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Pollen Micromorphology of Mangrove Species in South Sumatera Coastal Area, Indonesia

(Mikromorfologi Debunga Spesies Bakau di Kawasan Pantai Sumatera Selatan, Indonesia)

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ABSTRACT

Reports indicated a global decline in mangrove forest coverage, with particularly high levels in Sumatera, Indonesia. To effectively conserve these ecosystems, additional research is essential to obtain comprehensive data. Specifically, investigating pollen variation in mangrove species in South Sumatera is critical due to the current lack of information. This study aimed to determine the pollen morphology of various mangrove species in South Sumatera. Fieldwork was conducted around mangrove ecosystem area of Musi Estuary in Tanjung Api-api and Payung Island, South Sumatera. Each mature flower was placed in an envelope and stored an airproof container with silica gel. Herbarium specimens were also used for identification purpose. Pollens of nine mangrove species (*Avicennia alba, A. marina, Bruguiera gymnorhiza, B. sexangula, Excoecaria agallocha, Kandelia candel, Nypa fruticans, Rhizophora apiculata,* and *Sonneratia caseolaris*) were observed with a scanning electron microscope (SEM). Pollen SEM images were measured and morphological characteristics of pollens were recorded. The pollen of mangroves in South Sumatera coastal area varied in size (small and medium), ratio of polar/equatorial (prolate, isodiametric and oblate), shape (ellipse, triangular, triangular pyramid and spheroidal shape), polar view (circular, open semi-angular and intruding semi-angular), equatorial view (prolate-circular oval, spherical-apiculate and spherical-circular oval), outline (lobate, triangular and circular), aperture (tricolporate, triporate and monosulcate) and ornamentation (perforate, psilate, echinate reticulate and gemmate). The pollen morphology has been demonstrated to be effective in distinguishing various mangrove species in South Sumatera, and it can be used to produce a species identification key.

Keywords: Mangrove; micromorphology; pollen; scanning electron microscope; Sumatera

ABSTRAK

Laporan menunjukkan penurunan global dalam liputan hutan bakau, terutamanya pada paras yang tinggi di Sumatera, Indonesia. Bagi memulihara ekosistem ini dengan berkesan, penyelidikan tambahan adalah penting untuk mengumpulkan data yang komprehensif. Secara khusus, kajian variasi debunga pada spesies bakau di Sumatera Selatan adalah kritikal kerana kekurangan maklumat semasa. Kajian ini bertujuan untuk mengetahui morfologi debunga pelbagai spesies bakau di Sumatera Selatan. Kerja lapangan telah dijalankan di sekitar muara Musi di Tanjung Api-api dan Pulau Payung di Sumatera Selatan. Bunga matang diletak dalam sampul surat dan disimpan dalam bekas kedap udara dengan gel silika. Spesimen herbarium juga digunakan untuk tujuan pengecaman. Debunga bagi sembilan spesies bakau (*Avicennia alba, A. marina, Bruguiera gymnorhiza, B. sexangula, Excoecaria agallocha, Kandelia candel, Nypa fruticans, Rhizophora apiculata* dan *Sonneratia caseolaris*) diperhatikan di bawah mikroskop elektron pengimbasan (SEM).Imej SEM debunga diukur dan ciri morfologi debunga direkodkan. Debunga bakau dari pantai Sumatera Selatan berbeza daripada segi saiz (kecil dan sederhana), nisbah polar/ekuatorial (prolat, isodiametrik dan oblat), bentuk (elips, segi tiga, segi tiga piramid dan sferoidal), pandangan kutub (bulatan, terbuka semi-bersudut dan semi-bersudut dan semi-bersudut berbonjol), pandangan khatulistiwa (prolat-bulatan oval, sfera-apikulat dan sfera-bularan oval), garis besar (lobat, segi tiga dan bulat), apetur (trikoporat, triporat dan monosulkat) dan hiasan (berlubang, psilat, ekinat, retikulat dan gemmat). Ciri morfologi debunga telah terbukti berkesan dalam membezakan pelbagai spesies bakau di Sumatera Selatan, dan ia boleh digunakan untuk membina kekunci pengecaman spesies.

Kata kunci: Bakau; debunga; mikromorfologi; mikroskop imbasan elektron; Sumatera

Introduction

A mangrove is tropical coastal vegetation consisting of a shrub or tree that grows in coastal saline or brackish water. Mangroves are reported to protect beaches from storm damage (Imbert 2018) and to prevent erosion (Pennings et al. 2021) with their root systems that help bind soils, intensify sediment deposits and slow water flow. Furthermore, the root systems also trap pollutants or debris (Pradit et al. 2022) from the water to improve the quality of the water that streams to the ocean. Mangroves store massive amounts of CO_2 known as 'blue carbon' (Sasmito et al. 2020) which can be used to counter the greenhouse effect. Mangroves provide habitat and refuge to wildlife, such as spawning and nursery territory for marine species (Meilana, Hakim & Fang 2021; Nazneen et al. 2022), as well as rookeries, nesting and breeding areas (Gayathre, Kalaiarasan & Balasundari 2021) for coastal animals. Endangered species rely on mangrove habitats during some stage of their life cycle (Brame et al. 2019). Mangroves have the potential for ecotourism (Fisu et al. 2020; Spalding & Parrett 2019) to provide nature experiences for people (Marasinghe et al. 2021) such as fishing, birding, snorkeling, paddle boarding, kayaking and relaxing, as well as providing economic benefits as a nursery for commercial fish.

