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ARTICLE

THE ANATOMY OF STIPULES: CASE STUDIES IN DIFFERENT TYPES OF STIPULES

[*Anatomi Stipula: Studi Kasus pada Berbagai Jenis Stipula*]

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ABSTRACT

Stipule is an organs in plants that are small in size and usually located at the base of leaf. This research aims to determine the anatomical characteristics of stipules in seven plants with different types of stipules. The study was conducted using descriptive qualitative method. The anatomical preparations of stipules were made using two techniques: the free-hand section method to obtain paradermal sections and the paraffin method to obtain transverse sections. Based on the observation of anatomical structure, it is known that the types of constituent tissues in stipules resemble the types of constituent tissues in leaves, namely: cuticle, upper epidermis, palisade parenchyma, spongy parenchyma, vascular bundles, and lower epidermis Breadfruit (*Artocarpus altilis* (Parkinson) Fosberg), Cempedak (*Artocarpus integer* (Thunb.) Merr.), and Rubber Plant (*Ficus elastica* Roxb. ex Hornem). The parenchyma is found in homogen arrangement in The Noni/*Morinda citrifolia L.*) and Roses (*Rosa indica L.*) plants, whereas in Coffee (*Coffea canephora* Pierre ex A. Froehner) and Sandbox Tree (*Hura crepitans L.*) plants no vascular bundles were found.

Keywords: Anatomy, Plant Tissues, Stipules

ABSTRAK

Stipula merupakan organ yang terdapat pada tumbuhan dengan ukuran kecil yang biasanya terletak di pangkal tangkai daun. Penelitian ini bertujuan untuk mengetahui karakteristik anatomi stipula pada tujuh tanaman dengan jenis stipula yang berbeda. Penelitian ini dilakukan dengan metode kualitatif deskriptif. Preparasi anatomi stipula dilakukan dengan dua teknik, yaitu metode sayatan free-hand untuk memperoleh sayatan paradermal dan metode parafin untuk memperoleh sayatan melintang. Berdasarkan hasil pengamatan struktur anatomi, diketahui bahwa jenis jaringan penyusun pada berbagai jenis stipula menyerupai jenis jaringan penyusun pada daun yaitu: kutikula, epidermis atas, parenkim palisade, parenkim spons, ikatan pembuluh, dan epidermis bawah Sukun (Artocarpus altilis (Parkinson) Fosberg), Cempedak (Artocarpus integer (Thunb.) Merr.), dan Karet Merah (Ficus elastica Roxb. ex Hornem. Jaringan parenkim terdapat dalam bentuk yang tersusun seragam pada tanaman Mengkudu (Morinda citrifolia L.) dan Mawar (Rosa indica L.), sedangkan pada tanaman Kopi (Coffea canephora Pierre ex A. Froehner) dan Roda (Hura crepitans L.) tidak ditemukan ikatan pembuluh.

***Kata kunci**: Anatomi, Jaringan Tumbuhan, Stipula*

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INTRODUCTION

Leaves is an organ formed by several tissues, namely epidermal, ground tissue, and vascular tissue (Wulansari *et al*., 2020). Epidermal tissue has a function to coat the upper and lower tissue surfaces. The ground tissue in leaves is mesophyll tissue which contains many chloroplasts. Leaves have a vascular tissue that carries water and nutrients from the roots to the leaves and also transports the results of photosynthesis in the leaves to other plant organs (Ramdhini *et al*., 2021). In addition to the main structure, some leaves have additional organs that can provide additional benefits. One of the additional organs found on the leaves is the stipules (Tjitrosoepomo, 2013).

Stipules are organs in plants that are small in size and usually located at the base of the leaf, on the side of the base of the petiole attached to the stem (Tjitrosoepomo, 2013). Stipules may be an adjunct or appendage of a leaf (Majumdar, 1956) . Stipules have many functions, including protecting differentiated organs at the end of the stem, branch buds, and inflorescences in the leaf axils (Bezerra *et al*., 2024; Sharma & Kumar, 2012). In some plant species, stipules can be used as a basis in plant identification and classification, because their shape and size can be a characteristic that distinguishes one species from another (Zhang *et al*., 2022). In addition, the presence of stipules as an additional organ on the leaf indicates an interesting variation in plant adaptation to the environment and its function in the ecosystem.

The earlier research related to stipule has been conducted by several researchers (Capelli *et al*., 2017; Miguel *et al*., 2009; Sheue *et al*., 2003; Ye & Craene, 2024). Research on stipules by Ye & Ronse De Craene (2024) which summarizes previous research related to the appearance, location and morphology of stipules in families recognized by APG IV and reconstructs their taxonomy. Research conducted by Capelli *et al*, (2017) on the stipules of 12 plants in the Apocynaceae, showed that the stipules were modified into colleters, which are sticky or mucous substances that function to protect plants. Another study was conducted by Miguel *et al*., (2009) on the *Psychotria nuda* (Cham. & Schltdl.) Wawra plant in the Rubiaceae which was reviewed micromorphologically, anatomically, and crystal microanalysis which showed that the colleter stipula had a lachrymiform type, with a central axis elongated by the ground parenchyma and enveloped by a palisade layer, based on the results of microanalysis it was possible that this structure contained calcium dominance. Morphology, anatomy, ontogeny, and secretion in Rubiaceae (Tresmondi *et al*., 2015; Vitarelli & Santos, 2009)). Other related research on stipules in genus *Kandelia* has been carried out by Sheue *et al.*, (2003) which stated that stipules on mangrove have abaxial collenchyma but without sclereid ideoblast, colleters, finger-like rod with a stalk, aggregate into a triangular shape inside the base of the stipule. The function of mangrove stipules includes protecting young leaves and serving as a site for colleter accumulation for protective secretion.

