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Relationship of Dipterocarpaceae in Ketambe Research Station, Gunung Leuser National Park based on morphological diversity of vegetative organs

E Harnelly1*, A Sara2, Iqbar1, N Fathiya3, and A H Umam4

1Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
2Bachelor Program of Biology, Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
3Master Program of Biology, Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
4Forestry Department, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

*Corresponding author’s email: essy.harnelly@unsyiah.ac.id

Abstract. This study examines the relationship of Dipterocarpaceae in Ketambe Research Station Gunung Leuser National Park. This is based on the study of morphological diversity of vegetative organs which was carried out in July 2015 to June 2016 (one year). Quadrat sampling technique and purposive sampling technique methods were employed in this research and the data was analyzed using R2.10.0 program. Morphology identification and preservation of samples were done at Acehnese Herbarium, Department of Biology, Faculty of Mathematics and Natural Sciences, Syiah Kuala University. The results showed that there were five Dipterocarpaceae species in Ketambe Research Station which are Hopea dryobalanoides, Shorea parvifolia, Shorea lepidota, Shorea johorensis, and Parashorea lucida. These five species were grouped into three clusters, the first clusters consisted of Hopea dryobalanoides, the second cluster consisted of Parashorea lucida, and the third cluster consisted of Shorea johorensis, Shorea parvifolia, and Shorea lepidota. The closest relationship was Shorea parvifolia and Shorea lepidota with a distance of 3.464102. The furthest relationship was Hopea dryobalanoides and Parashorea lucida with a distance of 6.633250.

1. Introduction

Dipterocarpaceae is a family of plant that belongs to the large tree species which is commonly found in Indonesia especially in Sumatra, Borneo, Lombok, Bali, Java, Sulawesi and Papua. In Sumatra, Shorea, Hopea, Anisoptera, Vatica and Dipterocarpus are the most common Dipterocarpaceae genus found [1]. Dipterocarpaceae is commonly found in wet climates and high humidity, growing at an altitude of 0-800 meters above sea level, with rainfall of 2.000 mm/year [2]. Dipterocarpaceae has commercially valuable timber and non-timber production [1].

As a result of this, large scale logging of Dipterocarpaceae tree species has been in practice for years. This has led to a drastic reduction in the number of Dipterocarpaceae in the tropical rainforest, threatening its species existence and greatly reducing the numerous potentials of the plant [3].
If vegetation suffers natural or man-made disturbances, the recovery process will occur naturally through natural succession or human assistance through restoration or reforestation [4]. However, if the damage is inflicted continuously by humans, the process of succession will be difficult. Changes that occur within an ecosystem can cause genetic variation in forest plants. It is due to the spatial distribution of genetic information resulting from mutation, gene flow, genetic drift, and natural selection.

Gunung Leuser National Park area has good zoning for management such as the availability of core zone, jungle zone, utilization zone, rehabilitation zone, traditional zone, religious zone, and special zone. This makes it possible to avoid destruction in some areas [5]. However, currently, there are many other areas suffering deforestation. The losses of the habitat of various living things and habitat, as well as disruption of the hydrological cycle are some of the effects of forest encroachment. This led to the emergence of primary and secondary forest. We analyzed the vegetation in primary and logged-over forests to investigate the species composition in the Ketambe research station, Gunung Leuser National Park. Shorea was one of the genera of Dipterocarpaceae found in this area [6]. However, there is insufficient information on the relationship data of Dipterocarpaceae. Therefore, this research was conducted to compile data on the diversity of species of Dipterocarpaceae in Ketambe Research Station.

2. Materials and methods
2.1. Study Area
The research was conducted in Ketambe Research Station, Gunung Leuser National Park, Aceh Tenggara, Aceh Province, Indonesia (Figure 1). The research was carried out from July 2015 to June 2016.
2.2. Samples Collection
Sample of leaves, morphological characteristic, and photos of Dipterocarpaceae were collected from Ketambe Research Station, Gunung Leuser National Park, Aceh Tenggara (Figure 1). The samples were collected using quadrat sampling technique. The identification of the sample was done in the selected area by analyzing the species of Dipterocarpaceae. The morphological observation was done on the stem and leaf organs. Samples which have been identified will be collected as data to be stored in the Acehnese herbarium, Department of Biology, Universitas Syiah Kuala.

2.3. Data Analysis
The data of Dipterocarpaceae species was analyzed by R2.10.0 program which is presented in table 3 and figure 7.

