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LEAF ANATOMICAL CHARACTERS OF SEVERAL TRUE MANGROVE SPECIES

[*Karakter Anatomi Daun Beberapa Spesies Mangrove Sejati*]

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ABSTRACT

Anatomical characters of mangrove species have two important roles in mangrove studies that are as taxonomic supporting character and adaptation trait as a response to saline environment. Corks warts and sclereid are independent to environment, therefore those characters may be of taxonomic support. Mangrove species anatomical adaptation showed similar feature to drought stress or sclerophyll. The aim of this study is to distinguish anatomical characters of mangrove species that is taxonomical from habitat adaptation related anatomical characters. Fifteen true mangrove species from Banggai Kepulauan, Central Sulawesi and Banyuasin, South Sumatra were used to conduct this study. Paraffin method was used for leaf transversal section, while simple peeling using nitric acid was applied for epidermal section. The results showed that stomata distribution, cork warts, sclereid, and presence of water storage type were potential anatomical features for species identification. In addition, stomata type and epidermal cell walls also have the same potential but are still doubtful, therefore it will need to be studied further to ensure the useful of those characters. The use of anatomical characters for mangrove species identification, especially when they are in the vegetative stage, can quickly determine taxa at certain level. Those potential characters are such as glandular and non-glandular trichomes on the leaf surface.

Keywords: cork warts, cuticle, hypoderm, sclereid, sclerophyll

ABSTRAK

Karakter anatomi spesies mangrove memiliki dua peran penting sebagai karakter pendukung taksonomi dan bentuk adaptasi terhadap lingkungan masin. Karakter bintik hitam dan sklereid bersifat tetap, tidak terpengaruh lingkungan sehingga kemungkinan dapat digunakan untuk mendukung taksonomi. Bentuk adaptasi spesies mangrove ditunjukkan dengan karakteristik sklerofil yang menyerupai tumbuhan yang mengalami cekaman kekeringan. Penelitian ini bertujuan untuk membedakan karakter anatomi pada spesies mangrove sebagai pendukung taksonomi atau sebagai bentuk adaptasi habitat. Sebanyak 15 spesies mangrove dari Banggai Kepulauan, Sulawesi Tengah dan Banyuasin, Sumatra Selatan digunakan sebagai sampel untuk penelitian ini. Metode parafin digunakan untuk membuat irisan melintang, sementara itu pembuatan preparat epidermis menggunakan larutan asam nitrat. Hasil penelitian menunjukkan bahwa distribusi stomata, bintik hitam, sklereid, dan kehadiran jenis hipodermis berpotensi untuk identifikasi spesies. Selain itu, tipe stomata dan dinding sel epidermis juga mempunyai potensi yang sama tetapi masih lemah sehingga perlu dipelajari lebih lanjut untuk memastikan hal tersebut. Penggunaan karakter anatomi dalam identifikasi spesies mangrove, terutama saat spesies mangrove dalam tahap vegetatif, dapat secara cepat menentukan suatu taksa pada tingkat tertentu seperti trikoma kelenjar dan tanpa kelenjar yang ada di permukaan daun.

Kata Kunci: bitnik hitam, hypodermis, kutikula, sklereid, skerofil

INTRODUCTION

Mangrove was divided into two groups namely true mangrove and mangrove associates which were distinguished by saline environment requirement (Wang *et al.*, 2011; Tomlinson, 2016). According to Tomlinson (2016), true mangrove requires saline environment, therefore will not be found in any terrestrial habitat. On the other hand, saline environment is not the main factor of the growth of mangrove associate species (Wang *et al.*, 2011). There are approximately 54 species of true mangrove belonging to 15 families (Tomlinson, 2016). Of these, more than 30% species of mangrove are present in Indonesia *i.e.* 47 species belonging to 14 families (Noor *et al.*, 2006). As an important ecosystem, mangrove is habitat of some birds, fish and other marine animals, and has roles for temperature stability and nutrient cycling (Lugo and Snedaker, 1974; Macintosh and Ashton, 2002). In other words, mangrove is important for maintaining biodiversity and ecosystem services.

The habitat of mangrove affects the morphological and anatomical characteristics of mangrove plants to support its adaptation to this habitat. Those adaptation forms could be seen in cuticle, mesophyll and stomata, salt gland and water storage tissue and the increasing of vessel/ unit area (Lucena *et al.,* 2011; Lima *et al*., 2015). Other studies by Nurnida *et al.* (2012) and Surya and Hari (2018) found that anatomical adaptation in mangrove species was indicated by special structure such as presence of water storage tissue,

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thickened cuticle, and the occurrence of sclereid.

In addition, anatomical characters are also played an important role in the systematic of mangrove species. Distinctive characters possessed by each taxon were able to identify species which was found in sterile state. The application of anatomical characters as taxonomic diagnostic tool has been widely used. Anatomical characters are useful for systematic purposes (Metcalfe and Chalk, 1950), especially in mangrove species, epidermal, and cuticular characters could be used for species identification within genera such as *Avicennia, Lumnitzera*, and *Rhizophora* (Stace, 1966). Other study by Nurnida *et al.* (2012) indicated that the sclereid presence was important diagnostic character to distinguish *Rhizophora* from other genera within Rhizophoraceae. Although several studies have been conducted on anatomical characters, research in anatomical characters of mangrove species is still restricted, especially in Indonesia. Therefore, the aim of this study was to investigate the leaf anatomy of mangrove species for identification tools. Apart from being information about the potential of the anatomical characters for plant identification tools, especially mangrove plants, this study can also provide additional information about the characteristics of mangrove species in several habitats with different environmental factors. Furthermore, these characters may potentially be used as a basis for comparing tissue structure changes under the dynamic/changes of the mangrove habitat environment. These anatomical characteristics may also useful as one of the basis for selecting mangrove species that are suitable for planting in the context of restoring mangrove habitat and ecosystems.

MATERIAL AND METHODS

Study site

Several mangrove species were collected from Banyuasin, South Sumatra Province (2.323 – 2.361 S, 104.733 – 104.917 E) from 27 May to 10 June 2021 (Figure 1a). Other sampled mangrove species were collected from Tatakalai, Banggai Islands, Central Sulawesi (1.255 S, 123.421 E) from 25 June to 14 July 2019 (Figure 1b). There were 15 species representing seven families were collected in total (Appendix: Table 1). Generally, the mangrove vegetation in Banyuasin has different condition compared with those in Banggai Kepulauan. Mangrove ecosystem in Banyuasin is formed by the silt from the Musi River as the main freshwater body from the terrestrial area. Because of the flat topography and the thickness of the substrate, it drives the large mangrove areas with the various kind of mangrove species. The established mangrove species composition in Banyuasin area was more diverse and contain the high saline tolerant species (*e.g. Avicennia alba*) and also the species which need more fresh water *e.g. Sonneratia caseolaris*. On the other hand, Banggai Kepulauan is located near Molucca Sea which is facing the open sea, therefore the mangrove species were more tolerant toward high tide, sunlight, and saline content. Moreover, there are a few streams in this area so the input of the fresh water to the mangrove area is limited. Thus, the mangrove species diversity in Banggai Kepulauan is relatively less than Banyuasin.

