Fiber dimension and anatomy of *Acacia mangium* wood from two mother trees

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**Abstract.** Mangium (*Acacia mangium*) has been opted as one of potential species for the establishment of industrial timber estate in Indonesia, particularly to support the production of pulp and paper. In order to obtain mangium stands that produces high quality wood, one attempt can be carried out through the selection and development of potential mother trees from the selected provenances. This study aim to obtain information on fiber dimension and the anatomy of mangium wood from two different mother trees from Papua New Guinea provenance. The wood was collected from mangium estate in Wonogiri forest research which was established in 2012 and managed by the Center Forest Biotechnology and Tree Improvement. Maceration process followed Forest Product Laboratory guidance and the preparation followed Sass method. The wood anatomical terminology referred to IAWA (International Association of Wood Anatomists) list of microscopic features for hardwood identification was used to scrutinize the samples. The results showed that the average fiber dimension of mangium from the mother tree group 1 was 1239 micron (length), 25.96 micron (fiber diameter), and 3.67 micron (cell wall thickness). Those from the mother tree group 2 possess the dimension as follow: 1215 micron (length), 25.42 micron (fiber diameter), and 3.73 micron (cell wall thickness). The fiber quality of mangium fiber from both mother tree groups could be considered in the quality class II. The anatomical structure of mangium from both mother tree groups include vessels cells in radial multiples radial multiple of 2-3 or 4 cells; vesiured intervessel pits; parenchyma vascicentric and aliform; all ray cells procumbent and prismatic crystals in chambered axial parenchyma cells.

**1. Introduction**

Mangium wood (*Acacia mangium* Willd.) is widely known for its use as a fiber-producing material as well as construction, furniture and energy materials. Currently, mangium is one of the species selected for the development of timber estate in Indonesia. The main purpose for the species development is to meet the raw materials demand from the pulp and paper industry.

The conventional development of mangium plantations still uses seeds which are not resulted from the breeding technology. Therefore, the timber production is still not optimal yet. Due to this, a number of tree breeding techniques has been investigated. Many efforts have been made to breed mangium species in order to attain superior quality seeds with good quality wood.

One of the breeding techniques developed is through the selection of mother trees from the same provenance. The mother tree selection technique could affect several wood qualities such as density, cellulose content, tangential and radial shrinkage ratio (T/R ratio), initial moisture content, etc. [1, 2]. Nevertheless, less attention is still given to understand that specific breeding technique on the anatomical
structure of the wood. This paper thus aimed to investigate the fiber quality as well as the anatomical structure of mangium wood from 2 different mother trees from the same provenance (Papua New Guinea) which were originally planted in 2012 in Wonogiri research forest managed by the Center for Forest Biotechnology and Tree Improvement.

2. Materials and Methods
The main materials used were 4-year old mangium samples collected from the bottom and top parts of the original trunks (4 samples for each part). The diameter range of the wood was 400-500 mm. The original trunks were from two mother tree groups from Papua New Guinea provenance which were planted in Wonogiri research forest. Two trees were collected from each mother tree group.

The maceration process for determining fiber length, lumen diameter and wall thickness followed the method developed by Forest Product Laboratory in Rulliaty [3]. The derivatives factors values were counted following Nurrahman and Silitonga [4]. The determination of fiber quality class as a raw material for paper followed the guidance developed by Haroen [5]. The wood anatomical features were determined on transverse/cross, radial and tangential section which were prepared according to the Sass method [6]. IAWA list of microscopic features for hardwood identification was also used for the observation of wood anatomical features [7].

3. Results and Discussion
3.1 Mangium fiber dimension and quality
The fiber dimension of wood is one of the factors affecting the quality of pulp and paper. Fiber length, fiber diameter, lumen diameter and cell wall thickness also affect their derivatives factors values such as Runkle ratio, felting power, Muhlsteph ratio, flexibility ratio and coefficient of rigidity. Table 1 and Table 2 show the fiber dimension and their derivative factors of mangium wood investigated in this study. According to the fiber quality classification grade for pulp and paper raw materials [5], mangium fiber dimension and its derivative factors values are categorized into quality class II.

