82-88.

Bijalwan A, Dobriyal MJR, Bhartiya JK. 2014. A potential fast growing tree for agroforestry and carbon sequestration in India: *Anthocephalus cadamba* (Roxb.) Miq. Am J Agric For 2 (6): 296-301. DOI: 10.11648/j.ajaf.20140206.21.

Blohm JH, Evans R, Koch G, Schmitt U. 2016. Identification and characterisation of douglas-fir (*Pseudotsuga menziesii* (MIRB.) Franco) juvenile and adult wood grown in Southern Germany. Drewno 59 (197): 41-47. DOI: 10.12841/wood.1644-3985.C01.05.

Bowyer JL, Shmulsky R, Haygreen JG. 2007. Forest Products and Wood Science: An Introduction. 5th Edition. Iowa State Press, Ames, IA.

Cahyono TD, Wahyudi I, Priadi T, Febrianto F, Darmawan W, Bahtiar ET, Ohorella S, Novriyanti E. 2015. The quality of 8 and 10 years old samama wood (*Anthocephalus macrophyllus*). J Indian Acad Wood Sci 12 (1): 22-28. DOI: 10.1007/s13196-015-0140-8.

Chandel M, Sharma U, Kumar N, Singh B, Kaur S. 2013. In Vitro Studies on the Antioxidant/Antigenotoxic Potential of Aqueous Fraction from *Anthocephalus cadamba* Bark. Perspectives in Cancer Prevention-Translational Cancer. Springer India, Connaught Place, Delhi. DOI: 10.1007/978-81-322-1533-2.

Chaubey N, Singh VK, Savita, Quraishi MA. 2015. Corrosion inhibition of aluminium lloy in alkaline media by *Neolamarckia cadamba* bark extract as green inhibitor. Intl J Electrochem Sci 10 (1): 504-518. DOI: 10.1016/S1452-3981(23)05009-5.

Darmawan W, Nandika D, Rahayu I, Fournier M, Marchal R. 2013. Determination of juvenile and mature transition ring for fast growing sengon and *jabon* wood. J Indian Acad Wood Sci 10 (1): 1-9. DOI: 10.1007/s13196-013-0091-x.

Darmawan W, Nandika D, Sari RK, Sitompul A, Rahayu I, Gardner D. 2015. Juvenile and mature wood characteristics of short and long rotation teak in Java. Intl Assoc Wood Anat J 36 (4): 428-442. DOI: 10.1163/22941932-20150112.

Fajriani E, Ruelle J, Dlouha J, Fournier M, Hadi YS, Darmawan W. 2013. Radial variation of wood properties of *sengon* (*Paraserianthes falcataria*) and *jabon* (*Anthocephalus cadamba*). J Indian Acad Wood Sci 10: 110-117. DOI: 10.1007/s13196-013-0101-z.

Ganjewala D, Tomar N, Gupta AK. 2013. Phytochemical composition and antioxidant properties of methanol extracts of leaves and fruits of *Neolamarckia cadamba* (Roxb.). J Biol Act Prod Nat 3 (4): 232-240. DOI: 10.1080/22311866.2013.817748.

Hadi YS, Herliyana EN, Sulastiningsih IM, Basri E, Pari R, Abdillah IB. 2021. Physical and mechanical properties of impregnated polystyrene *jabon* (*Anthocephalus cadamba*) glulam. IOP Conf Ser: Earth Environ Sci 891: 012007. DOI: 10.1088/1755-1315/891/1/012007.

Hadi YS, Massijaya MY, Zaini LH, Pari R. 2019. Physical and mechanical properties of methyl methacrylate-impregnated wood from three fast-growing tropical tree species. J Korean Wood Sci Technol 47 (3): 324-335. DOI: 10.5658/WOOD.2019.47.3.324.

Hadi YS, Rahayu IS, Danu S. 2013. Physical and mechanical properties of methyl methacrylate impregnated *jabon* wood. J Indian Acad Wood Sci 10 (2): 77-80. DOI: 10.1007/s13196-013-0098-3.

Hadi YS, Rahayu IS, Danu S. 2015. Termite resistance of *jabon* wood impregnated with methyl methacrylate. J Trop For Sci 27 (1): 25-29.