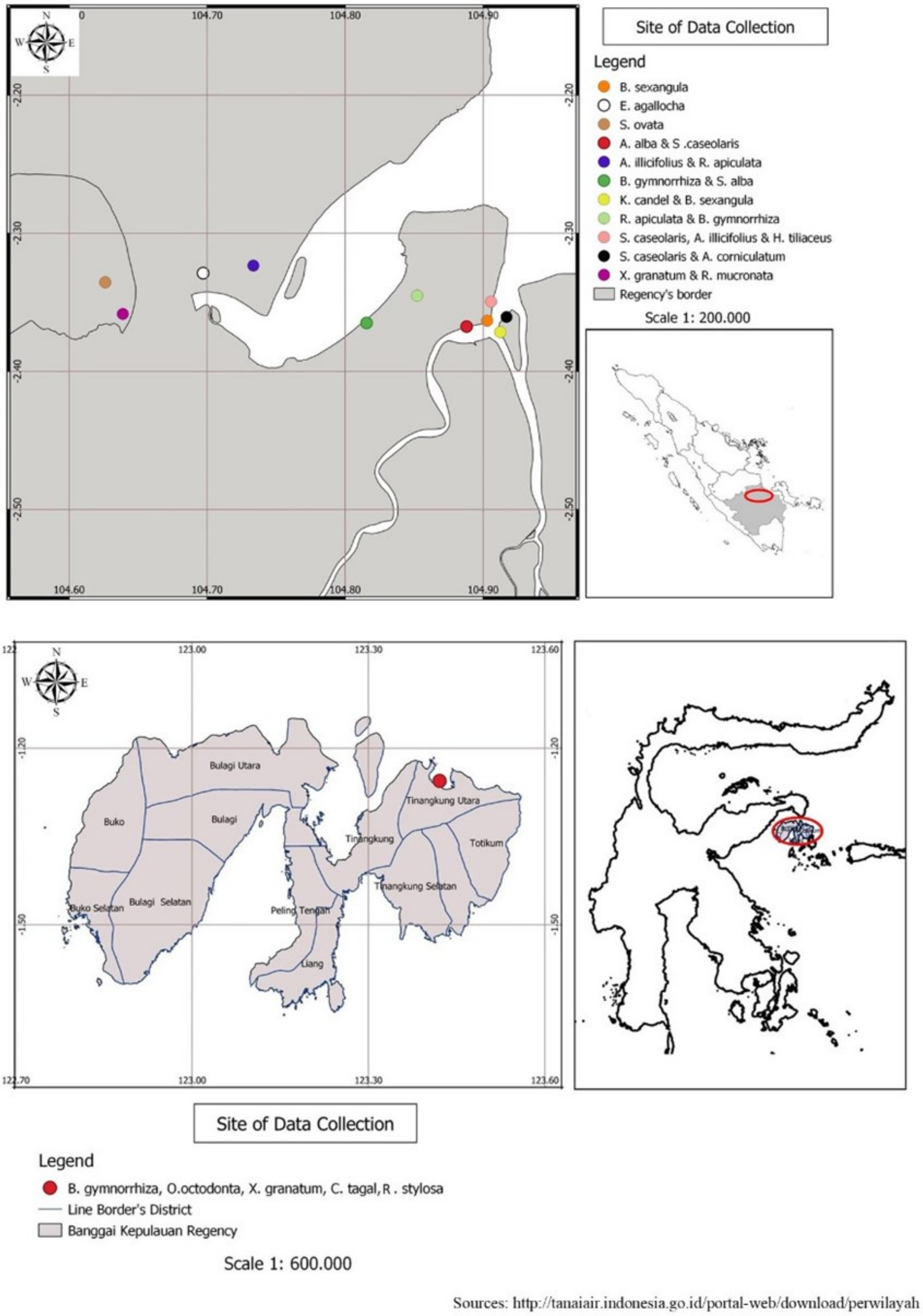
Sample collecting and processing

The collected sample leaves were mature leaf (at least from the fourth position of the apex leaf) and it stored in 70% of ethanol as soon as collected from the field. Then, three leaves of each sample were sectioned in the middle part with size of ± 1 × 1 cm^2. Similar to leaf blade, petiole samples were taken from the middle part of the petiole.

Laboratory work was conducted in Morphology, Anatomy and Cytology laboratorium of BRIN. Paraffin method based on Sass (1951) was used for making transverse sections. The samples were fixed in FAA, formaldehyde: ethanol: acetic acid: aquades (5:50:10:35), dehydrated in tert-butanol: ethanol series, and double staining with safranin O 1% and fast green 2%. Second method was paradermal section which using nitric acid (HNO_3): aquades (1:3) solution (Cutler, 1978) to peel the leaf surfaces and obtain the epidermal characters.

Micromorphology observation

Transversal dan paradermal sections were observed for micromorphology characters *i.e.* stomatal type, epidermal cell wall type of vascular bundle and other specific characters (Appendix). Observations were conducted using Nikon Eclipse 80*i* microscope with XCAM 1080 PHB 2.4 × 2.4 pixel and Beta View to take pictures.



a

b

Figure 1. The map of sample collection in Banyuasin, South Sumatra (a) and Banggai Kepulauan Regency, Central Sulawesi (b). (*Peta lokasi pengambilan sampel di Banyuasin, Sumatra Selatan (a) dan Kabupaten Banggai Kepulauan, Sulawesi Tengah (b)*).

RESULT

The result of anatomical characters observations showed that there is a diversity of anatomical characters and several of those have potential to be used to differentiate specified taxon level. Character details have been presented in the tables (Table 2, 3 and 4) in the Appendix.

Upper and lower leaf surfaces

All examined species has smooth periclinal epidermal cell wall on the upper surface and anticlinal cell wall of epidermis is angular and rounded, except *Excoecaria agallocha* which has sinuous anticlinal cell wall and beaded periclinal cell wall (Figure 2, Appendix: Table 2). Meanwhile, the leaf lower surface showed results that tended to be similar with the upper surface. Periclinal cell walls are generally smooth except *E. agallocha* which has beaded walls. In the other hand, anticlinal cell walls are angular and rounded, however, undulate cell walls are also found in *Acanthus ilicifolius* and sinuous in *E. agallocha* (Figure 2).

