Comparative anatomical characteristics of two aquatic species of the family Pontederiaceae

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Abstract

A comparative anatomy of vegetative parts of two aquatic species, viz. *Eichhornia crassipes* (Mart.) Solms–Laub. and *Monochoria vaginalis* (Burm.f.) Presl, both of which belong to the family Pontederiaceae, was conducted in the present study. In transverse section (T.S.) of lamina, both species revealed the presence of similar characteristics such as paracytic stomata, large air cavities, and abundant raphides. In surface view of midribs, stomata are absent and numerous air cavities are found in *E. crassipes*, whereas stomata are present and a few air cavities, as compared to those of *E. crassipes*, are observed in *M. vaginalis*. In T.S. of petioles, the arrangement of vascular bundles (i.e. smaller ones towards epidermis while larger ones towards cortex) is similar in both species. In T.S. of stems of *E. crassipes*, vascular bundles are surrounded by air cavities at the periphery region, whereas those are scattered inside the interior region of the cortex parenchyma, where no air cavity was examined. On the other hand, T.S. of rhizomes of *M. vaginalis* is akin to that of its petioles. Interestingly, air cavities observed in T.S. of roots of *E. crassipes* are very large, but no air cavity was detected in that of *M. vaginalis*. The data obtained in this study suggest that anatomical characters can serve as potential diagnostic tool in plant identification.

Key words: anatomy, air cavities, aquatic species, diagnostic tool, plant identification.

Introduction

The family Pontederiaceae consists of herbaceous, annual or perennial, freshwater aquatic monocotyledonous plants (Takhtajan, 1997). The family comprises of approximately 33 species and 9 genera from both the Old and New World tropics (Cook, 1998). Out of the 9 genera, *Eichhornia* is recognized as pantropical distributions, while *Monochoria* is occurred in Africa, Asia and Australia (Cook, 1996).

Eichhornia crassipes, commonly known as water hyacinth, is perennial and free floating herbs. The leaves are broadly ovate with inflated spongy petioles. Inflorescences are terminal, spike or panicle subtended by a bract and flowers all opening together. Flowers are irregular and perianth infundibular with bright yellow blotch at center surrounded by blue patch (Dassanayake, 2000).

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Previous anatomical studies with *E. crassipes* have emphasized on floral parts (Simpson & Burton, 2006). Anatomical data for vegetative organs such as leaf and root can be seen in the work of AL–Hadeethi *et al*. (2017). Because of its high capacity to absorb and tolerate elevated levels of pollutants, *E. crassipes* is one of the most studied floating aquatic plants and considered as a potential species to reduce water pollution (Harley,1990). In some cases, the effect of phytoremediation on the anatomical characteristics of *E. crassipes* has been documented (Pereira *et al*. 2017; Napaldet *et al*., 2019). Nonetheless, a comprehensive work on anatomical characters of vegetative parts as well as reproductive parts of wild plants of the species has not so far been carried out.

Monochoria vaginalis, commonly known as pickerel–weed, is perennial and rhizomatous emergent herbs. The leaves are broadly ovate to ovate oblong, dark green above and paler beneath. Inflorescences are terminal, raceme–like or subumble–like subtended by a bract. Perianth segments are six, free, subequal, the three inner tepals broader, tepals spreading at anthesis, afterwards becoming spirally twisted (Dassanayake, 2000).

Previous anatomical study with *M. vaginalis* was focused on floral parts (Strange *et al*., 2003). On the other hand, Narayanan and Kaliappan (2014) emphasized on the vegetative parts of the species such as leaf, rhizome, and root. Very recently, Udage and Yakandawala (2017) reported the leaf anatomy of the species collected from Sri Lanka. Nevertheless, available literature revealed that anatomical characteristics of *M. vaginalis* noted in the early researches are based on the plant specimens collected from very limited areas.

Indeed, previous anatomical studies on *E. crassipes* and *M. vaginalis* did not include the plant specimens collected from Myanmar. Therefore, an attempt was made to fill this gap in existing knowledge about anatomy of both species. The aim and objectives of the present study are to describe the comparative anatomy of the vegetative parts of *E. crassipes* and *M. vaginalis*, both of which were collected in small ponds in Bonebwet and Khuntaunggyi Villages, Shwebo Township, Myanmar.