According to previous researches, they have provided important information about the morphological characteristics and role of stipules. However, this research is still very limited, especially the studies on the anatomical structure of stipules that have not been conducted before. Therefore, this study focuses on exploring the anatomical structure of stipules in several plants in various tribes with different types of stipules.

The used stipules came from seven plants belonging to four families: Moraceae, Rubiaceae, Rosaceae, and Euphorbiaceae. These four families were chosen to know the morphological and anatomical variations of stipules from the four families. Furthermore, the results can be used as information to understand its function.

MATERIALS AND METHODS

This research is qualitative research with descriptive method. The research was carried out by making preparations of stipule anatomical tissues using two methods, namely the free-hands section method to obtain paradermal sections and the paraffin method to obtain transverse sections.

The materials used in this study are Breadfruit (*Artocarpus altilis* (Parkinson ex F.A. Zorn) Fosberg), Cempedak (*Artocarpus integer* (Thunb.) Merr.), Rubber Plant (*Ficus elastica* Roxb. Ex Hornem.), Noni (*Morinda citrifolia* L.), Coffee (*Coffea canephora Pierre* ex A. Froehner), Rose (*Rosa indica* L.), and Sandbox Tree (*Hura crepitans* L.), Formaldehyd Acetic Acid (FAA) solution,

alcohol (100%, 96%, 70%, 30%, 15%), pure xylol, 10% glycerin, safranin, 3% formalin, distilled water.

The seven plant species represent several types of stipules, including terminal stipules (*stipula terminalis*) found in *A.altilis, A.integer, F.elastica*; interpetiolar stipules (*stipula interpetiolaris*) in *M.citrifolia* and *C.canephora*; and adnate stipules (*stipula adnatae*) in *R.indica*. The sample used consisted of 3 individuals from each plant species.

The Free-Hands Section method is a simple histological preparation using fresh tissue or non-permanent slide(Lux *et al*., 2005). This method to obtained paradermal incision of the upper and lower surface of the stipule. The paraffin section method is a technique in which plant tissues are embedded in wax to achieve uniform stiffness, allowing thin sectioning with a microtome for internal structure observation and histochemical staining, ultimately producing a permanent slide (Miya *et al*., 2025). This method consist of fixation, aspiration, dehydration, dealcoholization, infiltration, trimming, affixing, staining, mouting. Microscopic observations were documented with photographs, followed by an analysis of the anatomical structures were found.

RESULTS

Based on observations *A.altilis* (Parkinson) Fosberg, *A.integer* (Thunb.) Merr., and *F. elastica* Roxb Ex. Hornem have complete constituent tissues consisting of: upper epidermis, palisade parenchyma, spongy parenchyma, vascular bundles, and lower epidermis (Table 1). *M.citrifolia* L. and *R.indica* L. also have complete constituent tissues such as leaves, but the parenchyma tissue is found in a uniform form. Whereas C.*canephora* Pierre ex A. Froehner and *H.crepitans* L.have no vascular bundle. These two species are arranged by upper epidermis, uniform parenchyma tissue, and lower epidermis.

Table 1. The result of stipules anatomy (*Hasil Pengamatan Anatomi Stipula*)

Plant Names (*Nama Tanaman)*	**Constituent Tissues (*Jaringan Penyusun*)**				
	Upper Epidermis (*Epidermis Atas*)	**Palisade Parenchyma (*Parenkim Palisade)***	**Sponge Parenchyma (*Parenkim Spons)***	**Vascular Bundle (*Jaringan Pembuluh)***	**Lower Epidermis (*Epidermis Bawah)***
Artocarpus altilis (Parkinson) Fosberg	+	+	+	+	+
Artocarpus integer (Thunb.) Merr.	+	+	+	+	+
Ficus elastica Roxb. Ex. Hornem	+	+	+	+	+
Morinda citrifolia L.	+	-	-	+	+
Coffea canephora Pierre ex A. Froehner	+	-	-	-	-
Rosa indica L.	+	-	-	+	+
Hura crepitans L.	+	-	-	-	+

***Artocarpus altilis* (Parkinson) Fosberg**

A transverse section of *A.altilis* (Parkinson) Fosberg stipules shows the arrangement of the constituent tissues namely cuticle, upper epidermis, palisade parenchyma, spongy parenchyma, vascular bundles, and lower epidermis (Figure 1a).

