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Fiber Morphology of *Syzygium tripinnatum* (Blanco) Merr. Stemwood and Branchwood and Their Derived Values

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ABSTRACT

Syzygium tripinnatum (Blanco) Merr. is an indigenous fruit tree species in the Philippines. This study characterizes the fiber morphology (fiber length, diameter, lumen diameter, and cell wall thickness) and derived values (Runkel ratio, slenderness ratio, flexibility ratio, Mulhsteph ratio, and rigidity coefficient) of *S. tripinnatum* wood grown in the Philippines. The results revealed that branchwood fibers were 1.610% longer, and both fiber and lumen diameters were 2.170% and 9.600% thicker, respectively, compared to stemwood. However, the cell wall thickness of stemwood was 1.670% greater than that of branchwood. In terms of derived values, stemwood exhibited higher values by 10.410% for the Runkel ratio, 0.580% for the slenderness ratio, 1.990% for the Mulhsteph ratio, and 3.030% for the rigidity ratio, while branchwood displayed a 7.350% higher flexibility ratio. Statistical analysis indicated no significant difference in fiber morphology or derived values between the two wood types. Based on the fiber morphology, *S. tripinnatum* wood is highly rigid and stiff, making it difficult to collapse, and thus less efficient for pulp and paper production, and bulkier for paper. However, the study suggests that *S. tripinnatum* could be suitable for construction, furniture, tool handles, cabinetry and pilings due to its cell wall thickness, Runkel ratio, flexibility ratio, Mulhsteph ratio, and rigidity coefficient. Further research into other properties of *S. tripinnatum* wood, considering factors such as tree maturity, height, sample size, and habitat would be crucial for accurately determining its suitability for the intended applications.

1. INTRODUCTION

The Philippines recorded more than 300 species of edible fruit-bearing trees, wherein more than half are endemic and native, but very few are cultivated commercially (Dulay et al., 2023). With a favorable climate and soil fertility, the Philippines become an ideal location for tropical fruit production. Also, promoting the local native fruits of the country that show huge market potential may help increase the incomes of the community, especially farmers and their families who are into fruit production and processing.

One of the economically useful indigenous fruit tree species in the country is *Syzygium tripinnatum* (Blanco) Merr. under the Myrtaceae family, commonly known as Hagis (Coronel, 2002). It is also native to some parts of Southeast Asia which primarily grow in the wet tropical biome and are characterized as a small to medium-sized evergreen tree growing up to 20 m high (Malabrigo and Umali, 2022). The fruits

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of *S. tripinnatum* can be processed into jam, jelly, wine, or juice, and can also be eaten raw and mixed with salt or sugar to neutralize its sour taste. The fruit was characterized as color white when young yet turned into cherry-like red when becomes ripened with a juicy and sour taste and could be processed into wine. *S. tripinnatum* was considered a lesser-known native fruit tree species and often overlooked not because of its unpleasant taste and not nutritious compared to other fruits, but due to its unfamiliarity.

Moreover, fruit-bearing trees are often overlooked as wood sources, with the timber industry traditionally focusing on fast-growing exotic species (Alipon et al., 2016). According to Marasigan et al. (2023) and Marasigan et al. (2024), 18 senile fruit-bearing trees cultivated in the Philippines, including *Syzygium cumini* (related to *S. tripinnatum*), can be used for various wood applications such as construction, plywood, flooring, furniture, and pulp and paper. *S. cumini*, classified under medium strength, is particularly suitable for these uses (Marasigan et al., 2024). Additionally, fruit-bearing trees are abundant in many areas in the Philippines, and harvesting senile or unproductive trees not only expands their potential for diverse applications, but also provides a sustainable timber alternative while offering farmers additional income (Del Castillo, 2021).

To date, there is limited literature on the botanical and morphological characteristics of *S. tripinnatum* trees, and no specific studies have addressed the wood properties and potential uses of this species not just in the Philippines but also worldwide. Thus, *S. tripinnatum* was classified as not evaluated (NE) plant under IUCN 2021-3 (Malabrigo and Umali, 2022). Mainstreaming of the native tree species nowadays would be of great help to spread awareness of their significant role in the ecological balance and sustainable ecosystem.

Understanding the wood properties of *S. tripinnatum* is crucial in promoting its potential uses. To evaluate the quality of its wood, it is vital to characterize the basic wood properties of this species to uncover the full potential and determine the suitability for proper utilization and sustainable production, while driving innovations in eco-friendly material science and advancing technical expertise in wood-based industry.