Materials and Methods

Plant specimens

Eichhornia crassipes (Mart.) Solms–Laub. and *Monochoria vaginalis* (Burm. f.) Presl examined in this study were collected in small ponds in Bonebwet and Khuntaunggyi Villages, Shwebo Township, Sagaing Region, Myanmar. The plants were identified according to the taxonomic descriptions of Dassanayake (2000).

Anatomical Study

Free hand sections of fresh specimens were cut using razor blade. Of these, good quality, thin sections were employed for the preparation of slides according to the published protocol (Johansen, 1940) with a few modifications. In brief, thin sections were treated with a few tiny pieces of chloral hydrate crystals and stained with safranin solution for 1 min. Excess stain was washed with an aliquot of distilled water. Afterwards, the sections were kept in dilute glycerin solution and mounted temporarily on a clean glass slide under a cover slip. Maceration of fresh specimens was also made by boiling them in equal volume of 50% of acetic acid solution and 50% of hydrogen peroxide solution. Slides prepared to use thin sections or macerates were observed under a light microscope and their photomicrographs were recorded.

Results

Anatomical Characteristics of *Eichhornia crassipes* (Mart.) Solms–Laub.

Internal structure of lamina

In dermal tissue system, the epidermal cells of both surface views are parenchymatous, polygonal or hexagonal in shape, cell walls are thin and straight stomata present on both surfaces, abundant, paracytic type; guard cells reniform. In transverse section, both upper and lower epidermis is a single layer (Fig. 1 A and B). In ground tissue system, mesophyll is differentiated into palisade parenchyma at the upper side and spongy aerenchyma at the lower side. Palisade parenchyma is 1 to 2 layers; spongy aerenchyma many–layered, cells loose, chloroplasts abundant, large air cavities (Fig. 1 C), and abundant raphides (Fig. 1 D). Vascular bundles are embedded in the ground tissue, smaller and larger vascular bundles, closed collateral; a bundle sheath of parenchymatous cells.

Internal structure of midrib

In dermal tissue system, the epidermal cells in surface views are parenchymatous, rectangular or polygonal in shape, cell walls thin and straight stomata are absent (Fig. 1 E). In transverse section, epidermis is a single layer. Ground tissue system is composed of hexagonal–shaped aerenchymatous cells and large air cavities. Vascular bundles are

diffused in the ground tissue, contact between aerenchyma with two different forms of vascular bundles, smaller and larger closed collateral; smaller bundle towards the periphery and larger lies in the center; bundle sheath parenchymatous cells (Fig. 1 F).

Internal structure of petiole

In transverse section, petioles are semicircular in outline. In dermal tissue system, the epidermal cells in surface view are parenchymatous, rectangular or polygonal in shape, cell walls are thin and straight, stomata are absent (Fig. 2 A). In transverse section, epidermis is one layer. Ground tissue system is composed of hexagonal–shaped aerenchymatous cells and large air cavities. Vascular bundles are diffused in the ground tissue, contact between aerenchyma with two different forms of vascular bundles, smaller and larger closed collateral; smaller bundle towards the periphery and larger lies in the center (Fig. 2 B).

Internal structure of stem

In transverse section, epidermis is one layer, cells barrel–shaped. In ground tissue system, hexagonal–shaped aerenchymatous cells towards the periphery with air cavity and polygonal–shaped parenchymatous cells towards the center. Vascular bundles are diffused in the ground tissue, closed collateral, oval–shaped (Fig. 2 C and D).

Internal structure of root

In dermal tissue system, epidermis of the root in transverse section is one layer, rectangular in shape. In ground tissue system, collenchyma cells below the epidermis, 2 to 3 layers, polygonal in shape; aerenchyma cells towards the center and large air cavities (Fig. 2 E). In vascular tissue system, vascular bundles are concentric or amphivasal, phloem is surrounded by the xylem (Fig. 2 F).

