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Analysis of morphological characteristics and phenetic relationship of ebony (*Diospyros* spp.) in Indonesia

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Abstract. *Rindyastuti R, Hapsari L, Wibowo AT. 2021. Analysis of morphological characteristics and phenetic relationship of ebony (*Diospyros *spp.) in Indonesia. Biodiversitas 22:* 2739-2754. *Diospyros* L. (Ebenaceae) is an economically important genus that covers over 500 plant species. Members of this group are known to produce hard, dark, high-quality timbers known as ebony trees, while other members are known as persimmon trees. There is limited information on the morphological characters and phenetic relationship of this genus from Indonesian archipelago. In this work, we reported the phenetic clustering of 14 species of Indonesian *Diospyros*, based on plant canopy, stem, leaves, and fruit characters, which was analyzed using UPGMA and Jaccard similarity index. The phenetic dendrogram divided the 14 species of *Diospyros* into two main clusters which separating Subgen. *Maba* and *Eudiospyros.* Further, subgen. *Maba* was clustered into a single cluster while subgen. *Eudiospyros* was divided into 3 sub-clusters as sister groups. The clustering in *Eudiospyros* was supported by low SI and bootstrap value, demonstrating the high morphological variation of the subgenus. The sectional separation of *Diospyros* spp. was considered as paraphyletic. In general, our phenetic clustering exhibited suitability and relevancy with previous classification. Fruit size and trichomes are very important in this phenetic clustering, especially to form *Eudiospyros* subgenus. Fruit trichomes were also special characters related to biogeographical distribution following the Wallace line theory.

Keywords: Conservation, dendrogram, *Diospyros*, ebony, species diversity

INTRODUCTION

Diospyros L. (Ebenaceae) is a plant group that covers important ebony species and persimmons. It is the largest genus of Ebenaceae family that includes over 500 species worldwide with great morphological diversity across Indo-pacific region (Duangjai et al. 2006; Walnofer 2001; White 1956). Several species belong to this genus, such as *D. celebica*, *D. pilosanthera*, *D. cauliflora*, and *D. ebenum* are known to produce valuable, high-quality timber such as for craft and music instruments (Bennet 2016). Other species such as *D. discolor, D. malabarica* and *D. hasseltii* are known to produce edible persimmons, making it an economically important genus (Kinho 2013; Bakhuizen van Den Brink 1937). More recently, many studies revealed medicinal bioactivities of *Diospyros* species such as antioxidant, anti-inflammatory, analgesic, anti-diabetic (Rauf et al. 2017; Howlader et al. 2012), anti-microbial (Nematollahi et al. 2011), and anti-cancer (Pratiwi and Nurlaeli 2020). *Diospyros* is dioecious, medium-sized tree rarely shrubs with mostly black and hard bole. Leaves are simple, alternate; inflorescence an axillary cyme, or with the pistil-late flowers solitary. The flowers are green, white or yellow, which are arranged few to many. Corolla is campanulate, salverform, tubular or urceolate, with 3-8 lobes. The stamens number are 2-many, mostly with 4-8 staminodia in pistillate flowers; ovary 3-16 celled. Fruits are large and berry, with persistent calyx, accrescent or not accrescent, and with 1-16 seeds (Duangjai et al. 2006).

On the basis of the monophyly phylogenetic classification using broader samples, Ebenaceae consists of two subfamilies, i.e., Lissocarpoideae and Ebenoideae and four genera *Euclea*, *Royena*, *Lissocarpa* and *Diospyros* (Duangjai et al. 2006). Among Ebenaceae, *Diospyros* is the only genus that naturally found in South East Asia including Indonesia. Meanwhile, the other genus *Euclea*, *Royena* and *Lissocarpa* were distributed in outer Asia. *Euclea* comprises 20 species which are distributed in Africa, Arabia, Socotra and Comoro Island (Retief et al. 2008). The genus *Royena* comprises 17 species in Africa and the genus *Lissocarpa* comprises 8 species which are distributed in northwestern South America (Turner et al. 2013).

According to Bakhuizen van den Brink (1936-1955), in South-East Asia and Pacific, *Diospyros* was divided into 5 subgenera, i.e., subgenus *Cargillia*, *Diospyros* (*Eudiospyros*), *Hierniodendron*, *Maba*, and *Mabacea*. Further, subgenus *Eudiospyros* was divided into 32 sections while *Maba* into 4 sections. The species were grouped based on morphological and anatomical characters. This was the last recorded effort to classify *Diospyros* spp. in South-East Asia and no revision by other

botanists has been made ever since. Morpho-taxonomical study of Indonesian *Diospyros* is very limited. Analysis of morphological characters of *Diospyros* spp. in Indonesia is also firstly reported. Duangjai et al. (2006) analyzed phylogenetic relationship of Ebenaceae *sensu lato* at subfamily level using plastid DNA sequence data from six regions and reported paraphyletic subfamilial classification (Duangjai et al. 2006). Further, they are suggesting further research with larger plant samples.

Several morpho-taxonomical studies have been conducted in *Diospyros*, including leaf flushing pattern of some *Diospyros* spp. (Putri and Chikmawati, 2015), wood anatomy and physical properties of *Diospyros blancoi* (Krisdianto and Abdurachman, 2005), morphometric differences of fruits, seeds, and pollen grains of some *Diospyros* spp. in Ukraine (Grygorieva et al. 2013 and Grygorieva et al. 2017), leaf macro and micromorphology of *Diospyros* spp. in China (Yi et al. 2016), morphology and phenetic relationship of endemic *Diospyros* spp. in Mascarene Islands (Mauritius) (Venkantasamy et al. 2006). Nevertheless, comprehensive morpho-taxonomic studies that can support taxonomical classification of the genus are still limited, especially for *Diospyros* that distributed in Indonesia. This study was conducted to support taxonomical, phytogeography and ecological studies of *Diospyros* distributed in Indonesia. Specifically, in this work we analyzed (i) the phenetic relationship among 14 *Diospyros* species in Indonesia based on morphological characteristics, (ii) the differentiating characters of each taxon and/or taxon group of *Diospyros* spp. which contribute to dendrogram construction, and (iii) the floristic distribution patterns in *Diospyros* spp. based on the biogeographical theory of Indonesian Archipelago.

Here we reported the morphological characters and sectional clustering of 14 Indonesian *Diospyros* species. We found that the clustering of these *Diospyros* to be paraphyletic, nevertheless it shows suitability and relevancy with previous plant classification by Bakhuizen van den Brink (1936-1955). Fruit size and fruit trichome were the two most important morphological characteristics in this phenetic clustering, especially to form the cluster of Eudiospyros subgenus. These two characters also demonstrated a strong correlation with the biogeographical distribution of Indonesian *Diospyros.*

MATERIALS AND METHODS

Study location

This study was conducted in Purwodadi Botanic Gardens/PBG, Indonesian Institute of Sciences/LIPI, Pasuruan, East Java, Indonesia. The plant living collections of *Diospyros* spp. in PBG are located at "vak"/ the code of plant location of "XXG and XXH". The morphological observation was conducted from April 2017 to March 2020.

Plant materials

The plant materials investigated in this study were 14 species of *Diospyros* spp. (Ebenaceae), *ex-situ* living collections of PBG. It comprises of two subgenera based on the classification by Bakhuizen van den Brink (1936-1955), i.e., *Maba* and *Eudiospyros*. Subgen. *Maba* consisted of two species; whilst subgen. *Eudiospyros* consisted of 12 species. Further, they belong to some different sections. The plant specimens were mostly originated from Eastern Indonesia, including East Java, South Kalimantan, North Sulawesi, Central Sulawesi, South East Sulawesi, South Sulawesi and Maluku Islands, with 4 endemic species to Kalimantan and Mollucas region. Species list, plant specimen origin, and species distribution were provided in Table 1.