Furthermore, staurocytic stomatal type was found on examined sample of *Bruguiera gymnorhiza* and *B. sexangula*. The cyclocytic characteristic found in *Rhizophora* species (Appendix: Table 2). However, there are species that have more than one type of stomata, such as *B. sexangula*, *Ceriops tagal* and *Rhizophora mucronata* (Appendix: Table 2). Simple non-glandular trichomes of *Osbornia octodonta* are distributed on upper and lower leaf surfaces (Figure 2 C and D). Whereas glandular trichomes with four head cells are found on both surfaces of leaves of *A. ilicifolius* (Figure 2 E and 4 E) and multicellular glandular trichomes are distributed on the lower leaf surfaces of *Avicennia alba* (Figure 4 F, Appendix). Furthermore, salt glands are seen obviously on upper and lower surfaces of *Aegiceras corniculatum* leaf (Figure 2 F).

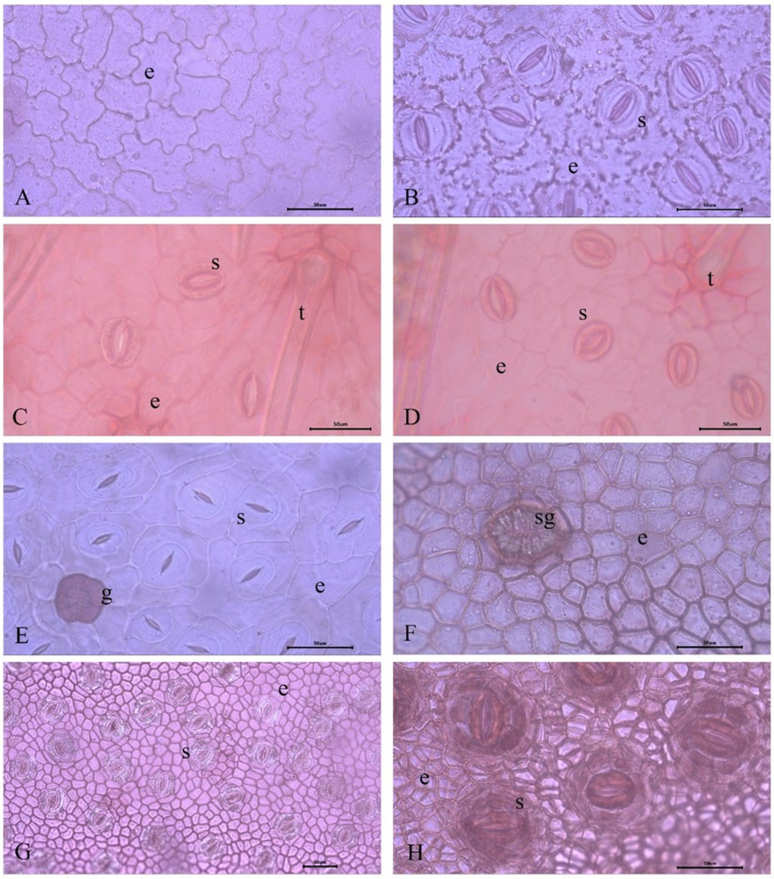


Figure 2. Sinuous and beaded epidermis (e) cell wall upper (A) and lower (B) of leaf surface on *E. agallocha*. Non glandular trichome (t) on both leaf surface of *O. octodonta* (C and D). Glandular trichome (g) and diacytic stomata (s) of *A. ilicifolius* (E) and salt gland (sg) of *Ae. corniculatum* (F). Actinocytic and cyclocytic stomata (s) on leaf lower surface of *B. gymnorhiza* and *Rhizophora apiculata*, respectively (G and H). Scale bar: 50 µm. (*Dinding sel epidermis (e) sinuous permukaan atas (A) dan bawah (B) daun E. agallocha. Trikoma tanpa kelenjar (t) pada kedua permukaan daun O. octodonta (C and D). Trikoma berkelenjar (g) dan stomata (s) diasitik pada A. ilicifolius (E) dan kelenjar garam (sg) pada Ae. corniculatum (F). Stomata (s) aktinositik dan siklositik masing-masing terdapat di permukaan bawah daun B. gymnorhiza dan R. apiculata (G and H). Bar skala: 50 µm*).

Water storage tissue and mesophyll

Hypoderm as one of water storage tissue types is composed by thin-walled cells and located below epidermal tissue. Generally, this tissue presents in the upper part of the leaf, but *Sonneratia caseolaris* does not have hypodermis on the upper side but a layer of hypodermis at the lower side of the leaf. In addition, this species also has water storage tissue in the middle of 4–8 layers (Figure 3 A). Meanwhile, some species have hypodermis at both side of the leaf. In the upper side of the leaf, *B. gymnorhiza* has single layer, while *C. tagal* and *R. mucronata,* have 2 layers and 4 layers, respectively. In the lower side, only *C. tagal* that seen has a layer of hypodermis (Figure 3 B, C, D, respectively).

