

RESEARCH NOTE

Fiber morphology of *arangen* (*Ganophyllum falcatum* Blume) stemwood and branchwood in San Gabriel, La Union, Philippines

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ABSTRACT. The fiber morphology (fiber length and diameter, lumen diameter, and cell wall thickness) and derived values (Runkel ratio, slenderness ratio, and flexibility ratio) of *arangen* (*Ganophyllum falcatum* Blume) stemwood and branchwood were evaluated to determine variation between wood types. These were used as bases in recommending the potential of *arangen* wood for various end-uses. The highest mean fiber length (1.22 mm), cell wall thickness (6.36 μm), Runkel ratio (1.68), and slenderness (57.47) were recorded in the tree with a diameter of 44 cm (D3), while the highest mean fiber diameter (9.71 μm), lumen diameter (21.96 μm), and flexibility ratio (43.55) were recorded in the tree with 34 cm diameter (D2). A trend of fiber length was observed as tree diameter increased, while the opposite trend was observed for cell wall thickness. Relative to wood types, stemwood recorded the highest mean for fiber length (1.20 mm), fiber diameter (21.90 μm) and lumen diameter (9.36 μm), cell wall thickness (6.26 μm), Runkel ratio (1.62), and slenderness ratio (56.71). Statistically, no significant variation was observed in the fiber morphology and derived values between stemwood and branchwood. Based on the fiber length and lumen diameter results, *arangen* fiber would be suitable for pulp and paper with a good beating process. On the other hand, *arangen* fibers might be stiff, difficult to collapse, and form bulkier paper with less bonded area signifying less suitability for pulp and paper production but would be potential for building or construction purposes regardless of wood types based on the cell wall thickness, Runkel ratio, and flexibility ratio results. Further, the physical, mechanical, and chemical characterization of *arangen* wood would be relevant information to consider to validate its suitability for the intended uses.

Keywords: endemic, lesser-known species, pulp and paper, termite-resistant wood, wood anatomy

INTRODUCTION

As an archipelagic country in the South East Asian Region, the Philippines provides a habitat for diverse flora and fauna. Approximately 3,600 identified native trees, 67% of which are endemic in the country. These endemic tree species play an important role in supporting native wildlife and maintaining the ecological balance. The locals also utilize them as the main raw materials for furniture, house, or building constructions. Unfortunately, many of these

native trees are endangered due to deforestation, overharvesting and exporting, and replacement by invasive alien species and monocrop plantations (De Jesus, 2021). Also, there are potential native tree species that are lesser known or of lesser concern that need to be characterized for proper utilization.

Particularly, *arangen* or scaly ash (*Ganophyllum falcatum* Blume), of the family Sapindaceae, is a large dioecious

canopy tree and evergreen rainforest tree that can reach a height of 40 to 50 m and maintain a straight bole up to 20–45 m with a diameter of 80–95 cm (Rodriguez, 2018). It is also known as *arangen iloko*, *bagusalai*, *gogo*, *gogong-langit*, *gogolingin*, *halas*, *malatumbaga*, *odo*, *palumpong*, *pararan*, *saleng*, and *tugabi* (NTFP-EP, 2021). It is propagated through seeds with an 80% germination rate in 2–4 weeks, wherein the fruit pulp is removed through maceration and drying (Dasuki, 1998).

Arangen has a strong, durable, and termite-resistant wood commonly used for bridges, house/building construction, and other construction materials (Sutcliffe & Malabrigo, 2020). It appears to be toxic to some subterranean termites such as *Coptotermes acinaciformis* Froggatt. and *Nasutitermes exitiosus* Hill. The compounds extracted from the wood of *arangen* were tried for termite-proofing buildings (Simpson, 2019) and proven to possess termiticidal activity (Dasuki, 1998). Further, the wood and the bark contain saponin and are used to make soap against head lice and as a fish poison. Its sawdust has been proven to be an appropriate medium for oyster mushroom (*Pleurotus ostreatus* Fries) cultivation, while the seed yields a solid fat used for illumination and hard soap (Dasuki, 1998; Fern, 2014). Also, *arangen* may have the potential for increased use from natural sources, and its potential as a plantation crop deserves more attention.