Morphological observation

Morphological characters, including quantitative and qualitative characters of 1 until 3 plant specimens for each species were observed using plant descriptions by Backhuizen van den Brink (1937; 1938) and the latest identification kit of *Diospyros* (Ebenaceae) by Ng (1978) for Bornean species. Species identifications were conducted by describing the morphological characters including canopy, stems, branches, leaves, fruits, and fruit calyx. It comprises 57 characters and derived into 193 character states (Table 2).

Data analysis

Morphological characters were scored using a reference number of "0" for characters that were not present in the plant samples and the number of "1" for characters that present in the plant samples. All characters were treated as independent, unordered, and of equal weight. The collected data were analyzed using statistical software PAST (Paleontological Statistics) ver.1.34 by multivariate cluster analysis, unweighted paired group algorithm (UPGMA), and Jaccard similarity index to construct a phenetic dendrogram, with 1000 bootstrap replications. Bootstrap support was categorized as strong (>85%), moderate (70-85%), weak (50-69%), and poor, (<50%) referring to Kress et al. (2002). Multivariate Jaccard similarity and distance indices were also conducted to generate similarity coefficients among species. Furthermore, analysis of the apomorphy characters (synapomorphy and autapomorphy) were performed to identify the differentiating characters of each operating taxonomic unit (OTU) and/or OTU group of *Diospyros* spp.

RESULTS AND DISCUSSION

Phenetic relationship of *Diospyros* spp.

Diospyros spp. showed high morphological variation, such as in bark texture, canopy, leaf shape, venation, leaf glands, trichome, leaf flushing, and fruit morphology. *Diospyros* spp. have various bark texture which ranges from smooth grooved, coarsely grooved, vertically grooved, lenticellate, and lenticellate grooved (Figure 2).

Table 1. Subgenus, section, species list, plant origin, and distribution of *Diospyros* spp.

Subgenus	Section	Species	Plant specimen origin	Distribution
Maba (J. R. et G. Forst.) Bakh.	*Forsteria* Bakh.	*D. ferrea* (Willd.) Bakh.	Maluku: Seram Island.	Peninsula Malayana, Sumatra, Java, Borneo, Philippines, Celebes, Moluccae, Nova Guinea, Nova Caledonia
	Miquela Bakh.	*D. andamanica* Bakh.	C. Sulawesi; S. Kalimantan	Peninsula Malayana, Borneo
Eudiospyros (L.) Bakh.	*Stelechantha* Bakh.	*D. cauliflora* Bl.	E. Java; Maluku	Indo China, Sumatra, Java, Lombok, Borneo, Phillippines, Celebes, Moluccas
	Ebenaster Bakh.	*D. discolor* Willd.	East Java	Philippines, British India, Penninsula Malayana, Sumatra govt. East. Sumatra, Borneo, Sarawak
		D. amboinensis Bakh.	Seram Island, Mollucas	Moluccas: Ambon
		D. lolin Bakh.	Mollucas	Mollucas island (Ambon, Hitoe, Banda, Ceram, Binoa, Ternate, Halmahera)
		D. celebica Bakh.	Sulawesi	Celebes, Manado: Poso
	Ptychocylix Bakh.	*D. pilosanthera* Blanco.	Kota Baru, S. Kalimantan	Pennisula Malayana, Sumatra, Java, Batam, West Borneo, Phillipines Basilan
	Nesindica Bakh.	*D. javanica* Bakh.	Trenggalek, East Java	Java, Lombok, Timor and Flores
		D. greshoffiana Kds. Ex Bakh.	S. Sulawesi	Celebes
	Glutinosa Bakh.	*D. malabarica* (Desr.) Kostel.	Bogor, Jawa Barat	Ceylon, India Britanica, Siam, Peninsula Malayana, P. Langkawi, Sumatra: Lampung, Java, Timor and Sumbawa, Celebes.
	Verruculosa Bakh.	*D. perfida* Bakh.	S. Kalimantan	South East Borneo
	Unidentified species	*Diospyros* sp.1	North Sulawesi	-
	Unidentified species	*Diospyros* sp.2	S.E. Sulawesi	-

The canopy shape of the genus is generally cone-shaped, however, it also displayed other morphological variation that ranges from cone-shape, intermediate, to irregular. The leaf also varies in shape and size. The shape is generally ranging from oval to elliptic, but several species are ovate, obovate, or even ovate-asymmetric shape (Figure 3, Table S1). Further, the leaf glands could be present or absent (Figure 4, Table S1). Fruit characters of *Diospyros* spp. vary in shape, size, color, groove, and their hairs or trichomes both at mature and dry stages (Figure 5). Several fruit characters are more important than others, such as fruit size, fruit trichomes, and fruit calyx.

Based on the clustering analysis result using UPGMA, we found that the subgenera division of *Diospyros* by Bakhuizen van den Brink (1937;1938) is monophyletic. The dendrogram of phenetic relationship divided the 14 species of *Diospyros* into two main clusters which separating Subgen. *Maba* and *Eudiospyros* with SI of 21% and supported by a very strong bootstrap value (100%); subgen *Maba* was served as an outgroup. Further, Subgen. *Maba* which consists of 2 species, i.e., *D. ferrea* and *D. andamanica* were clustered with SI of 35% and weak bootstrap of 67%. Meanwhile, subgen. *Eudiospyros* was divided into 3 sub-clusters as sister groups although it was supported by poor bootstrap value (33%), and SI of 26-41% (Figure 1, Table 3).

In details, within subgen. *Eudiospyros*, Cluster I consisted of 3 species, i.e., *D. perfida*, *Diospyros* sp.2 and *D. pilosanthera* var. *polyalthioides* with SI value 33% and bootstrap of 32%. Cluster II consisted of 3 species, i.e., *D. cauliflora*, *D. javanica*, and *D. greshoffiana* with SI of 30.5% and bootstrap 9%. Cluster III consisted of 6 species, which was separated into two sub-clusters *i.e D. malabarica*, *D. lolin*, *D. discolor*, and *D. amboinensis* (sub-cluster 1); *D. celebica* and *Diospyros* sp. (sub-cluster 2) with the SI value of 32% and bootstrap 14%. The low SI and bootstrap values were caused by the high variation of morphological characteristics in the subgen. *Eudiospyros.*

Differentiating morphological characteristics in *Diospyros* spp.

Differentiating morphological characteristics in *Diospyros* spp. which contribute to dendrogram construction of phenetic relationship was produced using the analyses of synapomorphy and autapomorphy characters. Synapomorphy is a derived trait shared by two or more groups of OTU, while autapomorphy is a derived trait that is unique to one OTU (Choudhuri 2014). The analysis of synapomorphy exhibited that the separation between *D. andamanica* and *D. ferrea* in subgen. *Maba* was supported by 31 characters especially fruit characters, such as fruit diameter <2 cm, color of young fruit light green but orange when mature, fruit fleshy, trichome absent, fruit surface smooth, fruit calyx with 3 lobes, smooth, thin and leafy. Meanwhile, subgen. *Eudiospyros* which consist of 12 species were clustered together due to only single character, i.e., the presence of fruit trichomes. This is in accordance with previous grouping of subgen. *Eudiospyros* by Bakhuizen van den Brink (1936-1955); *Eudiospyros* means "true *Diospyros*", it may refer to *Diospyros* species with one of the characteristic, i.e., the presence of fruit trichomes.