Hadiyane A, Dungani R, Dewi SP, Rumidatul A. 2018. Effect of chemical modification of *jabon* wood (*Anthocephalus cadamba* Miq.) on morphological structure and dimensional stability. J Biol Sci 18 (4): 201-207. DOI: 10.3923/jbs.2018.201.207.

Irawan US, Purwanto E. 2014. White *jabon* (*Anthocephalus cadamba*) and red *jabon* (*Anthocephalus macrophyllus*) for community land rehabilitation: Improving local propagation efforts. J Agri Sci 2 (3): 36-45. DOI: 10.12735/as.v2i3p36.

Kabe A, Darmawan W, Massijaya MY. 2013. Ciri finir kupas kayu *jabon* (*Anthocephalus cadamba*). Jurnal Ilmu Pertanian Indonesia 18 (3): 133-139.

Komariah RN, Hadi YS, Massijaya YM, Suryana J. 2015. Physical-mechanical properties of glued laminated timber made from tropical small-diameter logs grown in Indonesia. J Korean Wood Sci Technol 43 (2): 156-167. DOI: 10.5658/WOOD.2015.43.2.156.

Krisnawati H, Kallilo M, Kanninen M. 2011. *Anthocephalus cadamba* Miq.: Ecology, Silviculture, And Productivity. Center for International Forestry Research, Bogor.

Lempang M. 2014. Basic properties and potential uses of red *jabon*. Jurnal Penelitian Kehutanan Wallace 3 (2): 163-175. DOI: 10.18330/jwallacea.2014.vol3iss2pp163-175. [Indonesian]

Lenz P, Auty D, Achim A, Beaulieu J, Mackay J. 2013. Genetic improvement of white spruce mechanical wood traits-early screening by means of acoustic velocity. Forest 4 (3): 575-594. DOI: 10.3390/f4030575.

Lestari ASRD, Hadi YS, Hermawan D, Santodo A. 2018. Physical and mechanical properties of glued laminated lumber of pine (*Pinus merkusii*) and *jabon* (*Antocephalus cadamba*). J Korean Wood Sci Technol 46 (2): 143-148. DOI: 10.5658/WOOD.2018.46.2.143.

Mahmud SZ, Hashim R, Saleh AH, Sulaiman O, Saharudin NI, Ngah ML, Masseat K, Husain H. 2017. Physical and mechanical properties of juvenile wood from *Neolamarckia cadamba* planted in West Malaysia. Maderas. Cienc Technol 19 (2): 225-238. DOI: 10.4067/S0718-221X2017005000020.

Malik J, Ozarska B. 2019. Mechanical characteristics of impregnated white *jabon* wood (*Anthocephalus cadamba*) using merbau extractives and selected polymerised merbau extractives. Maderas Cienc Technol 21 (4): 573-586. DOI: 10.4067/S0718-221X2019005000413.

Malik J, Santoso A, Jasni, Ozarska B. 2022. Biological resistance of *jabon* wood against subterranean and drywood termites after combined impregnation and compression treatment. Wood Res J 13 (1): 34-42.

Mansfield SD, Parish R, Ott PK, Hart JF, Goudie JW. 2016. Assessing the wood quality of interior spruce (*Picea glauca* × *P. engelmannii*): Variation in strength, relative density, microfibril angle, and fiber length. Holzforschung 70 (3): 223-234. DOI: 10.1515/hf-2015-0008.

Martawijaya A, Kartasujana I, Mandang YI, Prawira SA, Kadir K. 1989. Atlas Kayu Indonesia Volume 2. Center for Research and Development of Forest Product, Indonesia. [Indonesian]

Miranda I, Sousa V, Pereira H. 2011. Wood properties of teak (*Tectona grandis*) from a mature unmanaged stand in East Timor. J Wood Sci 57 (3): 171-178. DOI 10.1007/s10086-010-1164-8.

Mompewa NM, Yunianti AD, Larekeng SH. 2019. Anatomy structure cell wall of *jabon* merah (*Anthocephalus macrophyllus*) wajo provenance. Penennial J 15 (1): 58-61. DOI: 10.24259/perennial.v15i1.6496.