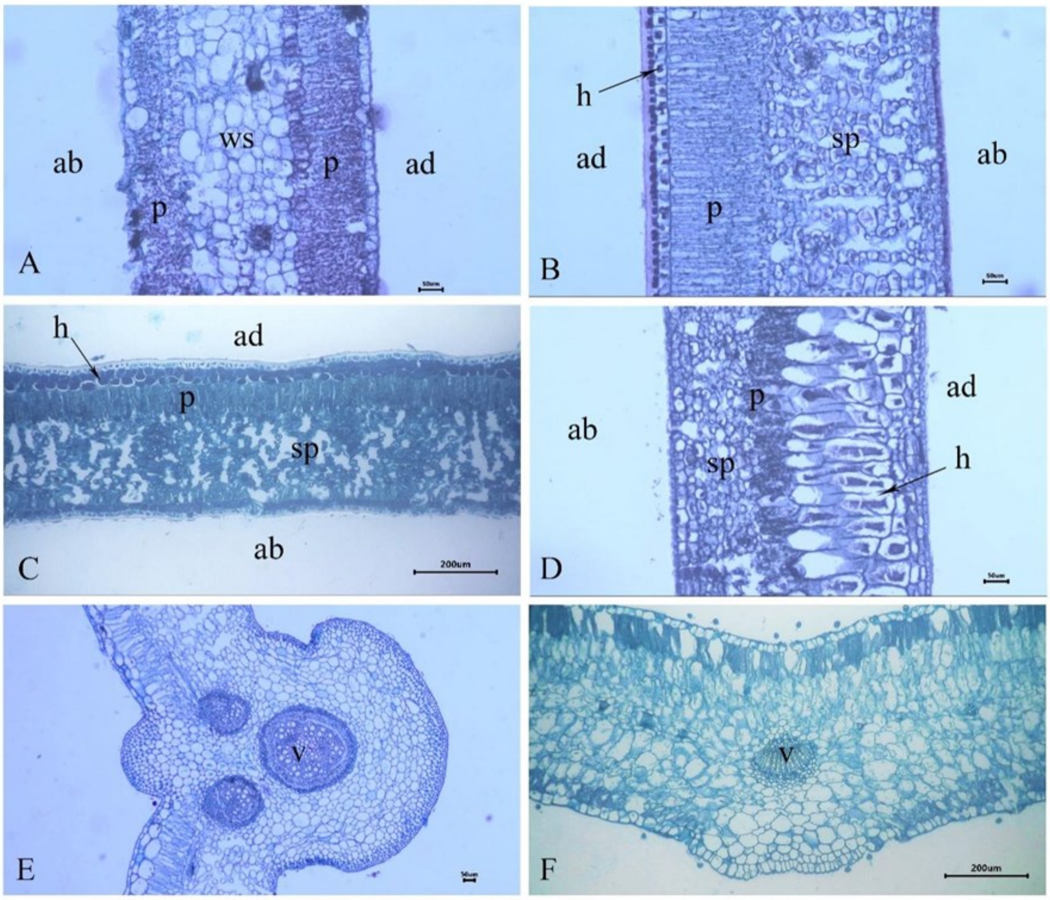


Figure 3. Leaf transversal sections. Water storage (ws) in the middle part of *S. caseolaris* leaf (A) and hypodermis (h) exist in layers of *B. gymnorhiza* (B), *C. tagal* (C) and *R. mucronata* (D). Vascular bundle (v) at midrib of *A. ilicifolius* (E) and *O. octodonta* (F). ab: lower leaf surface, ad: upper leaf surface, p: palisade, sp: sponge tissue. Scale bar: 50 µm, except C and F: 200 µm (*Irisan melintang daun. Jaringan penyimpan air (ws) terletak di bagian tengah daun S. caseolaris (A) dan lapisan hipodermis (h) terdapat pada B. gymnorhiza (B), C. tagal (C) dan R. mucronata (D). Berkas pengangkut (v) midrib A. ilicifolius (E) dan O. octodonta (F). ab: permukaan bawah daun, ad: permukaan atas daun, p: palisade, sp: jaringan bunga karang. Bar skala: 50 µm, kecuali C dan F: 200 µm*).

Based on mesophyll structure, examined mangrove species in this study were dorsiventral and isobilateral (Figure 3, Appendix: Table 3). Almost all examined species are dorsiventral, except *C. tagal*, *O. octodonta* and *S. caseolaris* which have palisade in both sides of the leaf (isobilateral).

Vascular bundle

Vascular bundle of midrib is mostly arc shape (Figure 3, Appendix: Table 3), except for *A. ilicifolius* which has free vascular bundle (Figure 3 E). Some species have arc shape with additional vascular bundles, such as in *E. agallocha* and *S. caseolaris* or arc with inwardly ends found in *Av. alba* and *B. gymnorhiza* (Appendix: Table 3). In additional, vascular bundle of some species are surrounded by lignified cells such as those in *Ae. corniculatum* and *Xylocarpus granatum*.

The vascular bundle in the petiole has same basic shape of midrib vascular bundle, namely arc, closed-ring and independent vascular bundle (Appendix: Table 4). Arc is common shape that can be found in several mangrove species such as *Av. alba, B. gymnorhiza* and *O. octodonta* (Figure 4). Closed-ring vascular bundle appear in *X. granatum* (Figure 4) and *Rhizophora* species and independent vascular bundles were found in *A. ilicifolius*.

Additional characters

Other characters that may be found in mangrove species are cork warts and sclereid. Cork warts in *Rhizophora* are distributed in lower part of the leaf (Figure 4). This cork warts are only seen in *Rhizophora* species. In addition to cork warts, sclereid also appeared in *Rhizophora* and other genera of Rhizophoraceae as well as *Av. alba*, *S. caseolaris* and *Ae. corniculatum* (Appendix). Sclereid present as fiber and branchy sclereid (Figure 4 D).