Table 2. Morphological characteristics of *Diospyros* spp. observed in this study

Plant parts	Morphological character and character state
Canopy	Canopy shape: cone/pyramidal, cone-irregular, irregular
Stem	Stem color: light brown, dark brown, blackish brown, black, grayish green Stem surface texture: smoothly grooved, coarsely grooved, vertically grooved, lenticelatte, lenticelatte grooved
Leaf	Leaf shape: ovate, elliptic, obovate, oval, ovate-asymetric Leaf length (cm): 0-10, 10-20, 10-30, 10-40 Leaf width (cm): 0-10, 10-15, 15-20 Leaf apex: acute, acuminate, obtuse, rounded Leaf base: acute, cuneate, acute-rounded, cuneate-truncate, cuneate-cordate, truncate-subcordate Pair number of vein: 5-10, 5-15, 10-20 Venation (main and lateral): less visible, slightly visible, visible, very visible Lateral venation pattern: straight (90 degrees), less straight (45-90 degree), ascending straight, ascending Intramarginal venation: looped, not looped Anastomosing of lateral venation: near to leaf margin, 1/4-1/5 from leaf margin, 1/3 from margin, 1/2 from margin Vein domination: present, intermediate, absent Midrib: sunken, intermediate, prominent Trichome on upper leaf: present, absent Trichome of downside leaf: present, absent Trichome of downside midrib: present, absent Color of upper leaf: light green, dark green, brownish-green, blackish green Color of downside leaf: light green, dark green, whitish green Leaf margin: entire, wavy Leaf texture: membranaceous, membranaceous-paperaceous, paperaceous Leaf glands: present, absent Pair number of leaf glands: 0-10, 10-20 Leaf surface: flat, slightly bullate, less bullate, bullate Trichome in petiole: present, absent Trichome color in petiole: absent, light brown, dark brown, blackish, brown-reddish, greenish Flushing color: light brown, dark brown, greenish, reddish
Fruit	Fruit shape: depressed globose, ellipsoid, ovoid Fruit diameter (cm): < 2, 2-5, 5-10, >10 Fruit length (cm): <1, 1-2, 2-5, 5-10 Color of young fruit: light green, dark green, yellow Fruit flesh: not fleshy, intermediate, fleshy Fruit groove: present, absent Wooden fruit: present, absent Fruit apex: acute, obtuse flat, depressed obtuse Trichome of young fruit: present, absent Trichome density of young fruit: absent, not dense, dense Trichome color of young fruit: absent, brown, golden brown, orange, silvery green Trichome of mature fruit: present, absent Trichome density of mature fruit: absent, not dense, dense Trichome color of mature fruit: absent, light green, dark green, reddish-brown Fruit surface: smooth, lenticellate, dense hairy Color of dry fruit: brown, black, red Mature fruit dry: smooth, wrinkle, decayed, drying hard wooden
Fruit calyx	Shape of fruit calyx: campanulate, simple round shape, bowl shape, isodiametric, flatten triangularly Fruit calyx diameter (cm): < 1, 1-2, 2-4, 4-6 cm Length of fruit calyx lobes (cm): <1, 1-2, 2-4 Number of fruit calyx lobes: 3, 4, 4-5 Shape of fruit calyx lobes: acute triangular, acuminate triangular, triangular Fruit calyx position of young fruit: flat, half-covering, whole covering, spreading Fruit calyx position of mature fruit: half-covering, whole covering, reflexed Calyx lobes margin: entire, reflexed, wavy Texture of fruit calyx: thin leafy, thick leafy, woody Thickness of fruit calyx: thin, thick Surface of fruit calyx: smooth, dense hairy, smooth lenticellate, coarsely lenticellate

Cluster I of subgen. *Eudiospyros* consists of 3 species, i.e., *D. perfida*, *Diospyros* sp.2 dan *D. pilosanthera* var. *polyalthioides*. It possessed 20 synapomorphy characters, such as leaf shape ovate and elliptic with leaf length 10-30 cm and width 0-15 cm, fruit shape globose with diameter 2-5 cm and length 2-5 cm, color of young fruit light green, trichome of young and mature fruit present. *D. cauliflora*, *D. javanica* dan *D. greshoffiana* were grouped in cluster II because they are supported by 19 synapomorphic characters such as leaf shape oval, width 0-10 cm, lateral venation are ascending, vein domination present, trichome of upper leaf absent, trichome of downside leaf absent, leaf margin entire, leaf texture membranaceous, leaf glands absent, fruit diameter <2 cm, length 1-2 cm, fruit has no groove and with nonwoody pericarp, fruits are hairy to densely hair, with fruit calyx lobes <1 cm, 4-lobed, flat and thick. Whilst, cluster III which consist of 6 species, i.e., *D. malabarica*, *D. lolin*, *D. discolor*, *D. amboinensis*, *D. celebica*, and *Diospyros* sp. have morphological similarities on 7 characters such as trichome at downside of leaf and petiole leaf, trichome of young and mature fruit and shape of fruit calyx lobes.

Moreover, sub-cluster 1 in cluster III shared similarities of 16 characters, such as leaf trichome present in upper, downside and petiole, fruit trichome present, and fruit calyx 4-lobed with acute triangular shape. Whereas, the 3 of 4 species in this cluster, i.e., *D. lolin*, *D. discolor*, and *D. amboinensis* grouped in sect. *Ebenaster*, while *D. malabarica* grouped in sect. *Glutinosa*. Result from this study implies further outlook to the sect. *Glutinosa*, especially by describing the lesser-known member of this section such as *D. pseudomalabarica* Bakh., *D. koeboeensis* Bakh., *D. britanno-borneensis* Bakh., *D. eburnea* Bakh., and *D. siamensis* Hochr. The placement revision of *D. malabarica* into other section could be established if it is supported by sufficient evidence.

Some autapomorphic characters were also identified in this study and became key characters for each *Diospyros* species. *D. ferrea* is one of species included in subgen. *Maba*; it has smooth fruit surface and 3-lobed fruit calyx, this species was also especially characterized by very small fruit (<1 cm in diameter). *D. javanica* was characterized by silvery-green trichomes of young fruit. The specimen of *D. pilosanthera* has paperaceous leaf and reddish leaf flushing, which are very important characteristics distinguishing this species from the others. Further, this species is considered as the variant of *polyalthioides*. Variant of *polyalthioides* has a larger fruit calyx than *D. pilosanthera* (6 cm in diameter) with very wavy calyx lobes, while *D. pilosanthera* has smaller and simpler calyx lobes (1.5-2 cm in diam.). However, *D. pilosanthera* var. *polyalthioides* is considered as the synonim of *D. polyalthioides*. *D. lolin* has truncate-subcordate leaf base and reddish-brown trichome of mature fruit. *D. malabarica* has leaf venation that anastomosing 1/2 from leaf margin and has isodiametric 4-lobed fruit calyx. *D. discolor* has leaf with 10-40 cm long, fruit diameter >10 cm, and orange trichome of young fruit. *D. amboinensis* has 10-20 cm wide leaf with slightly bullate surface. Whilst, one unidentified species of *Diospyros* sp.1 has lenticellate grooved bark, ovate-asymmetric leaf, yellow young fruit with reflexed fruit calyx.