3. Results and Discussion
The results showed that there were five Dipterocarpaceae species found in the area, i.e. pepening (*Hopea dryobalanoides*), kayu merah (*Shorea parvifolia*), semantok (*Shorea lepidota*), meranti kacar (*Shorea johorensis*), and entap (*Parashorea lucida*). Furthermore, the relationship of these samples will be analyzed based on morphological characteristics (Table 1 and Table 2).

**Table 1. Morphological characteristic code of five dipterocarpaceae**

| No. | Characters          | *Hopea dryobalanoides* | *Shorea parvifolia* | *Shorea lepidota* | *Shorea johorensis* | *Parashorea lucida* |
|-----|---------------------|------------------------|---------------------|-------------------|---------------------|---------------------|
| 1   | Stem color          | 2                      | 3                   | 4                 | 5                   | 1                   |
| 2   | Tree stature        | 1                      | 1                   | 1                 | 1                   | 1                   |
| 3   | Bark color          | 1                      | 2                   | 3                 | 4                   | 5                   |
| 4   | Surface of stem bark| 1                      | 2                   | 3                 | 1                   | 2                   |
| 5   | Rod shape           | 4                      | 1                   | 1                 | 2                   | 3                   |
| 6   | Buttress            | 1                      | 1                   | 1                 | 1                   | 1                   |
| 7   | Leaf color          | 2                      | 1                   | 1                 | 2                   | 1                   |
| 8   | Leaf shape          | 1                      | 1                   | 3                 | 1                   | 2                   |
| 9   | Leaf type           | 1                      | 1                   | 1                 | 1                   | 1                   |
| 10  | Phyllotaxis         | 1                      | 1                   | 1                 | 1                   | 1                   |
| 11  | Leaf tip            | 1                      | 2                   | 2                 | 1                   | 2                   |
| 12  | Leaf base           | 1                      | 2                   | 2                 | 1                   | 3                   |
| 13  | Leaf edge           | 1                      | 1                   | 1                 | 1                   | 2                   |
| 14  | Leaf venation       | 1                      | 1                   | 1                 | 1                   | 1                   |
| 15  | Leaf top surface    | 1                      | 1                   | 1                 | 1                   | 2                   |
| 16  | Leaf undersurface   | 1                      | 2                   | 1                 | 4                   | 3                   |
| 17  | Leaf length         | 1                      | 2                   | 2                 | 2                   | 3                   |
| 18  | Leaf diameter       | 1                      | 2                   | 2                 | 2                   | 3                   |
| 19  | Length of the petiole| 1                     | 1                   | 3                 | 3                   | 1                   |
| 20  | Petiole             | 1                      | 1                   | 1                 | 2                   | 3                   |
Table 2. Definition of morphological characteristic code of five Dipterocarpaceae

| No. | Characters                      | Code                                                                 |
|-----|--------------------------------|----------------------------------------------------------------------|
| 1.  | Stem color                      | 1 = brown, 2 = dark brown, 3 = reddish brown, 4 = dark violet, 5 = gray |
| 2.  | Tree stature                    | 1 = large tree                                                       |
|     | Bark color                      | 1 = Brown with gray striated, 2 = brown-pinkish, 3 = yellow with resin pattern, 4 = gray-yellowish dark brown, 5 = dark gray |
| 3.  | Surface of stem bark            | 1 = lepidus, 2 = shallow-groove, 3 = deep-groove                     |
| 4.  | Stem shape                      | 1 = cylindric, 2 = cylindric, 3 = twisted, 4 = not straight and twisted |
| 5.  | Buttress                        | 1 = available, 2 = none                                             |
| 6.  | Leaf color                      | 1 = dark green, 2 = yellowish green                                  |
| 7.  | Leaf shape                      | 1 = ovate, 2 = elliptical, 3 = oblong                               |
| 8.  | Leaf type                       | 1 = single leaf                                                     |
| 9.  | Phyllotaxis                     | 1 = alternate leaves                                                |
| 10. | Leaf tip                        | 1 = acuminate, 2 = short acuminate                                  |
| 11. | Leaf base                       | 1 = round, 2 = obtuse, 3 = truncatus                                 |
| 12. | Leaf edge                       | 1 = integer, 2 = crenate                                            |
| 13. | Leaf venation                   | 1 = pinnatifid leaf                                                 |
| 14. | Leaf top surface                | 1 = laevis, 2 = glaber                                              |
| 15. | Leaf undersurface                | 1 = scaber, 2 = scaber, 3 = hispidus, 4 = laevis                    |
| 16. | Leaf length                     | 1 = (1-10), 2 = (>10-20), 3 = (>20-30) cm                           |
| 17. | Leaf diameter                   | 1 = (1-5), 2 = (>5-10), 3 = (>10-15) cm                             |
| 18. | length of the petiole           | 1 = (0.1-1), 2 = (>1-2), 3 = (>2-3) cm                              |
| 19. | petiole                         | 1 = round, 2 = glaber-round, 3 = not sheathed                       |