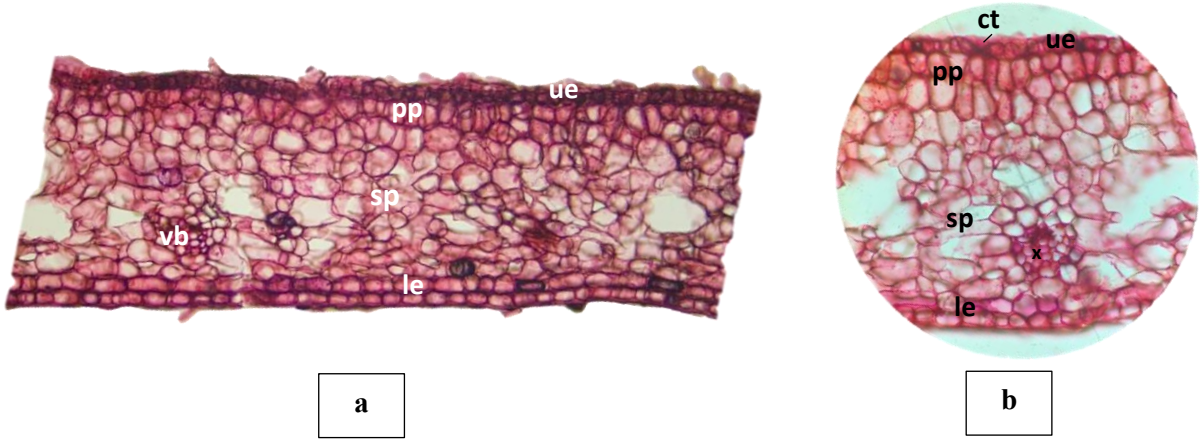


Figure 1. Anatomy structure of *A.altilis* (Parkinson) Fosberg) stipules on transversal section (*Struktur anatomi penampang melintang stipula A.altilis* (Parkinson) Fosberg); (ct) = cuticle (*kutikula*); (ue) = upper epidermis (*epidermis atas*); (pp) = palisade parenchyma (*parenkim palisade*); (sp) = sponge parenchyma *(parenkim spons*); (vb) = vascular bundle (*ikatan pembuluh*); (x) = xylem; (p) = phloem; (le) = lower epidermis (*epidermis bawah*). Notes: magnification (a) 100x (*perbesaran 100x*); (b) 400x (*perbesaran 400x*).

Based on Figure 1, it is known that the upper epidermis consists of one layer of cells, while the lower epidermis consists of two layers of cells (Figure 1b). The parenchyma tissue near the epidermal tissue is tightly arranged and close to each other, while the parenchyma in the center has more loose arrengement. Vascular bundles consist of xylem and phloem. Generally, it can be concluded that the anatomical structure of breadfruit stipules has same structure with leaf anatomical structure.

The epidermal tissues showed polygonal shaped cells with straight anticlinal cell wall in the upper paradermal, while irregular shaped cell with sinuous anticlinall cell wall in lower paradermal sections (Figure 2), in the lower epidermis cell wall is thicker (Figure 2a) and in the upper paradermal it is thinner and there are several simple type unicellular trichomes that appear on the surface of the epidermis (Figure 2b).

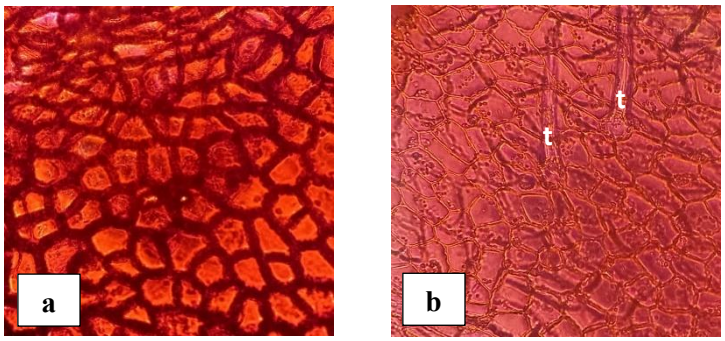


Figure 2. Epidermis Tissues of *A.altilis* (Parkinson) Fosberg) stipules *(Jaringan epidermis stipula A.altilis* (Parkinson) Fosberg).; (a) lower paradermal section (*penampang paradermal bagian bawah*); (b) upper paradermal section (*penampang paradermal bagian atas*); (t) = trichome (*trikoma*). Notes: magnification 400x (*perbesaran 400x*).

***Artocarpus integer* (Thunb.) Merr.**

The transverse section of *A.integer* (Thunb.) Merr. stipules plants shows the arrangement of the constituent tissues from outside to inside, namely upper epidermis (outside), palisade parenchyma, sponge parenchyma, vascular bundles, and lower epidermis (inside) (Figure 3).

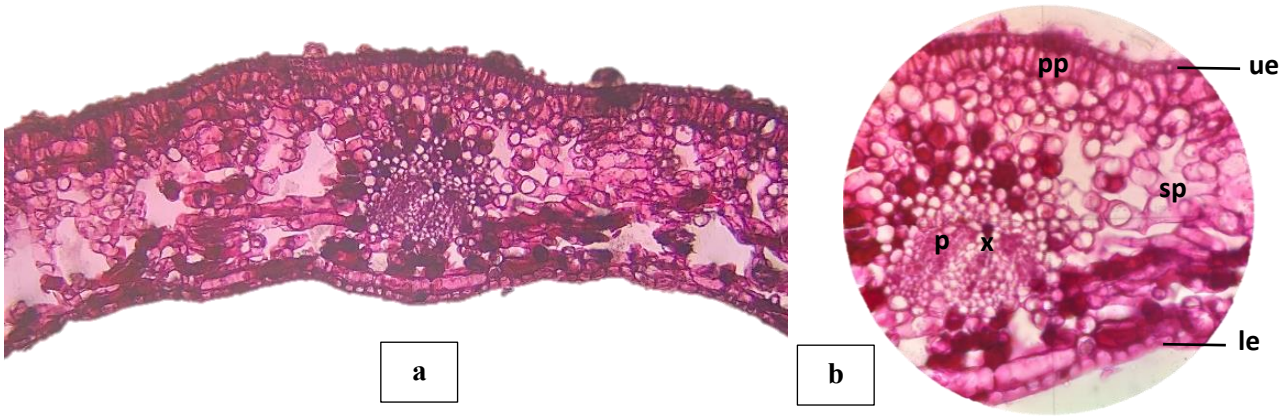


Figure 3. Anatomy structure of *A.integer* (Thunb.) Merr. stipules on transversal section (*Struktur anatomi penampang melintang A.integer* (Thunb.) Merr.; (ue) = upper epidermis (*epidermis atas*); (pp) = palisade parenchyma (*parenkim palisade*); (sp) = sponge parenchyma *(parenkim spons*); (x) = xylem; (p) = phloem; (le) = lower epidermis (*epidermis bawah*). Notes: magnification (a) 100x (*perbesaran 100x*); (b) 400x (*perbesaran 400x*).