Despite the potential of *arangen*, particularly its wood, it is considered the least concerned tree species and quite overlooked based on the IUCN 2020–2 (Sutcliffe & Malabrigo, 2020). For this reason, more information is needed about the properties of this species. To further assess the quality of *arangen* wood, it is vital to have a characterization and understanding of its basic properties for proper and efficient utilization. Thus, this study aims to characterize the fiber morphology of *arangen* stemwood and branchwood with different diameters. This study provides significant information on the characteristics of *arangen* wood, specifically on the fiber morphology that ultimately impacts the wood product properties for wood-based industry and scientific purposes. Hence, this is a pioneering study in the country and will also serve as a basis for further study about *arangen* tree species and related topics.

METHODOLOGY

Plant materials and wood samples collection

Arangen wood samples were collected at San Gabriel, La Union (Figure 1). The wood samples with three replications were taken from the stemwood and

branchwood of the selected three naturally grown or wild *arangen* trees with different diameters at breast height (DBH) (D1 – 26 cm, D2 – 34 cm, and D3 – 44 cm) using the increment borer. Stem 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 collecting wood samples, the holes in the trees caused by increment borer were patched with wood and painted to keep away from the wood-boring/degrading macro/microorganisms like fungi and insects. Considering the location and availability of *arangen* trees in the natural stand/area, a systematic selection of tree sample diameters and their age/maturity were disregarded.

Fiber morphology of *arangen* wood

Fiber maceration. Matchstick-sized samples were prepared from the collected wood samples and then macerated in equal volumes of 50% acetic acid and 50% hydrogen peroxide (50% concentration) following the procedure of Espiloy *et al.* (1999). The maceration was done in a water bath and heated for six hours 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.

Fiber measurement. Before fiber measurement, the macerated samples inside the test tubes were shaken to further separate the different structural elements. Thirty undamaged or unbroken fibers were observed per replicate under the Phenix 300 series microscope and measured using ImageJ Software. The fibers' length, diameter, and lumen diameter were measured, while cell wall thickness was determined based on the difference between fiber diameter and lumen diameter.

Derived values. Using the data measured from fiber characterization, the derived values such as Runkel ratio (1), Slenderness ratio (2), and Flexibility ratio (3) were computed using the equation used by Villareal *et al.* (2020).

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

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

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

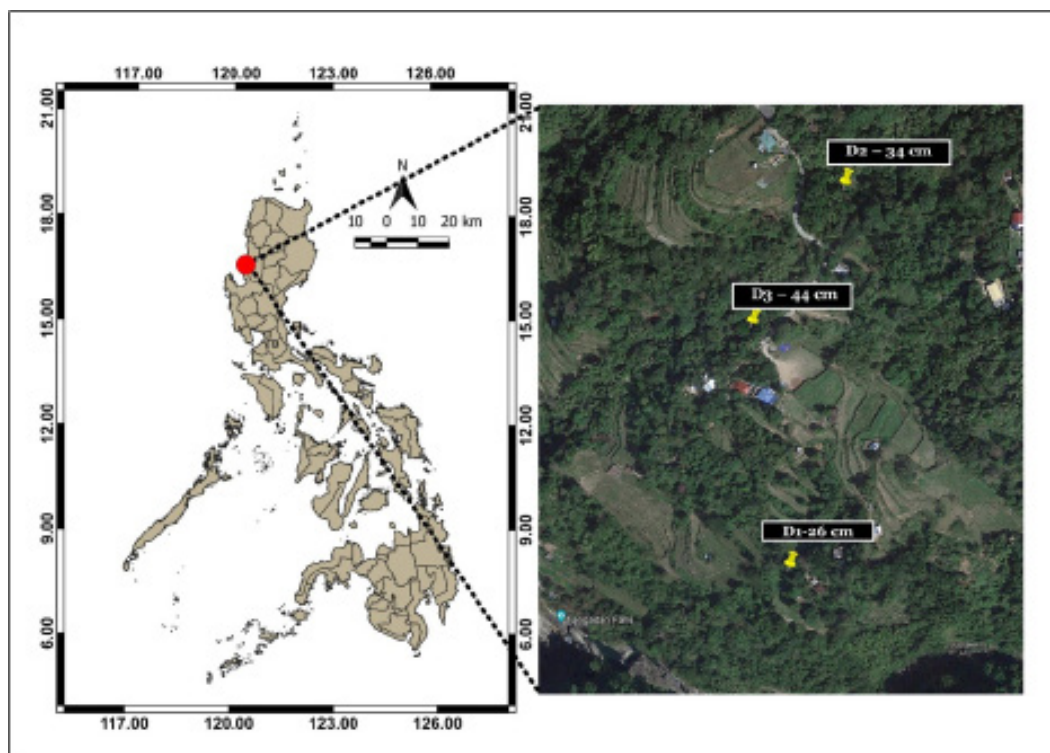


Figure 1. Location map of *arangen* wood samples in San Gabriel, La Union, Philippines.

