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Comparative Anatomical Characteristics of Emergent Aquatic Herbs-*Monochoria vaginalis* (Burm. F.) Presl. and *Monochoria hastata* Solms. (Pontederiaceae)

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Abstract: The present investigation explores and compares the detailed anatomical features of an emergent aquatic herb of *Monochoria vaginalis* and *Monochoria hastata*, belonging to water-hyacinth family, Pontederiaceae. These weedy plants are claimed to be highly nutritious and medicinally valuable among many ethnic communities throughout India. But due to their morphological similarity among the related species of this family, identification and utilization of the plant has been ignored and urbanization has resulted in eradication of the herb on the basis of environmental wet land pollution issues. Both species exhibits unique hydromorphic anatomical features related to the adaptability of the plant to the aquatic environment. Though both species share most of the anatomical features in common, few differences observed in the leaf anatomy like dorsiventral lamina, brachy-paratetracytic stomata of *M. vaginalis* and isobilateral lamina and paracytic or cytoecytic stomata of *M. hastata* will provide valuable information for the plant identification. Even though both the species share common morphological features in common which make them difficult to identify, the microscopical variations observed from the current report helps in identification and will meet the demand of standardization requirements of medicinal herbs.

Key words: *Monochoria vaginalis*, water-hyacinth, Pontederiaceae, ethno-medicine, aquatic weed, brachy-paratetracytic stomata, *Monochoria hastata*

INTRODUCTION

The plants of wetland ecosystems played an important role in the life of human beings in earlier days as food, fodder, medicine etc., but with the advancement of agriculture and urbanization, the uses of wetland aquatic herbs are neglected and they are treated as noxious weeds and the wetlands as a menace. Aquatic plants face a great threat of extinction, due to the lack of awareness on their nutritional values in favor of the exotic ones (Swapna *et al.*, 2011). In recent decades, the resurgence of focus is slowly moving towards the wild and aquatic plants of wetland ecosystem to meet the increasing demand for novel herbal drugs (Bhowmik *et al.*, 2013; Ng *et al.*, 2012).

Monochoria vaginalis is a small annual aquatic plant and is one of the two species within the genus, the other being *Monochoria hastata* (Sastri, 1962). Both the species are gregarious in habit and are similar in morphology, *M. vaginalis* (Burm. f.) Presl. of

Pontederiaceae (Water-Hyacinth) family is an emergent aquatic herb with short, sub-erect spongy root-stocks commonly found in rice fields, throughout India and widely distributed in Asian countries like South Korea, Japan, China etc. (Zheng *et al.*, 2013). The IUCN has classified *M. vaginalis* as least concerned in the Red list. This aquatic plant which is claimed to be a noxious weed has numerous medicinal properties (Palani *et al.*, 2011), the Kattunaiykar, Paniya and Chetti tribes of Wayand district of Kerala, use the entire plant, except the rootstock as vegetable (Pradeesh *et al.*, 2013) and the juice of the fresh leaves for the treatment of diabetes (Narayanan and Kumar, 2007). Traditional healers of Tamilnadu use the powdered rootstock as Dentrifices (Ganesan, 2008), whereas, the ethnic communities of Assamese in Assam consume the decoction of rootstock for the treatment of toothache and asthma (Sarma and Saikia, 2010).

Monochoria hastata Solms. is an emergent aquatic herb with elongate, creeping, spongy rootstock found in the margins of tanks and ponds, swamps, ditches and

brackish water, almost throughout India, Srilanka and South East Asia (Sastri, 1962), in the northern territories like Australia, the only records are from floodplains of Finniss, Reynolds and Wildman rivers. Northern territory Government has classified the species as vulnerable in the list of threatened species of the Northern Territory. Tender stalks and leaves of the plant are eaten as vegetable; ethnic communities of Tinsukia District of Assam consume the juice of the leaf as digestive (Buragohain, 2011), the plant extract is applied locally on boils for quick healing by Tripuri tribes (Bhowmik *et al.*, 2013).

Even though these plants are claimed to be medicinally rich in terms of ethno-medicinal practices, considerably very less research has been carried on systematics as well as on its medicinal and nutritional properties (Latha and Latha, 2013), due to the difficulty in identification of the aquatic herb from their morphologically similar species. Hence, the present study is an initialization for the first time to explore and compare the detailed anatomy of the two species of *Monochoria* to confirm their botanical identity which would help in conservation of these vulnerable and least concerned aquatic weeds.

MATERIALS AND METHODS

Plant materials: Fresh, entire plants were collected from the marshy lake (*M. hastata*) and from the streams (*M. vaginalis*) of Ambalavayal, Wayanad District, Kerala, India, in the month of December 2012. The plant specimens were authenticated by Botanical Survey of India, Tamilnadu Agricultural University, Coimbatore. A voucher specimen of *M. vaginalis* (BSI SRC/5/23/2011-12) and *M. hastata* (BSI SRC/5/23/2012-2013) has been preserved in the laboratory for future use. Care was taken to select healthy plants and normal organs. The required samples of different organs were fixed in FAE (formaldehyde, acetic acid, 50% ethanol, 5:5:90, v/v/v). After 24 h of fixing, the material was processed following the conventional dehydration methods and was embedded in paraffin (Sass, 1940).

Preparation of paraffin sections: Serial transverse sections (10-12 μ m) were made from the paraffin embedded plant organs with the help of Rotary microtome. The sections were stained with Toluidine blue (O'Brien *et al.*, 1964), further subjected to a series of changes with ethanol-xylene and mounted in Canada balsam (Johansen, 1940).

Examination: All the anatomical investigations were documented with photographs of different magnifications obtained from Nikon photolab2 light microscope. For normal observations bright field was used and for the study of calcium oxalate crystals polarized light was employed.