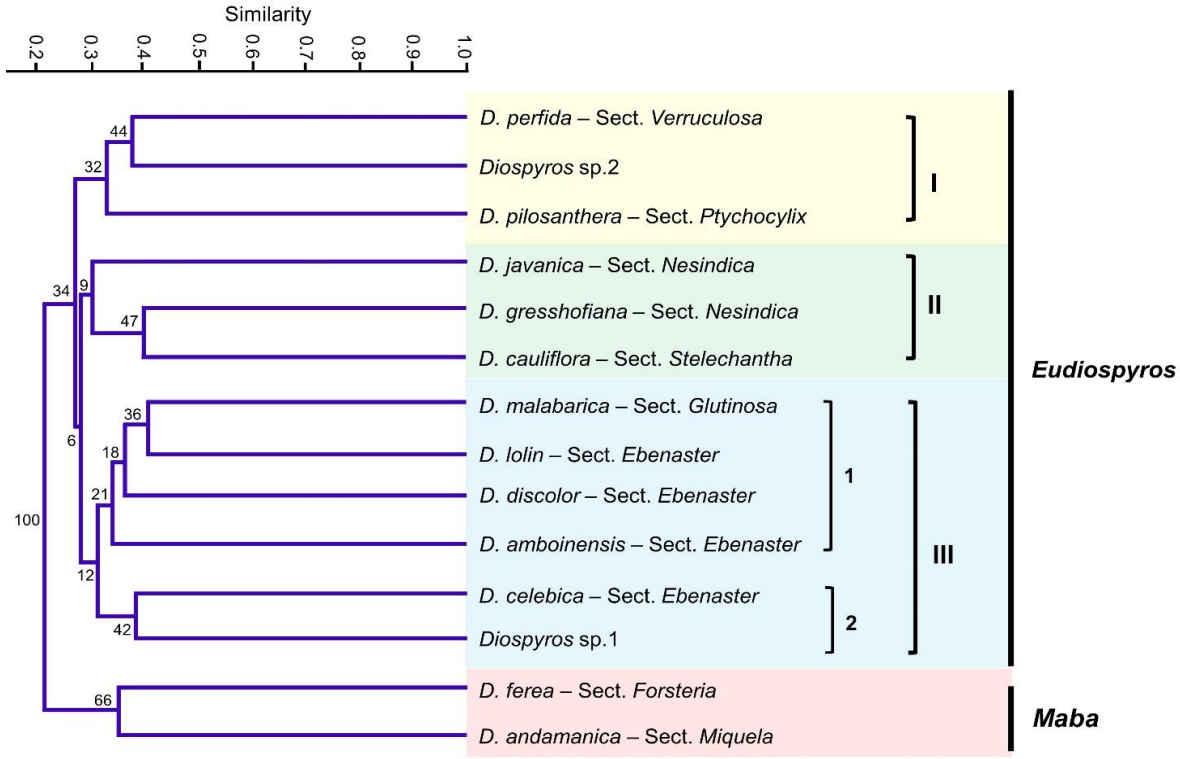

Figure 1. Dendrogram of phenetic relationship of 14 species of *Diospyros* spp. in Indonesia using Jaccard Similarity Index.

Tabel 3. Similarity index (%) among 14 species of *Diospyros* spp.

No.	Species name	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
D1	*D. ferrea*	100													
D2	*D. andamanica*	34.83	100												
D3	*D. cauliflora*	15.84	32.22	100											
D4	*D. discolor*	16.35	19.42	17.65	100										
D5	*D. amboinensis*	20.41	22.45	28.57	31.52	100									
D6	*D. lolin*	21.00	23.00	25.00	37.78	39.08	100								
D7	*D. celebica*	14.56	23.71	28.57	30.11	29.67	28.72	100							
D8	*D. pilosanthera*	15.69	20.00	21.88	22.22	20.41	24.74	26.88	100						
D9	*D. javanica*	29.67	27.66	32.95	21.00	24.21	28.72	28.26	15.69	100					
D10	*D. greshoffiana*	17.65	28.42	40.00	35.16	25.00	33.70	34.83	30.43	27.66	100				
D11	*D. malabarica*	14.15	28.13	36.36	34.78	31.52	40.91	30.11	27.37	28.72	29.47	100			
D12	*D. perfida*	21.43	31.52	32.58	24.49	25.26	27.08	26.60	32.22	26.60	34.44	37.08	100		
D13	*Diospyros* sp.1	11.21	19.80	29.67	35.56	29.35	35.56	38.37	26.60	21.43	32.97	34.07	25.00	100	
D14	*Diospyros* sp.2	20.20	21.00	26.88	22.00	29.35	27.08	32.22	33.71	25.26	32.97	24.49	37.93	34.83	100

A **B** **C** **D** **E**

Figure 2. Variation of bark surface: A. Vertically grooved bark of *D. amboinensis*, B. Coarsely grooved bark with cauline fruit of *D. cauliflora* C. Smoothly grooved bark of *D. celebica*, D. Lenticellate bark of *D. perfida*, E. Lenticellate grooved bark of *D. greshoffiana.*

A **B** **C** **D** **E**

Figure 3. Variation of leaf shape in *Diospyros* spp.: A. Ovate leaf of *D. javanica* B. Elliptic-lanceolate leaf of *D. celebica*, C. Oval-lanceolate leaf of *D. cauliflora*, D. Obovate leaf of *D. amboinensis* E. Ovate-asymmetric leaf of *Diospyros* sp.1

A **B**

Figure 4. Variation of leaf glands: A. The absence of leaf glands in *D. pilosanthera*, B. The presence of leaf glands in *D. discolor*

Key to the species of *Diospyros* spp.

Diospyros L.

Trees rarely shrubs, evergreen, dioecious, small to medium-sized trees 5-40 m height, conus/pyramidal to irregular canopy, hard bole with bark brownish, greyish to black. Leaves are simple, alternate, 12-40 cm long, 2.5-20 cm wide, membranaceous, paperaceous to coriaceous, trichome in upper and/or downside, leave base cuneate, round to sub-heartshaped, leaf apex acute to acuminate; inflorescence an axillary cyme, or with the pistil-late flowers solitary. Flowers are green, white or yellow, which are arranged few to many; corolla campanulate, salverform, tubular or urceolate, with 3-8 lobes; stamens number 2-many, mostly with 4-8 staminodia in pistillate flowers; ovary 3-16 celled. Fruits large and berry, with persistent calyx, accrescent or not accrescent; 3-5 lobes; flat, reflexed, wavy margined, spreading; leafy to woody; thin to thick; clasping the whole fruit and shorten with age or not, and with 1-16 seeds.