Statistical analysis

T-test was used to compare the difference in fiber morphology and derived values of the wood types. The statistical analysis was generated using RStudio v. 2020 (R Core Team, 2020).

RESULTS AND DISCUSSION

Fiber morphology of *arangen* wood

The fiber morphology of *arangen* stemwood and branchwood, such as fiber length, fiber diameter, lumen diameter, and cell wall thickness, was presented in Table 1.

Fiber length (mm). The longest fiber was recorded in D3 with 1.22 mm, followed by D2 (34 cm) with 1.13 mm, and D1 (26 cm) with 1.10 mm. The result showed an increasing trend of fiber length as tree diameter increased. This signifies that trees with larger diameters tend to exhibit longer fiber lengths. This result supports the findings of Taylor (1973) on *Eucalyptus grandis* Hill ex Maiden grown in South Africa, wherein rapidly elongating stems exhibit longer fibers. On the other hand, the mean fiber length from stemwood 1.20 mm was relatively longer than the fibers of

branchwood (1.09 mm). However, statistical analysis showed no significant difference between stemwood and branchwood. This result supports the findings of Kaei *et al.* (2014) on plumwood having longer fiber on stemwood than branchwood with 0.98 and 0.97 mm, respectively. Similarly, Bhat *et al.* (1989) findings on eleven tropical Indian hardwoods grown in Kerala and Yaman (2014) on *Ficus carica* L. ssp. *carica* showed shorter branchwood fibers than stemwood fibers.

Table 1. Fiber morphology and derived values of *arangen* stemwood and branchwood.

Property	Wood type		Significant level of difference (P-value)
	Stemwood	Branchwood	
Fiber length (mm)	1.20	1.09	0.1387 ^{ns}
Fiber diameter (μm)	21.90	21.25	0.4232 ^{ns}
Lumen diameter (μm)	9.36	9.14	0.8189 ^{ns}
Cell wall thickness (μm)	6.26	6.05	0.4253 ^{ns}
Derived value			
Runkel ratio	1.62	1.56	0.7834 ^{ns}
Slenderness ratio	56.71	52.68	0.1905 ^{ns}
Flexibility ratio	42.09	42.37	0.9273 ^{ns}

^{ns} – not significant at 5% level

The mean fiber length of *arangen* was relatively comparable with hardwoods (1.0 mm) (Anupam *et al.*, 2016) and 3-, 5-, and 7-year-old *Falcata* trees (1.16, 1.14, and 1.17, respectively) (Alipon *et al.*, 2021), shorter compared to softwoods (3.5 mm), and longer than the fibers of *Eucalyptus tereticornis* (0.72 mm), *E. grandis* (0.92 mm) (Sharma *et al.*, 2011), *Aquilaria cumingiana* (Decne.) Ridl. (0.98 mm) (Villareal *et al.*, 2022), and *M. azedarach* L. (0.57 mm) (Megra *et al.*, 2022). Based on the groupings devised by Salehi (2001), the fibers of *arangen* fall under the second group, which is characterized to have an average fiber length ranging from 0.9 to 1.9 mm. According to Sharma *et al.* (2011), long fibers with thin cell walls were much preferable for pulp and paper manufacturing since the longer the fiber, the higher the tearing resistance of the paper. Also, cited in the study of Suansa and Al-Mefarrej (2020), fibers with an average of greater than 0.4 mm are considered suitable raw materials for papermaking. Thus, based on the results, *arangen* fiber length would be suitable for pulp and paper.