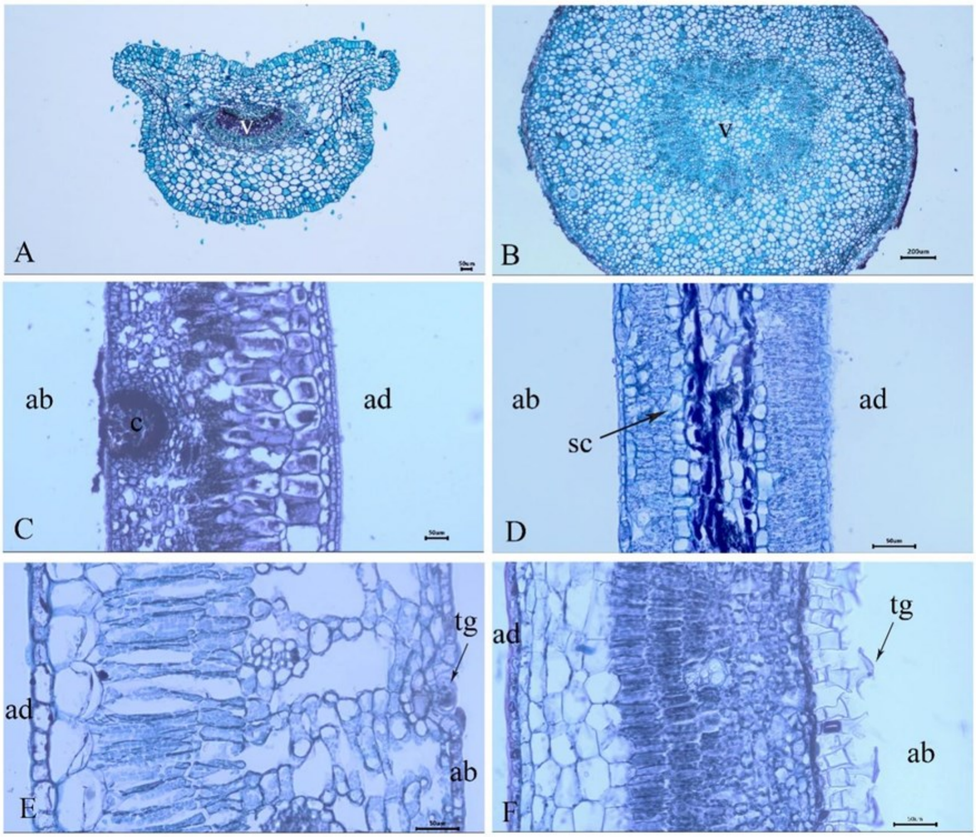


Figure 4. Arc vascular bundle (v) of *O. ocotodonta* (A) and closed-ring vascular bundle (v) of *X. granatum* (B) petiole. Cork warts (c) exist in *R. mucronata* (C) and branchy sclereid (sc) in *S. caseolaris* (D). Two types of glandular trichomes (tg) of *A. ilicifolius* (E) and *Av. alba* (F). ab: lower leaf surface, ad: upper leaf surface. Scale bar: 50 µm and 200 µm of B (*Berkas pengangkut (v) tangkai daun berbentuk busur terdapat pada O. ocotodonta (A) dan cincin terlihat pada X. granatum (B). Bintik hitam (c) yang ada pada helaian daun R. mucronata (C) dan branchy sclereid (sc) pada S. caseolaris (D). Dua tipe trikoma berkelenjar (tg) yang berbeda pada A. ilicifolius (E) dan Av. alba (F). ab: permukaan bawah daun, ad: permukaan atas daun. Bar skala: 50 µm and 200 µm (B)*).

Drusse crystal present in all species, except *A. ilicifolius* that does not have $CaCO_3$ crystal. However, *X. granatum* also has solitary prism crystal other than drusse (Appendix: Table 3). Those crystal do not only exist in the leaf, but also in the petiole.

DISCUSSION

Epidermal characters for taxon identification

Epidermal features were used as significant characters for taxa identification (Nishida and van der Werff, 2011), likewise in mangrove species. The use of those characters for identification was stated by Stace (1966) for species that have similarity at vegetative stage such as the use of stomata position to epidermal cells and guard cells size. Stomatal distribution, whether stomata was present in the upper or lower epidermis and secondly, trichome was also found to be suitable characters for taxonomic diagnosis (Stace, 1966; Seshavatharam and Srivalli, 1989).

Mostly, anticlinal cell wall of epidermis is angular and rounded, however there are some species which have undulate or sinuous cell wall such as *A. ilicifolius* and *E. agallocha*. As stated by Surya and Hari (2017), straight anticlinal cell wall with thick cuticle was one of character of xeromorphic plants. Low availability of water to the plant can be induced by saline soils, so plants growing on these condition often showed adaptations similarity to those from dry habitats by saline condition.

Nevertheless, most of the mangrove species have hypostomatic leaves. Amphistomatic leaves are also found in three examined species. The amphistomatic leaf of mangrove species were also showed by Stace (1966) and Surya and Hari (2017) in *Lumnitzera* and *Soneratia alba*. Most of the observed stomata type that are found in this study is anomocytic. However, staurocytic, cyclocytic, actinocytic and diacytic type are also seen in several species. The diversity of stomata types within leaf or species is common to happen. Surya and Hari (2016) showed that two species of *Bruguiera* in Kerala had both anomocytic and paracytic types (stoma type has two neighboring cell which parallel to the pore). Likewise, Tihurua *et al.* (2020) also found two stomata types (staurocytic and anomocytic) within a species of *B. cylindrica*.

Leaf transversal section and taxon identification

One type of water storage tissue in mangrove species is hypoderm. Other water storage tissue is non chlorophyllous cells with thin wall that are arranged between upper and lower palisade (Stace, 1966). Although the existence of water storage in mangrove species was an indication of adaptation to the environment condition (Samadder and Jayakumar, 2015), but the water storage type might be a special trait and also be able to distinguish taxa at a certain level such as genera within a family or among families. For instance, within Rhizophoraceae, the presence of hypoderm in *Rhizophora* and *Bruguiera* were limited to the upper part of the leaf, while hypoderm in the genus *Ceriops* appeared in both parts of the leaf. Whereas, the number of hypoderm layers may depend on environment condition that was indicated by variation of hypoderm layer numbers in *Rhizophora* and *Bruguiera* species (Poompozhil and Kumarasamy, 2014; Surya and Hari, 2016). *Sonneratia* can be separated by the existence of water storage in the middle part of the leaf (Supplementary 1: Table 3) as well as the presence of palisade might be useful for species diagnose within genus such as *Sonneratia* or genera within Rhizophoraceae. Another character which was often used for taxa identification was vascular bundle type (Metcalfe and Chalk, 1950; Dickinson, 1998). However, in the true mangrove species, vascular bundle has not shown enough variation and differentiation that this character is useful as a supporting character for taxa identification.

The presence of cork warts in *Rhizophora* species exclusively could be utilized to separate this genus to others within same family and this is in concordance with the result from Samadder and Jayakumar (2015) and Surya and Hari (2017). However, this feature also appeared in *Mezilaurus* that distinguished it from other genera within Lauraceae (Vaz *et al.*, 2018). Cork warts that were observed in mangrove species are not only indicate differences among taxa, but also reflect some characters that could be affected by its environmental condition. Cork warts existed as air way from atmosphere to plant tissue, aerenchym cells in particular, and were produced during leaf initiation (Evans and Bromberg, 2010).

In the term of sclereid presence, our result revealed that sclereid was not exclusively present in *Rhizophora*, but also in other genera. Our study agreed with Lucena *et al.* (2011) which found sclereid in a species of *Avicennia, Av. schaueriana*, (Lythraceae). Seshavatharam and Srivalli (1989) even found sclereid in other species such as *Lumnitzera racemosa* (Combretaceae) and *Aegilitis rotundifolia* (Plumbaginaceae). Therefore, the presence of sclereid in some species of different family indicated that this trait is probably less useful to be used in the taxa diagnosis. According to Surya and Hari (2017), the presence of this sclereid was also an adaptation form to salinity environment by its role on mechanical support or water storage capillary (Samadder and Jayakumar, 2015). Therefore, the presence of sclereid in those mangrove species need to be investigated further in details to prove that the existence of this trait in some families were not only because of environmental factors but also as a unique character of taxon.

Based on previous studies (Stace 1965; Seshavataram and Srivalli, 1989; Nurnida *et al*., 2012) and current study which have different environmental condition, several characters such as cork warts, sclereid presence, type of water storage and palisade distribution and vascular bundle type may be useful for mangrove species identification and classification among family, genera or within genus. However, further research is still needed, such as adding more mangrove species samples from different areas with more varied environmental condition to get conserved and firmed characters.

CONCLUSION

Adaptation forms of mangrove species to its habitat are the presence of cork warts, of presence of sclereid, type of water storage, type salt gland type and palisade distribution. On the other hand, at the same time those characters may have potential to be supporting character for mangrove species identification and classification of certain taxa. Furthermore, characters such as stomata distribution, type and presence of glandular and non-glandular trichomes may potentially useful to be used for identification tools in particular mangrove taxa.