RESULTS

Morphology studies

***Monochoria vaginalis*:** Leaves are variable in size, 5-10 by 3.2-5 cm from linear to ovate or ovate-cordate, usually acuminate (Fig. 1a, b); petioles of the lower leaves are long, stout and terete, the peduncles emerge from the channeled sheaths of the uppermost leaves. Inflorescence is centripetal; flowers are blue, usually spotted with red; in subspicate racemes with one large anther and 5 small anthers. Ovary is ellipsoid and glandular. Fruit is ellipsoid, glandular outside. Seeds are 0.8 mm long, ellipsoid, rounded at each end, pale, with many brown ribs. (Krithikar and Basu, 2012). Root stock is short, sub-erect and spongy (Fig. 1c).

***Monochoria hastata*:** An emergent aquatic herb with stems approximately 0.7-1.2 m long (Fig. 1d). Leaves long-petioled, sagittate, hastate or cordate; the basal leaves are arrow-shaped (Fig. 1e). The inflorescence of 25-60 flowers is in a dense spike 6-9 cm long. The flowers are purplish blue or violet blue dotted with red, 13-16 mm long in sub-umbellate racemes; One anther is coloured blue, 6 mm long; the other 5 anthers are yellow and 4 mm long. The seed capsule is 7 mm long and 5-6 mm diameter. Rootstock is dense, long, sub-erect and spongy with numerous lateral roots (Fig. 1f) (Sastri, 1962).

Anatomical features of leaf

***Monochoria vaginalis*:** Surface view revealed squarish epidermal cells with a very thin cuticle. The leaf exhibits hydromorphic features with numerous wide air-chambers, poorly developed xylem elements, reduced sclerenchyma cells and amphistomatic (stomata found on both upper and lower surfaces) lamina. The leaf has less prominent vein with distinct vascular bundle (Fig. 2a) and the region of the midrib is 700 μ m thick with fairly large epidermis. The vascular bundle of the midrib is collateral consisting of few thin walled, angular xylem elements and thick mass of phloem elements (Fig. 2b). Poorly lignified, thin layer of sclerenchyma elements encloses the vascular bundle which in turn is embedded in a thick sheath of parenchymatous ground tissue.

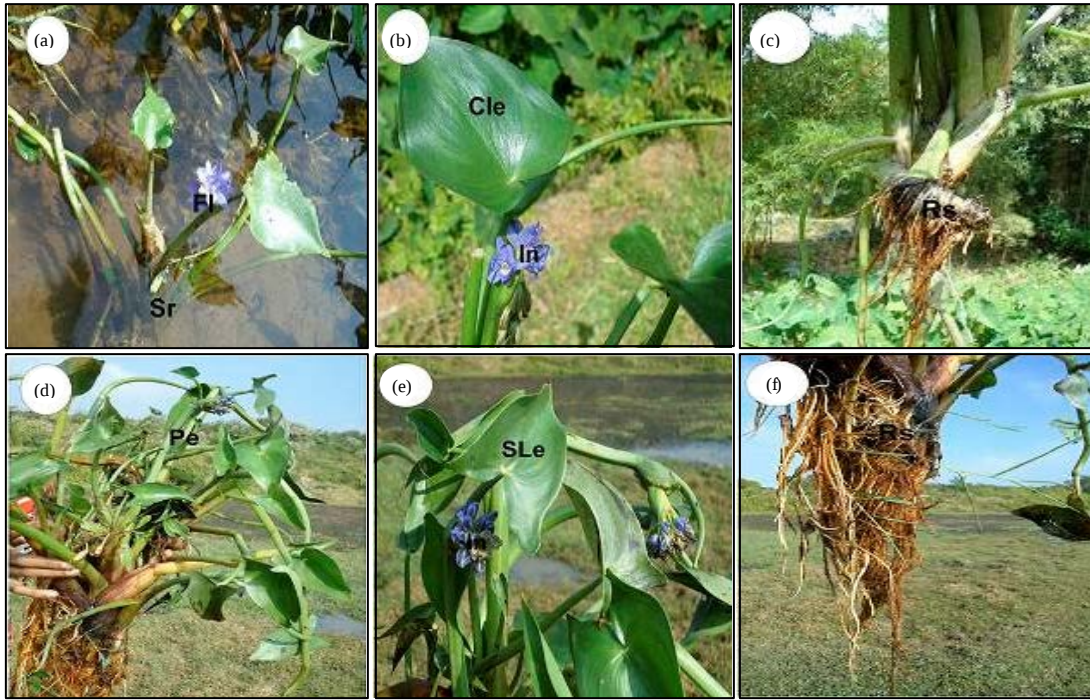


Fig. 1(a-f): *Monochoria vaginalis* (a) Plant with leaves and flowers, (b) Cordate leaf, (c) Short rootstock. *Monochoria hastata* (d) Whole plant of *M. hastata* (e) Leaves and flowers of *M. hastata*, (f) Dense rootstock of *M. hastata*, Fl: Flower, Cle: Cordate leaf, SLe: Sagittate leaf, Rs: Rootstock, Pe: Petiole, Sr: Submerged rootstock, In: Inflorescence. Scale bars: (a, b, c, d, e and f) = 5 mm

***Monochoria hastata*:** The leaf exhibits hydromorphic features. Midrib is not prominent; it projects in to short, semicircular abaxial surface and a flat adaxial surface (Fig. 2g). The midrib is 700 μm thick and the abaxial side of the midrib is 250 μm wide. The vascular bundle of the midrib consists of few xylem elements of which the meta-xylem element is the wide, circular and thin walled. Phloem occurs beneath xylem strand in the form of a circular mass. The entire vascular bundle is surrounded by two or three layers of fibres (Fig. 2h).