Fiber diameter (μm). The largest fiber diameter was recorded in D2 with 21.96 μm , followed by D3 with 21.69 μm , and D1 with 21.07 μm . Between wood types, stemwood fiber (21.90 μm) showed larger fiber than branchwood (21.25 μm). This trend conforms with the result obtained by Yaman (2014) on *F. carica* L. ssp. *carica*, in contrast with the result of Kiaei *et al.* (2014) on plumwood, shows a larger fiber diameter of branchwood than stemwood. Although, no significant difference was observed in this study. The variation in the result proves that wood is a highly variable and complex material that exhibits variation between and within species and even within a tree. The fiber diameter of *arangen* was relatively thinner than those of hardwoods (25.0 μm), softwood (35.0 μm) (Kiaei *et al.*, 2014), *Gmelina* (27.16 μm) (Prabawa, 2017), and 3- and 7-year-old *falcata* trees (35.44 μm and 38.01 μm , respectively) (Alipon *et al.*, 2021), but larger than those of *Acacia nilotica* L. (18.50 μm), *Casuarina equisetifolia* Forst. (14.50 μm) (Subrahmanyam *et al.*, 2004), *E. tereticornis* (14.60 μm), *E. grandis* (19.20 μm) (Sharma *et al.*, 2011), plumwood (13.77 for stemwood and 16.83 for branchwood) (Kiaei *et al.*, 2014), and *M. azedarach* (13.45 μm) (Megra *et al.*, 2022).

Lumen diameter (μm). Like fiber diameter, the largest lumen diameter was recorded in D2, with 9.71 μm , while D3, with 8.97 μm , records the lowest. The lumen diameter observed from stemwood (9.36 μm) was larger than branchwood (9.14 μm). This result agrees that lumen diameter increases as the tree's age or maturity increases, considering the maturity

of stemwood compared to branchwood even within a tree (Alipon *et al.*, 2021). Anupam *et al.* (2016) also pointed out that fiber lumen varies for different species. Likewise, Moya Roque and Tomazelo-Filho (2007) reported that lumen diameter could be attributed to the physiological development of wood as the tree grows in girth and ages. However, no significant difference was observed. The result was relatively thinner than *F. carica* L. ssp. *carica* (12.50 μm for stemwood and 12.40 μm for branchwood) (Yaman, 2014), *Gmelina* (21.12 μm) (Prabawa, 2017), 3- and 7-year-old (31.70 and 28.90 μm , respectively) (Alipon *et al.*, 2021), and *M. azedarach* (13.03 μm) (Megra *et al.*, 2022), but larger than those of *A. nilotica* (6.12 μm), *C. equisetifolia* (2.80 μm) (Subrahmanyam *et al.*, 2004), *E. tereticornis* (5.12 μm), *E. grandis* (6.67 μm) (Sharma *et al.*, 2011), plumwood (5.60 μm for stemwood and 7.99 μm for branchwood) (Kiaei *et al.*, 2014). Kiaei *et al.* (2014) reported that lumen diameter contributes to the beating process of pulp and paper production due to liquid penetration in the empty spaces of the fibers. Based on the study result, the beating process of *arangen* fibers would be favorable.

Cell wall thickness (μm). The thickest cell wall was recorded in D3 with 6.36 μm , followed by D2 with 6.12 μm and D1 with 5.99 μm . An increasing trend of the result was observed as the tree diameter decreased. Regarding wood types, stemwood cell wall (6.26 μm) was relatively thicker than the branchwood (6.05 μm). This result conforms to the general trend of increasing cell wall thickness as age increases and considering the juvenile wood property of branch that commonly exhibits thin cell walls. Yaman (2014) observed the same result trend on *F. carica* L. ssp. *carica* showing stemwood cell wall relatively thicker than branchwood. In comparison with *E. tereticornis* (4.74 μm) (Sharma *et al.*, 2011), plumwood (4.08 μm for stemwood and 4.42 μm for branchwood) (Kiaei *et al.*, 2014), *F. carica* L. ssp. *carica* (4.50 μm for stemwood and 3.60 μm for branchwood) (Yaman, 2014), *gmelina* (3.01 μm) (Prabawa, 2017), 3- and 7-year-old (3.27 μm and 3.14 μm , respectively) (Alipon *et al.*, 2021), *A. cumingiana* (4.36 μm) (Villareal *et al.*, 2022), and *M. azedarach* (2.52 μm) (Megra *et al.*, 2022), the cell wall of *arangen* fibers was relatively thicker. While relatively comparable with *A. nilotica* (5.40 μm), *C. equisetifolia* (5.84 μm) (Subrahmanyam *et al.*, 2004), and *E. grandis* (6.27 μm) (Sharma *et al.*, 2011). Moreover, it was shown that the *arangen* fiber could be more rigid and produce less dense paper considering cell wall thickness governs the fiber flexibility and the bulkiness of paper (Sharma *et al.*, 2011). The fibers with short and thin-walled exhibit a plastic formation that offers more surface contact and bonding (Dutt *et al.*, 2005).