This study also provides significant data on the characteristics of *S. tripinnatum* wood that would serve as a basis for further studies on this species and related topics. Particularly, this study aims to characterize the fiber morphology and derived values of *S. tripinnatum* stemwood and branchwood, which ultimately affects final wood product properties and energy efficient production for sustainable forest management and eco-friendly product development.

2. METHODOLOGY

2.1 Plant materials and wood samples collection

S. tripinnatum wood samples were collected at Don Mariano Marcos Memorial State University - North La Union Campus, Bacnotan, La Union (16°43′32″N 120°23′16″E), Philippines with an elevation ranging from 45-50 meter above sea level (m.a.s.l.) (Figure 1), typically experiences a Type I climate under the Philippine climate classification system.

Wood samples with three (3) replications were taken from the two wood types (i.e., stemwood and branchwood) of the selected three (3) mature *S. tripinnatum* trees, with an estimated age of 20 years old with different diameters at breast height (DBH) (D_1-18 cm, D_2-23 cm, and D_3-29 cm). Using the increment borer, the wood samples were gathered. Stemwood samples were collected from the trees' DBH, while branch samples were collected at the first branch of the tree with a 10 cm diameter and above. After the wood sample extraction, the holes caused by increment borer in the trees were patched with wood and painted to prevent wood-boring/degrading macro/ microorganisms like fungi and insects.

2.2 Fiber morphology of *S. tripinnatum* wood

2.2.1 Fiber maceration

Matchstick-sized samples were prepared from the collected wood samples and then macerated in equal volumes (1:1) of acetic acid and hydrogen peroxide (50% concentration) following the procedure of Villareal et al. (2022a). The maceration was done in a water bath and heated for 6-h until the samples turned white and soft to separate individual fibers. The samples were then washed with distilled water until acid-free and subjected to microscopic observation and measurement.

2.2.2 Fiber measurement

Before fiber measurement, the macerated samples inside the test tubes were shaken to ensure the separation of different structural elements. Thirty undamaged fibers were observed per replicate under the Phenix 300 series microscope and measured using

ImageJ Software. The fibers' length, diameter, and lumen diameter of each fiber were measured following the International Association of Wood Anatomists (IAWA) standard (Wheeler et al., 1989), while the cell wall thickness was determined based on the difference between the fiber diameter and lumen diameter.

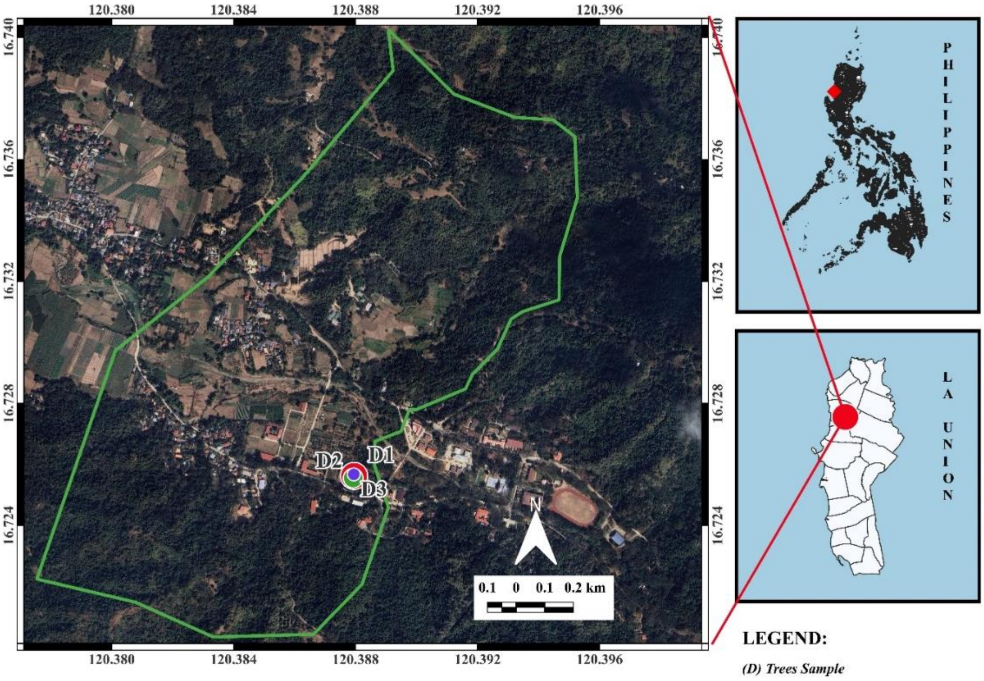

Figure 1. Location map of the collected *S. tripinnatum* wood samples

2.2.3 Derived values

Based on the fiber morphology data, the derived values such as Runkel ratio (1), slenderness ratio (2), flexibility ratio (3), Mulhsteph ratio (4), and rigidity coefficient (5) were computed using the equations used by Hartono et al. (2022). The assessment of the potential of *S. tripinnatum* as raw materials for pulp and paper production was conducted using the Indonesian Timber Assessment Criteria as Raw Materials for Pulp and Paper (Hartono et al., 2022).