Globally, mangrove forest covers have reported decreasing by approximately 3,363 km^2 with a 0.13% average annual rate from 2000 to 2016 (Goldberg et al. 2020). Indonesia is one of the top 10 countries in Southeast Asia with the highest average annual rate of mangrove deforestation (0.26%) between 2000 and 2012 (Friess et al. 2019) with the hotspots in Sumatera and Kalimantan (Richards & Friess 2016). For example, more than 22,513.2 ha of mangroves in North Sumatera were reportedly lost between 1990 and 2015 (Basyuni & Sulistiyono 2018). In South Sumatera, meanwhile, there was a substantial loss of primary mangrove forest of more than 50% over 35 years between 1985 and 2020, and the remaining primary mangrove forest area was only 2,936 ha in 2020 (Eddy et al. 2021). More research, therefore, is needed to obtain data as complete as possible to assist in conservation efforts and the preservation of the mangroves.

Most of the studies on mangroves in South Sumatera were related to ecology, diversity of flora, fauna and funga, physiology, biochemistry, mangrove-cover loss, carbon emission, carbon stock, environmental parameters and sedimentation analyses (Afriyani et al. 2017; Asshidiq, Rozirwan & Hendri 2020; Barus et al. 2019; Dalimunthe et al. 2022; Darmawan et al. 2020; Delta, Rozirwan & Hendri 2021; Dwirastina 2009; Eddy & Basyuni 2020; Eddy, Milantara & Basyuni 2021; Eddy et al. 2021, 2019; Ernanto, Agustriani & Aryawaty 2010; Hartoni & Agussalim 2013; Heirina, Rozirwan & Hendri 2020; Hermialingga, Suwignyo & Ulqodry 2020; Indica, Ulqodry & Hendri 2011; Indriani, Marisa & Zakaria 2009; Lyusta, Agustriani & Surbakti 2017; Mukhlis, Rozirwan & Hendri 2018; Purwiyanto 2013; Purwiyanto & Agustriani 2017; Putri, Fauziyah & Elfit 2013; Rahmat, Fauziyah & Sarno 2015; Riyanti et al. 2019; Sarno, Marisa & Army 2020; Sarno, Marisa & Sa'Diah 2013; Sarno et al. 2020; Sarnubi, Sarno & Marisa 2020; Sukardjo 1987; Suwignyo et al. 2012; Ulqodry, Bengen & Kaswadji 2010; Winata et al. 2017; Yuliana et al. 2019). There has never been any research on the pollen characteristics of mangrove vegetation in South Sumatera. Whereas in other areas, studies of pollen characteristics of some mangrove vegetation were conducted intensively (Assemien 1969; Bertrand 1983; Langenheim, Hackner & Bartlett 1967; Ludlow-Wiechers & Alvarado 1983; Mohd-Arrabe & Noraini 2013; Muller & Caratini 1977; Noraini et al. 2017; Qodriyyah, Suedy & Haryanti 2015; Vezey et al. 1988).

Apart from morphological identification, pollen-based identification was also reportedly useful to delimit species. Pollen characters are meaningful in solving complicated issues of various taxa in their classification. Pollen morphology, such as grain size, the number of pores and exine sculpturing are the most distinctive features for species delimitation (Ragho 2020). The pollen morphology, including its shape and structure, can provide valuable information for identifying and classifying various taxa and solving taxonomic issues within a particular group of plants (Britannica 2023). In mangrove species, pollen is important even if they consist of several different species and families (Tomlinson 1986). Pollen morphology, however, is an aid to morphological studies for taxonomists and a useful tool for species delimitation. Therefore, it is necessary to investigate the pollen variation in mangrove species in South Sumatera. Furthermore, there is no study on the characteristics of pollen from mangrove vegetation in this area. This study aimed to determine the pollen grain morphology of various mangrove species in South Sumatera. The study is expected to add value to the taxonomic study of mangrove species.

Materials and Methods

The fieldwork was conducted around mangrove ecosystem in Musi Estuary, Tanjung Api-api and Payung Island, South Sumatera, Indonesia in May 2021 (Figure 1). Pollen samples were collected from the mature flowers of mangrove species. Each mature flower was placed in an envelope and kept in an airproof container with silica gel. Herbarium specimens were also used for the identification purpose of the species using the method of Rugayah et al. (2004), and the processing of herbarium specimens by Djarwaningsih, Sunarti and Kramadibrata (2002) was followed. Supporting data were recorded and photographs of the fresh specimens were also taken. All specimens were stored in the Herbarium Bogoriense (BO), National Research and Innovation Agency, Indonesia. Identification of the specimens was conducted by consulting with BO collection and various references such as Giesen et al (2006), Ng and Sivasothi (2001), and Noor, Khazali and Suryadiputra (2012). Accepted names of the species were validated with relevant references and online database portals (Damayanto, Fastanti & Dalimunthe 2020).

Pollens were observed with a scanning electron microscope (SEM) in the Zoology Characterization Laboratories, National Research and Innovation Agency, Cibinong City, Bogor Regency, West Java Province, Indonesia. Pollens from the anthers were simply sown on carbon tape at a stub and coated with gold using a coater model IB-2 Giko Engineering, Japan. The samples were observed in a Jeol JSM-IT200 SEM at 650–10,000× magnification. SEM images of pollen were measured and morphological characteristics of pollens were recorded. Data were observed and analyzed to determine the morphological variations of mangrove pollens. Based on pollen morphology, an identification key to the mangrove species in South Sumatera was provided. Terminology of pollen morphology followed Halbritter et al. (2018) and Nugroho (2014). Pollen identification was done using website https://www.paldat.org.