Lamina

***Monochoria vaginalis*:** The lamina is dorsiventral, adaxial epidermis consists of thick rectangular cells, whereas the abaxial epidermis possesses cylindrical cells. Stomata are seen on both the sides. A narrow zone of thin, loosely packed palisade cells occurs below the abaxial epidermis (Fig. 2c). The median part of the lamina contains a horizontal row of wide air-chambers, divided by vertical partitions. Vascular bundles are distributed both in the adaxial, abaxial regions and in the vertical partitions. The vascular bundles are collateral with a few wide, thin walled xylem elements and a small nest of phloem elements. The

vertical partitions of the air-chambers possess prominent vascular strands with parenchymatous bundle sheath. The strands have two or more wide, thin walled meta-xylem elements and small mass of phloem elements situated on the outer part, facing the palisade zone of the lamina (Fig. 2c).

***Monochoria hastata*:** Lamina is uniformly smooth, even and isobilateral, amphistomatic and hydromorphic. The lamina is 320 μm thick. The adaxial epidermis is thin and cells are cylindrical; stomata occur at the level of the epidermis. The abaxial epidermis is also thin and the cells are squarish and thin walled. Mesophyll tissue is differentiated in to adaxial zone of vertically elongated pillar like, compact palisade cells and shorter, cylindrical palisade cells in the abaxial side. Median part of the lamina possesses wide circular air chambers divided by vertical partition filaments. Small or large vascular bundles are located within the partitions and the vascular bundles are collateral with wide meta-xylem element and narrow protoxylem elements. The vascular bundles are enclosed in a sheath of parenchyma cells. The marginal portion of

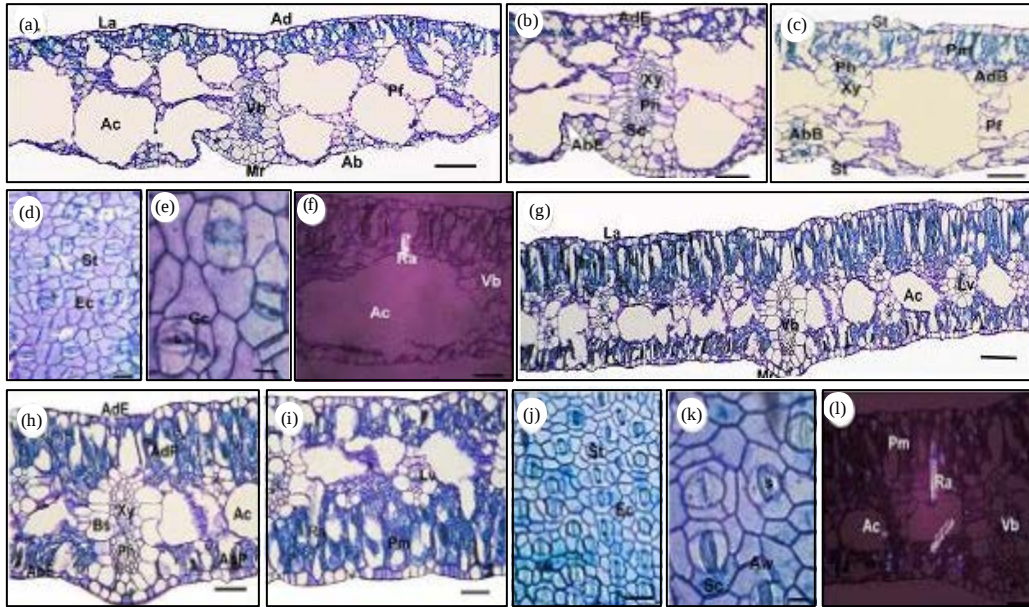


Fig. 2(a-l): *Monochoria vaginalis*, (a) Transverse section of leaf through the midrib, (b) Mid rib, (c) Lamina, (d) Para dermal section of epidermis, (e) Stomata enlarged, (f) Raphides under polarized light. *Monochoria hastata*, (g) Transverse section of leaf through the midrib, (h) Mid rib, (i) Lamina, (j) Para dermal section of epidermis, (k) Stomata enlarged, (l) Raphides under polarized light. Ab: Abaxial side, Ac: Air chamber, Ad: Adaxial side, Mr: Mid rib, Vb: Vascular bundle, Pf: Partition filament, Ph: Phloem, Xy: Xylem, Sc: Sclerenchyma, Ep: Epidermis, Pm: Palisade mesophyll, St: Stomata, AdB: Adaxial bundle, AbB: Abaxial bundle, AbE: Abaxial epidermis, AdE: Adaxial epidermis, Pf: Partition filament, La: Lamina, Lv: Lateral vein, Bs: Bundle sheath, Ra: Raphide, Ec: Epidermal cells, Mt: Mesophyll tissue, Pcr: Prismatic crystals, Aw: Anticlinal wall, S: Stoma, Gc: Guard cell, AdP: Adaxial Palisade, AbP: Abaxial Palisade Scale bars: (a, g) = 1 mm, (b) = 350 μ m, (c, d, f, h, i, j, l) = 250 μ m, (e, k) = 100 μ m

the leaf is conical, measuring 150 μ m thick. The epidermis along the marginal part consists of squarish thick walled cells. Air-chambers are absent in the marginal part and the vascular bundles are reduced in size (Fig. 2i).

Raphides

***Monochoria vaginalis*:** Calcium oxalate crystals of raphides are frequently seen in the mesophyll tissue of the midrib. The raphide is a cylindrical bundle of many thin pointed needles (Fig. 2f). Raphides are 20 μ m thick and 50 μ m long.

***Monochoria hastata*:** Calcium oxalate, needle shaped crystals are seen in thick long cylindrical bundles. The needles are thin with pointed ends, they aggregate in to compact bundles and these raphide bundles are diffusely distributed in the lamina and are varied in orientation, they appear as bright bundles when viewed under polarized light (Fig. 2l). The raphides are 130 μ m long and 20 μ m thick.

Epidermal cells and stomata

***Monochoria vaginalis*:** Para dermal sections were used for studying the stomatal type and epidermal cells. The stomata are present on both upper and lower sides of the lamina. The stomata are brachy-paratetracytic type (Fig. 2d). A stoma has two lateral subsidiary cells and two larger polar subsidiary cells situated on the upper and lower poles of the guard cells. The guard cells are oblong, elliptic measuring 20 $\times$ 50 μ m in size. The epidermal cells are fairly thick walled, angular and compact (Fig. 2e).