The upper epidermis consists of one layer of cells, while the lower epidermis consists of two layers of cells. The palisade parenchyma tissue is close to the epidermal tissue, tightly arranged and close to each other, while the sponge parenchyma in the center has cavities between cells. The parenchyma is found around the vascular bundles sheath. The vascular bundle consists of xylem and phloem elements. Overall, it can be concluded that the anatomical structure of *A.integer* stipules has a type of tissue structure resembling the anatomical structure of leaves.

The anatomical structure of epidermal tissue in the stipules of *A.integer* plants shows the characteristics of the epidermis. Epidermis cell shape is irregularly with sinuous anticlinal cell wall on both upper and lower paradermals (Figure 4). On the upper paradermal there are trichomes as found in (Figure 4c) showing the attachment of the base of the trichome to the epidermal tissue.

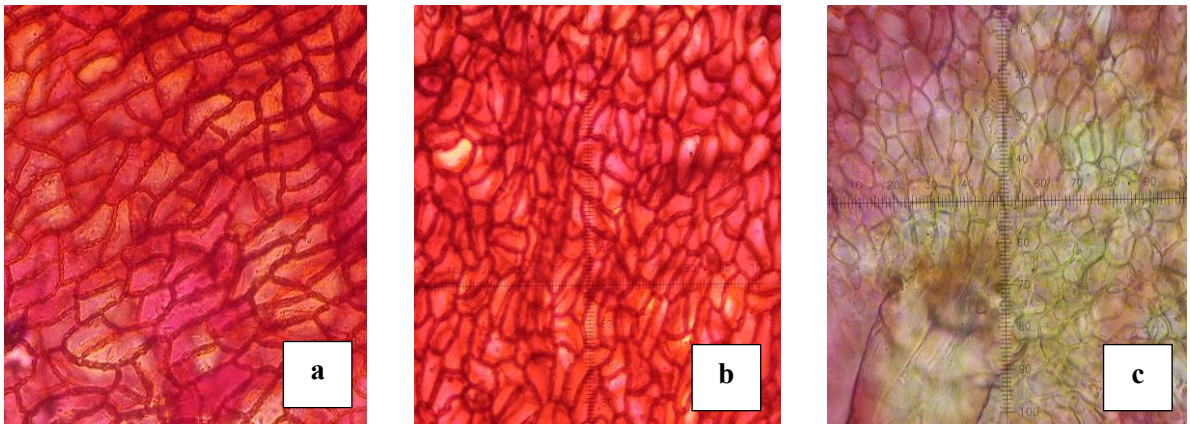


Figure 4. Epidermis tissues of *A.integer* (Thunb.) Merr.) stipules (*Jaringan epidermis stipula A.integer* (Thunb.) Merr.).; (a) lower paradermal section (*penampang paradermal bagian bawah*); (b) Upper paradermal section (*penampang paradermal bagian atas*); (c) Upper paradermal section near the trichome attachment (*penampang paradermal atas di dekat perlekatan trikoma*). Notes: magnification 400x (*perbesaran 400x*).

***Ficus elastica* Roxb. Ex Hornem.**

Transverse section of *Ficus elastica* Roxb. Ex Hornem stipules showing the arrangement of the constituent tissues of the upper epidermis (outer), palisade parenchyma, sponge parenchyma, vascular bundles, and lower epidermis (inner) (Figure 5).

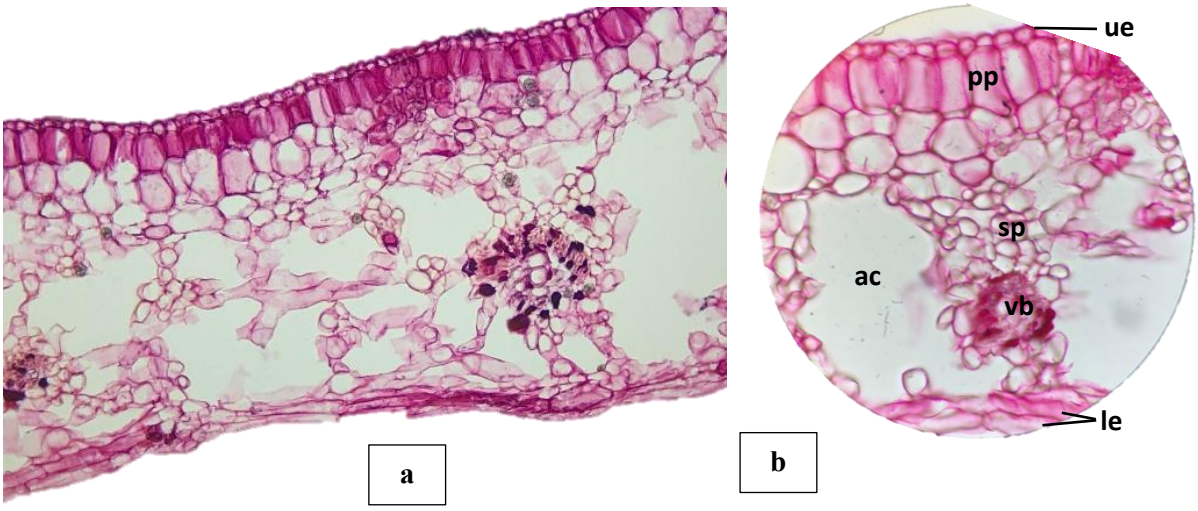


Figure 5. Anatomy structure of *F.elastica* Roxb ex. Hornem) stipules on transversal section (*Struktur anatomi penampang melintang stipula F.elastica* Roxb ex. Hornem).; (ue) = upper epidermis (*epidermis atas*); (pp) = palisade parenchyma (*parenkim palisade*); (sp) = sponge parenchyma *(parenkim spons*); (ac) = air cavity (*rongga udara*); (vb) = vascular bundle (*ikatan pembuluh*); (le) = lower epidermis (*epidermis bawah*). Notes: magnification (a) 100x (*perbesaran 100x*); (b) 400x (*perbesaran 400x*).