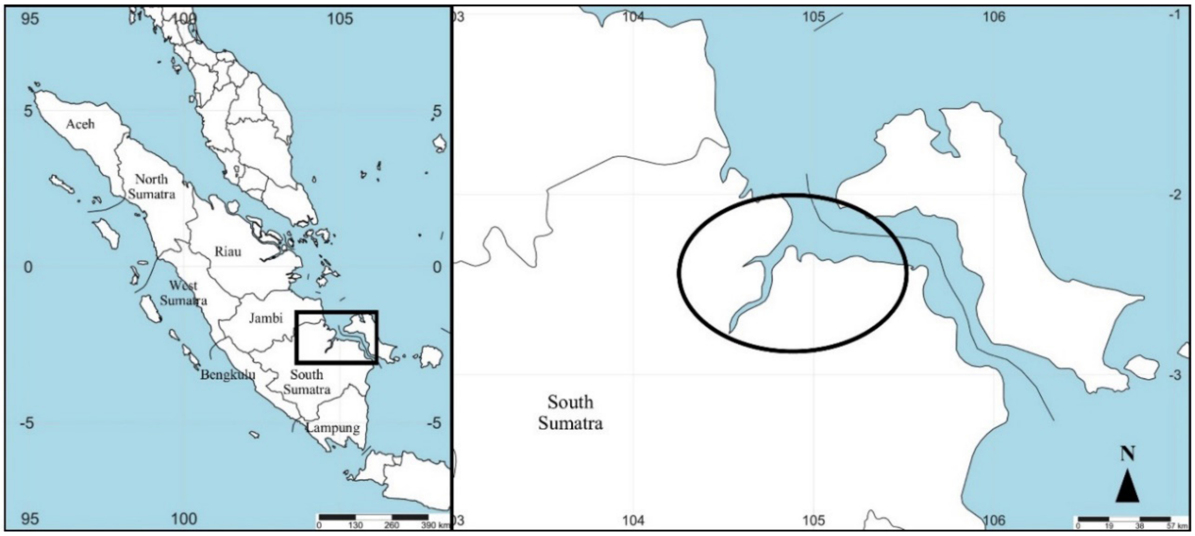

FIGURE 1. Fieldwork location (black circle) in Banyuasin Regency, South Sumatra, Indonesia

RESULTS AND DISCUSSION

Pollens of nine mangrove species in South Sumatera coastal area were successfully obtained and observed with SEM (Table 1; Figures 2-5), namely *Avicennia alba* Blume, *Avicennia marina* (Forssk.) Vierh., *Bruguiera gymnorhiza* (L.) Lam., *Bruguiera sexangula* (Lour.) Poir., *Excoecaria agallocha* L., *Kandelia candel* (L.) Druce, *Nypa fruticans* Wurmb, *Rhizophora apiculata* Blume, and *Sonneratia caseolaris* (L.) Engl. All the species are classified as true mangrove species. Most species belong to the Rhizophoraceae (four species), followed by Acanthaceae (two species), Lythraceae (one species), Euphorbiaceae (one species) and Arecaceae (one species) (Table 1). More than 50% of the pollen samples were collected from Tanjung Api-api and the rest were collected from Payung Island (Table 1).

Some pollen characters of South Sumatera mangrove species were observed, namely polar and equatorial length, value and the ratio of polar/equatorial (P/E), shape, size, unit, symmetry, outline, polar view, equatorial view, aperture and ornamentation (Table 2). Based on Halbritter et al. (2018), the mangrove pollen sizes in this study were divided into two categories: small (10-25 µm) and medium (25-50 µm). Small pollen size was found on *A. marina, B. gymnorhiza, B. sexangula, E. agallocha,* and *R. apiculata*, while medium size was found on *A. alba, K. candel, S. caseolaris,* and *N. fruticans*. According to Castillo-Cárdenas, Sanjur and Toro-Perea (2015), the size of pollen grains is an evolutionary trend that may be related to better adaptation to extreme environment. However, pollen size is a feature that is difficult to distinguish between genera in mangrove species because the size variation range is very broad (Chumchim & Khunwasi 2011).

The shape types of pollen grains are based on the polar/equatorial (P/E) ratio, which is the length of the polar axis between the two poles (P) compared to the equator diameter (E). The measures from the equatorial view of a pollen grain and spore vary from sub-oblate to perprolate and commonly show radial symmetry, isopolarity, and hexacolpate with micro reticulate or bireticulate sculpture (Celenk et al. 2008). Halbritter et al. (2018) divides the P/E ratio into three categories: prolate (polar axis longer than the equatorial diameter), isodiametric (polar axis equal to the equatorial diameter), and oblate (polar axis shorter than the equatorial