1. Medium sized-tree up to 10 m, bole straight, canopy conus-shaped, leaves alternate, elliptic, lanceolate to elliptic, leaves 12-40 cm long, 2.5-20 cm width, membranaceous, paperaceous to coriaceous, smooth in upper leaf, trichome at downside, leave base cuneate, round to sub-heartshaped, leaf apex acute to acuminate.
   a. bole black and hard, young trees with very leafy and conus-shaped canopies, leaves lanceolatte to elliptic ……..... ***D. celebica***
   b. young trees not leafy, canopy shape conus/pyramidal to irregular, leaves elliptic to oval ……..….. (2)
2. a. leaves large, 12-40 cm long, 2.5-20 cm width, elliptic to obovate, margin wavy, bullate surface, fruit size around 10 cm in diameter ….…..... ***D. amboinensis***
   b. leaves large or medium, leaf margin entire ..... (3)
3. a. leaves medium size 10-20 cm long, 3-10 cm wide, fruit cauline, fruit 1.3-2 cm in diameter …….. ***D. cauliflora***
   b. leaves 10-20 cm long, 3-10 cm wide, fruit noncauline ……..……...……..… (4)
4. a. leaves alternate, oval to elliptic, 12-40 cm long, 2.5-20 cm width, leaves margin entire, fruits 10 cm in diameter, globose to depressed globose, densely orange to brown fruit trichome ……..…….. ***D. discolor***
   b. leaves alternate, elliptic-oval, leaves and fruit with small-size ……...…….….. (5)
5. a. fruits 7 cm in diameter, dark green when young, yellow when mature, covered by brown trichomes and easily removed trichome, acute triangular lobes of fruit calyx…… ……..…… …… ***D. lolin***
   b. Fruits smaller than 5 cm in diameter, covered by trichomes ……...……...… ……. (6)
6. a. Leaf alternate, elliptic, lanceolate, oval, 12-20 cm long, 2.5-10 cm width, fruits 4-5 cm in diameter, globose, covered by brown trichomes, fruit calyx is large, 4-6 cm in diameter … …...……. …… ***D. malabarica***
   b. fruits large or small, globose or ellipsoid …..…… (7)
7. a. leaf alternate, elliptic-oval, ovate, 12-20 cm long, 2.5-10 cm width, fruits 4-5 cm in diameter, globose, covered by brown trichomes, fruit calyx clasping the whole fruits and shorten with age ……... ***D. perfida***
   b. leaf alternate, elliptic-oval, 12-20 cm long, 2.5-10 cm width, fruits less than 4 cm in diameter, covered by dense brown trichomes, fruit calyx not clasping and shortened by age ……..……...…… (8)
8. a. Fruit with dense light brown trichome, simple and flat fruit calyx …….. ***D. greshoffiana***
   b. Fruit smaller, fruit calyx slightly reflexed to reflexed or spreading ……..…….…….. (9)
9. a. fruit covered by dense silvery trichomes, lobes fruit calyx slightly reflexed ……..……. ***D. javanica***
   b. lobes of fruit calyx reflexed, margin wavy expanded to 4-6 cm in diameter, fruit covered by dense light brown trichomes …….. ***D. pilosanthera* var. *polyalthioides***
10. a. fruits 1.5-2 cm in diameter, ellipsoid, green when young, fruit surface smooth and lenticellate, fleshy, orange when mature ..... ***D. andamanica***
    b. fruits 1.5-2 cm in diameter, ellipsoid, green when young, fruit surface smooth, fleshy, orange when mature .... ***D. ferrea***

Figure 5. Fruit and fruit calyx characteristics of *Diospyros* spp.: A. *D. ferrea*, B. *D. andamanica*, C. *D. celebica*, D. *D. malabarica*, E. *D. amboinensis* F. *Diospyros* sp.1 G. *D. lolin*, H. *D. discolor*, I. *D. greshoffiana*, J. *D. cauliflora* K. *D. javanica* L. *Diospyros* sp.2, *M. D. perfida*, and N. *D. pilosanthera* var. *polyalthioides*. Scale bar: A, B, C, D, I, J, K, M, N = 1 cm, E, F, G, H = 10 cm, L = 2 cm

Discussion

Phenetic relationship and morphological characters

The living collections of *Diospyros* spp. were characterized by referring to some previous morphological descriptions by Bakhuizen van den Brink (1937; 1938) which described *Diospyros* species of South East Asia and Ng (1978) described species of Borneo, Putri and Chikmawati (2015) studied leaf flushing characters, also Gosline (2009) and Provance et al. (2008) described new species of Cameroon and Mesoamerica, respectively. Plant morphological characters used in this study included canopy characters, the details of venation, the presence of leaf glands, trichome characters, leaf flushing characters, and fruit flesh and groove characters both in a fresh and dry stage. Flowers were not characterized in this study because of the absence of female or bisexual plants in the collection. Fruit calyx is generally small or large, flat or spreading, leafy or woody textured, flat or reflexed, entire

or wavy margined, and growing in unique and special features such as clasping the whole fruits when young then shorten with age, like in *D. perfida*. This characters is important for species identification because it is distinctive for species level (Rindyastuti, 2021).

Sectional separation of *Diospyros* spp. resulted in this study is considered as paraphyletic; since some different sections were clustered together and not clearly separated. However, in general, our phenetic clustering of *Diospyros* spp. support previous plant classification of *Diospyros* spp. of South East Asian region by Backhuizen van den Brink (1936-1955), especially in the sect. *Ebenaster* (cluster III), with the exception of *D. malabarica* (sect. *Glutinosa*) which nested into this cluster. Likewise, sect. *Verruculosa* nested into cluster I together with sect. *Ptychoclyx*; whilst sect. *Stelechantha* nested with sect. *Nesindica* in cluster II. This finding could serve as a new reference to sectional separation in classification of *Diospyros* spp. in South East Asia especially in Indonesian archipelago.

Differentiating morphological characteristics in *Diospyros* spp. which contribute to phenetic dendrogram construction was produced using the analyses of synapomorphy and autapomorphy characters. From the analyses of synapomorphy and automorphy, it revealed that some vegetative and generative characteristics are important for taxonomical grouping and clustering, such as leaf size, leaf margin, and details of venation. Fruit size and trichomes are two generative characters that significantly determine the dendrogram clustering of this taxa. According to Liu and Qin (2013) fruit morphology of plant family is useful characters in taxonomy. Trichomes are epidermal organs briefly introduced to have physiological functions such as in reflectance, energy balance, sun protection, drought resistance, gas exchange, insect, and disease resistance (Xiao et al. 2017). Trichomes showed taxonomical significance in many plant groups such as Cucurbitaceae, Rosaceae, *Prunus* spp. (Yang et al. 2018; Wang et al. 2019), *Phlomoides* (Lamiaceae) (Seyedi and Salmaki, 2015), *Ballota* (Lamiaceae) (Osman, 2012), Convolvulaceae (Ashfaq et al. 2019), etc. Vegetative trichome varies in size, type, number, density, etc., genetically encoded by specific genes (Yang et al. 2018) and serve as a taxonomical determinant (Creller and Werner, 1996). Whilst, study on generative trichomes such as fruit trichomes are still limited (Xue et al. 2018), therefore, this study results will provide a start point in understanding the morphology, development, functions and significance of generative trichomes in plants. In *Diospyros* group, generative trichome characters could be investigated in detail for the colors, densities and microstructures.

Other important characters from this analysis are fruit calyx shape. Persistent fruit calyx is one of rare morphological characters in plants introduced to protect the developing fruit from predators as well as from desiccation.Its variation is often correlated with differences in dispersal methods. Fruit calyces vary from inflated, accrescent to non-accrescent (Deanna et al. 2019). Persistent fruit calyx including its diverse and modified morphological characteristics is regulated by specific genes (Pei et al. 2016; Deanna et al. 2019). In *Diospyros* spp., fruit calyx is a specific characteristic to species identities that serve as important characters for species identification (Rindyastuti, 2021), therefore it has less relevance to differentiating characters for dendrogram clustering or taxonomical classification to infra-specific level, i.e., section or genera level.

The study results also indicated that *Diospyros* could be recognized not only from morphological characteristics of generative organs, but also vegetative organs, such as the shape and size of leaf, leaf surface, details in venation, and the characters of leaf trichomes. According to Hickey and Wolfe (1975), vegetative plant organs could serve as a good species determinant which provides strong evidence for taxonomical study in Dicotyledoneae. *Diospyros* spp. is slow grower and dioecious with separated male and female plants in one species which leads to difficulties in observing complete generative characters and conducting species identification. This could be resolved by developing identification method using vegetative characters. The availability of taxonomical system using morphological characteristics of vegetative organs is very important for practical identification of this taxa.