Based on Figure 5, the upper epidermis consists of one layer of cells, while the lower epidermis consists of two layers of cells. Both epidermis appear to have clear differences in shape. The palisade parenchyma tissue is adjacent to the epidermal tissue, densely arranged and close to each other, while the spongy parenchyma in the center has cavities between cells. The parenchyma is found around the vascular bundles sheath.

Epidermal tissue in stipules has different epidermal characteristics, the lower epidermis cells are rectangular shape with undulate anticlinal cell wall (Figure 6a) while upper epidermis cells are polygonal with straight wall (Figure 6b).

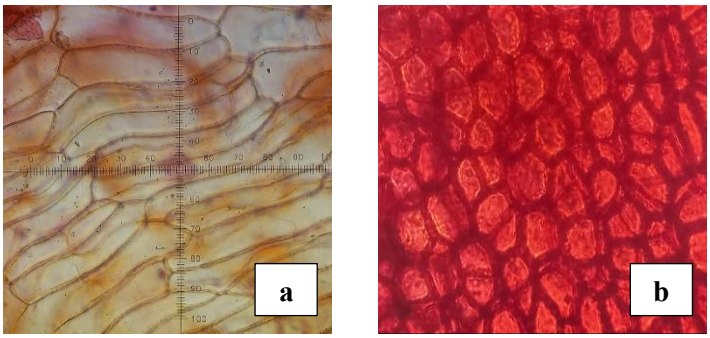
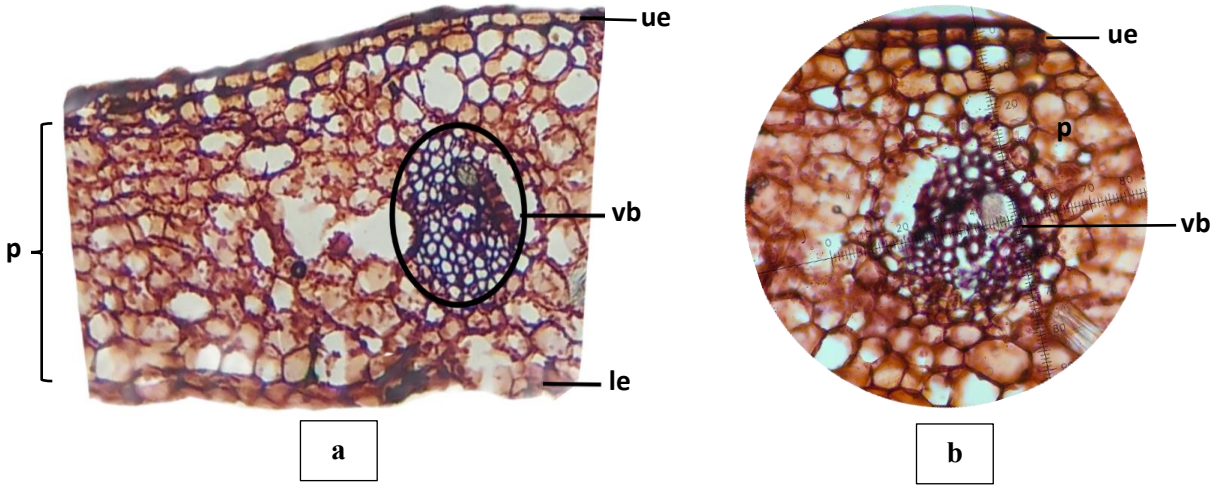


Figure 6. Epidermis tissues of *F.Elastica* Roxb ex. Hornem stipules (*Jaringan epidermis stipula F.Elastica* Roxb ex. Hornem).; (a) lower paradermal section (*penampang paradermal bagian bawah*); (b) upper paradermal section (*penampang paradermal bagian atas*). Notes: magnification 400x (*perbesaran 400x*).

***Morinda citrifolia* L.**

The transverse section of *M.citrifolia* L. stipules shows the arrangement of the constituent tissues namely upper epidermis, parenchyma tissue, vascular bundles, and lower epidermis (Figure 7). Based on the observation, the upper and lower epidermal tissues consist of one layer of cells. Vascular bundles consist of xylem and phloem elements (Figure 7a).



Gambar 7. Anatomy structure of *M.citrifolia* L. stipules on transversal section (*struktur anatomi penampang melintang stipula M.citrifolia* L.).; (ue) = upper epidermis (*epidermis atas*); (p) = parenchyma (*parenchyma*); (vb) = vascular bundle (*ikatan pembuluh*); (le) = lower epidermis (*epidermis bawah*). Notes: magnification (a) 100x (*perbesaran 100x*); (b) 400x (*perbesaran 400x*).

The epidermal tissue of *M.citrifolia* L is arranged by polygonal cells shape with straight anticlinal cell wall on the lower paradermal while the upper paradermal rectangular cell shape with straight anticlinall wall (Figure 8). In the lower paradermal, the epidermis has a thick cell wall and there are several stomata scattered with parasitic type, namely there are stomata with cover cells surrounded by one or more neighboring cells with a long axis that is parallel between cover cells and neighboring cells (Figure 8a).