$$\text{Runkel ratio} = \frac{2 \times \text{Cell wall thickness}}{\text{Lumen diameter}} \quad (1)$$

$$\text{Slenderness ratio} = \frac{\text{Fiber length}}{\text{Fiber diameter}} \quad (2)$$

$$\text{Flexibility ratio} = \frac{\text{Lumen diameter}}{\text{Fiber diameter}} \times 100 \quad (3)$$

$$\text{Mulhsteph ratio (\%)} = \frac{\text{Fiber diameter}^2 - \text{Lumen diameter}^2}{\text{Fiber diameter}^2} \times 100 \quad (4)$$

$$\text{Rigidity coefficient} = \frac{\text{Cell wall thickness}}{\text{Fiber diameter}} \quad (5)$$

2.3 Statistical analysis

T-test analysis was used to compare the stemwood and branchwood fiber morphology and derived values of *S. tripinnatum*. The statistical analysis was carried out using Jamovi version 2.3 (Jamovi Project, 2022).

3. RESULTS AND DISCUSSION

3.1 Fiber morphology

The fiber morphology (e.g., fiber length, fiber diameter, lumen diameter, and cell wall thickness) of *Syzygium tripinnatum* Blanco (Merr.) stemwood and branchwood and other *Syzygium* species, were presented in Table 1.

3.1.1 Fiber length (mm)

The result of the study showed that the longest fiber was recorded in D_2 (23 cm diameter) with 1.473 mm, followed by D_3 (29 cm diameter) with 1.434 mm, while the shortest was recorded in D_1 (18 cm diameter) with 1.428 mm. On the other hand, the mean fiber length of branchwood (1.450 mm) was 1.610% longer than stemwood (1.427 mm). However, the observed difference in fiber length was not significant (p-value of 0.697). Moreover, the mean fiber length of *S. tripinnatum* was relatively longer than *Eucalyptus tereticornis* Sm. (0.720 mm), *Eucalyptus grandis* W.Hill ex Maiden (0.920 mm) (Sharma et al., 2011), and *Aquilaria cumingiana* (Decne.) Ridl. (0.980 mm) (Villareal et al., 2022a). However, the result was relatively comparable with 3-, 5-, and 7-year-old *Falcata* trees (1.160, 1.140, and 1.170 (mm), respectively) (Alipon et al., 2021). In comparation to other *Syzygium* species (Table 1), *S. tripinnatum* fiber was longer than *S. fruticosum* (Roxb.) DC., *S. nervosum* DC., and *S. praecox* (Roxb.) Rathakr. & N.C. Nair, while shorter than *S. cumini* (L.) Skeels, *S. jambos* (L.) Alston, *S. album* Q.F. Zheng, and *S. brevistylum* (C.B. Rob) Merr. According to Thumm and Dickson (2013), fiber length is positively correlated with wood density, flexural strength, and stiffness. Based on this, the results suggest that compared to *E. tereticornis*, *S. fruticosum*, *S. nervosum*, and *S. praecox*, *S. tripinnatum* may exhibit higher flexural strength and stiffness, enabling it to withstand higher bending loads. However, it could have lower strength than *S. cumini*, *S. jambos*, *S. album*, and *S. brevistylum*.

Table 1. Fiber morphology of *Syzygium tripinnatum* Blanco (Merr.) stemwood and branchwood and other *Syzygium* species

Species	Fiber length (mm)	Fiber diameter (µm)	Lumen diameter (µm)	Cell wall thickness (µm)
S. Tripinnatum Blanco (Merr.)				
(Stemwood)	1.427	26.023	8.853	8.587
(Branchwood)	1.450	26.590	9.703	8.443
S. cumini (L.) Skeels*	1.767	25.130	18.620	3.260
S. fruticosum (Roxb.) DC.*	1.287	23.300	16.660	3.320
S. jambos (L.) Alston*	1.658	22.200	11.620	5.290
S. nervosum DC.*	1.405	24.040	17.910	3.070
S. praecox (Roxb.) Rathakr. & N.C. Nair*	1.362	20.760	14.390	3.180
S. album Q.F. Zheng**	1.578	20.660	4.420	8.095
S. brevistylum (C.B. Rob) Merr.***	1.688	26.000	12.000	7.000