Anatomical Characteristics of *Monochoria vaginalis* (Burm.f.) Presl

Internal structure of lamina

In dermal tissue system, the epidermal cells of both surfaces similar in parenchyma, polygon or hexagon in shape, cell walls in thin and straight stomata present on both surfaces, abundant, paracytic type; guard cells reniform (Fig. 3 A and B). In transverse section, both upper and lower epidermis is a single layer. In ground tissue system,

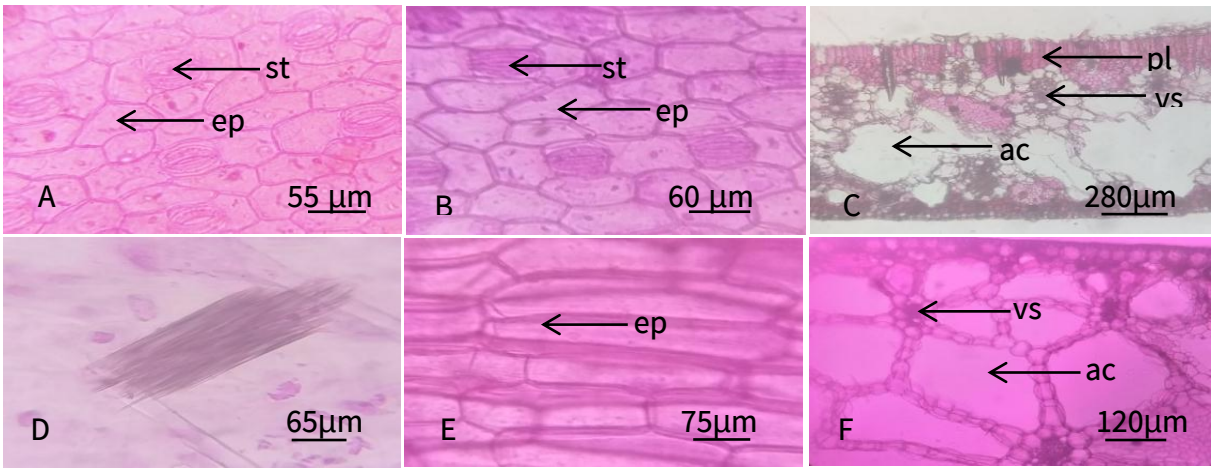

Figure 1 Internal structure of leaf and midrib of *Eichhornia crassipes* (Mart.) Solms–Laub. **A.** Upper surface view of leaf showing epidermal cells and stomata. **B.** Lower surface view of leaf showing epidermal cells and stomata. **C.** T.S of lamina showing palisade, spongy aerenchyma cells, vascular bundles and air cavities. **D.** A closed up view of lamina showing raphides. **E.** Surface view of midrib showing epidermal cells. **F.** T.S of midrib showing aerenchyma cells and smaller and larger vascular bundles and air cavities. (ac – air cavity, ep – epidermis, pl – palisade, st – stomata, vs – vascular bundle)