3.1. Morphological Characteristics of Five Dipterocarpaceae

3.1.1. Hopea dryobalanoides. *Hopea dryobalanoides* is one of the merawan plants which has the stature of a tree. *H. Dryobalanoides* has a general characteristic i.e. dark brown stem, tall stem, cylindrical, buttress and stilt root with scaly bark. The Leaf shape is round egg (ovatus). The leaf arrangement (phyllotaxis) is alternate, the petiole is round and long shape, the leaf base is rounded (rotundus) and it has a flat leaf edge (integer). Top surface of the leaf is slippery while the undersurface of the leaf is rough. When dry, the color of leaf top surface is slightly brown while the lower surface of the leaf is russet. On a Pinnatifid leaf, the secondary venation is driobalanoid and the tertiary venation is almost invisible. The leaf tip is long acuminate. This plant has a range of spread in peninsular Malaysia, Sumatra, and Borneo [7]. The local name used for *H. dryobalanoides* in Ketambe area is pepening (Figure 2).

![Figure 2. Stem of *Hopea dryobalanoides* (a); Leaves of *Hopea dryobalanoides* (b)](image-url)
3.1.2. *Shorea parvifolia*. *Shorea parvifolia* is one of red *meranti* plants which has a stature of the large tree which is about 65 m in height. The striking characteristic of *S. parvifolia* is its reddish brown stem. The shape of the stem is erect with buttress and surface of the bark is shallow. The leaf arrangement (*phyllotaxis*) is alternate, its leaf blade shape is circular oval (*ovatus*) which is narrowed with leaf tip. The leaf tip is short acuminate. The leaf base is rounded (*obtusus*), its margin is entire/smooth throughout (integer), and the leaf has green color. Top surface of the leaf is slippery, while undersurface of the leaf is rough with a short indumentum and feathers that are slightly tight. When dry, color of the leaf’s top surface is brown, while the leaf undersurface is russet. Leaf pinnatifid is very clear and it has swollen gland like small node at the leaf base vein (domatia). Secondary venation is straight and slightly curved near the leaf edge. The most distinctive feature of the red wood plant is its *domatia* gland which swells at the leaf base. The swelling is clearly visible on the undersurface of the leaf. This plant is commonly found in Thailand, Peninsular Malaysia, Sumatra, Bangka Belitung, and Borneo [7]. The local name used for *S. parvifolia* in Ketambe area is kayu merah (Figure 3).

![Figure 3](image)

**Figure 3.** Stem of *Shorea parvifolia* (a); Leaves of *Shorea parvifolia* (b)

3.1.3. *Shorea lepidota*. *Shorea lepidota* is one of red *meranti* plants which is no longer found in the ketambe area due to illegal logging that occurred in recent years. This plant has very good wood for timber. Common feature of *S. lepidota* is its dark brownish-colored stems. The shape of stem grows erect with buttress and with the surface of the inner bark. This plant has a large tree stature. The leaf shape is oval (*oblong*) and its arrangement (*phyllotaxis*) is alternate. The petiole is round and the leaf base is rounded (*obtusus*). The leaf edge is entire/smooth throughout (integer) and leaf tip has short acuminate shape. Top surface of the leaf is slippery, while undersurface of the leaf is rough. When dry, the top surface of leaf is slightly brown, while the under surface of leaf is russet. Pinnatifid leaf, when it is dry, the color is same with its leaf blade. Secondary venation is initially straight, curved at near the leaf edge or throughout its length of the leaf. This plant is commonly found in Peninsular Malaysia and Sumatra [7]. The local name used for *S. lepidota* in Ketambe area is semantok (Figure 4).
3.1.4. *Shorea johorensis*. *Shorea johorensis* is one of the red meranti plants. This plant has a common characteristic with a large tree stature. The shape of its stem is cylindrical and buttress with gray color. Bark surface is scaly and peeling thin. It is a single leaf, with a leaf arrangement (*phyllotaxis*) that is alternate. The shape of the blade is round egg (*ovatus*), leaf tip has long acuminate shape, leaf base is rounded (*rotundus*), and leaf edge is entire/smooth throughout (*integer*). The leaf surface is slippery on both sides. The color of the blade surface is dark green and the bottom is light green. The petiole is round with length of approximately 1 cm. Pinnatifid leaf with the secondary venation is slightly curved near the leaf edge. This plant is commonly found in Peninsular Malaysia, Sumatra, and widely spread in Borneo [7]. The local name used for *S. johorensis* in Ketambe area is meranti kacar (Figure 5).