TABLE 1. List of mangrove species studied in South Sumatera coastal area

Species	Family	Location	Collection code
Avicennia alba	Acanthaceae	Payung Island	SHD 108
Avicennia alba	Acanthaceae	Tanjung Api-api	IPGPD 1187
Avicennia marina	Acanthaceae	Tanjung Api-api	IPGPD 1141
Bruguiera gymnorhiza	Rhizophoraceae	Tanjung Api-api	SHD 91
Bruguiera gymnorhiza	Rhizophoraceae	Tanjung Api-api	IPGPD 1137
Bruguiera sexangula	Rhizophoraceae	Payung Island	SHD 102
Bruguiera sexangula	Rhizophoraceae	Payung Island	IPGPD 1192
Excoecaria agallocha	Euphorbiaceae	Tanjung Api-api	IPGPD 1178
Kandelia candel	Rhizophoraceae	Payung Island	IPGPD 1186
Nypa fruticans	Arecaceae	Payung Island	IPGPD 1206
Rhizophora apiculata	Rhizophoraceae	Tanjung Api-api	IPGPD 1179
Rhizophora apiculata	Rhizophoraceae	Payung Island	IPGPD 1225
Sonneratia caseolaris	Lythraceae	Tanjung Api-api	SHD 100

diameter). In this study, the P/E ratio prolate was found in *A. alba, A. marina, B. sexangula, E. agallocha, K. candel,* and *R. apiculata.* The P/E ratio oblate was found in *B. gymnorhiza* and *N. fruticans*. *Sonneratia caseolaris* had an isodiametric P/E ratio that was different from other mangrove species. *Bruguiera gymnorhiza* and *B. sexangula* in this study had different P/E ratios. Therefore, the clustering of *Bruguiera* members into one group cannot be attributed to the P/E ratio alone. Otherwise, *A. alba* and *A. marina* can be grouped into one group because they share the same P/E ratio.

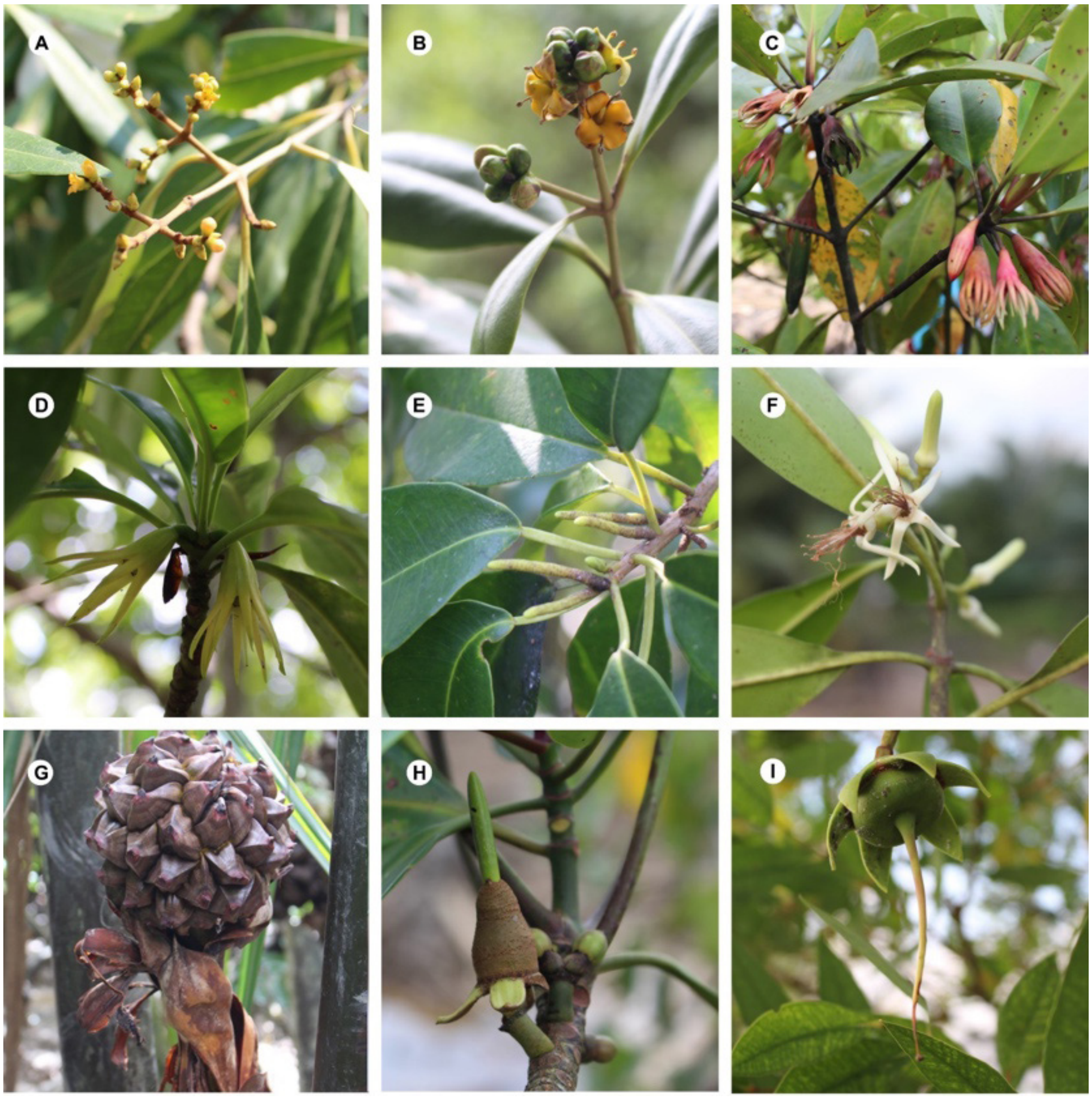

FIGURE 2. Mangrove species in South Sumatra coastal area. A. *Avicennia alba*, B. *Avicennia marina*, C. *Bruguiera gymnorhiza*, D. *Bruguiera sexangula*, E. *Excoecaria agallocha*, F. *Kandelia candel*, G. *Nypa fruticans*, H. *Rhizophora apiculata* and I. *Sonneratia caseolaris*. Photos: Irfan Martiansyah