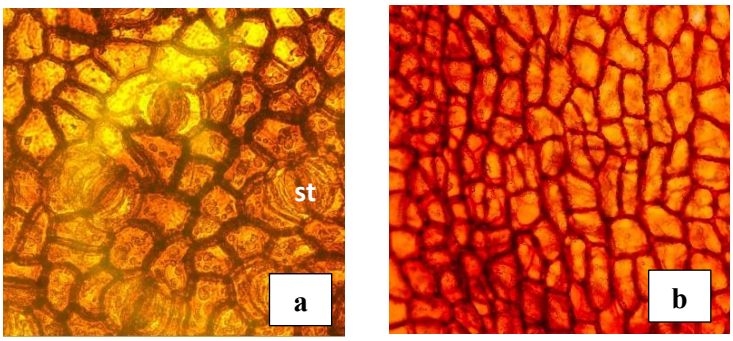


Figure 8. Epidermis tissues of *M.citrifolia* L. (*jaringan epidermis stipula M.citrifolia* L.).; (a) lower paradermal section (*paradermal bawah*); (b) upper paradermal section (*paradermal atas*); (st) = stomata. Notes: magnification 400x (*perbesaran 400x*).

***Coffea canephora* Pierre ex A.Froehner**

A transverse section of *C.canephora* Pierre ex A. Froehner stipules shows the constituent tissues consisted only of epidermis and parenchyma (Figure 9).

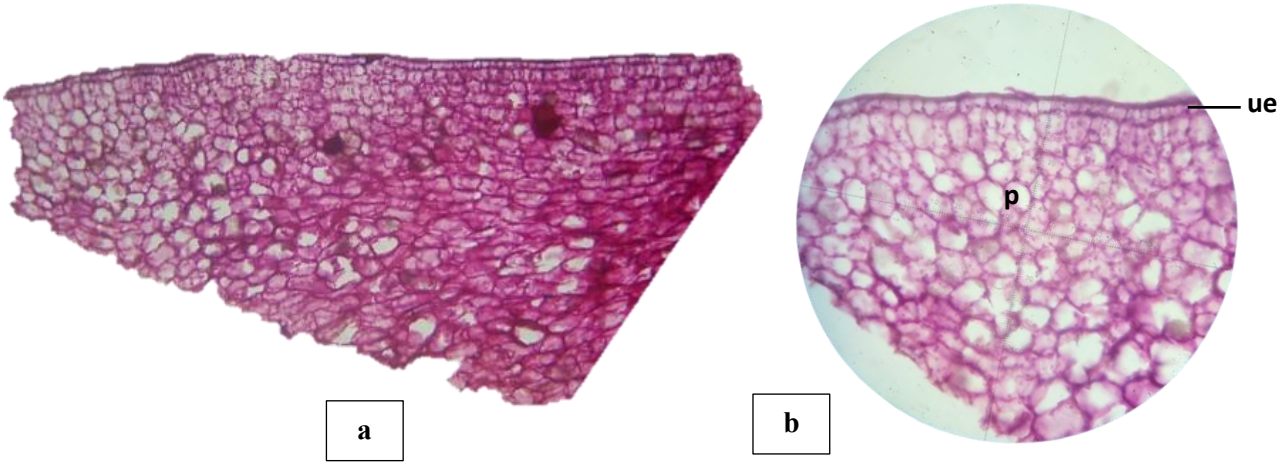


Figure 9. Anatomy structure of *C.canephora Pierre* ex A. Froehner stipules on transversal section (*struktur anatomi penampang melintang stipula C.canephora* Pierre ex A. Froehner).; (ue) = upper epidermis (*epidermis atas*); (p) = parenchyma (*parenkim*). Notes: magnification (a) 100x (*perbesaran 100x*); (b) 400x (*perbesaran 400x*).

Based on Figure 9, the upper epidermal tissue in coffee stipules is arranged close together consisting of one layer of cells, while the anatomical structure of this tissue generally includes a lower epidermis, but this layer was not observed in the current sample. The missing layer could be attributed to a sectioning error or insufficient slicing of the tissue. The parenchyma tissue has the same shape from outside to inside. Overall, the anatomical structure of the stipules on coffee is only composed by epidermal and parenchymal tissues. The parenchyma tissue was found to be uniform in shape.

The anatomical structure of the epidermal tissue of the coffee plant stipules has epidermal characteristics, the lower epidermis cells are rectangular shape with sinuous anticlinal cell wall while upper epidermis cells are polygonal with straight wall (Figure 10).

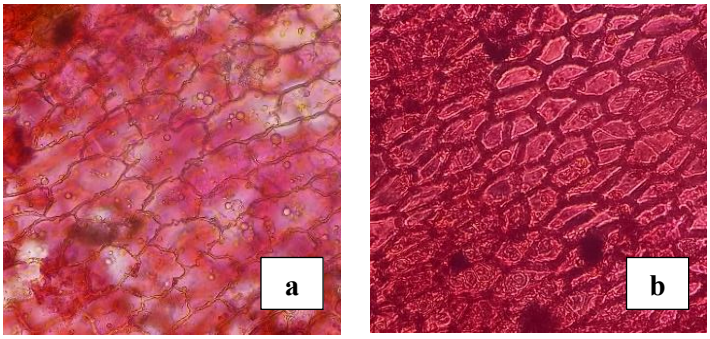


Figure 10. Epidermis tissues of *C.canephora* Pierre ex A.Froehner stipules (*jaringan epidermis stipula C.canephora* Pierre ex A.Froehner).; (a) lower paradermal section (*penampang paradermal bawah*); (b) upper paradermal section (*penampang paradermal atas*). Notes: magnification 400x (*perbesaran 400x*).