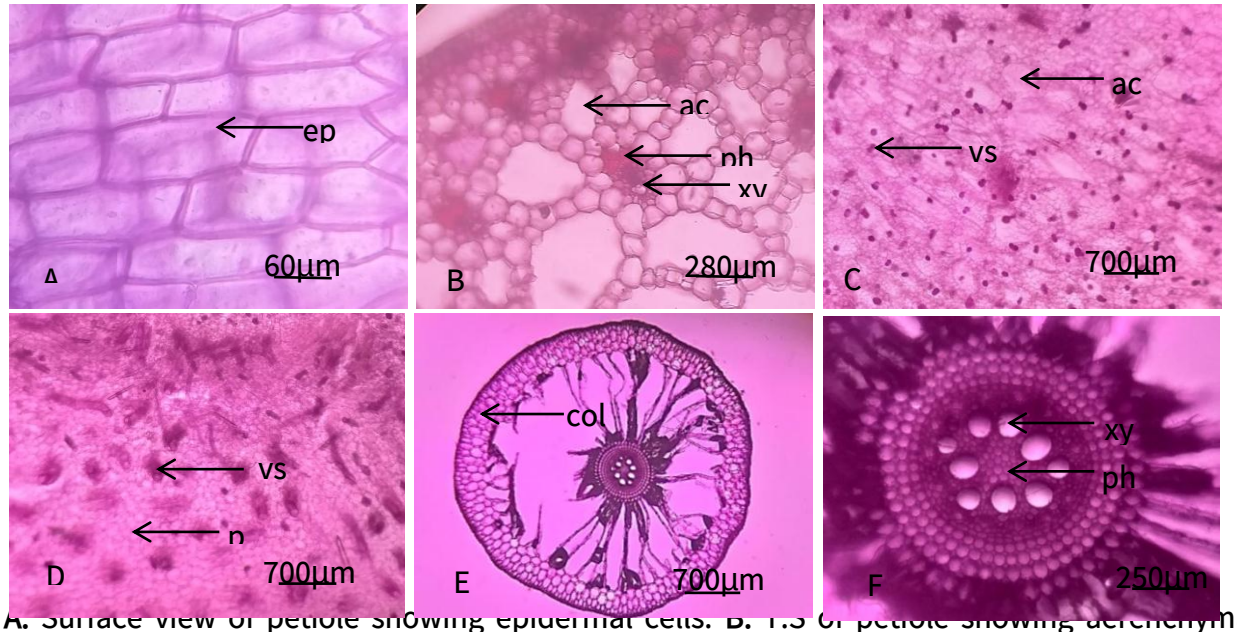

Figure 2 Internal structures of petiole, stem and root of *Eichhornia crassipes* (Mart.) **A.** Surface view of petiole showing epidermal cells. **B.** T.S of petiole showing aerenchyma cells, smaller and larger vascular bundles and air cavities. **C.** T. S of stem showing aerenchyma cells and vascular bundles. **D.** T. S of stem showing parenchyma cells and vascular bundles. **E.** T. S of root showing collenchyma cells, air cavities and vascular

bundles. **F.** A closed up view of root showing vascular bundle. (ac – air cavity, col – collenchyma, ep – epidermis, p – parenchyma, ph – phloem, vs – vascular bundle, xy – xylem) mesophyll is differentiated into palisade parenchyma at the upper side and spongy aerenchyma at the lower side. Palisade parenchyma is 1 to 2 layers; spongy aerenchyma cells loose, chloroplast abundant, large air cavities, and abundant raphides. In vascular tissue system, vascular bundles are embedded in the ground tissue, closed collateral; a bundle sheath parenchymatous (Fig. 3 C); raphides cylindrical bundle, many thin pointed needles (Fig. 3 D).

Internal structure of midrib

In dermal tissue system, epidermal cells in surface view are parenchymatous, polygonal or hexagonal in shape, cell walls are thin and slightly wavy stomata are paracytic type (Fig. 3 E). In transverse section, both upper and lower epidermis is a single layer. Ground tissue system is composed of irregular–shaped parenchymatous cells and large air cavities.