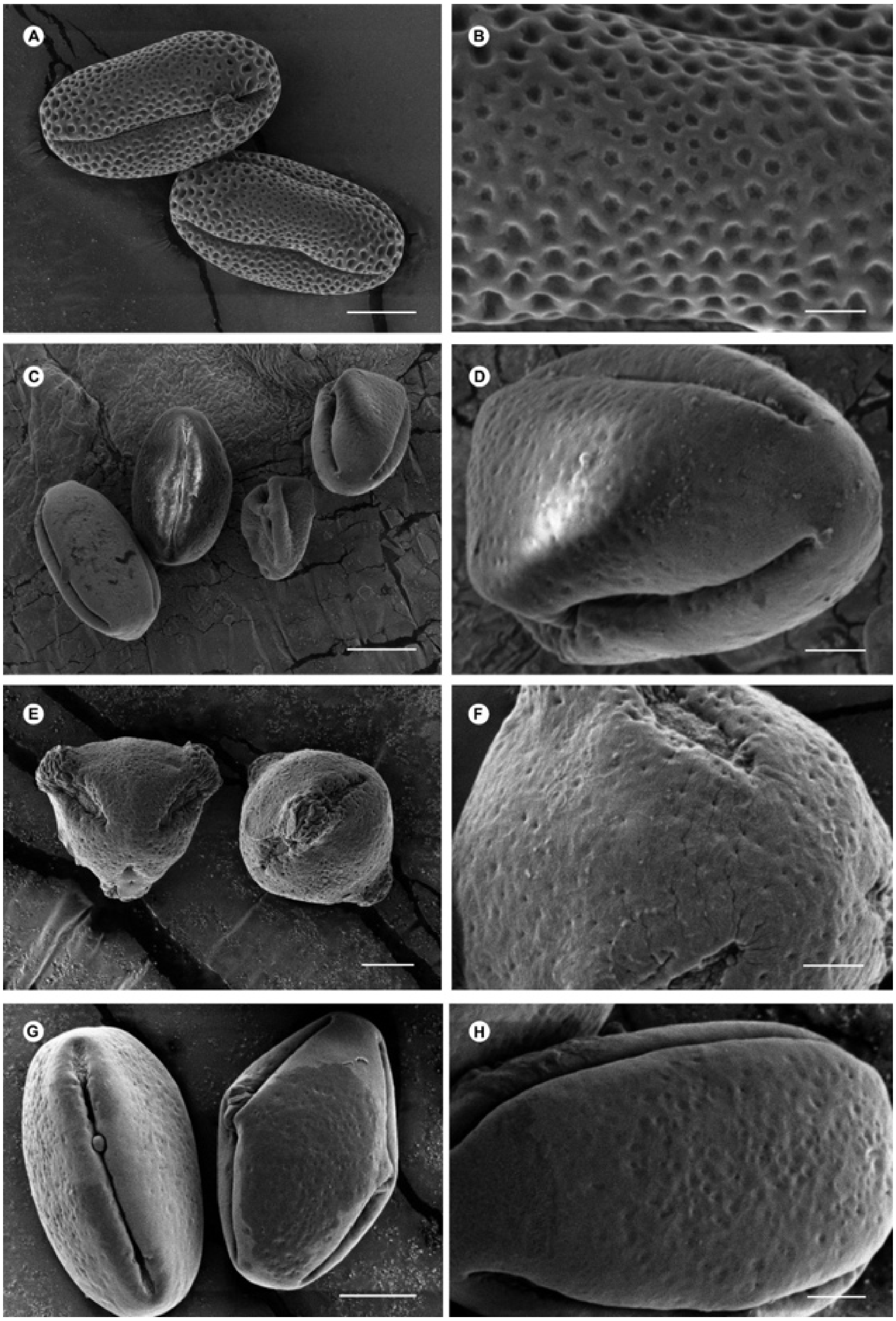

FIGURE 3. Pollen grains of *Avicennia alba*, *Avicennia marina*, *Bruguiera gymnorhiza* and *Bruguiera sexangula*. A. *Avicennia alba,* scale 10 μm; B. *Avicennia alba,* scale 2 μm; C. *Avicennia marina*, scale 10 μm; D. *Avicennia marina*, scale 2 μm; E. *Bruguiera gymnorhiza*, scale 5 μm; F. *Bruguiera gymnorhiza*, scale 2 μm; G. *Bruguiera sexangula*, scale 5 μm; and H. *Bruguiera sexangula*, scale 2 μm