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Table 1. Examined species of true mangroves (*Spesies mangrove yang diteliti*).

No.	Family	Species	Collectors	Coll. no.	Origin
1	Acanthaceae	*Acanthus ilicifolius* L.	P. W. K. Hutabarat; T. Nasution, Sutikno, D. Surya	PWH 594	Banyuasin, South Sumatra
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 42	Banyuasin, South Sumatra
2		*Avicennia alba* Blume	I. P. G. P. Damayanto, I. Apandi, S. H. Dalimunthe, I. Martiansyah, D. F. Syah, Y. Pratama	IPGPD 1147	Banyuasin, South Sumatra
			I. P. G. P. Damayanto, I. Apandi, S. H. Dalimunthe, I. Martiansyah, D. F. Syah, Y. Pratama	IPGPD 1187	Banyuasin, South Sumatra
3	Euphorbiaceae	*Excoecaria agallocha* L.	P. W. K. Hutabarat; T. Nasution, Sutikno, D. Surya	PWH 591	Banyuasin, South Sumatra
4	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	I. P. G. P. Damayanto, I. Apandi, S. H. Dalimunthe, I. Martiansyah, D. F. Syah, Y. Pratama	IPGPD 1190	Banyuasin, South Sumatra
			I. P. G. P. Damayanto, I. Apandi, S. H. Dalimunthe, I. Martiansyah, D. F. Syah, Y. Pratama	IPGPD 1246	Banyuasin, South Sumatra
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 43	Banyuasin, South Sumatra
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 100	Banyuasin, South Sumatra
5		*Sonneratia ovata* Backer	P. W. K. Hutabarat; T. Nasution, Sutikno, D. Surya	PWH 634	Banyuasin, South Sumatra
6	Meliaceae	*Xylocarpus granatum* J.Koenig	P. W. K. Hutabarat; T. Nasution, Sutikno, D. Surya	PWH 654	Banyuasin, South Sumatra
			Leg. ign.	s.n.	Banggai Kepulauan, Central Sulawesi
7	Primulaceae	*Aegiceras corniculatum* (L.) Blanco	I. P. G. P. Damayanto, I. Apandi, S. H. Dalimunthe, I. Martiansyah, D. F. Syah, Y. Pratama	IPGPD 1195	Banyuasin, South Sumatra
8	Myrtaceae	*Osbornia octodonta* F.Muell.	Leg. ign.	s.n.	Banggai Kepulauan, Central Sulawesi

Table 1. Examined species of true mangroves (*Spesies mangrove yang diteliti*).

9	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	Leg. ign.	s.n.	Banggai Kepulauan, Central Sulawesi
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 74	Banyuasin, South Sumatra
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 91	Banyuasin, South Sumatra
10		*Bruguiera sexangula* (Lour.) Poir.	S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 98	Banyuasin, South Sumatra
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 105	Banyuasin, South Sumatra
11		*Ceriops tagal* (Perr.) C.B.Rob.	Leg. ign.	s.n.	Banggai Kepulauan, Central Sulawesi
12		*Kandelia candel* (L.) Druce	I. P. G. P. Damayanto, I. Apandi, S. H. Dalimunthe, I. Martiansyah, D. F. Syah, Y. Pratama	IPGPD 1186	Banyuasin, South Sumatra
13		*Rhizophora apiculata* Blume	P. W. K. Hutabarat; T. Nasution, Sutikno, D. Surya	PWH 593	Banyuasin, South Sumatra
			S. H. Dalimunthe, I. P. G. P. Damayanto, I. Martiansyah, I. Apandi, Yogi, Firman	SHD 92	Banyuasin, South Sumatra
14		*Rhizophora mucronata* Poir.	P. W. K. Hutabarat; T. Nasution, Sutikno, D. Surya	PWH 653	Banyuasin, South Sumatra
15		*Rhizophora stylosa* Griff.	Leg. ign.	s.n.	Banggai Kepulauan, Central Sulawesi

Table 2. Epidermis characters of true mangrove species (*Karakter epidermis spesies mangrove*).

No.	Family	Species	Coll. no.	Upper epidermis			
				Cell wall		Cell shape	Stomata
				Periclinal	Anticlinal		
1	Acanthaceae	*Acanthus ilicifolius* L.	PWH 594	Smooth	Angular	Polygonal	-
			SHD 42	Smooth	Angular	Polygonal	-
2		*Avicennia alba* Blume	IPGPD 1147	Smooth	Angular	Polygonal	-
			IPGPD 1187	Smooth	Angular	Polygonal	-
3	Euphorbiaceae	*Excoecaria agallocha* L.	PWH 591	Beaded	Sinuous	Irregular	-
4	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	IPGPD 1190	Smooth	Angular	Polygonal	Anomocytic
			IPGPD 1246	Smooth	Angular	Polygonal	Anomocytic
			SHD 43	Smooth	Angular	Polygonal	Anomocytic
			SHD 100	Smooth	Angular	Polygonal	Anomocytic
5		*Sonneratia ovata* Backer	PWH 634	Smooth	Angular	Polygonal	Anomocytic
6	Meliaceae	*Xylocarpus granatum* J.Koenig	PWH 654	Smooth	Angular	Polygonal	-
			Leg. ign. s.n.	Smooth	Angular	Polygonal	-
7	Primulaceae	*Aegiceras corniculatum* (L.) Blanco	IPGPD 1195	Smooth	Angular, rounded	Polygonal	-
8	Myrtaceae	*Osbornia octodonta* F.Muell.	Leg. ign. s.n.	Smooth	Angular	Polygonal	Anomocytic
9	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	Leg. ign. s.n.	Smooth	Angular, rounded	Polygonal	-
			SHD 74	Smooth	Angular, rounded	Polygonal	-
			SHD 91	Smooth	Angular	Polygonal	-
10		*Bruguiera sexangula* (Lour.) Poir.	SHD 98	Smooth	Angular	Polygonal	-
			SHD 105	Smooth	Angular	Polygonal	-
11		*Ceriops tagal* (Perr.) C.B.Rob.	Leg. ign. s.n.	Smooth	Rounded	Polygonal	-
12		*Kandelia candel* (L.) Druce	IPGPD 1186	Smooth	Angular	Polygonal	-
13		*Rhizophora apiculata* Blume	PWH 593	Smooth	Angular	Polygonal	-
			SHD 92	Smooth	Angular	Polygonal	-
14		*Rhizophora mucronata* Poir.	PWH 653	Smooth	Angular	Polygonal	-
15		*Rhizophora stylosa* Griff.	Leg. ign. s.n.	Smooth	Angular, rounded	Polygonal	-

Table 2. Epidermis characters of true mangrove species (continued)
(*Karakter epidermis spesies mangrove*) (*lanjutan*).