Derived values

The derived values of *arangen* stemwood and branchwood, such as the Runkel ratio, slenderness ratio, and flexibility ratio, were presented in **Table 1**.

Runkel ratio. The highest value of the Runkel ratio was recorded in D3 with 1.68, followed by D1 (1.62) and D2 (1.46). The stemwood fiber (1.62) showed a relatively higher Runkel ratio than the branchwood fiber (1.56), which corroborates the findings of Kiaei *et al.* (2014) on plumwood with 1.56 Runkel ratio from stemwood higher than from branchwood with 1.21 Runkel ratio. However, no significant result was observed between stemwood and branchwood of *arangen*. Moreover, the result of the study was relatively higher compared to 3-, 5- and 7-year-old *Falcata* trees (0.24, 0.22, and 0.26, respectively) (Alipon *et al.*, 2021), *A. cumingiana* (0.39) (Villareal *et al.*, 2022), and *M. azedarach* (0.39) (Megra *et al.*, 2022). Sharma *et al.* (2011) stipulated that a Runkel ratio below 1 exhibits good mechanical strength properties and is suitable from the viewpoint of papermaking. Kiaei *et al.* (2014) also specified that the standard values of the Runkel ratio are less than 1. Based on the Runkel ratio of the study, *arangen* fibers might be stiff, difficult to collapse and form bulkier paper with less bonded area regardless of wood types and diameters.

Slenderness ratio. The highest result for the slenderness ratio was recorded in D3 with 57.47, followed by D1 (53.91) and D2 (52.70). The slenderness ratio of stemwood (56.71) was relatively higher than branchwood. This result supports the findings of Kiaei *et al.* (2014) that stemwood showed a higher slenderness ratio than branchwood. The result of the study was relatively higher than those of 3-, 5-, and 7-year-old *falcata* trees (34.33, 31.98, and 31.90, respectively) (Alipon *et al.*, 2021), *A. cumingiana* (30.95) (Villareal *et al.*, 2022), and *M. azedarach* (42.47) (Megra *et al.*, 2022), but lower compared to plumwood with 73.28 (stemwood) and 58.85 (branchwood). Further, the slenderness result of *arangen* was within the acceptable value higher than 33 (Kiaei *et al.*, 2014). Statistically, no significant difference in the slenderness ratio was observed between stemwood and branchwood.

Flexibility ratio. The highest flexibility ratio of *arangen* was recorded in D2 at 43.55, followed by D1 (42.43) and D3 (40.72). The result also revealed a higher flexibility ratio in branchwood (42.37) than stemwood (42.09). The result conforms with the findings of Kiaei *et al.* (2014) that branchwood showed a relatively higher flexibility ratio than stemwood. Also, the result was comparable with the stemwood of plumwood (41.38)

while lower than those of branchwood of plumwood (48.58) (Kiaei *et al.*, 2014), 3-, 5- and 7-year-old *Falcata* trees (81.99, 82.78, and 82.84, respectively) (Alipon *et al.*, 2021), *A. cumingiana* (72.31) (Villareal *et al.*, 2022), and *M. azedarach* (96.9) (Megra *et al.*, 2022).

Based on the flexibility groupings developed by Ekhuemelo & Tor (2013), *arangen* wood fibers were considerably rigid, signifying less suitability for pulp and paper production relating to the cell wall thickness and Runkel ratio results. The flexibility ratio expresses the potential of fibers to collapse during the beating or drying of the paper web. The collapsed fibers provide more bonding area, and the degree of fiber bonding depends greatly on the flexibility of individual fibers (Zobel & Van Buijtenen, 1989).

CONCLUSION

The fiber morphology (fiber length, fiber diameter, lumen diameter, and cell wall thickness) and derived values (Runkel ratio, slenderness ratio, and flexibility) of *arangen* stemwood and branchwood with different diameters were characterized in this study. Statistically, no significant difference was observed in all properties between stemwood and branchwood. Based on the fiber length and lumen diameter results, *arangen* fiber would be suitable for pulp and paper with a favorable beating process.

Arangen fibers might be stiff, difficult to collapse, and form bulkier paper with less bonded area signifying less suitability for pulp and paper production, but would be potential for building or construction purposes regardless of wood types based on the cell wall thickness, Runkel ratio, and flexibility ratio results. Further, the physical, mechanical, and chemical characterization of *arangen* wood would be relevant information to consider to validate its suitability for the intended uses.

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