Suggestion of species identity

Two species of *Diospyros* sp. analyzed in this study are identified into the genus level. Morphological descriptions of these species are difficult to support identification until species level. However, the clustering dendrogram showed that *Diospyros* sp.1 grouped with the other 4 species from the sect. *Ebenaster* in the cluster III sub-cluster 2, thus this species is possibly classified into sect. *Ebenaster*. *Diospyros* sp.1 was characterized to have globose fruits, with 5 cm in diameter, fruit surface is densely velvet and reddish-brown colored while fruit calyx is woody and erect. Furthermore, *Diospyros* sp.1 has high morphological similarities with *D. celebica*, by possessing 32 synapomorphic characters. The leaf length is 10-30 cm with 0-10 cm wide, lateral venation pattern ascending, intramarginal venation with no looped, upper leaf are smooth, downside leaf are hairy, leaf flushings are greenish, fruits are ellipsoid, mature fruit is light brown-colored, fruit is intermediate fleshy, fruit pericarp is hard or woody, and fruit surface is dark green that turning to brown trichomes when mature. However, the erect and densely haired fruit calyx exhibited that this specimen is different from a well-known endemic species to Celebes, *D. celebica*.

Diospyros sp.2 is another unidentified species that showed high similarity with *D. javanica* and *D. greshoffiana*, it is closely related to *D. venenosa* which are distributed at Sulawesi. However, this unidentified specimen has globose fruit with 1.5-2 cm in diameter with pistil residual, while *D. venenosa* has depressed globose fruit with 1-2 cm long and 1.5-3 cm in diameter. On the basis of the dendrogram analysis, this unidentified specimen grouped into Cluster I together with *D. perfida* and *D. pilosanthera* var. *polyalthioides*. Thus, this species could be identified as one of the species of sect. *Nesindica*, *Ptychocylix* or *Verruculosa*. Further examination subjected to both unidentified species compared to larger specimens

of *Diospyros* spp. is required to support species identification.

Implications to biogeographical distribution

The biogeographic pattern of plant species in the Indonesian archipelago is characterized by the abundance of narrowly distributed species, where some species are often endemic to an island. Among the species of *Diospyros* studied, there are several endemic species, such as *D. perfida* which is endemic to Kalimantan, *D. celebica* and *D. greshoffiana* which endemic to Sulawesi and *D. amboinensis* which endemic to Mollucas (Figure 6) (Bakhuizen van den Brink 1937; Rindyastuti 2021). Generally, biogeographical distribution of plants leads to the variation of plant morphology even to speciation (Tan et al. 2020). Wallace's line theory underlined that the species from Kalimantan are generally separated from the species from Sulawesi and East Indonesia, i.e., Mollucas and Papua (Michaux 2010). The flora of western Indonesia has different morphological characters from the species distributed in the eastern part such as Sulawesi and Maluku (Culmsee and Leuschner 2013). However, Ebenaceae is a small plant family that may show but considered not to dominate this separating pattern (Van Welzen and Slik 2009). The outlook to biogeographical distribution and morphological variation of *Diospyros* species throughout Indonesian archipelago will provide more information for this taxa.

Based on the dendrogram analysis, the species which are distributed in Kalimantan *i.e. D. pilosanthera* var. *polyalthioides* and *D. perfida* (cluster I) tends to be separated from the species that are distributed in Java, Sulawesi and Mollucas Islands (cluster II and III). The species distributed in Sulawesi esp. the endemic species (*D. celebica* and *D. gresshofiana*), have special characters differentiating them from the species distributed in the western of Indonesia, especially Kalimantan, *i.e.* the thick, velvety but not easily removed fruit trichomes. The species distributed in Kalimantan have quite dense sometimes short trichomes that easily removed by age (*D. perfida,* and *D. pilosanthera* var. *polyalthioides*).

The biogeographic pattern of native plant species, especially those with narrow and endemic distribution areas, can also indicate the ecological characteristics of plant habitats (Nuzhyna and Gaydarzhy 2015; Pyakurel and Wang 2013). Habitat of *Diospyros* spp. in Kalimantan such as mixed dipterocarp forest is characterized by wetter climate, which is very different from drier habitat in Sulawesi with edaphic karst environments that often lead to water stress. Habitat differences correlated with differences in leaf morphology, where *Diospyros* spp. from Sulawesi developed a more persistent and denser fruit trichome. A dense trichome is able to reduce transpiration rate at warmer temperature or sun-exposed area as an adaptation form to water shortage conditions (Perez-estrada et al. 2000; Morandi et al. 2007; Salehi-Lisar and Bakhshayeshan-Agdam, 2016; Pyakurel and Wang, 2013).

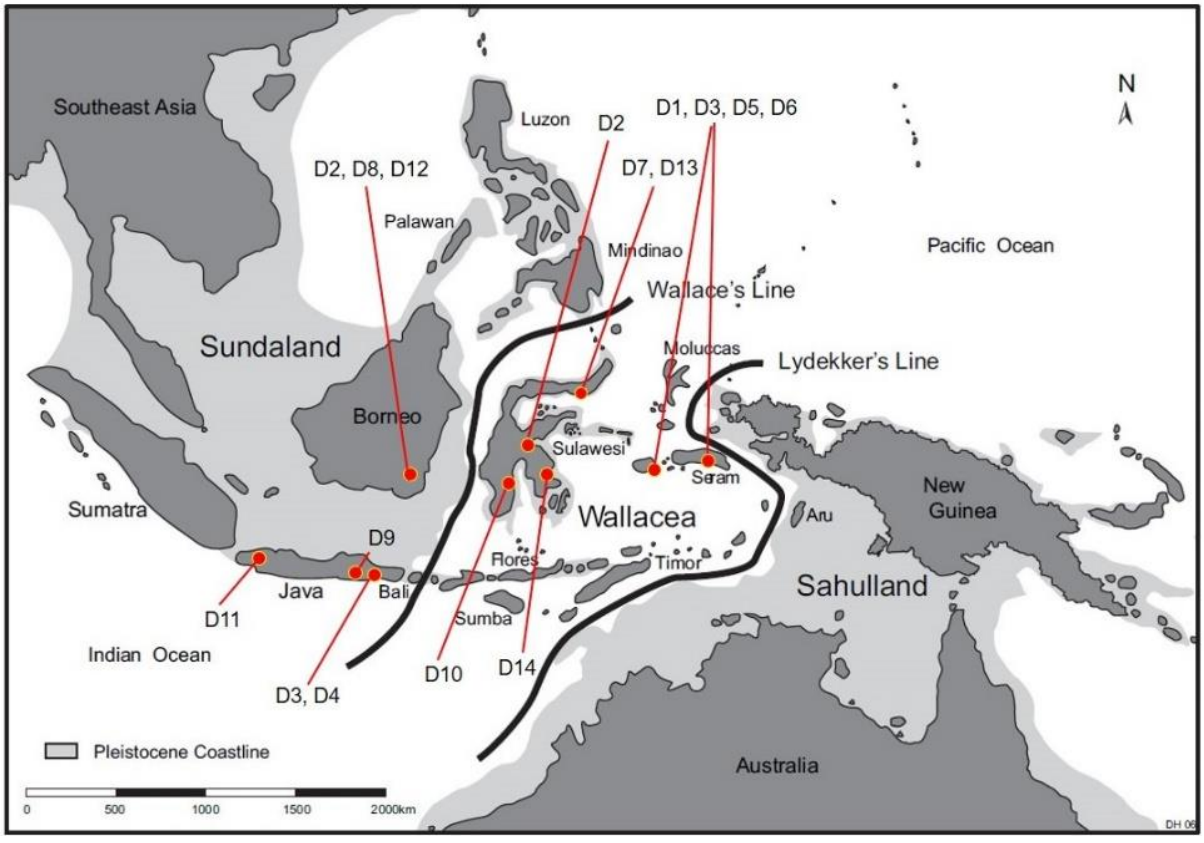

Figure 6. Biogeographic distribution of 14 species of *Diospyros* spp. examined in this study.