No.	Family	Species	Coll. no.	Lower epidermis			
				Cell wall		Cell shape	Stomata
				Periclinal	Anticlinal		
1	Acanthaceae	*Acanthus ilicifolius* L.	PWH 594	Smooth, undulate	Angular, rounded	Irregular	Diacytic
			SHD 42	Smooth	Angular, undulate	Irregular	Diacytic
2		*Avicennia alba* Blume	IPGPD 1147	Smooth	Angular, rounded	Polygonal	Anomocytic
			IPGPD 1187	Smooth	Angular, rounded	Polygonal	Anomocytic
3	Euphorbiaceae	*Excoecaria agallocha* L.	PWH 591	Beaded	Sinuous	Irregular	Anomocytic
4	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	IPGPD 1190	Smooth	Angular	Polygonal	Anomocytic
			IPGPD 1246	Smooth	Angular	Polygonal	Anomocytic
			SHD 43	Smooth	Angular	Polygonal	Anomocytic
			SHD 100	Smooth	Angular	Polygonal	Anomocytic
5		*Sonneratia ovata* Backer	PWH 634	Smooth	Angular	Polygonal	Anomocytic
6	Meliaceae	*Xylocarpus granatum* J.Koenig	PWH 654	Smooth	Angular	Polygonal	Anomocytic
			Leg. ign. s.n.	Smooth	Angular	Polygonal	Anomocytic
7	Primulaceae	*Aegiceras corniculatum* (L.) Blanco	IPGPD 1195	Smooth	Angular, rounded	Polygonal	Actinocytic
8	Myrtaceae	*Osbornia octodonta* F.Muell.	Leg. ign. s.n.	Smooth	Angular	Polygonal	Anomocytic
9	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	Leg. ign. s.n.	Smooth	Angular, rounded	Polygonal	Anomocyti, staurocytic
			SHD 74	Smooth	Angular, rounded	Polygonal	Anomocytic
			SHD 91	Smooth	Angular	Polygonal	Actinocytic
10		*Bruguiera sexangula* (Lour.) Poir.	SHD 98	Smooth	Angular	Polygonal	Anomocytic
			SHD 105	Smooth	Angular	Polygonal	Staurocytic, actinocytic
11		*Ceriops tagal* (Perr.) C.B.Rob.	Leg. ign. s.n.	Smooth	Rounded	Polygonal	Anomocyti, cyclocytic
12		*Kandelia candel* (L.) Druce	IPGPD 1186	Smooth	Angular	Polygonal	Anomocytic
13		*Rhizophora apiculata* Blume	PWH 593	Smooth	Angular	Polygonal	Cyclocytic
			SHD 92	Smooth	Angular	Polygonal	Cyclocytic
14		*Rhizophora mucronata* Poir.	PWH 653	Smooth	Angular	Polygonal	Actinocytic, cyclocytic
15		*Rhizophora stylosa* Griff.	Leg. ign. s.n.	Smooth	Angular, rounded	Polygonal	anomocytic, cyclocytic

Table 3. Leaf transversal section (*Potongan melintang daun*).

No.	Family	Species	Coll. no.	Leaf type	Water storage			Palisade	
					Hypodermis		Parenchyma	Upper	Lower
					Upper	Lower			
1	Acanthaceae	*Acanthus ilicifolius* L.	PWH 594	Dorsiventral	1	_	_	2	_
			SHD 42	Dorsiventral	1	_	_	1–2	_
2		*Avicennia alba* Blume	IPGPD 1147	Dorsiventral	4–5	_	_	3	_
			IPGPD 1187	Dorsiventral	4	_	_	3	_
3	Euphorbiaceae	*Excoecaria agallocha* L.	PWH 591	Dorsiventral	1–2	_	_	2	_
4	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	IPGPD 1190	Isobilateral	_	1	4–6	2–3	3
			IPGPD 1246	Isobilateral	_	_	8	4	3
			SHD 43	Isobilateral	_	1	4	2–3	1–2
			SHD 100	Isobilateral	_	1	4	2–3	2–3
5		*Sonneratia ovata* Backer	PWH 634	Dorsiventral	_	_	_	3–4	_
6	Meliaceae	*Xylocarpus granatum* J.Koenig	PWH 654	Dorsiventral	2–3	_	_	2	_
			Leg. ign. s.n.	Dorsiventral	1	_	_	2	_
7	Primulaceae	*Aegiceras corniculatum* (L.) Blanco	IPGPD 1195	Dorsiventral	3	_	_	2–3	
8	Myrtaceae	*Osbornia octodonta* F.Muell.	Leg. ign. s.n.	Isobilateral	_	_	_	2	1
9	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	Leg. ign. s.n.	Dorsiventral	1	_	_	2–3	_
			SHD 74	Dorsiventral	1	_	_	3–4	_
			SHD 91	Dorsiventral	1	_	_	2–4	_
10		*Bruguiera sexangula* (Lour.) Poir.	SHD 98	Dorsiventral	1–2	1	_	2–3	_
			SHD 105	Dorsiventral	1	_	_	2–3	_
11		*Ceriops tagal* (Perr.) C.B.Rob.	Leg. ign. s.n.	Isobilateral	2	1	_	1–2	1
12		*Kandelia candel* (L.) Druce	IPGPD 1186	Dorsiventral	2	_	_	2–3	_
13		*Rhizophora apiculata* Blume	PWH 593	Dorsiventral	3–4	_	_	2–3	_
			SHD 92	Dorsiventral	4–5	_	_	3	_
14		*Rhizophora mucronata* Poir.	PWH 653	Dorsiventral	4	_	_	2	_
15		*Rhizophora stylosa* Griff.	Leg. ign. s.n.	Dorsiventral	1	_	_	1–3	_

Table 3. Leaf transversal section (continued) (*Potongan melintang daun*) (Lanjutan)