***Monochoria hastata*:** Stomata occur on both the upper and lower surfaces of the lamina. They are diffused and random in distribution. The stomata are either paracytic or cytotytic, the former being more in frequency (Fig. 2j), the paracytic stoma has two wing like subsidiary cells, one on either side of the guard cells and parallel to the guard cells (Fig. 2k). In the cytotytic type, a stoma is surrounded by four subsidiary cells, two cells being polar and other two

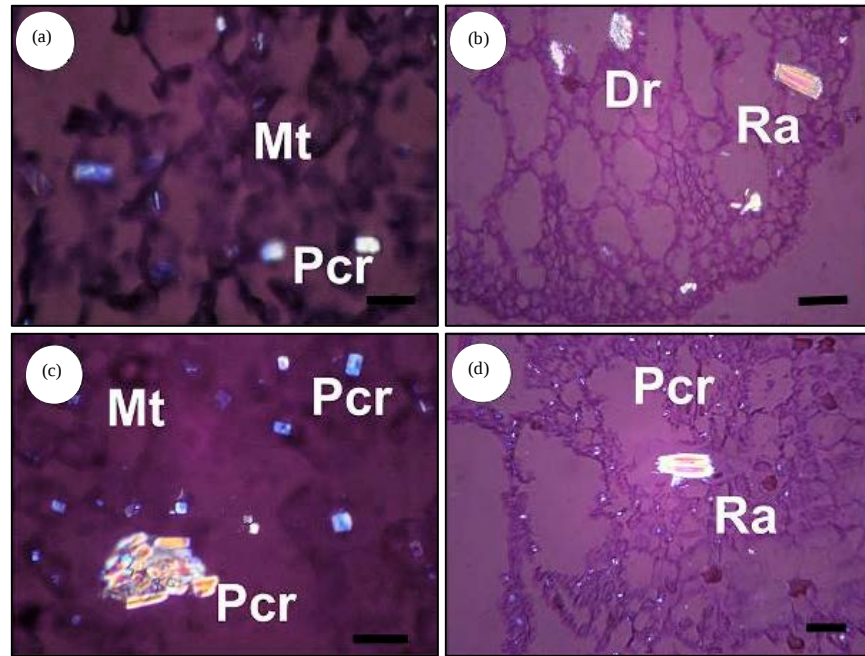


Fig. 3(a-d): *Monochoria vaginalis* (a and b), *Monochoria hastata* (c and d) Mesophyll under polarized light, Ra: Raphides, St: Stomata, Ec: Epidermal cells, Mt: Mesophyll tissue, Pcr: Prismatic crystals. Scale bars: (a, b and c) = 250 μ m

being lateral in position. The guard cells are $15 \times 30 \mu\text{m}$ in size. The epidermal cells are polyhedral in outline; the anti-clinal walls are thick and straight.

Crystals

***Monochoria vaginalis*:** Calcium oxalate crystals are abundant, especially, in the mesophyll tissues of the lamina (Fig. 3a) the crystals are mostly raphides which are thick cylindrical bundles of several thin needles; occasionally spherical spiny balls of crystals called druses are also observed with the needle shaped bundles. The raphides are $40 \times 80 \mu\text{m}$ in size (Fig. 3a, b).

***Monochoria hastata*:** Calcium oxalate crystals of prismatic type are randomly distributed in the mesophyll tissue of the leaf (Fig. 3d), the crystals are solitary and sometimes occur in large aggregates (Fig. 3c).

Anatomical features of petiole

***Monochoria vaginalis*:** In sectional view, the proximal part of the petiole is circular. Petiole is 1.9 mm thick continuous layer of small epidermal cells followed by two or three layers of compact parenchyma cells. The remaining major part of the petiole has a large number of circular or polygonal air-chamber divided by thin uniseriate partition filaments (Fig. 4a). Situated within the

junctions of the partition filaments are circular vascular strands possessing, thin walled xylem elements and small clusters of phloem (Fig. 4b). The vascular bundles in the central part of the petiole are larger than those in the peripheral part (Fig. 4c). Raphide types of crystals were commonly observed in the cells of the partition filaments. Distal part of the petiole has a wide central canal surrounded by three or four layers of smaller air-chambers with uniseriate filaments; vascular bundles have well developed xylem and phloem elements. The air-chambers possess thin plate stellate parenchyma cells forming thin diaphragm (Fig. 4b).

***Monochoria hastata*:** Petiole is elliptical in sectional view, 2.6 mm in horizontal plane and 1.7 mm in vertical plane (Fig. 4d). It consists of small squarish epidermal cells with thick cuticle. The ground tissue consists of outer dense zone of short palisade cells and with thin palisade cells in the inner zone, followed by a wide region of three layers of air-chambers, divided by thin uniseriate partition filaments. Located in the intercepts of the partition filaments are collateral vascular bundles (Fig. 4f) with two or three wide circular xylem elements and a small mass of phloem elements. The vascular strand is enclosed by thick layer of fibres (Fig. 4e). The central core of the