Source: * Wangkhem et al. (2020); ** Sun et al. (2023); *** FPRDI (1996)

Based on the groupings devised by Salehi (2001), the fibers of *S. tripinnatum* fall under the second group which is characterized to have an average fiber length ranging from 0.9 to 1.9 mm and classified as medium-length of fiber under the Forest Product Research and Development Institute (FPRDI) (1996). According to Sharma et al. (2011), paper made from a longer fiber exhibited higher tearing resistance, and long fibers with thin cell walls were much preferable for pulp and paper manufacturing. Further, fibers with an average greater than 0.4 mm are considered suitable raw materials for papermaking (Suansa and Al-Mefarrej, 2020), while fibers of 1 to 5 mm length are commonly used for making composite materials (Madsen et al., 2013). Thus, *S. tripinnatum* fibers might be ideal for pulp and paper with a tolerable tearing strength and could potentially be used as a raw material for composite boards in furniture and structural applications when the trees become senile.

3.1.2 Fiber diameter (µm)

The results showed that D_1 had the largest fiber diameter, measuring 26.850 µm, followed by D_2 at 26.540 µm, and D_3 at 25.530 µm. The larger fiber diameter observed in D_1 could be attributed to a higher proportion of juvenile wood than the other diameter classes. According to Kartikawati et al. (2024), juvenile wood typically has a larger fiber diameter than mature wood. It is also observed that fibers in stemwood (26.020 µm) were 2.170% thinner than the fibers in branchwood (26.590 µm). However, the observed difference of fiber diameter between stemwood and branchwood was not significant with a p-value of 0.161. As compared to the fiber diameter of *E. tereticornis* (14.600 µm), and *E. grandis* (19.200 µm) (Sharma et al., 2011), *S. tripinnatum* fiber was relatively larger. However, it was thinner than the fibers of 3- and 7-year-old *Falcata* trees (35.440 µm and 38.010 µm, respectively) (Alipon et al., 2021). As shown in Table 1, *S. tripinnatum* fiber was relatively larger than other *Syzygium* species. According to Yahaya (2001), wood with a larger fiber diameter tends to exhibit higher strength properties. Thus, the relatively larger fiber diameter of *S. tripinnatum* suggests that this species could potentially possess higher strength than the other *Syzygium* species.

3.1.3 Lumen diameter (µm)

With the largest fiber diameter, D_1 also exhibited the largest lumen diameter, measuring 10.590 µm. This was followed by D_2 (9.640 µm) and D_3 (7.610 µm). The higher lumen diameter observed in D_1 is likely due to the greater proportion of juvenile wood in this diameter class, an occurrence also reported by Kartikawati et al. (2024) in *Diospyros kaki* wood. However, the proportion of juvenile and mature wood was not explored in the present study. This presents an interesting area for future research on this species to determine which diameter class has the higher proportion of mature wood for optimal wood production.

As to wood type, branchwood (9.703 µm) showed 9.600% larger lumen than stemwood (8.853 µm). However, analysis showed that the difference in result was not significant with a p-value of 0.147. The mean result of the study was relatively larger compared to *E. tereticornis* (5.120 µm), and *E. grandis* (6.670 µm) (Sharma et al., 2011), but thinner than 3- and 7-year-old *Falcata* trees (31.700 µm and 28.900 µm, respectively) (Alipon et al., 2021). Moreover, the majority of the *Syzygium* species (Table 1) exhibited larger lumen diameter than *S. tripinnatum*, except for *S. album.* According to Izani et al. (2008), wood with a larger lumen diameter tends to have lower relative density and strength properties. As shown in Table 1, the lumen diameter of *S. tripinnatum* was smaller compared to other *Syzygium* species, except for *S. album*, supporting the notion that this species could have better relative density and strength properties, reinforcing the earlier claim about its fiber diameter. Kiaei et al. (2014) noted that lumen diameter influences the beating process in pulp and paper production, as larger lumen diameters allow for better liquid penetration in the fibers. Based on this, *S. tripinnatum* fibers might facilitate an effective beating process.

3.1.4 Cell wall thickness (µm)

With the thinnest fiber and lumen diameter, D_3 recorded the thickest cell wall with 8.960 µm, followed by D_2 (8.450 µm) and D_1 (8.130 µm). The thicker cell wall in D_3 could indicate a higher proportion of mature wood in this diameter class. According to Kartikawati et al. (2024), mature wood typically has a thicker cell wall than juvenile wood which was also displayed in this present study.