Nugroho N, Savitri RLW, Karlinasari L. 2011. Physical and mechanical properties of *jabon* wood (*Anthocephalus cadamba*). For Prod Sci Technol 4 (2): 58-64.

Nurhasybi, Sudrajat DJ. 2019. Growth performance of *Acacia mangium* provenance in Parung Panjang, Bogor and its correlation with physical and mechnical wood properties. IOP Conf Ser: Earth Environ Sci 359: 012003. DOI:10.1088/1755-1315/359/1/012003.

Palermo GP de M, Latorraca JV de F, de Carvalho AM, Calonego FW, Severo ETD. 2015. Anatomical properties of *Eucalyptus grandis* wood and transition-age between the juvenile and mature woods. Eur J Wood Wood Prod 73 (6): 775-780. DOI: 10.1007/s00107-015-0947-4.

Pandey A, Negi PS. 2016. Traditonal uses, phytochemistry and pharmacological properties of *Neolamarckia cadamba*: A review. J Ethnopharmacol 181:118-135. DOI: 10.1016/j.jep.2016.01.036.

Prihartini E, Maddu A, Rahayu IS, Kurniati M, Darmawan W. 2020. Improvement of physical properties of *jabon* (*Anthocephalus cadamba*) through the impregnation of nano-SiO2 and melamin formaldehyde furfuril alcohol copolymer. IOP Conf Ser: Mat Sci Eng 935: 012061. DOI:10.1088/1757-899X/935/1/012061.

Rahayu I, Darmawan W, Nugroho N, Nandika D, Marchal R. 2014. Demarcation point between juvenile and mature wood in sengon (*Falcataria moluccana*) and *jabon* (*Anthocephalus cadamba* Miq.). J Trop For Sci 26 (3): 331-339.

Rahmayanti, Erniwati, Hapid A. 2016. Sifat fisika kayu *jabon* (*Anthocephalus cadamba* Miq.) berdasarkan arah aksial dari Desa Alindau Kabupaten Donggala Sulawesi Tenggara.. Warta Rimba 4 (1): 56-64. [Indonesian]

Sandalayuk D, Lahjie AM, Simarangkir, Rusllim Y. 2020. Carbon absorbtion of *Anthocephalus cadamba* and *Swietenia macrophylla*. King in Gorontalo, Indonesia. J Bio Environ Sci 16 (5): 24-30.

Soerianegara I, Lemmens RHMJ. 1993. Plant resources of Southeast Asia No 5 (1) Timber trees: Major Commercial Timbers. Pudoc Scientific Publishers, Wageningen, Netherlands.

Sudrajat DJ, Ayyasy Y, Siregar IZ, Karlinasari L. 2021. Mahogany (*Swietenia macrophylla* King.) as urban tree: tree growth and quality variation in a progeny test. IOP Conf Ser: Earth Environ Sci 918: 012042. DOI: 10.1088/1755-1315/918/1/012042.

Sutrisno, Syamsudin TS, Alamsyah EM, Purwasasmita BS. 2015. Synthesis and characterization of bio-based nanomaterials from *jabon* (*Anthocephalus cadamba* (Roxb.) Miq) wood bark: an organic waste material from community forest. J Math Fundam Sci 47 (2): 205-218.DOI: 10.5614/j.math.fund.sci.2015.47.2.7.

Tsoumis G. 2013. Wood as raw material: Source, stucture, chemical composition, growth, degradation and identification focuses on the scientific advancements in general forestry. Pergamon Press, Oxford.

Uar NI. 2014. Reliability of sonic tomography to detect agarwood in *Aquilaria microcarpa* Baill. J Indian Acad Wood Sci 11 (1): 65-71. DOI: 10.1007/s13196-014-0119-x.

Widiyanto A, Siarudin M. 2016. Karakteristik sifat fisik kayu *jabon* (*Anthocephalus cadamba* Miq) pada arah longitudinal dan radial. Jurnal Hutan Tropis 4 (2): 102-108. [Indonesian]

You R, Zhu N, Deng X, Wang J, Liu F. 2021. Variation in wood physical properties and efects of climate for diferent geographic sources of Chinese fr in subtropical area of China. Sci Rep 11: 4664. DOI: 10.1038/s41598-021-83500-w.