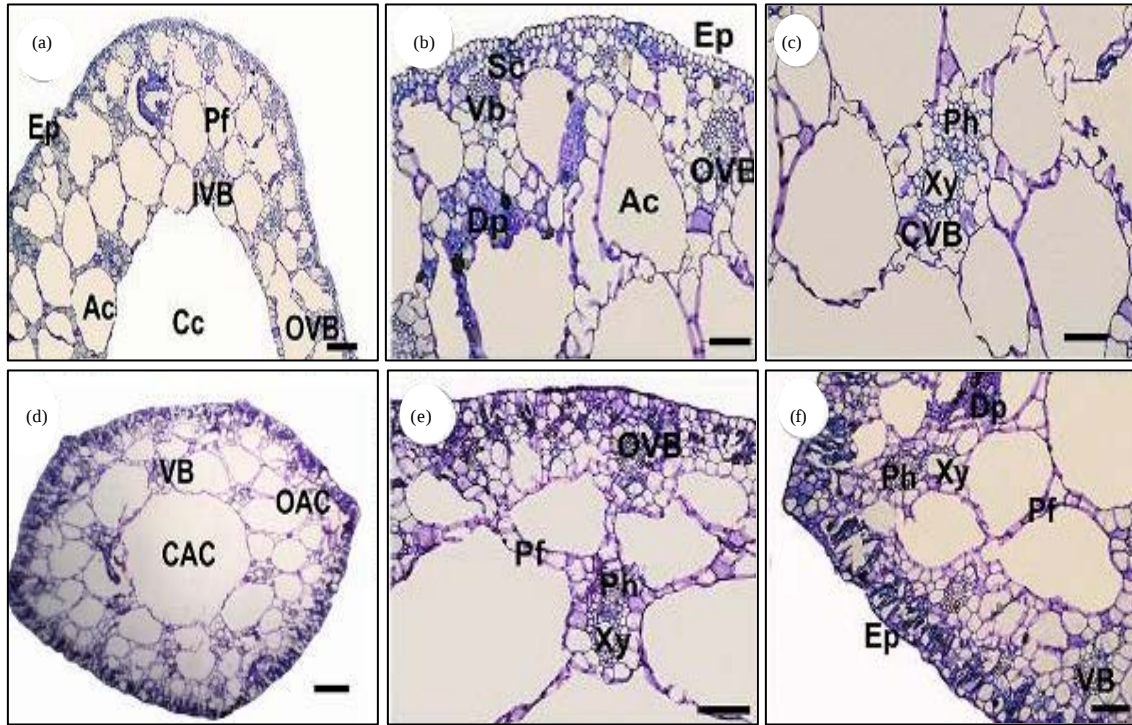


Fig. 4(a-f): *Monochoria vaginalis*-Transverse section of petiole (a) Partial view, (b) Marginal region of Petiole, (c) Central vascular bundle region. *Monochoria hastata* (d) Transverse section of petiole, (e) Outer vascular bundle region, (f) Marginal region of Petiole. Ep: Epidermis, Ac: Air chamber, CVB: Central vascular bundles, OVB: Outer vascular bundle, Ra: Raphides, Pf: Partition filament, IVB: Inner vascular bundle, Vb: Vascular bundle, Sc: Sclerenchyma, Oac: Outer aerenchyma, Cac: Central aerenchyma, Dp: Diaphragm, Ph: Phloem, Xy: Xylem, Cc: Central canal. Scale bars: (a, d)=1 mm, (b, c, e and f) = 350 μ m

petiole is occupied by wide circular air-canal (Fig. 4d) the air-chambers have thin membranous plate of circular cells; these plates are called diaphragm.

Anatomical features of stem

***Monochoria vaginalis*:** Stem is circular or elliptical in sectional view, 3 mm thick consisting of wide aerenchymatous cortex with central stele of vascular elements (Fig. 5a). Vascular elements are present in both peripheral and middle portions of the cortex (Fig. 5b). The central stele has wide circular xylem elements and small group of phloem elements in the outer boundary of the stele. The central part of the stele has small air-chambers and parenchymatous ground tissue. Small vascular strands are distributed in the central ground tissue of the stele (Fig. 5c). Starch grains are observed in the ground parenchyma of the stem.

***Monochoria hastata*:** The cross sectional outline of the stem is circular and similar to that of the petiole excepting

the absence of wide central canal in the stem. The stem is 3 mm thick. The epidermal layer is intact, comprising thick walled squarish cells (Fig. 5d). The epidermis is deeply sunken forming a wide cavity; within this cavity occurs the stoma (Fig. 5e), along the inner part of the epidermis is seen a thick, continuous cylinder of chlorenchyma cells. Small circular vascular bundles are embedded in the chlorenchyma cylinder; these vascular bundles possess parenchymatous bundle sheath. The entire central part of the stem has dense reticulate, uniseriate partition filament which enclose wide circular air-chambers (Fig. 5d). In the intersections of the partition filaments occur a vascular bundle, with wide one or two xylem elements and small cluster of phloem elements. The vascular bundles have sclerenchyma caps or parenchyma bundle sheath (Fig. 5f).