Stemwood fibers (8.587 µm) recorded 1.670% thicker cell walls than branchwood fibers (8.443 µm). The result further validates the findings on Plumwood by Kiaei et al. (2014), and *G. falcatum* by Villareal et al. (2022b) that cell wall thickness increases as the wood matures, considering the property of the branch usually having juvenile wood and commonly exhibits thinner cell walls than the mature wood from the stem. However, analysis revealed no significant difference in cell wall thickness between wood types with a p-value of 0.681. The mean result of cell wall thickness was relatively thicker than *E. tereticornis* (4.740 µm), *E. grandis* (6.270 µm) (Sharma et al., 2011), 3- and 7-year-old *Falcata* trees (3.270 µm and 3.140 µm) (Alipon et al., 2021), and *A. cumingiana* (4.360 µm) (Villareal et al., 2022a). Compared to other *Syzygium* species (Table 1), *S. tripinnatum* fibers exhibited thicker cell wall. Cell wall thickness increases towards maturity. The present result suggests that *S. tripinnatum* fiber could be more rigid and produce less dense paper since the cell wall governs the fiber flexibility and the bulkiness of paper (Sharma et al., 2011). Furthermore, due to its thicker cell wall compared to *E. tereticornis*, Falcata trees, *A. cumingiana*, and other *Syzygium* species, *S. tripinnatum* could likely have better relative density and higher strength properties (NagarajaGanesh and Rekha, 2020).

3.2 Derived values

The derived values of *S. tripinnatum* stemwood and branchwood, such as the Runkel ratio, slenderness ratio, flexibility ratio, Mulhsteph ratio, and rigidity coefficient were presented in Table 2.

Table 2. Derived values of *Syzygium tripinnatum* Blanco (Merr.) stemwood and branchwood

Derived values	Wood type		Significant level of difference (p-value)
	Stemwood	Branchwood	
Runkel ratio	1.950	1.747	0.265^{ns}
Slenderness ratio	54.833	54.513	0.877^{ns}
Flexibility ratio (%)	34.017	36.520	0.272^{ns}
Mulhsteph ratio (%)	88.387	86.623	0.275^{ns}
Rigidity coefficient	0.330	0.320	0.288^{ns}

ns-not significant at 0.05 significant level

3.2.1 Runkel ratio

The highest Runkel ratio was recorded in the larger diameter (D_3) with a value of 2.840, followed by D_2 and D_1 having 2.070 and 1.890 Runkel ratio values, respectively. This result might be due to a higher proportion of mature wood in D_3 than D_2 and D_1. Also, the result showed an increasing trend wherein as the diameter increases, the Runkel ratio also increases. In terms of wood types, stemwood fibers (1.950) exhibited a 10.410% higher Runkel ratio than branchwood fibers (1.747). This result also conforms to the diameter status of the stem and branch since the stem diameter is normally larger than the branch diameter. On the other hand, no significant difference (p-value of 0.265) was observed signifying a comparable result of wood types. Moreover, the result of the study was relatively higher compared to *S. brevistylum* (1.170) (FPRDI, 1996), 3-, 5-, and 7-year-old *Falcata* trees (0.240, 0.220, and 0.260, respectively) (Alipon et al., 2021), and *A. cumingiana* (0.390) (Villareal et al., 2022a). Sharma et al. (2011) and Kiaei et al. (2014) stated that a Runkel ratio below 1.0 tends to indicate thin-walled fibers with good mechanical strength properties and are considered as the standard values that are relatively favorable in the viewpoint of papermaking. Based on the Runkel ratio results, the fiber of *S. tripinnatum* might be stiff, and difficult to collapse, thus forming bulkier paper with less venue for bonding, and relatively good for general construction purposes, cabinetry, tool handling, and pilings (FPRDI, 1996; Malabrigo and Umali, 2022). A similar observation was noted by Marasigan et al. (2024) on *S. cumini*, a species related to *S. tripinnatum*. They stated that the wood from this species is suitable for various applications, including construction, plywood, flooring, furniture, and pulp and paper production.