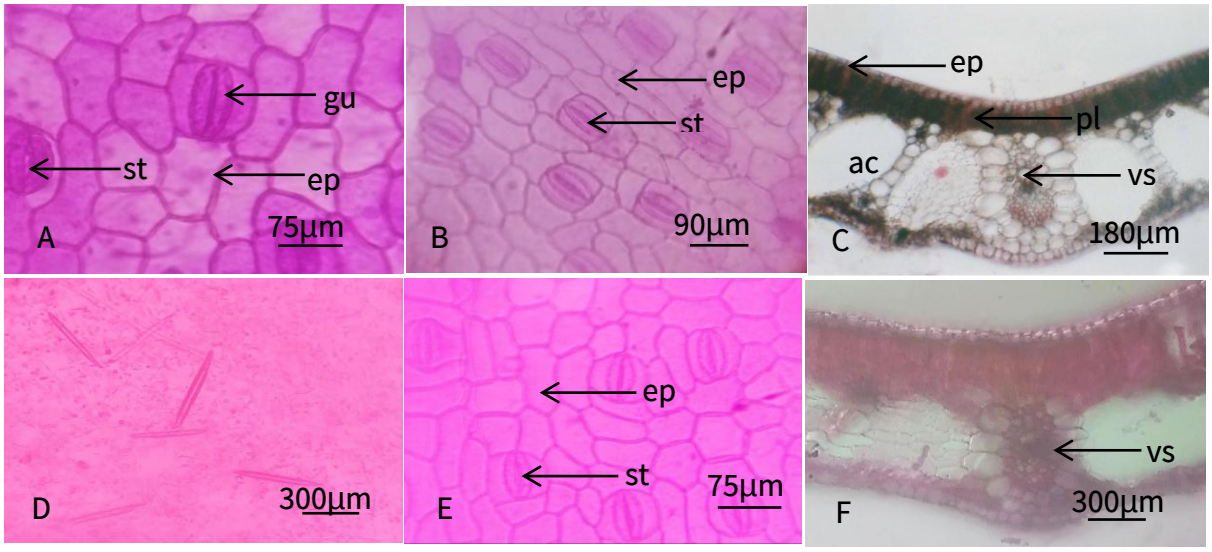

Figure 3 Internal structure of leaf and midrib of *Momochoria vaginalis* (Burm.f.) Pres

A. Upper surface view of leaf showing epidermal cells and stomata. **B.** Lower surface view of leaf showing epidermal cells and stomata. **C.** T.S of lamina showing palisade, spongy parenchyma, vascular bundles and air cavities. **D.** A closed up view of leaf showing raphides. **E.** Surface view of midrib showing epidermal cells and stomata. **F.** T.S of midrib showing vascular bundle and air cavities. (ac – air cavity, ep – epidermis, gu – guard cell, pl – palisade, st – stomata, vs – vascular bundle) In vascular tissue system, vascular bundles are embedded in the ground tissue, closed collateral; bundle sheath single, parenchymatous cells (Fig. 3 F).

Internal structure of petiole

In transverse section, petioles are semicircular in outline. In dermal tissue system, epidermal cells in surface view are parenchymatous, elongated lengthwise, cell walls thick, polygonal, anticlinal walls straight and smooth, cells compact; stomata paracytic type (Fig. 4 A). Both upper and lower epidermis in T.S is one layer. Ground tissue system is composed of parenchymatous, aerenchymatous cells and air cavities; parenhymatous cells towards the epidermis, 2 to 3 layers, polygonal in shape; aerencymatous cells towards the center, hexagonal in shape. Vascular bundles are diffused in the ground tissue, contact between aerenchyma cells with two different forms of vascular bundles, smaller and larger closed collateral, oval–shaped. Smaller bundle towards the periphery and larger lies in the center, xylem and phloem well developed (Fig. 4 B).

Internal structure of rhizome

In transverse section, epidermis is one layer, cells barrel–shaped, anticlinal wall straight, outer and inner walls convex; cuticle thin layer. Ground tissue system is composed of hexagonal–shaped aerenchymatous cells and air cavities. Vascular bundles are diffused in the ground tissue, contact between aerenchyma with two different forms of vascular bundles, smaller and larger closed collateral; smaller bundles towards the periphery and larger lies in the center (Fig. 4 C and D).