Table 1. Fiber dimension of 4-year old mangium from 2 mother tree groups

| Mother tree | Fiber length, µm | Fiber diameter, µm | Lumen diameter, µm | Cell wall thickness, µm |
|-------------|------------------|--------------------|--------------------|------------------------|
| I           | 1239.5±53.92     | 25.96±0.19         | 18.12±0.14         | 3.67±0.17              |
| II          | 1215.8±53.96     | 25.42±0.05         | 17.95±0.08         | 3.73±0.09              |

According to Haroen [5] and Kasmudjo [8], density and fiber dimension affect the pulp yield and quality resulted from the pulping process. Syafii and Siregar [9] also stated that the pulp properties of a wood can be predicted based on its fiber dimension and derivative factors values.

The fiber length of mangium wood studied ranges from 1215 µm to 1239 µm and cell wall thickness from 3.67 µm to 3.73 µm. The fiber length of A. mangium in present study was higher than average fibre dimension of 4-year-old and 8-year-old A. mangium grown in Malaysia (933.7 µm and 1017.5 µm) [10]. According to Lim et al., [11], the mean fibre length of trees (age: 20-year) was 1048 µm whereas for the 16-year the mean fibre length was 954 µm. In contrast, fibre wall thickness in this study was commonly smaller than which grown in Malaysia (3.3 µm, 4.3 µm, 8 µm and 9 µm). Based on IAWA classification [7], this mangium fiber length is in medium class (900-1600 µm). According to Kasmudjo [8], the common range of the fiber length of broad-leaf wood species is 800-1500 µm. The fiber length is a crucial parameter since it contributes to the quality of paper tearing strength [9].
According to the fiber quality grade shown in Table 3, the Runkle ratio of the studied mangium fiber is relatively low (0.4). A fiber with low Runkle ratio is a very good raw material for pulp production due to its thin wall, wide lumen diameter, easy to flatten, and possesses high tensile and bursting strength [9]. Nevertheless, the felting power of the studied mangium fiber is also low (47). A fiber with high felting power value is more flexible and has better tearing strength than that with low felting power [9]. Muhlsteph ratio of the studied mangium fiber is classified into medium class (49-51). The lower the Muhlsteph ratio is, the higher the pulp sheet density and its strength are [9].

### Table 2. Quality grade of 4-year old mangium fibers for pulp and paper raw materials

| No. | Mother tree | Fiber length, µm | Runkle ratio | Felting power | Muhlsteph ratio (%) | Flexibility ratio of rigidity | Total score | Fiber quality |
|-----|-------------|-----------------|--------------|---------------|---------------------|-----------------------------|-------------|---------------|
| 1.  | I           | 1239.5±53.92    | 0.40         | 47.74         | 51.24%              | 0.69                        | 0.14        | 400 II       |
|     | Score       | 50              | 75           | 50            | 75                  | 75                          | 75          |              |
| 2.  | II          | 1215.8±53.96    | 0.41         | 47.81         | 49.17%              | 0.70                        | 0.14        | 400 II       |
|     | Score       | 50              | 75           | 50            | 75                  | 75                          | 75          |              |

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### Table 3. Fiber quality grade [5]

| Unit                  | I       | II      | III     | IV      |
|-----------------------|---------|---------|---------|---------|
| Fiber length (L), (micron) | Limit | Value | Limit | Value | Limit | Value | Limit | Value |
| 2200                  | 100     | 1600-2200 | 75     | 900-1600 | 50    | 900   | 25    |
| Runkle ratio (2w/l)   | 0.25    | 100     | 0.25-0.50 | 75     | 0.5-1.0  | 50    | 1.0  | 25    |
| Felting power (L/d)   | 90      | 100     | 70-90   | 75     | 40-70    | 50    | 40   | 25    |
| Muhlsteph ratio (%)   | 30      | 100     | 30-60   | 75     | 60-80    | 50    | 80   | 25    |
| Flexibility (l/d)     | 0.80    | 100     | 0.60-0.80 | 75     | 0.40-0.60 | 50    | 0.40 | 25    |
| Rigidty coefficient (W/d) | 0.10   | 100     | 0.10-0.15 | 75     | 0.15-0.20 | 50    | 0.20 | 25    |
| Total                 | 600     | 450     | 300     | 150     |
| Ranges                | 451-600 | 301-450 | 151-300 | <150    |