Anatomical features of rhizome

***Monochoria vaginalis*:** The rhizome has thick epidermal layer of papillate cells with wide aerenchymatous cortex.

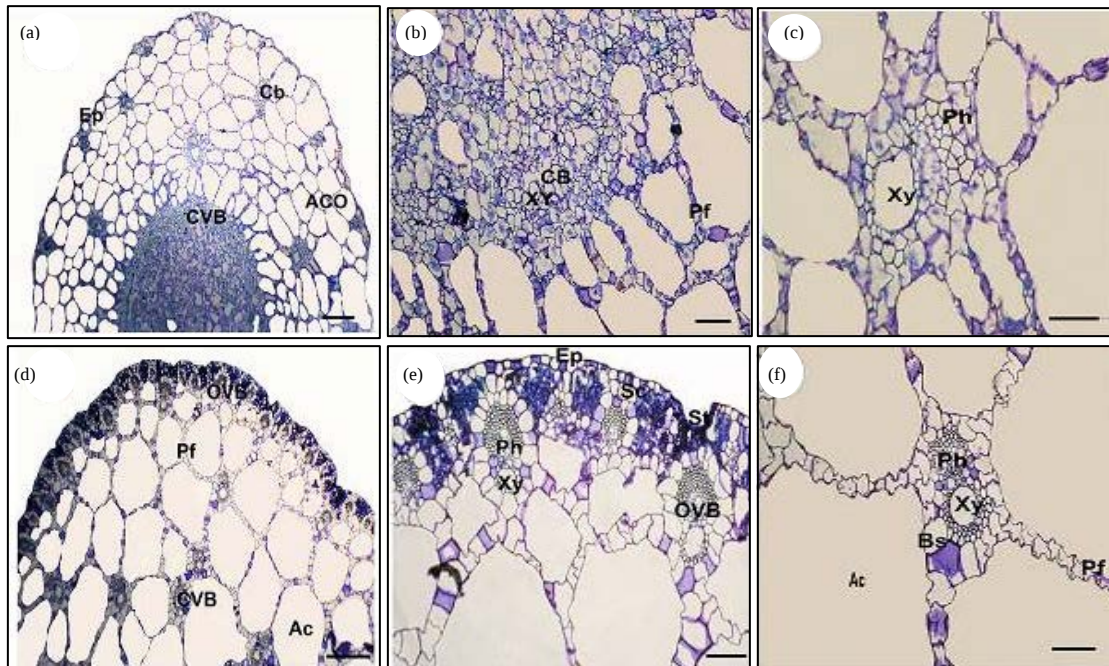


Fig. 5(a-f): *Monochoria vaginalis* transverse section of stem (a) Partial view, (b) Central zone, (c) Central Bundle. *Monochoria hastata* (d) Partial view, (e) Marginal part (f) Central Bundle. Ep: Epidermis, Cb: Cortical bundle, CVB: Central vascular bundle, OVB: Outer vascular bundle, Sc: Sclerenchyma, St: Stomata, Ac: Aerenchyma, Pf: Partition filament, Bs: Bundle sheath, Aco: Aerenchymatous cortex, Xy: Xylem, Ph: Phloem, Ac: Air chamber, MB: Middle bundle. Scale bars: (a and d) = 1 mm, (b and e) = 350 μ m, (c and f) = 250 μ m

The air-chambers of the cortex are divided by thick uniseriate large celled partitions (Fig. 6a) large and prominent vascular strands are sparsely distributed in the cortical region. Lateral roots are seen emerging from the central stele of the rhizome (Fig. 7a). The lateral roots are fully developed before they emerge from the cortex of the rhizome. The lateral roots observed in the cortex region are circular and have well developed epidermis with two layers of compact outer cortical cells, middle wide zone of radially elongated narrow air-chambers divided by radial uniseriate partition filaments and inner four or five layers of compact parenchyma cells (Fig. 6d).

In the central core of the stele occur, wide, circular xylem elements and phloem elements in the outer zone (Fig. 6b). The central stele consists of peripheral xylem strands and phloem strands (Fig. 6c). Stellar lamellae are present in the central part which include well developed angular xylem elements and prominent mass of phloem elements. Starch grains occur densely in the cortical cells and in the central ground parenchyma cells (Fig. 6b). Raphide bundles of calcium oxalate needles are frequently seen in the rhizome.

***Monochoria hastata*:** The rhizome has thin continuous epidermal layer of small squarish cells, wide

aerenchymatous cortex and solid stellar cylinder. The cortex consists of about 15 layers of large polygonal air-chambers, separated from each other by thin uniseriate partition filaments. In the aerenchymatous cortical zone occur, many circular vascular bundles which are located in the place where the partition filaments unite (Fig. 6d). Vascular bundles in the periphery of the rhizome are smaller and the size of the bundles increases progressively towards the centre with few vertical row of proto-xylem elements. Phloem occurs as circular mass xylem. Thick mass of bundle cap fibres encloses the vascular bundles (Fig. 6f).

Two layers of pericyclic fibers and endodermis is observed in the stellar region of the rhizome. Along the outer part of the stele and adjoining the pericycle occur tangentially flat dense masses of xylem elements and phloem tissue in a collateral manner (Fig. 6e). Small collateral vascular bundles are scattered in the ground tissue of the stele. Starch grains are densely filled in the partition filaments of stellar region.

Anatomical features of root

***Monochoria vaginalis*:** The roots that are seen in the surface of the rhizome are either thin or thick. The thin roots have quite wide, thin walled central meta-xylem