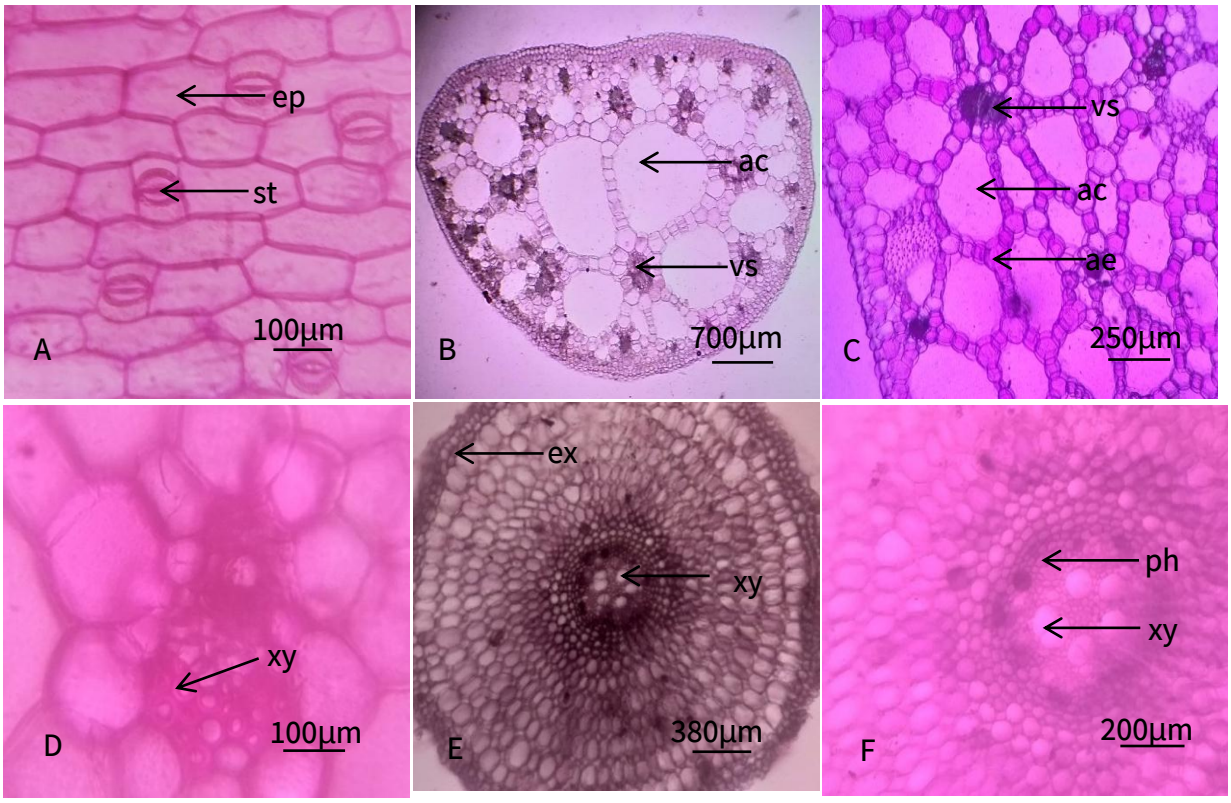

Figure 4 Internal structure of petiole, rhizome and root of *Monochoria vaginalis* (Burm.f.) Presl

A. Surface view of petiole showing epidermal cells and stomata. **B.** T.S of petiole showing aerenchyma cells, smaller and larger vascular bundles and air cavities. **C.** T. S of rhizome showing cortex, vascular bundles and air cavities. **D.** A closed up view of rhizome showing vascular bundle. **E.** T. S of root showing cortex and vascular bundle. **F.** A closed up view of root showing vascular bundle (ac – air cavity, ae – aerenchyma, ep – epidermis, ex – exodermis, p – parenchyma, ph – phloem, st – stomata, vs – vascular bundle, xy – xylem,)

Internal structure of root

In dermal tissue system, epidermis of the root in transverse section is one layer, rectangular in shape. Ground tissue system is composed of exodermis, cortex, endodermis and pericycle. Exodermis is 1 to 2 layers, parenchyma, rectangular or polygonal in shape; cortex parenchymatous cells polygonal; endodermis is one layer, parenchymatous cell (Fig. 4 E). In vascular tissue system, vascular cylinder, polyarch; phloem distributed at the periphery of the xylem (Fig. 4 F).