***Rosa indica* L.**

The transverse section of *R.indica* L. stipules has constituent tissues, namely upper epidermis, parenchyma tissue, vascular bundles, and lower epidermis (Figure 11). The upper epidermis on the stipules consists of two layers of cells, while the lower epidermis consists of one layer of cells. Parenchymal tissue has the same shape from outside to inside. There are vascular bundles located between the parenchyma tissues.

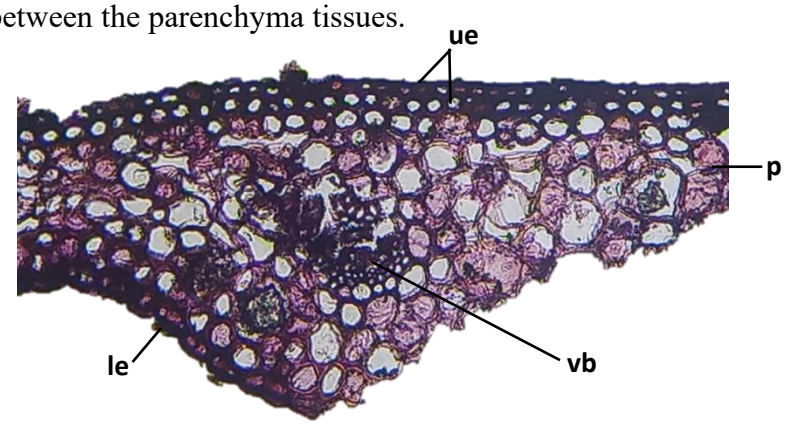


Figure 11. Anatomy structure of *R.indica* L. stipules on transversal section (*struktur anatomi penampang melintang stipula R.indica* L.).; (ue) = upper epidermis (*epidermis atas*); (p) = parenchyma (*parenchyma*); (vb) = vascular bundle (*ikatan pembuluh*); (le) = lower epidermis (*epidermis bawah*). Notes: magnification 100x (*perbesaran 100x*).

Epidermal tissue in rose stipules has the characteristics of epidermis, namely: irregular cell shape with straight anticlinal cell walls in both upper and lower paradermal (Figure 12).

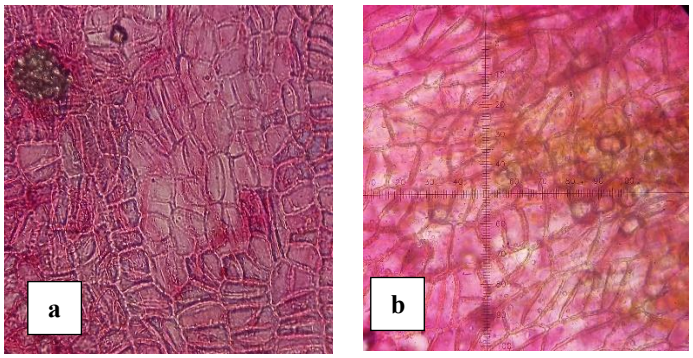


Figure 12. Epidermis tissues of *R.indica* L. stipules (*jaringan epidermis stipula R.indica* L.; (a) upper paradermal section (*paradermal atas*); (b) lower paradermal section (*paradermal bawah*). Notes: magnification 400x (*perbesaran 400x*).

***Hura crepitans* L.**

A transverse section of the stipules of *Hura crepitans* L. plant shows the constituent tissues namely: upper epidermis, parenchyma, and lower epidermis (Figure 13).

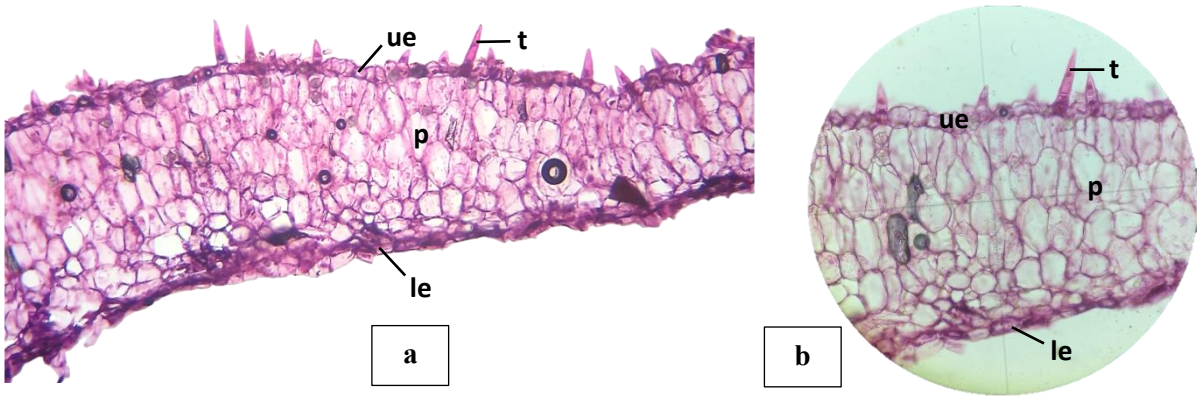


Figure 13. Anatomy structure of *H.crepitans* L. stipules on transversal section (*struktur anatomi penampang melintang stipula H.crepitans* L.).; (t) = trichome (*trikoma*); (ue) = upper epidermis (*epidermis atas*); (p) = parenchyma (*parenkim*); (le)= lower epidermis (*epidermis bawah*). Notes: magnification (a) 100x (*perbesaran 100x*); (b) 400x (*perbesaran 400x*).