The flexibility ratio of the studied mangium fiber is also in medium class (0.69-0.70). This parameter is the ratio between lumen diameter and fiber diameter. Syafii and Siregar [9] stated that a fiber with high flexibility ratio has thin wall and a shape that is easy to change. The ability to change shape assists in improving the contact between the fiber surfaces. As a further result, better bonding between fibers is created and the pulp sheet produced will have good strength quality [9]. On the other hand, a fiber with low flexibility ratio has small lumen diameter. As a result, the pulp sheet and paper produced will be thick with uneven surface and low bursting strength [12].
The rigidity coefficient of the studied mangium fiber is also in medium class (0.14). The rigidity coefficient is the ratio between the fiber wall thickness and fiber diameter. The lower the coefficient value is, the higher the tensile strength of the paper [9]. Table 2 further shows that the fiber quality of the studied mangium is at II grade. It matches the research result of Nirsatmanto et al. [13] that Acacias species used were classified as level II. This result means that the quality of the studied fiber meets the requirement as raw material for pulp and paper production.

3.2. General features and anatomical structure of mangium wood

The general features of the heartwood of mangium wood is indicated by its colour shades, from pale brown to dark brown. Its sapwood, on the other hand, has colour shades from pale yellow to yellow. Nevertheless, the heartwood has not developed yet in the studied mangium wood due to its young age. Other features are smooth to quite coarse texture; straight to intertwined fiber; quite shiny, plain, slippery and hard surface. The anatomical features are shown in Table 4 and Figure 1-3 below.

Table 4. The anatomical features of 4-year old mangium

| No. | Features            | Information                                                                                                                                 |
|-----|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Growth ring         | indistinct                                                                                                                                   |
| 2   | Vessels             | diffuse, solitary and radial multiples of 2-3 and sometimes 4; the average length is 339.14 ± 17.91 μm, the average diameter is 201.12 ± 14.13 μm; simple perforation plates; intervessel pits alternate and vestured (Figure 1) |
| 3   | Parenchyma          | vasicentric, aliform; four (3-4) cells per parenchyma strand length (Figure 1)                                                                 |
| 4   | Ray cells           | all ray cells procumbent; ray width 1 to 3 cells (Figure 2)                                                                                   |
| 5   | Fiber cells         | Fibers with simple to minutely bordered pits; fibres thin-to thick-walled; the mean fibre lengths is 1239.5 ± 53.92 μm (for mother tree group 1) and 1215.8 ± 53.96 μm (for mother tree group 2); the mean wall thickness is 3.67 ± 0.17 μm (for mother tree group 1) and 3.73 ± 0.09 μm (for mother tree group 2) (Figure 3) |
| 6   | Mineral inclusion/deposit | Prismatic crystals present in chambered axial parenchyma cells                                                                                     |

Species of A. mangium belonging to the family Leguminosae. This species is native to Australia, Papua New Guinea, and Indonesia [11]. The sapwood and heartwood of A. mangium have distinct colours. The sapwood is often white or yellowish white and the heartwood is yellowish brown to golden-brown when fresh [10,11]. Growth rings of A. Mangium are absent, vessels is solitary and diffuse, in radial multiples of 2-3 (-4); parenchyma is mainly scanty paratracheal to very thinly vasicentric, occasionally aliform, strand length of 2 to 4 cells; perforation simple; intervessel pits alternate; tyloses absent or sparse; ray mostly 1-2 cells wide rarely 3 and prismatic crystals present in chambered axial parenchyma cells [10,11]. The observation carried out for the anatomical structure of the 4-year old mangium wood is in harmony with the above statements.
4. Conclusion
The fiber of 4-year old mangium collected from Wonogiri research forest has II quality grade. Its quality meets the requirement as raw material for pulp and paper. The observation carried out for the anatomical structure of the 4-year old mangium wood supports previous record on the same species.

Figure 1. Transverse section (a) showing vessel and parenchyma

Figure 2. Radial (b) and tangential (c) section showing ray cells procumbent and ray width 1 to 3 cells

Figure 3. Vessels and fibers of *Acacia mangium* in maceration
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