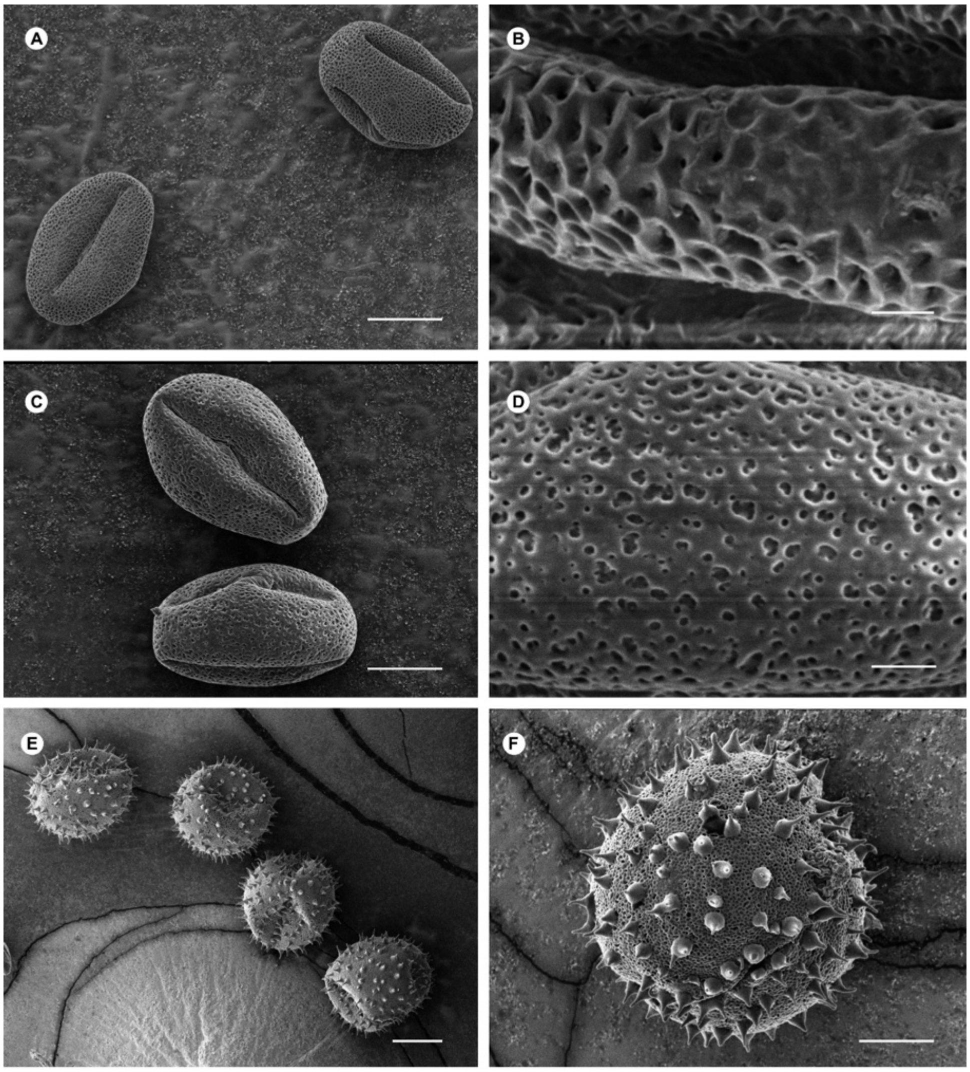

FIGURE 4. Pollen grains of *Excoecaria agallocha*, *Kandelia candel,* and *Nypa fruticans*: A. *Excoecaria agallocha*, scale 10 μm; B. *Excoecaria agallocha*, scale 2 μm; C. *Kandelia candel*, scale 10 μm; D. *Kandelia candel*, scale 2 μm; E. *Nypa fruticans*, scale 20 μm; and F. *Nypa fruticans*, scale 10 μm

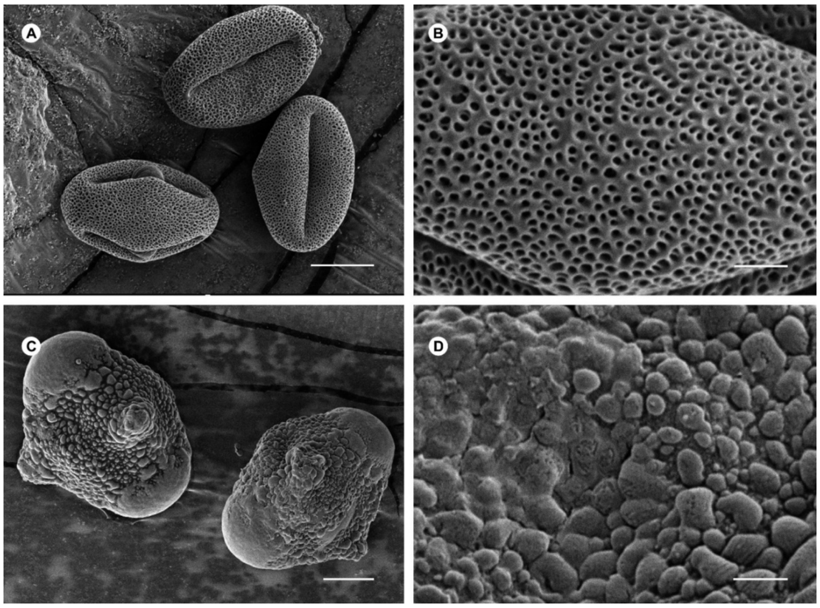

FIGURE 5. Pollen grains of *Rhizophora apiculata* and *Sonneratia caseolaris*. A. *Rhizophora apiculata*, scale 10 μm; B. *Rhizophora apiculata*, scale 2 μm; C. *Sonneratia caseolaris*, scale 10 μm; and D. *Sonneratia caseolaris*, scale 2 μm