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Table S1. Morphological characteristic of 14 *Diospyros* species in Indonesia

No.	Chc.	D1	D2	D3	D4	D5	D6	D7
1	BC	Black	Light brown	Dark brown	Light brown	Blackish brown	Black	Blackish brown
2	BT	Smooth grooved	Smooth grooved	Coarsely grooved	Vertically grooved	Vertically grooved	Vertically grooved	Vertically grooved
3	CS	Irregular	Conus-irregular	Conus-irregular	Conus	Conus	Conus	Conus
4	LS	Ovate, oval-elliptic	Elliptic, oblong	Elliptic, oblong	Ovate, oval, elliptic, oblong	Elliptic, obovate, ovate	Elliptic, ovate, obovate	Elliptic, lanceolate
5	LL	4-8.5 cm	10-22 cm	9-27 cm	11-33 cm	15-32 cm	10-34 cm	19.1-23.4 cm
6	LW	2-5 cm	2.8-5.7 cm	3-6.3 cm	5 - 15 cm	10-15 cm	4.5-15 cm	4.13-5.1 cm
7	LA	Obtuse, rounded	Acute	Acuminate	Short acuminate	Acute	Acute, short acuminate	Acute-acuminate
8	LB	Acute	Acute-cordate	Cuneate	Acute, subcordate, Cordate, rounded	Truncate, subcordate	Acute, rounded, subcordate	Cuneate - truncate
9	PNV	5-7 pairs	7-11 pairs	10-12 pairs	10-22 pairs	11-17 pairs	12-14 pairs	15 - 20 pairs
10	V	Less visible	Visible	Visible	Slightly visible	Visible	More visible	Slightly visible
11	LVP	Less straight	Ascending-straight	Ascending	Ascending-straight	Ascending	Straight (900)	Ascending
12	IV	Looped	no looped	Looped	no looped	Looped	Looped	no looped
13	M	Sunken above	Intermediate sunken	Prominent above	Intermediate sunken	Sunken above	Intermediate sunken	Intermediate sunken
14	ALV	1/3 from leaf margin	Very near leaf margin	1/4 to 1/5 from leaf margin	1/3 from leaf margin	1/3 from leaf margin	1/3 from leaf margin	1/4 to 1/5 from leaf margin
15	VD	Intmd	Present	Present	Absent	Present	Present	Absent
16	TUL	Absent	Absent	Absent	Absent	Absent	Absent	Absent
17	TDL	Absent	Absent	Absent	Present	Present	Present	Present
18	TDM	Present	Present	Absent	Present	Absent	present	Present
19	CUL	Blackish green	Dark green	Dark green	Brownish green	Dark green	Brownish green	Light green
20	CDL	Dark green	Light green	Light green	Dark green	Dark green	Dark green	Whittish green
21	LM	Entire	Entire	Entire	Entire	Wavy	Wavy	Entire
22	LT	Membranaceous	Membranaceous	Membranaceous	Membranaceous	Membranaceous	Membranaceous	Membranaceous-paperaceous
23	LG	Absent	Present	Absent	Present	Present	Present	Absent
24	PNLG	0	7-12 pairs	0	9-16 pairs	4-6 pairs	4-6 pairs	0
25	LS	Bullate	Flat	Bullate	Flat	Slightly bullate	Bullate	Flat
26	TP	Present	Present	Absent	Present	Present	Present	Present
27	TCP	Light brown	Reddish brown	Absent	Dark brown	Blackish	Light brown	Light brown
28	LFC	Light brown	Light brown	Light brown	Greenish	Light brown	Light brown	Greenish
29	FS	Globose	Ellipsoid	Ovoid-globose	Globose-depressed globose	Globose	Globose	Ellipsoid-globose
30	FD	0.8-1.3 cm	1.6-1.9 cm	1.5-2 cm	8-13 cm	7-11 cm	4.5-6 cm	1.93-2.92

31	FL	0.95-1.5 cm	2-2.7 cm	1.5-1.9 cm	6-9 cm	6-9 cm	4.5-5 cm	1.63 - 3.27 cm
32	CYF	Light green	Light green	Dark green	Dark green	Light green	Light green	Light green
33	CMF	Orange	Orange	Yellow	Orange	Orange	Orange	Light brown
34	FF	Fleshy	Fleshy	intmd	Intmd	Non fleshy	Intmd	Intmd
35	FG	Absent	Absent	Absent	Absent	Absent	Absent	Present
36	WF	Absent	Present	Present	Absent	Absent	Present	Present
37	FA	Obtuse flat	Obtuse flat	Acute	Depressed obtuse	Depressed obtuse	Obtuse flat	Acute
38	TYF	Absent	Absent	Present	Present	Present	Present	Present
39	TDYF	Absent	Absent	Dense	Dense	Dense	Not dense	Dense
40	TMF	Absent	Absent	Present	Present	Present	Present	Present
41	TDMF	Absent	Absent	Not dense	Not dense	Not dense	Not dense	Dense
42	TCYF	Smooth	Smooth	Lenticelate	Dense hairy	Smooth	Dense hairy	Dense hairy
43	TCMF	Absent	Absent	Light green	Dark green	Light green	Reddish brown	Dark green
44	FS	Smooth	Smooth	Lenticelate	Dense hairy	Smooth	Dense hairy	Dense hairy
45	CDF	Red	Brown	Brown	Red	Brown	black	Black
46	MF	Decayed	Wrinkle	Wrinkle	Decayed	Smooth	Decayed	Smooth
47	SFC	Bowl shape	Simple round shape	Simple round shape	Flatten triangular	Flatten triangular	Flatten triangular	Flatten triangular
48	FCD	0.7-0.8 cm	1-1.4 cm	2-2.5 cm	4 cm	2.5-3 cm	2 cm	2-2.2 cm
49	LFCL	0.7-0.8 cm	1-1.4 cm	2-2.5 cm	4 cm	2.5-3 cm	2-2.3 cm	2-2.2 cm
50	NFCL	Lobes 3	Lobes 3	Lobes 4	Lobes 4	Lobes 4	Lobes 4	Lobes 4
51	SFCL	Triangular bunga	Acute triangular	Acute triangular	Acute triangular	Acute triangular	Acute triangular	Acute triangular
52	FCPMF	Half-covering	Flat	Flat	Flat	Flat	Flat	Flat
53	FCPYF	Flat	Flat	Flat	Flat	Flat	Flat	Flat
54	CLM	Entire	Entire	Entire	Wavy	Entire	Reflexed	Entire
55	TFC	Thin leafy	Thin leafy	Woody	Woody	Thin leafy	Woody	Thin leafy
56	TFC	Thin	Thin	Thick	Thick	Thin	Thick	Thin
57	SFC	Smooth	Smooth	Hairy	Coarsely lenticellate	Hairy	hairy	Hairy

Table S1. Morphological characteristic of 14 *Diospyros* species in Indonesia (*con't*)