3.1.5. *Parashorea lucida*. *Parashorea lucida* is the most widely found plant in Ketambe Research Station. *Parashorea lucida* has a common characteristic which is a brown stem with a large tree stature. The shape of the stem is slightly twisted and buttress. The bark surface is shallow. The shape of its leaf blade is ellipticus. The leaf arrangement (*phyllotaxis*) is alternate leaves, and leaf tip is acuminate. The leaf has green color with the underside of the leaf appearing slightly whitish, and the edge of the leaf is slightly crenate. The petiole has a round and long shape giving it a slender look and the leaf base is attached into the truncate from base of the leaf. Top surface of the leaf is glabrous (without feathers),
while undersurface of the leaf is rough-hairy. Leaf pinnatifid and leaf veins are more prominent and very clear. This plant is commonly found in Sumatra, Sarawak, and Borneo [7]. The local name used for *P. lucida* in Ketambe area is entap (Figure 6).

![Figure 6. Stem of Parashorea lucida (a); Leaves of Parashorea lucida (b)](image)

3.2. Phenetic Analysis

The morphological observation of five Dipterocarpaceae species in Ketambe Research Station area shows the similarities and differences of some organs. The data is presented in dendrogram and matrix of similarity (Figure 7 and Table 3).

![Figure 7. Dendogram Phenetic Analysis of Five Dipterocarpaceae Species](image)
### Table 3 Similarity Matrix of Five Dipterocarpaceae Species

|                | Hopea dryobalanoides | Shorea parvifolia | Shorea lepidota | Shorea johorensis | Parashorea lucida |
|----------------|----------------------|-------------------|-----------------|-------------------|-----------------|
| Hopea dryobalanoides | 0                   |                   |                 |                   |                 |
| Shorea parvifolia    | 4.242641             | 0                 |                 |                   |                 |
| Shorea lepidota      | 5.830952             | 3.464102          | 0               |                   |                 |
| Shorea johorensis    | 6.164414             | 4.690416          | 4.898979        | 0                 |                 |
| Parashorea lucida    | 6.633250             | 5.291503          | 6.000000        | 6.000000          | 0               |

*Table Information:
1. Blue number : closest distance
2. Green number : furthest distance

The dendogram shows the existence of three clusters in the grouping of Dipterocarpaceae species. In cluster 1 there is *Hopea dryobalanoides*, cluster 2 there is *Parashorea lucida*, and cluster 3 there are *Shorea johorensis*, *Shorea parvifolia*, and *Shorea lepidota*. The result showed that *Shorea parvifolia* and *Shorea lepidota* have the closest relationship among the other five Dipterocarpaceae species with a similarity value of 3.464102 (Cluster 3). The cluster shows that *Shorea johorensis* is in the same cluster with *Shorea parvifolia* and *Shorea lepidota* but it has the farthest relationship distance between them. In contrast to the results of research by [8], [9], and [10], who used DNA analysis, that *Shorea johorensis* formed a separate group with *Shorea parvifolia*. *Parashorea lucida* formed a separate cluster with *Shorea johorensis*, *Shorea parvifolia*, and *Shorea lepidota*. This is consistent with the result of research by [11]. However, it is contrary to the research carried out by [12] and [10] where *Shorea parvifolia* showed a closer relationship with *Parashorea lucida*. *Hopea dryobalanoides* has the farthest relationship with other Dipterocarpaceae species, especially with *Parashorea lucida* which has a distance of 6.633250. It can be seen immediately that *Hopea dryobalanoides* and *Parashorea lucida* have different genera because the two plants have a farther relationship distance. In addition, the morphological characters of both Dipterocarpaceae species are quite diverse. Therefore, the smaller the similarity distance between the two species the closer the relationship between them. Meanwhile, the farther the similarity distance between two species the farther the relationship between them.

According to [13], plants with the same group have closer relationships and vice versa. This study obtained three genera of Dipterocarpaceae i.e. *Hopea*, *Parashorea*, and *Shorea*. *Hopea* has a farther relationship than the two other genera (*Shorea* and *Parashorea*). Based on the morphological character of the five Dipterocarpaceae species, *Hopea dryobalanoides* has more different forms of morphology. Therefore, *Hopea dryobalanoides* has the farthest relationship among the five Dipterocarpaceae species. Based on morphological characters, comparing, and measuring distances relationship of plants will produce different results with DNA analysis. However, relationship analysis with morphological characters is also indispensable for researchers in the field because environmental conditions are one of the factors forming plant morphology characteristics besides the results of gene expression.

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