3.2.2 Slenderness ratio

The result showed that the highest value of slenderness ratio was recorded in D_3 (61.650), followed by D_2 (56.370), and D_1 (54.880) with the same trend of result to Runkel ratio. As for wood types, stemwood (54.833) recorded a 0.580% higher slenderness ratio than branchwood (54.513). This result corroborates the findings of Kiaei et al. (2014) on Plumwood exhibiting higher stemwood value (73.280) than branchwood (58.850). However, the analysis showed a comparable result (p-value of 0.877). The present result was relatively higher than those of 3-, 5-, and 7-year-old *Falcata* trees (34.330, 31.980, and 31.900, respectively) (Alipon et al., 2021), and *A. cumingiana* (30.950) (Villareal et al., 2022a). Moreover, the slenderness result of *S. tripinnatum* was within the acceptable value for papermaking which is 33 and above (Kiaei et al., 2014). This result further suggests the suitability of *S. tripinnatum* fibers for papermaking manufacture. Compared to Falcata trees and *A. cumingiana*, composite board made from *S. tripinnatum* could potentially have a higher modulus of elasticity and rupture, owing to its higher slenderness ratio (Ayrilmis et al., 2017).

3.2.3 Flexibility ratio (%)

Opposite to runkel and slenderness ratios, the sample with a larger stem diameter recorded the smallest value of 30.070% (D_3), while the D_1 with a smaller stem diameter recorded the highest value of 38.370% flexibility ratio. Likewise, the stemwood flexibility ratio (34.017%) was 7.350% lower than branchwood (36.520%). This result conforms to the findings of Kiaei et al. (2014) that branchwood (48.580%) showed a relatively higher flexibility ratio than stemwood (41.380%). However, this difference in the present result was not significant with a p-value of 0.272. Also, *S. tripinnatum* result was lower compared to 3-, 5-, and 7-year-old *Falcata* trees (81.990%, 82.780%, and 82.840%, respectively) (Alipon et al., 2021), and *A. cumingiana* (72.310 %) (Villareal et al., 2022a). Based on the flexibility groupings developed by Bektas et al. (1999), *S. tripinnatum* wood fibers were considerably rigid, signifying less efficiency and might require more chemicals to process and breakdown lignin component. Technically, the flexibility ratio underscores the potential of fibers to collapse during the beating of the paper web which greatly provides more bonding area (Zobel and Van Buijtenen, 1989). With higher flexibility ratio, it is expected to display higher tensile strength (Hartono et al., 2022).

3.2.4 Mulhsteph ratio (%)

The highest value of Mulhsteph ratio was recorded in D_3 with 91.115%, followed by D_2 (86.807%) and D_1 (84.444%). Further, stemwood with 8.387% Mulhsteph ratio showed a 1.990% higher than branchwood having 86.623% Mulhsteph ratio. Statistically, the result showed no significant difference (p-value of 0.275) indicating comparable Mulhsteph ratios of stemwood and branchwood. Based on the classification used by Hartono et al. (2022), the *S. tripinnatum* mulhsteph ratio falls in quality class III which is considered a high value that tends to produce a plastic paper which difficult to tear when folded. The result of the study was in the same class (quality class III) of *Dendrocalamus asper* (Schult.) Backer (Hartono et al., 2022), *Dendrocalamus strictus* (Roxb.) Nees, and *Guadua angustifolia* Kunt. (Marasigan et al., 2024), while the African wood fibers studied by Lestari et al. (2023) fell under quality class I. The value of the Mulhsteph ratio affects the tear and tensile strength, pulp's density, and the smoothness and durability of the paper (Hartono et al., 2022; Lestari et al., 2023).

3.2.5 Rigidity coefficient

The result showed a higher rigidity coefficient in D_3 (0.351), followed by D_2 (0.318) and D_1 (0.303). As to wood types, stemwood with 0.330 rigidity coefficient recorded a 3.030% higher than branchwood having 0.320 rigidity coefficient, although not a significant result. Moreover, this rigidity coefficient result of *S. tripinnatum* falls in quality class III with values greater than 0.15 based on the classification used by Hartono et al. (2022). The result of the study was in the same class (quality class III) *D. strictus* and *G. angustifolia* (Marasigan et al., 2024), while *D. asper* (Hartono et al., 2022) and African wood (Lestari et al., 2023) fell under quality class II. The rigidity coefficient is directly related to paper stiffness while inversely related to paper tensile strength. This means that the higher values of rigidity coefficient resulted to an increased stiffness, while the lower values of rigidity coefficient typically result in better tensile strength (Herlina et al., 2018; Lestari et al., 2023). Fibers with low rigidity coefficient value signify a good value wherein the fiber will be more flexible, and the paper produced will not easily be torn when given a tensile load (Hartono et al., 2022). With the present result, paper made from *S. tripinnatum* fibers seems to display high rigidity and stiffness but might easily tear when given a tensile load.