No.	Chc.	D8	D9	D10	D11	D12	D13	D14
1	BC	Light brown	Blackish brown	Light brown	Blackish brown	Dark brown	Grayish green	Light brown
2	BT	Smooth grooved	Smooth grooved	Lenticellate	Smooth grooved	Smooth grooved	Lenticellate grooved	Lenticellate
3	CS	Conus-irregular	Irregular	Conus	Conus-irregular	Conus-irregular	Conus	Conus
4	LS	Elliptic, obovate	Elliptic, oval, ovate	Elliptic, ovate, obovate	Elliptic, oval, ovate, obovate	Elliptic, ovate	Elliptic, oval, ovate, obovate	Elliptic, oval, ovate, obovate
5	LL	11-28 cm	10-22 cm	10-24 cm	8-21 cm	12-30 cm	15-27 cm	16-24.5 cm
6	LW	4.5-11 cm	3-7.5 cm	4.5-8.5 cm	3.5 -8 cm	4-11 cm	4.5-8.5 cm	6-11 cm
7	LA	Acute	Acute	Acute, short acuminate	Short acuminate	Acuminate	Acuminate	Acute
8	LB	Cuneate	Acute-rounded	Cuneate	Cunneate, cordate, sub cordate	Acute-rounded	Cuneate	Acute
9	PNV	12-14 pairs	7-10 pasang	8-11 pairs	9-12 pairs	7-10 pairs	8-12 pairs	6-9 pairs
10	V	More visible	Slightly visible	Slightly visible	Visible	Visible	Visible	Visible
11	LVP	Straight (900)	Ascending	Ascending	Less straight	Ascending	Ascending	Ascending
12	IV	No looped	no looped	no looped	no looped	no looped	no looped	Looped
13	M	Prominent above	Intermediate sunken	Intermediate sunken	Intermediate sunken	Intermediate sunken	Intermediate sunken	Sunken above
14	ALV	Very near l.margin	1/3 from leaf margin	1/4 to 1/5 from leaf margin	1/2 from leaf margin	Very near leaf margin	1/3 from leaf margin	1/4 to 1/5 from leaf margin
15	VD	Present	Present	Present	Present	Present	Intmd	Present
16	TUL	Present	Absent	Absent	Absent	Absent	Absent	Absent
17	TDL	Present	Absent	Absent	Present	Absent	Present	Present
18	TDM	Present	Absent	Present	Present	Present	Present	Present
19	CUL	Dark green	Brownish green	Brownish green	Dark green	Dark green	Light green	Dark green
20	CDL	Light green	Dark green	Light green	Dark green	Light green	Light green	Light green
21	LM	Entire	Entire	Entire	Entire	Entire	Entire	Entire
22	LT	Paperaceous	Membranaceous	Membranaceous	Membranaceous-paperaceous	Membranaceous	Membranaceous	Membranaceous
23	LG	Absent	Absent	Absent	Present	Absent	Present	Absent
24	PNLG	0	0	0	4-6 pairs	0	4-7 pairs	0
25	LS	Bullate	Flat	Bullate	Flat	Flat	Flat	Bullate
26	TP	Present	Absent	Present	Present	Present	Present	Present
27	TCP	Light brown	Absent	Dark brown	Blackish	Greenish	Light brown	Light brown
28	LFC	Reddish	Light brown	Greenish	Light brown	Light brown	Greenish	Light brown
29	FS	Globose	Ellipsoid	Depressed globose	Globose	Globose	Ellipsoid	Globose
30	FD	2-2.7 cm	1.5-2 cm	1.7-1.8 cm	3.9 - 4.8 cm	4- 4.7 cm	5-5.5 cm	1.6-2.2 cm

31	FL	2.5-2.8 cm	1.5-2 cm	1.6-1.7 cm	4-4.6 cm	3.3-4 cm	5.5-6 cm	2-2.5 cm
32	CYF	Light green	Light green	Dark green	Dark green	Light green	Yellow	Light green
33	CMF	Light brown	Yellow	Light brown	Yellow	Brownish green	Light brown	Light brown
45	CDF	Brown	black	Brown	black	Black	Brown	Brown
34	FF	Intmd	Intmd	Non fleshy	Intmd	Non fleshy	Intmd	Non fleshy
35	FG	Present	Absent	Absent	Absent	Absent	Absent	Absent
36	WF	Absent	Present	Present	Present	Present	Present	Present
37	FA	Depressed obtuse	Obtuse flat	Depressed obtuse	Obtuse flat	Depressed obtuse	Acute	Acute
38	TYF	Present	Present	Present	Present	Present	Present	Present
39	TDYF	Present	Dense	Not dense	Not dense	Present	Dense	Dense
40	TMF	Present	Absent	Present	Present	Present	Present	Present
41	TDMF	Not dense	Absent	Not dense	Not dense	Not dense	Dense	Dense
42	TCYF	Dense hairy	Smooth	Dense hairy	Dense hairy	Lenticelate	Dense hairy	Dense hairy
43	TCMF	Dark green	Absent	Dark green	Light green	Light green	Dark green	Dark green
44	FS	Dense hairy	Smooth	Dense hairy	Dense hairy	Lenticelate	Dense hairy	Dense hairy
46	MF	Wrinkle	Smooth	Drying hardwood	Drying hardwood	Smooth	Wrinkle	Drying hardwood
47	SFC	Bowl shape	Campanulate	Bowl shape	Isodiametry	Bowl shape	Flatten triangular	Campanulate
48	FCD	4-5.5 cm	2-2.5 cm	1.6-1.7 cm	4-5 cm	4-4.8 cm	3.8-4.3 cm	2-2.5 cm
49	LFCL	2.5-3 cm	2-2.5 cm	1.6-1.7 cm	4-5 cm	4-4.8 cm	3.8-4.3 cm	2-2.5 cm
50	NFCL	Lobes 4-5	Lobes 4	Lobes 4	Lobes 4	Lobes 3	Lobes 4	Lobes 4-5
51	SFCL	Acuminate triangular	Triangular wavy	Acute triangular	Acute triangular	Acute triangular	Acute triangular	Triangular wavy
52	FCPMF	Flat	Half-covering	Flat	Flat	Whole covering	Reflexed	Whole covering
53	FCPYF	Spreading	Flat	Flat	Flat	Half-covering	Spreading	Half Covering
54	CLM	Wavy	Reflexed	Entire	Reflexed	Entire	Reflexed	reflexed
55	TFC	Thin leafy	Thick leafy	Woody	Woody	Woody	Woody	Thick leafy
56	TFC	Thick	Thick	Thick	Thick	Thick	Thick	Thick
57	SFC	Hairy	Hairy	Coarsely lenticelate	Hairy	Coarsely lenticelate	Hairy	Smooth

Note: Chc.: Characters; BC:Bark color; BT: Bark texture; CS: Canopy shape; LS: Leaf shape; LL: Leaf length; LW:Leaf width; LA:Leaf apex; LB: Leaf base; PNV: Pair number of vein, V:Venation (main and lateral); LVP: Lateral venation pattern; IV: Intramarginal venation; M: Midrib; ALV: Anastomosing of lateral venation; VD: Vein domination; TUL: Trichome of upper leaf; TDL: Trichome of downside leaf; TDM: Trichome of downside midrib; CUL: Color of upper leaf; CDL: Color of downside leaf; LM: Leaf margin; LT:Leaf texture; LG:Leaf glands; PNLG: Pair number of leaf glands; LS: Leaf surface; TP: Trichome in petiole; TCP: Trichome color in petiole; LFC: Leaf flushing color; FS: Fruit shape; FD: Fruit diameter; FL: Fruit length; CYF: Color of young fruit; CMF: Color of mature fruit; CDF: Color of dry fruit; FF: Fruit flesh; FG: Fruit groove; WF: Wood of fruit; FA: Fruit apex; TYF: Trichome of young fruit; TDYF: Trichome density of young fruit; TMF: Trichome of mature fruit; TDMF: Trichome density of mature fruit; TCYF: Trichome color of young fruit; TCMF: Trichome color of mature fruit; FS: Fruit surface; MF: Mature fruit; SFS: Shape of fruit calyx; FCD: Fruit calyx diameter; LFCL: Large of fruit calyx lobes; NFCL: Number of fruit calyx lobes; SFCL: Shape of fruit calyx lobes; FCPMF: Fruit calyx position of mature fruit; FCPYF: Fruit calyx position of young fruit; CLM: Calyx lobes margin; TFC: Texture of fruit calyx; TFC: Thickness of fruit calyx; SFC: Surface of fruit calyx.; intmd: intermediate