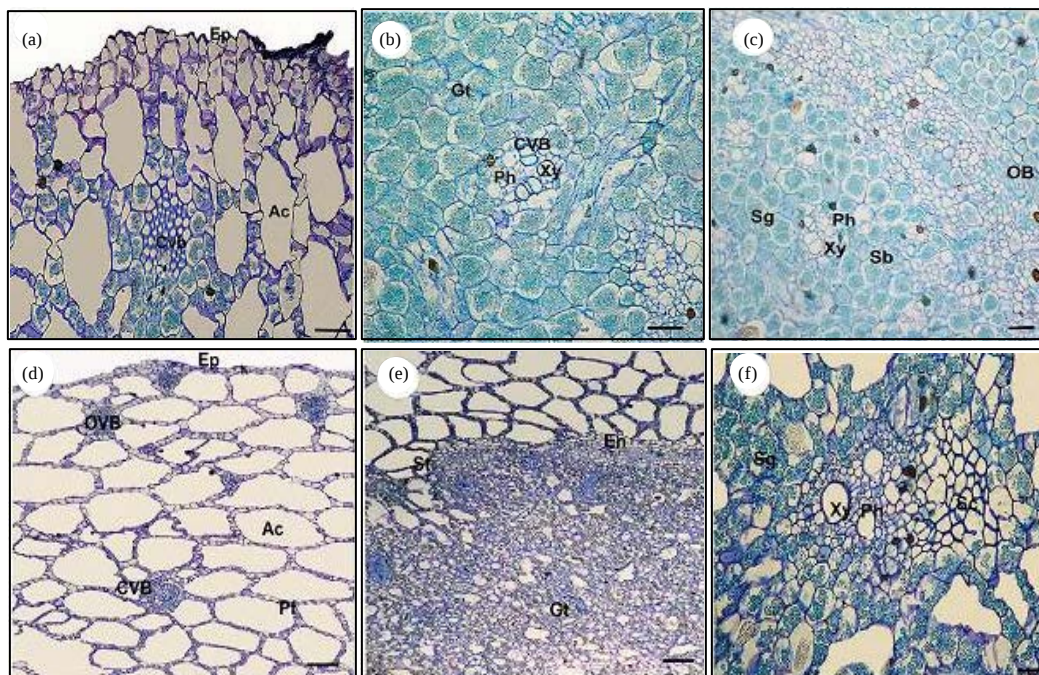


Fig. 6(a-f): *Monochoria vaginalis* transverse section of Rhizome (a) Outer zone, (b) Outer zone of Stele portion, (c) Central zone of Stele portion. *Monochoria hastata* (d) Cortical aerenchymatous region, (e) Central stelar zone, (f) Central Vascular bundle region, SG: Starch grains, OVB: Outer vascular bundle, Xy: Xylem, GT: Ground tissue, CVB: Central vascular bundle, Aco: Aerenchymatous cortex, Ro: Root, Mco: Middle cortex, Oco: Outer cortex, Mxy: Metaxylem, Pxy: Protoxylem, Pf: Partition filament, En: Endodermis, Ep: Epidermis, Ac: Air chamber. Scale bars: (a) = 250 μ m, (b and f) = 100 μ m, (c) = 1 mm, (d) = 350 μ m, (e) = 250 μ m

elements and phloem strands in between the proto-xylem elements. The cortex is aerenchymatous (Fig. 7a). The thick rows have three layers of compact inner cortical cells, prominent layer of endodermis and thin layers of pericycle. The xylem elements have central wide meta-xylem cells and outer several protoxylem elements alternating with phloem elements (Fig. 7b).

***Monochoria hastata*:** Lateral roots emerge from the stele and run through the cortex, lateral roots have distinct and prominent epidermal layers with aerenchymatous cortex and dense circles of spherical parenchyma cells enclosing the stele (Fig. 7c, d).

Anatomical features of flower

***Monochoria vaginalis*:** The flowers are bisexual and possess 6-perianth members, 6 stamens and tricarpeal, syncarpous ovary with many ovules. In cross sectional-view, the flower show 6 perianth members which include three outer and three inner members (Fig. 8a) the perianth members are thick in the middle and generally thin on the lateral margins. Perianth has several vascular

strands situated all along the median portions. Alternating with the vascular strands are wide chambers. Vascular strands are collateral having a small group of xylem elements and phloem elements. The ground tissue is parenchymatous and compact. The wall of the ovary is uniformly 100 μ m thick, consisting of thin inner and outer epidermis of small thin walled cells. Small vascular strands are seen in the median part of the ovary wall (Fig. 8b). The ovary has three carpels and the axial placenta is divided in to many thin radial segments. The ovules are attached on the surface of lobed placenta.

***Monochoria hastata*:** The flower is epigynous with inferior ovary. The ovary is tricarpeal, syncarpous and three celled. The axile placental tissue is forked and intrudes into carpel, the seeds are borne at tips of the forked placenta (Fig. 8e, f) numerous seeds are observed in each carpel.

Fruits and seeds

***Monochoria vaginalis*:** The ovary develops into a capsule in which numerous seeds are attached on the

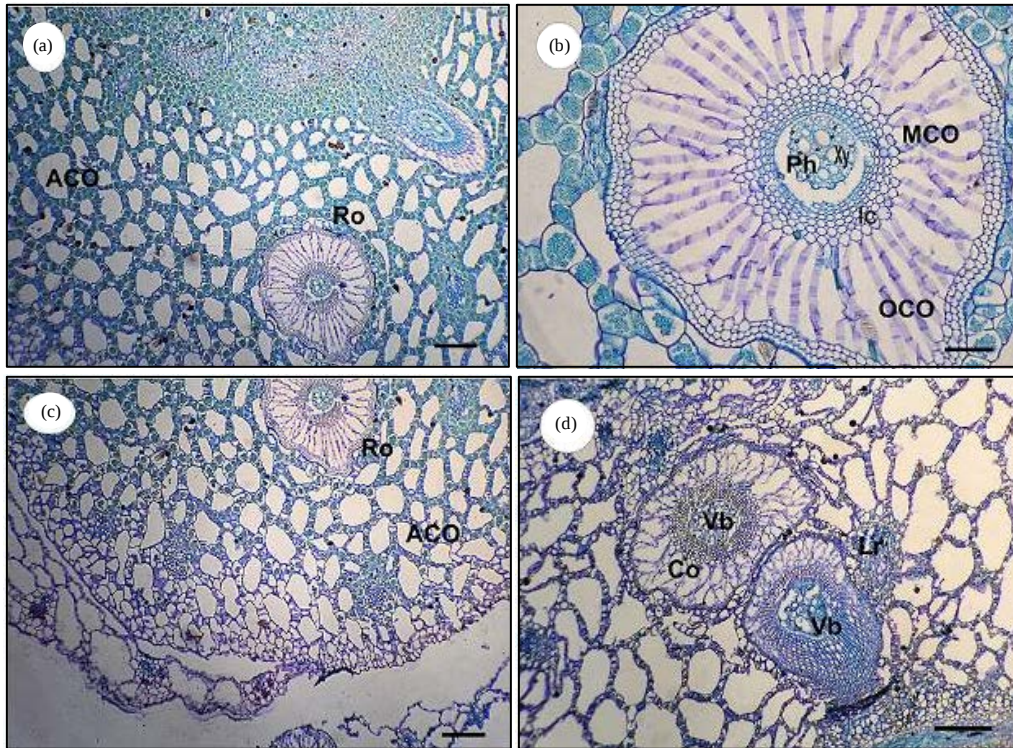


Fig. 7(a-d): (a) Transverse section of thin root, (b) Stellar portion of thin root, (c) Transverse section of thin root, (d) Stellar portion of thick root. Ac: Air chamber, Mx: Metaxylem, Px: Protoxylem, Ph: Phloem, En: Endodermis. (a and c) = 350 μ m, (b and d) = 100 μ m