4. CONCLUSION

This study characterized the fiber morphology (fiber length, fiber diameter, lumen diameter, and cell wall thickness) and derived values (Runkel ratio, slenderness ratio, flexibility ratio, Mulhsteph ratio, and rigidity coefficient) of *S. tripinnatum* stemwood and branchwood. Results revealed that stemwood had thicker cell walls and higher values for the Runkel ratio, slenderness ratio, Mulhsteph ratio, and rigidity coefficient. In contrast, branchwood exhibited longer fibers, larger fiber and lumen diameters and higher flexibility ratio values. However, no significant differences were observed in any properties between stemwood and branchwood. Based on the fiber morphology, *S. tripinnatum* wood fibers are characterized as highly rigid and stiff which difficult to collapse potentially leading to bulkier paper with less bonded area, signifying less efficiency and suitability for pulp and paper requiring more chemicals to process. However, the result also suggested that *S. tripinnatum* wood would be potential for construction purposes, cabinetry, tool handling, and pilings based on the cell wall thickness, Runkel ratio, flexibility ratio, Mulhsteph ratio, and rigidity coefficient results. Farmers who cultivate this tree for fruit production might consider utilizing the wood for various applications or selling it to the wood industry once it reaches senility, rather than converting it to fuelwood. Further, characterization of the basic wood properties (i.e., physical, mechanical, and chemical properties) and technological properties (e.g., machining, veneering, seasoning) of *S. tripinnatum* wood in consideration of the maturity of trees, height levels, greater sample size, and habitat would be relevant information and factors to consider validating its suitability for the intended uses accurately.

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(3) Analysis and/or interpretation of data: Jayric F. Villareal, Cindy E. Poclis, Oliver S. Marasigan

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(5) Revising the manuscript for significant intellectual content: Jayric F. Villareal, Cindy E. Poclis, Oliver S. Marasigan

(6) Approval of the version of the manuscript to be published: Jayric F. Villareal, Cindy E. Poclis, Oliver S. Marasigan

DECLARATION OF COMPETING INTERESTS

The authors declare no conflict of interest.

REFERENCES

Alipon MA, Alcachupas PL, Bondad EO, Cortiguerra EC. Assessing the utilization of Falcata [*Falcataria moluccana* (Miq.) Barneby & J. W. Grimes] for lumber production. Philippine Journal of Science 2016;145(3):225-35.

Alipon MA, Bondad EO, Gilbero DM, Jimenez JP, Emmanuel PD, Marasigan OS. Anatomical properties and utilization of 3-, 5-, and 7-yr-old Falcata (*Falcataria moluccana* Miq. Barneby & J.W. Grimes) from CARAGA Region, Mindanao Philippines. Philippine Journal of Science 2021;150(5):1307-19.

Ayrilmis N, Akbulut T, Yurttaş E. Effects of core layer fiber size and face-to-face core layer ratio on the properties of three-layered fiberboard. BioResources 2017;12(4):7964-74.

Bektas I, Tutus A, Eroglu H. A study of the Suitability of Calabrian Pine (*Pinus brutia* Ten.) for Pulp and Paper Manufacture. Turkish Journal of Agriculture and Forestry 1999;23(3):589-99.

Coronel RE. Collection, Propagation and Conservation of Indigenous Fruits in thePhilippines. Acta Hortic 2002; 575:211-9.

Del Castillo MC. Philippine Wood Products Report. United States Department of Agriculture, Foreign Agricultural Service; 2021.

Dulay ED, Codilan AL, Galang MA, Tiburan CL, Veran GML, Balonga BP, et al. Diversity and conservation status of indigenous fruit trees in selected mountains of CALABARZON, Philippines. Ecosystems and Development Journal 2023;13(2):77-90.

Forest Products Research and Development Institute (FPRDI). Utilization of Lesser-Used Species (LUS) as Alternative Raw Materials for Forest-Based Industries. Japan: International Tropical Timber Organization (ITTO); 1996.

Hartono R, Purba FVA, Iswanto A, Priadi T, Sutiawan J. Fiber quality of yellow bamboo (*Bambusa vulgaris* vitata) from forest area with special purpose Pondok, Buluh, Simalungun Regency, North Sumatera Province. IOP Conference Series: Earth and Environmental Science 2022;1115(1):1315-755.

Herlina, Istikowati WT, Fatriani. Chemical analysis and fiber of pandan rasau (*Pandanus helicopus*) as an alternative raw material for paper pulp. Journal of the Sylva Scientaeae 2018;1(2):150-9.