TABLE 2. Pollen grain morphological characteristics of the mangrove species

Pollen characters	Mangrove species								
	A. alba	*A. marina*	*B. gymnorhiza*	*B. sexangula*	*E. agallocha*	*K. candel*	*N. fruticans*	*R. apiculata*	*S. caseolaris*
Polar axis length (μm)	17.48 (17.31±0.2) 17.14	13.83 (12.54±0.2) 11.25	11.25 (11.13±0.2) 11.00	11.29 (10.97±0.2) 10.64	12.66 (11.69±0.2) 10.73	16.16 (14.64±0.2) 13.12	27.37 (31.57±0.2) 35.66	16.00 (15.88±0.2) 15.76	21.60 (24.90±0.2) 28.20
Equatorial length (μm)	35.00 (34.59±0.2) 34.17	25.21 (23.99±0.2) 22.77	15.50 (14.25±0.2) 13.00	19.47 (17.10±0.2) 18.70	21.76 (21.6±0.2) 21.44	27.82 (27.62±0.2) 27.42	43.17 (39.76±0.2) 36.34	25.08 (24.88±0.2) 24.68	40.91 (40.15±0.2) 39.39
Value of polar/ equatorial	0.50	0.52	0.78	0.64	0.54	0.53	0.79	0.64	0.62
Ratio of polar/ equatorial	Prolate	Prolate	Isodiametric	Prolate	Prolate	Prolate	Isodiametric	Prolate	Oblate
Shape	Ellipse	Ellipse	Triangular pyramid	Ellipse	Ellipse	Ellipse	Spheroidal	Ellipse	Triangular
Size	Medium	Small	Small	Small	Small	Medium	Medium	Small	Medium
Unit	Monad	Monad	Monad	Monad	Monad	Monad	Monad	Monad	Monad
Symmetry	Isopolar	Isopolar	Isopolar	Isopolar	Isopolar	Isopolar	Isopolar	Isopolar	Isopolar
Outline	Lobate	Lobate	Triangular	Lobate	Lobate	Lobate	Circular	Lobate	Triangular
Polar view	Open, circular	Open, semi-angular	Open, semi-angular	Open, semi-angular	Open, circular	Open, circular	Open, circular	Open, circular	Intruding, semi-angular
Equatorial view	Prolate, circular oval	Prolate, circular oval	Spherical, apiculate	Prolate, circular oval	Prolate, circular oval	Prolate, circular oval	Spherical, circular oval	Prolate, circular oval	Spherical, apiculate
Aperture	Tricolporate	Tricolporate	Tricolporate	Tricolporate	Tricolporate	Tricolporate	Monosulcate	Tricolporate	Triporate
Ornamentation	Perforate	Psilate	Psilate	Psilate	Perforate	Perforate	Echinate	Reticulate	Gemmate

Pollen shape is a three-dimensional form of a pollen grain according to the P/E ratio. The shape of pollen in this study varied from an ellipse, triangular, triangular pyramid to spheroidal shape. The ellipse shape of pollen was commonly found on mangrove species of South Sumatera, particularly on *A. alba, A. marina, B. sexangula, E. agallocha, K. candel,* and *R. apiculata*. The triangular shape was found in *S. caseolaris*. The triangular pyramid shape was found in *B. gymnorhiza, Nypa fruticans* was found to have a spheroidal shape. All the species included in this study had pollen units only in the form of monads. Monads are characterized by only one unit of pollen grain. Some species of mangrove (*N. fruticans, R. apiculata,* and *S. caseolaris*) were also reported to have monad unit (Dahlia, Syafrizal & Hariani 2019). Meanwhile, the pollen symmetry of all species in this study was isopolar, which means that their equatorial faces were symmetrical due to the similarity of their distal and proximal poles (Halbritter et al. 2018), resulting in a consistent pattern across all the species.

A polar view is a form of pollen grain observed from the polar side. The polar view category followed Nugroho (2014). In this study, the shape of the polar view varied from open circular, open semi-angular to intruding semi-angular. The open circular has rounded pollen with wide open colpus. This type of pollen occurred in several species, i.e., *A. alba, E. agallocha, K. candel, R. apiculata,* and *N. fruticans.* Open semi-angular is triangular pollen with wide open colpus, and it was found in *A. marina, B. gymnorhiza* and *B. sexangula.* Intruding semi-angular is triangular pollen with shallowed colpus, and it was only observed in *S. caseolaris*. The polar view of pollen is generally circular, but it can vary among different species and genera, as shown in *Avicennia*. *Avicennia marina* is an excellent example of a discriminatory high-fidelity species, known for its low pollen dispersal as shown by a recent pollen grain study (Bellini et al. 2015).

The shape of equatorial view is a form of pollen grain observed from the equatorial side, and the equatorial view categories followed the classification of Nugroho (2014). In this study, the shape of equatorial view varied from prolate-circular oval, spherical-apiculate to spherical-circular oval. The prolate-circular oval is the oval-shaped pollen grains where the colpus is pulled towards each pole. This type of pollen occurred in several species, including *A. alba, A. marina, B. sexangula, E. agallocha, K. candel,* and *R. apiculata.* The spherical-apiculate is a round shape with a tapered equatorial end, and it was found in *S. caseolaris* and *B. gymnorhiza.* On the other hand, the spherical-circular oval shows the symmetry of the round shape, and it was only found in *N. fruticans.* The shape of the equatorial view varies among different species, and it can even vary within genus, as shown in *Bruguiera*.

In this study, variation in pollen grain outlines was discovered, specifically lobate, triangular and circular outlines. The lobate outline is the polar view of the pollen grains that bulge in the interpertural area, and it was found in *A. alba, A. marina, B. sexangula, E. agallocha, K. candel,* and *R. apiculata.* The triangular outline is a contour of pollen grains in polar/equatorial view with a three-sided shape that was observed in *S. caseolaris* and *B. gymnorhiza*. On the other hand, a circular outline is the contour of pollen grains in polar/equatorial with a rounded shape, and it was only observed in *N. fruticans*. There are not many pollen morphological studies of mangrove species discuss the outline characteristics. However, Halbritter et al. (2018) considered this feature important in describing the contours of the pollen surface from either a polar or equatorial view.