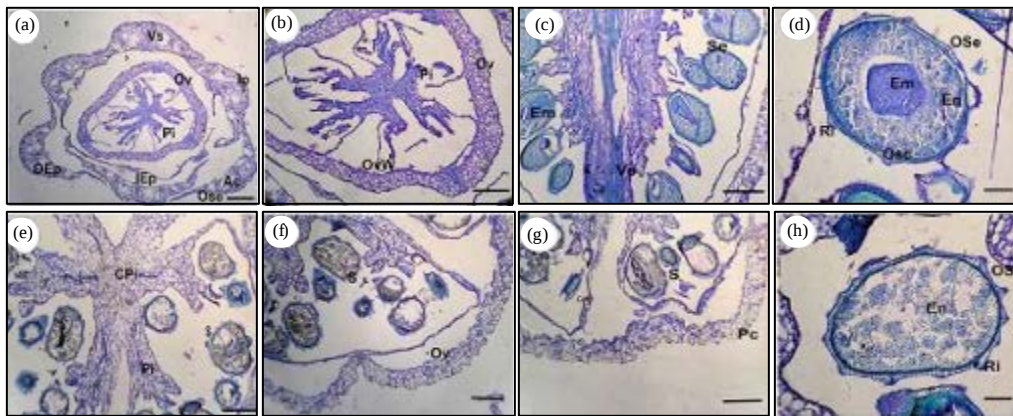


Fig. 8(a-h): *Monochoria vaginalis* (a) Transverse section of flower showing perianth and ovary (b) Transverse section of ovary, (c) Longitudinal section of Fruit, (d) Transverse section of Seed. *Monochoria hastata* (e) Transverse section of gynoeceum showing central axile placentum and branched intruding placental tissues with seeds attached on the branches, (f) Transverse section of Ovary-one carpel with seeds, (g) Transverse section of Seed. Vs: Vascular strand, Ip: Inner perianth, Ov: ovule, Op: Outer perianth, Pl: Placentum, Ovw: Ovarywall, Oep: Outer epidermis, Iep: Inner epidermis, Se: Seed, Sc: Seed coat, Em: Embryo, Isc: Inner seed coat, Osc: Outerseed coat, Ri: Ridge, En: Endosperm. Scale bars: (a, b, c, e, f, g) = 1 mm, (d and h) = 350 μ m

placenta with long funicle (Fig. 8c) the seeds are cylindrical measuring 800 µm long and 350 µm thick. Seed is densely endospermous, the endosperm is nuclear type lacking cell walls and cells. The seed has thin seed coat with small lignified cells and 10 short conical ridges found along the circumference. The embryo is cylindrical with long thick cotyledon (Fig. 8d).

***Monochoria hastata*:** Seeds are cylindrical and thick. They are 500×800 µm in size. They are endospermous. The seed coat consists of an epidermal layer of narrow thin cells, a middle layer of osteosclereids and inner thin layer of thick walled, darkly stained cells. The outer epidermal layer has about 14 ridges and shallow furrows. The seeds contain copious endosperm with outer thin layer of small thick walled cells which become vertically elongated in the region of ridges (Fig. 8g, h).

DISCUSSION

The Pontederiaceae is a small, exclusively palustrine and aquatic family of herbaceous monocotyledons. It comprises of 6-9 genera and about 30-35 species (Sastri, 1962). The genus *Monochoria* C. Presl is represented by two native species in India, namely, *M. vaginalis* (Burm.f) Presl and *M. hastata* (L.) Solms. Both the species are emergent aquatic herbs which look very similar in identity like, colour of the flower petals, arrangement of leaves, appearance of rhizomes and roots etc., *M. vaginalis* is distributed in the streams and paddy fields, whereas *M. hastata* is commonly seen in the river banks and in the banks of marshy lakes. Since these are aquatic weeds which invade the common water bodies are commonly considered as nuisance to the wetland and are least concerned, being ethno-medicinally claimed to be rich in nutritional and medicinal aspects. The current work has been focused to explore and compare the anatomical characters of *M. vaginalis* and *M. hastata* which will be useful in the authentication of the plant specimen. Morphologically minor difference are observed like the shape of the leaf; *M. vaginalis* is cordate (heart shape) and *M. hastata* is sagittate (arrow shape), longer petioles, sub-umbellate inflorescence and denser rootstock of *M. hastata*. Both the plants exhibit typical hydromorphic anatomical features to adapt the wet land environment, most of the anatomical features are commonly shared by both the species like, amphistomatic epidermis, presence of raphides, distribution of starch grains densely in the cortical and ground parenchyma, tricarpeled ovary and syncarpous ovary and large aerenchymatous lacunae in the cortex of all the vegetative organs like petiole, stem, rhizomes and roots to facilitate the internal oxygen transfer and an outer barrier consisting of an epidermis and cuticle to prevent oxygen loss.

Few variations in the anatomical features are of great systematic value. Leaves of *M. vaginalis* are dorsiventral with brachy-paratetracytic stomata and larger aerenchymatous lacunae; whereas the leaves of *M. hastata* are isobilateral with paracytic or cytotytic stomata and smaller aerenchyma, the stem possess sunken stomata which is not observed in the other species. Raphides, druses and prismatic crystals are scattered in the mesophyll of the *M. vaginalis* but druses are absent in *M. hastata*. These variations may be due to their adaptability to the environment in which they are found. Uniseriate thin partition filaments, filled with raphides separating the aerenchymatous tissues of the vegetative organs, numerous aerenchymatous chambers throughout the vegetative parts, ribbed seeds and presence of one blue anther in the flowers of both the species are the characteristic features of the *Monochoria* genus.

These anatomical characters of *M. vaginalis* and *M. hastata* will help to resolve the taxonomic problems, confirms the botanical identity and can reveal several adaptation natures of the plants to the environment. Strong emphasize in the importance of the detailed anatomical study of the other genus of the Pontederiaceae family to solve the identification problem is recommended to conserve the extinction of these medicinally potent aquatic weeds.

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