Based on Figure 13b, the epidermis consists of one layer of cells on the upper and lower. On the upper epidermis there are simple type unicellular trichomes. The parenchyma tissue has the same shape from outside to inside.

Epidermal tissue of *H.crepitans* L. stipules has epidermal characteristics, namely irregular cell shape on the upper paradermal (Figure 14a), while on the inner paradermal has a rectangular cell shape with undulate anticlinal cell wall (Figure 14c). On the upper paradermal there are many simple type unicellular trichomes attached to the surface of the epidermis (Figure 14b).

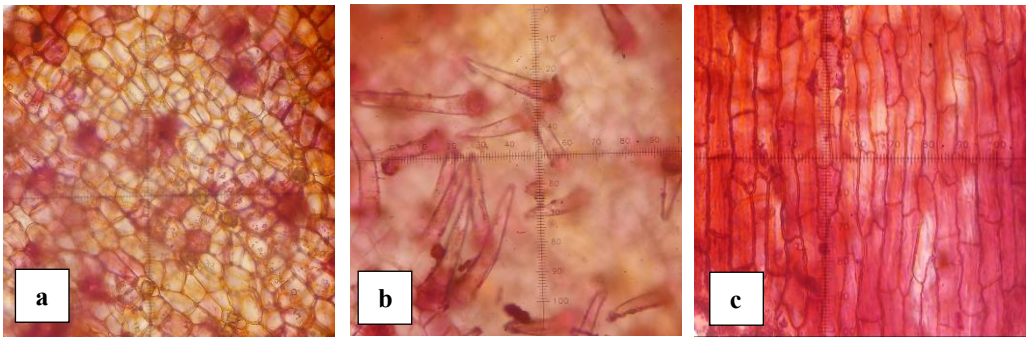


Figure 14. Epidermis tissues of *H.crepitans* L.(*jaringan epidermis stipula H.crepitans* L.; (a) upper paradermal section (*penampang paradermal atas*); (b) trichomes on upper paradermal section (*banyak trikoma pada paradermal atas*); (c) lower paradermal section (*penampang paradermal bawah*).

DISCUSSION

Based on the anatomical structure of stipules in several plants, stipules generally have a structure that resembles the anatomy of leaves. Some species such as the constituent tissues of the stipules of the *A.altilis* (Parkinson ex F.A. Zorn) Fosberg, *A. integer* (Thunb.) Merr.), and *F. elastica* Roxb. Ex Hornem. have same anatomical structure as leaf structure and this result agreed to Evert (2006). This data is reinforced by previous theories which state that leaves are arranged by dermal tissue, namely the epidermis, vascular tissue, and mesophyll tissue consisting of palisade and sponge parenchyma (Evert, 2006). However, a research showed that stipules of some plants have uniform parenchyma tissue (Bezerra *et al*., 2024). In this our study, uniform parenchyma tissue was found in *M.citrifolia* L. and *R.indica* L. plants. According to previous research stipules also contribute to the process of photosythesis, Giovanardi *et al*., (2018) proven that phtosynthetic electron flow are active

in pea stipules, although the level of activity is lower than the leaflets. Anatomically, the parenchyma tissue contains many chloroplasts. According to Evert (2006), parenchyma containing chloroplasts serves as a place for photosynthesis. In previous research by Sharma & Kumar, (2012) also states that stipules have the green coloration of clorophyll are photosynthetically active. Furthermore, some stipules can also produce mucus (Dalvi *et al*., 2014), and sometimes contain protein and starch (de Faria *et al*., 2019; Fernandes *et al*., 2016). These findings are consistent with previous research, which shows that the morphological features of green stipules facilitate the process of photosynthesis.

Stipules on *C.canephora* Pierre ex A. Froehner and *H.crepitans* L.are without vascular bundles. Based on the results of morphological observations on the stipula, it shows the characteristics of the stipule in the form of very thin leaves and does not have veins, indicating that anatomically, cell reversal occurs to the cortex only until no vascular bundles are formed. This is also supported by the anatomical structure that shows the absence of vascular bundles. According to Evert (2006), vascular bundles are found in leaves in the form of morphological structures called veins. To date, no references have been found that specifically address the absence of vascular tissue in this part. One possible explanation is that the stipule is a temporary structure, which may not develop extensive vascularization.

Based on the results of this study, it can be concluded that in addition to functioning as a protector of young leaves and developing buds, stipules also play a role in photosynthesis, because they have parenchymal tissue containing chloroplasts.

CONCLUSION

Anatomically, the constituent tissues of the stipules have different variations arrangement of anatomical structure. The constituent tissues in the stipules of the plants Breadfruit (*A.altilis* (Parkinson ex F.A. Zorn) Fosberg), Cempedak (*A.integer* (Thunb.) Merr.), and Rubber Plant (*F.elastica* Roxb. Ex Hornem.) have a complete structure that resembles to leaf. The constituent tissues in the stipules of Noni (*M.citrifolia* L.) and Rose (*R.indica* L.) plants have a tissue structure that resembles leaves, but both species have a homogenparenchyma tissue. Vascular bundles are not present in the stipules of Coffee (*C.canephora* Pierre ex A. Froehner) and Rose (*R.indica* L.).

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AUTHOR CONTRIBUTIONS

AK: contributed to the research data collection, article preparation, and manuscript revision. E: corresponding author: conceptualized the research, analyzed the data, helped draft the article, and finalized the manuscript; DJS: reviewer for this student research.

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