No.	Family	Species	Coll. no.	Trichome				$CaCO_3$ crystal	Schlereid	Gland	Cork warts	Vascular bundle of midrib
				Glandular		Non glandular						
				Upper	Lower	Upper	Lower					
1	Acanthaceae	*Acanthus ilicifolius* L.	PWH 594	+	+	-	-	-	-	-	-	3 independent vascular bundle
			SHD 42	+	+	-	-	-	-	-	-	3 independent vascular bundle
2		*Avicennia alba* Blume	IPGPD 1147	+	-	-	-	Druse	+	-	-	Arc with inward tips
			IPGPD 1187	+	-	-	-	Druse	+	-	-	Arc with inward tips
3	Euphorbiaceae	*Excoecaria agallocha* L.	PWH 591	-	-	-	-	Druse	-	-	-	Arc with 2 additional vascular bundles at the upper site
4	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	IPGPD 1190	-	-	-	-	Druse	+	-	-	2 free flat arcs with 2 additional lateral vascular bundles
			IPGPD 1246	-	-	-	-	Druse	+	-	-	2 free flat arcs
			SHD 43	-	-	-	-	Druse	+	-	-	Arc with inward tip
			SHD 100	-	-	-	-	Druse	+	-	-	Flat arc with 3 small arcs at the upper site
5		*Sonneratia ovata* Backer	PWH 634	-	-	-	-	Druse	+	+	-	Arc with inward tip and surrounded by lignified cells and 2 additional lateral vascular bundles
6	Meliaceae	*Xylocarpus granatum* J.Koenig	PWH 654	-	-	-	-	Druse, prism	-		-	Arc and additional vascular bundle at upper site. This vascular surrounded by lignified cells
			Leg. ign. s.n.	-	-	-	-	Druse, prism	-		-	Arc and small additional vascular bundle at upper site. This vascular surrounded by lignified cells

7	Primulaceae	*Aegiceras corniculatum* (L.) Blanco	IPGPD 1195					Druse	+	+	-	Arc with 2 additional vascular bundles at the upper site and surrounded by lignified cells
8	Myrtaceae	*Osbornia octodonta* F.Muell.	Leg. ign. s.n.	-	-	+	+	Druse	-		-	Flat arc
9	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	Leg. ign. s.n.					Druse	+		-	Arc with inward tip, 2 additional lateral vascular bundles
			SHD 74	-	-	-	-	Druse	-	-	-	Arc with inward tip, 2 additional lateral vascular bundles
			SHD 91	-	-	-	-	Druse	-	-	-	Arc with inward tip, 2 additional lateral vascular bundles
10		*Bruguiera sexangula* (Lour.) Poir.	SHD 98	-	-	-	-	Druse	-	-	-	Arc with inward tip, 2 additional lateral vascular bundles
			SHD 105	-	-	-	-	Druse	-	-	-	Arc with inward tip, 2 additional lateral vascular bundles
11		*Ceriops tagal* (Perr.) C.B.Rob.	Leg. ign. s.n.					Druse	+		-	Separated vascular bundles are arranged as closed ring and single vascular bundle in the middle
12		*Kandelia candel* (L.) Druce	IPGPD 1186	-	-	-	-	Druse	-		-	Separated vascular bundle form closed ring with single vascular bundle in the middle and 2 additional lateral vascular bundles
13		*Rhizophora apiculata* Blume	PWH 593	-	-	-	-	Druse	+	+	+	Separated vascular bundles form closed ring with additional arc vascular bundle in the center
			SHD 92	-	-	-	-	Druse	+	+	+	NA
14		*Rhizophora mucronata* Poir.	PWH 653					Druse	+	+	+	Separated arc shape vascular bundles and a crescent vascular bundle in the middle and 2 additional lateral vascular bundles
15		*Rhizophora stylosa* Griff.	Leg. ign. s.n.					Druse	+		+	Separated flat arcs form with 2 flat arcs in the upper site

Table 4. Transversal section of petiole (Potongan melintang tangkai daun).

No.	Family	Species	Coll. no.	Vascular bundle	$CaCO_3$ crystal	Trichome		Schlereid	Gland
						Glandular	Non glandular		
1	Acanthaceae	*Acanthus ilicifolius* L.	PWH 594	＞3 independent vascular bundles	-	+	-	-	-
			SHD 42	＞3 independent vascular bundles	Drusse	+	-	-	-
2		*Avicennia alba* Blume	IPGPD 1147	Arc with inward tips	Druse	+	-	+	-
			IPGPD 1187	Arc with inward tips	Druse	+	+	+	-
3	Euphorbiaceae	*Excoecaria agallocha* L.	PWH 591	3 separated flat arcs	Druse	-	-	-	-
4	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	IPGPD 1190	Flat arc with inward tips	Druse	-	-	+	-
			IPGPD 1246	Flat arc with inward tips	Druse	-	-	+	-
			SHD 43	Flat arc with inward tips	Druse	-	-	+	-
			SHD 100	NA	NA	NA	NA	NA	NA
5		*Sonneratia ovata* Backer	PWH 634	Arc with inward tips and 2 additional lateral vascular bundles	Druse	-	-	+	-
6	Meliaceae	*Xylocarpus granatum* J.Koenig	PWH 654	Closed-ring surrounded by lignified cells	Druse	-	-	-	-
			Leg. ign. s.n.	Closed-ring	Druse	-	-	-	-
7	Primulaceae	*Aegiceras corniculatum* (L.) Blanco	IPGPD 1195	Arc with 2 additional arcs at the upper site	Druse	-	-	+	+
8	Myrtaceae	*Osbornia octodonta* F.Muell.	Leg. ign. s.n.	Flat arc	Druse	-	-	-	+

Table 4. Transversal section of petiole (Potongan melintang tangkai daun).

9	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	Leg. ign. s.n.	Arc with invaginated tips	Druse	-	-	-	-
			SHD 74	Arc with invaginated tips	-	-	-	-	-
			SHD 91	Arc with invaginated tips	Druse	-	-	-	-
10		*Bruguiera sexangula* (Lour.) Poir.	SHD 98	Closed-ring with arc in the middle	Druse	-	-	-	-
			SHD 105	3 separated flat arcs and 2 separated flat arcs in upper site	Druse	-	-	-	-
11		*Ceriops tagal* (Perr.) C.B.Rob.	Leg. ign. s.n.	Separated oval vascular bundles with 2 small vascular bundles in the middle	Druse	-	-	-	-
12		*Kandelia candel* (L.) Druce	IPGPD 1186	Separated oval vascular bundle with 2 separated flat arcs in the center	Druse	-	-	-	-
13		*Rhizophora apiculata* Blume	PWH 593	Oval with flat arc vascular bundle in the middle which is connected to lateral part of main vascular bundle	Druse	-	-	+	-
			SHD 92	Oval with flat arc vascular bundle in the middle which is connected to lateral part of main vascular bundle	Druse	-	-	+	-
14		*Rhizophora mucronata* Poir.	PWH 653	Oval with flat arc vascular bundle in the middle which is connected to lateral part of main vascular bundle	Druse	-	-	+	-
15		*Rhizophora stylosa* Griff.	Leg. ign. s.n.	Oval with flat arc vascular bundle in the middle	Druse	-	-	+	-