An aperture is the area of the pollen wall that significantly differs from the surrounding surface morphologically and/or anatomically (Halbritter et al. 2018). Aperture types observed in this study were tricolporate, triporate, and monosulcate. Tricolporate is the pollen grain with three colpus, and it was found in *A. alba, A. marina, B. gymnorhiza, B. sexangula, E. agallocha, K. candel,* and *R. apiculata.* Triporate is a pollen grain with three pori, and it was only found in *S. caseolaris*. Monosulcate is characterized by pollen grain with a colpus, and it was only observed in *N. fruticans*. The aperture types of mangrove species found in this study is in line with the studies of Chumchim and Khunwasi (2011), Dahlia, Syafrizal and Hariani (2019), Husnudin et al. (2022), and Mao et al. (2012). However, Husnudin et al. (2022) and Mao et al. (2012) used the term monocolpate, which according to Halbritter et al. (2018) is a superfluous terminology that should use monosulcate.

In palynology, ornamentation is applied to study the surface features of pollen. In this study, five ornamentation types were found on mangrove species in South Sumatera, namely perforate, psilate, echinate, reticulate and gemmate. Perforate refers to pollen wall with holes larger than 1 μm in diameter, and it was found in *A. alba, E. agallocha,* and *K. candel*. Psilate refers to a nearly smooth surface of the pollen wall, and it was found in *A. marina*, *B. gymnorhiza,* and *B. sexangula*. Echinate refers to pollen wall with a spine longer and/or wider than 1 μm, and it was observed only in *N. fruticans*. Reticulate refers to pollen wall with reticulum, and it was recorded in *R. apiculata*. Gemmate is pollen wall with gemae larger than 1 µm in diameter, and it was found in *S. caseolaris*. The results of this study were partially similar to those of Chumchim and Khunwasi (2011), except that perforate ornamentation was in *A. marina* and psilate was in *R. apiculata*.

The identification key to the mangrove species in Tanjung Api-api and Payung Island based on pollen characters is shown as follows.

1	a.	Ornamentation gemmate; aperture triporate	*S. caseolaris*
	b.	Ornamentation perporate, psilate, echinate, or reticulate; aperture tricolporate or monosulcate	2
2	a.	Ornamentation echinate; aperture monosulcate	*N. fruticans*
	b.	Ornamentation perporate, psilate, or reticulate; aperture tricolporate	3
3	a.	Ornamentation reticulate	*R. apiculata*
	b.	Ornamentation perporate or psilate	4
4	a.	P/E ratio isodiametric; outline triangular; equatorial view spherical-spiculate	*B. gymnorhiza*
	b.	P/E ratio prolate; outline lobate; equatorial view prolate-circular oval	5
5	a.	Polar view open-circular; ornamentation perforate	6
	b.	Polar view open-semi angular; ornamentation psilate	7
6	a.	Pollen size small (10-25 µm)	*E. agallocha*
	b.	Pollen size medium (25-50 µm)	8
7	a.	Polar axis length 10.64-11.29 µm; equatorial length 18.70-19.47 µm	*B. sexangula*
	b.	Polar axis length 11.25-13.83 µm; equatorial length 22.77-25.21 µm	*A. marina*
8	a.	Polar axis length 17.14-17.48 µm; equatorial length 34.17-35.00 µm	*A. alba*
	b.	Polar axis length 13.12-16.16 µm; equatorial length 27.42-27.82 µm	*K. candel*

Apart from morphological identification, pollen-based identification is useful in delimiting the species. Pollen of mangrove species is important even though mangroves consist of several different species and families (Tomlinson 1986). A recent study in Semarang, West Java reported variation in the size, index, shape, symmetry, aperture, polarity and ornamentation of the pollens for nine mangrove species (Qodriyyah, Suedy & Haryanti 2015). A few recent studies have also successfully developed identification keys for mangrove species in Peninsular Malaysia, Thailand, South China Sea and South Brazil (Chumchim & Khunwasi 2011; Mao et al. 2012; Noraini et al. 2017; Rodrigues et al. 2023).

Several studies of mangrove pollens used light microscopy in addition to SEM microscopy (Chumchim & Khunwasi 2011; Phuphumirat et al. 2016; Rodrigues et al. 2023). It is suggested that the combination of light and SEM microscopy observations is necessary. The light microscopy observation is able to describe the ornamentation of pollens while the SEM is able to provide detailed information on the pollen surface structure. In conclusion, the study of the mangrove trees of South Sumatera added useful characteristics of the pollen morphology. As with any morphological study, more comprehensive data will assist more conceivable analyses on phylogeny and relationships among mangrove species at coastal areas.

Conclusion

Pollens of nine mangrove species (*Avicennia alba, A. marina, Bruguiera gymnorhiza, B. sexangula, Excoecaria agallocha, Kandelia candel, Nypa fruticans, Rhizophora apiculata,* and *Sonneratia caseolaris*) from South Sumatera coastal area varied in size, ratio of polar/ equatorial, shape, polar view, equatorial view, outline, aperture, and ornamentation. The pollen morphology has been demonstrated to be effective in distinguishing various mangrove species in South Sumatera, and it can be used to provide a species identification key. Further research is needed with a more diverse and number of species to complement current research.

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