Table 1 Comparative anatomical characteristics of *Eichhornia crassipes* (Mart.) Solms–Laub. and *Monochoria vaginalis* (Burm.f.) Presl

Species / Structure	*Eichhornia crassipes* (Mart.) Solms–Laub.	*Monochoria vaginalis* (Burm.f.) Presl
Lamina	Stomata paracytic type, spongy aerenchyma many–layered.	Stomata paracytic type, spongy aerenchyma cells loose.
Midrib	Stomata absent, vascular bundles diffused in the ground tissue, two different forms bundles, smaller and larger.	Stomata paracytic type, vascular bundles embedded in the ground tissue.
Petiole	Stomata absent. Ground tissue is composed of aerenchymatous cells and large air cavities,	Stomata paracytic type. Ground tissue is composed of parenchymatous, aerenchymatous cells and air cavities.
Stem/ Rhizome	Ground tissue is composed of aerenchymatous cells towards the periphery with air cavity and parenchymatous cells towards the center.	Ground tissue is composed of aerenchymatous cells and air cavities.
Root	Ground tissue is composed of collenchyma cells below the epidermis; aerenchyma cells towards the center and large air cavities, vascular bundles concentric or	Ground tissue system is composed of exodermis, cortex, endodermis and pericycle, vascular cylinder, polyarch; phloem distributed at the periphery of

	amphivasal.	the xylem.

Discussion and Conclusion

The present work has been emphasized to examine and compare the vegetative anatomy of two aquatic species such as *Eichhornia crassipes* (Mart.) Solms–Laub. and *Monochoria vaginalis* (Burm.f.) Presl, both of which were assigned to the family Pontederiaceae. The observed anatomical characters of the two species reveals some variations which will be useful in the plant identification (Table 1).

The epidermal cells of the leaves of *E. crassipes* are covered with a thin layer of cuticle. Paracytic type stomata, large air cavities and abundant raphides are observed in lamina. Those characters are consistent with the report of AL–Hadeethi *et al*. (2017).The vascular bundles in T.S of lamina are of two different forms, smaller and larger closed collateral vascular bundles. Some of them are in contact with the epidermis while the others are located in the center of the leaf. The above mentioned characters are in line with the statements of AL–Hadeethi *et al*. (2017).

In T.S of petiole, vascular bundles are closed collateral, diffused in the ground meristem contact between as by the aerenchyma cells, and bundle sheath parenchymatous. Large air cavity is abundant and thus provides buoyancy to the plant. The characters documented here are in accordance with the statements of AL–Hadeethi *et al*. (2017). In T.S of stem, ground tissue is comprised of hexagonal–shaped aerenchymatous cells towards the periphery with air cavity and polygonal–shaped parenchymatous cells towards the center. Vascular bundles are diffused in the ground tissue, closed collateral. In T.S of root, epidermis one layered and collenchyma cells 2– to 3– layered. The vascular bundles are concentric or amphivasal. The characters described here are in accordance with the statements of AL–Hadeethi *et al*. (2017).

The epidermal cells of the leaves of *M. vaginalis* are covered with a thin layer of cuticle. The leaves exhibit hydromorphic features with numerous air cavities. The vascular bundles are closed collateral and bundle sheath parenchymatous. The observed characters in this work are agreed with the descriptions of Narayanan & Kaliappan (2014).

In T.S of petiole, ground tissue is composed of parenchyma, 2–to 3– laryered and air cavities. The vascular bundles have well developed xylem and phloem. The bunldes in the central part of the petiole are larger than those in the peripheral part. Those characters found in this study are in accordance with the reports of Narayanan & Kaliappan (2014). In T.S of rhizome, ground tissue is composed of hexagonal–shaped aerenchymatous cells and air cavities. The vascular bundles in the periphery of the rhizome are smaller and the size of the bundles increases progressively towards the center. All these characters noted here are similar with the reports of Narayanan & Kaliappan (2014).

Ground tissue of root is composed of exodermis, cortex, endodermis and pericycle. Exodermis 1– to 2– layered, parenchymatous, rectangular, polygonal or oval in shape; cortex cells parenchymatous and polygonal; endodermis 1–layered, parenchymatous. In

vascular tissue system, vascular cylinder, polyarch; phloem distributed at the periphery of the xylem; xylem towards the center. Those characters examined in this work are congruent with the previous records of Narayanan & Kaliappan (2014).

In conclusion, anatomical characters can serve as a promising tool in the botanical identification of plant species, although molecular phylogeny has been widely used in the taxonomy of higher plants (e.g. APG IV, Byng *et al.* 2016).

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