Izani MAN, Sahri MH. Wood and cellular properties of four new Hevea species. Proceedings of the FORTROP II International Conference; Bangkok, Thailand; 2008.

Jamovi Project. Jamovi (Version 2.3) [Internet]. 2022 [cited 2024 Jul]. Available from: https://www.jamovi.org.

Kartikawati E, Bienitta, Prastiwi FW, Nugroho WD. Determination of the boundary between juvenile-mature wood of *Diospyros kaki* and their wood anatomical variations. Journal of the Korean Wood Science and Technology 2024;52(2):191-203.

Kiaei M, Tajik M, Vaysi R. Chemical and biometrical properties of plumwood and its application in pulp and paper production. Ciencia y tecnología 2014;16(3):313-22.

Lestari D, Ningsih RV, Fahrussiam F. Anatomical properties and quality of african wood fiber as a raw material for pulp and paper. Perennial 2023;19(2):17-22.

Madsen B, Brondsted P, Andersen TL. Biobased Composites: Materials and Potential Applications as Wind Turbine Blade Materials. Advances in Wind Turbine Blade Design and Materials. Amazon; 2013. p. 363-86.

Malabrigo PL, Umali AGA. Alay: Philippine Native Trees at the Victor O. Ramos Arboretum. Philippine Native Tree Enthusiasts (PNTE). Quezon City: 2022. p. 1-322.

Marasigan OS, Alipon MA, Bondad EO. Senile fruit-bearing trees as possible timber alternative: Physical and mechanical properties. Journal of Tropical Forest Science 2023;35(3):350-65.

Marasigan OS, Alipon MA, Bondad EO, Hopia KA, Mundin MAM. Physical and mechanical properties of thirteen senile fruit-bearing trees in the Philippines and their potential uses. Journal of Tropical Forest Science 2024;36(1):91-104.

NagarajaGanesh B, Rekha B. Intrinsic cellulosic fiber architecture and their effect on the mechanical properties of hybrid composites. Archives of Civil and Mechanical Engineering 2020;20(4):1-12.

Salehi K. Study and Determine the Properties of Chemi-Mechanical Pulping High Yields from bagasse. Wood and Paper Research No. 232, Research Institute of Forests and Rangelands; 2001.

Sharma AK, Dutt D, Upadhyaya JS, Roy TK. Anatomical, morphological, and chemical characterization of *Bambusa tulda*, *Dendrocalamus hamiltonii*, *Bambusa balcooa*, *Malocana baccifera*, *Bambusa arundinaceae*, and *Eucalyptus tereticornis*. Bioresources 2011;6(4):5062-73.

Suansa NI, Al-Mefarrej HA. Branchwood properties and potential utilization of this variable resource. Bioresources 2020; 15(1):479-91.

Sun M, Cao C, Zuo L, Yue X, Zhan M, Xu B. Study on basic wood properties of critically endangered species *Syzygium album*. Wood Research 2023;68(1):1-16.

Thumm A, Dickson AR. The influence of fibre length and damage on the mechanical performance of polypropylene/wood pulp composites. Composites Part A: Applied Science and Manufacturing 2013;46(1):45-52.

Villareal JF, Abasolo WP, Mendoza RC, Maldia LSJ. Fiber morphology and extractive content of *Aquilaria cumingiana* (Decne.) Ridl. wood from Davao Oriental, Philippines. Philippine Journal of Science 2022a;151(5):1623-31.

Villareal JF, De Guzman WB, Cortado JG, Poclis CE. Fiber morphology of Arangen (*Ganophyllum falcatum* Blume) stemwood and branchwood in San Gabriel, La Union, Philippines. Ecosystems and Development Journal 2022b;12(2):97-102.

Wangkhem M, Sharma M, Sharma CL. Comparative wood anatomical properties of genus *Syzygium* (Family Myrtaceae) from Manipur, India. Indonesian Journal of Forestry Research 2020;7(1):27-42.

Wheeler EA, Baas P, Gasson PE. IAWA list of microscopic features for hardwood identification. IAWA Bulletin 1989;10(3):219-332.

Yahaya MIB. Quality assessment of two timber latex clones of rubberwood (*Hevea brasiliensis*) [dissertation]. Serdang, Malaysia: Faculty of Forestry, University of Putra Malaysia; 2001.

Zobel BJ, Van Buijtenen JP. Wood Variation: Its Causes and Control. Berlin, Heidelberg, New York: Springer-Verlag; 1989.