

SYSTEMATICS, DISTRIBUTION AND ANATOMY OF THE TWO INDIAN SPECIES OF THE GENUS *ELATINE* L.

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ABSTRACT

The paper presents an illustrated description of *Elatine ambigua* Wight and *E. triandra* Schkuhr (*E. americana* Arn.) of the family Elatinaceae with data on their distribution, pollen and general anatomy. The present collection of the two species from Ramappa and Pakhal, Andhra Pradesh, represents a second area of their distribution apart from Madras State. Additional features on their anatomy have been recorded. On the basis of field observations and anatomical features the species are grouped under floating-leaved anchored hydrophytes. The achlorophyllous epidermis and ledged guard cells, which are not in tune with typical characters of hydrophytes are regarded as of vestigial nature. *E. ambigua* is represented by two forms, one mesic and the other aquatic, which are considered to be ecoadaptive forms or ecads rather than two different genetic races. The anatomical characters are found to be too simplified to help in establishing the taxonomic position of the family.

INTRODUCTION

Elatine L., one of the two genera of the less known family Elatinaceae consists of about 20 species which are all small glabrous herbs of mostly swampy or muddy and inundated localities and distributed in temperate and tropical zones of both the hemispheres (Willis and Shaw, 1966). From India two species of the genus have been recorded both from Madras State, *E. triandra* Schkuhr from Nilgiris (Schmidt cf. Dyer, 1874; Gamble, 1915), Courtallam and Chingleput (Subramanyam, 1962) and *E. ambigua* Wight from Madras (Gamble, l.c.) and Tanjore (Wight, 1838; Gamble, l.c.). The present authors have collected the two species from Ramappa and Pakhal (district Warangal, Andhra Pradesh) which is significant because for the first time they are being reported from places apart from Madras State. Since the two species have not been fully described and illustrated in the Indian floras, it has been felt to fill this gap. Further, since the two species are quite scarce and as aquatics structurally much specialised, a detailed account of their anatomy is also included here.

SYSTEMATICS AND DISTRIBUTION

Elatine L., Sp. Pl. 367. 1753.

Small prostrate glabrous herbs of inundated muddy localities, moist soil of half-dried tanks and sandy mud-flats of river-beds. Leaves opposite or whorled, shortly stalked. Stipules ovate, dentate. Flowers solitary, axillary, minute, 2-4-merous. Sepals shortly connate at the base. Petals obtuse, longer

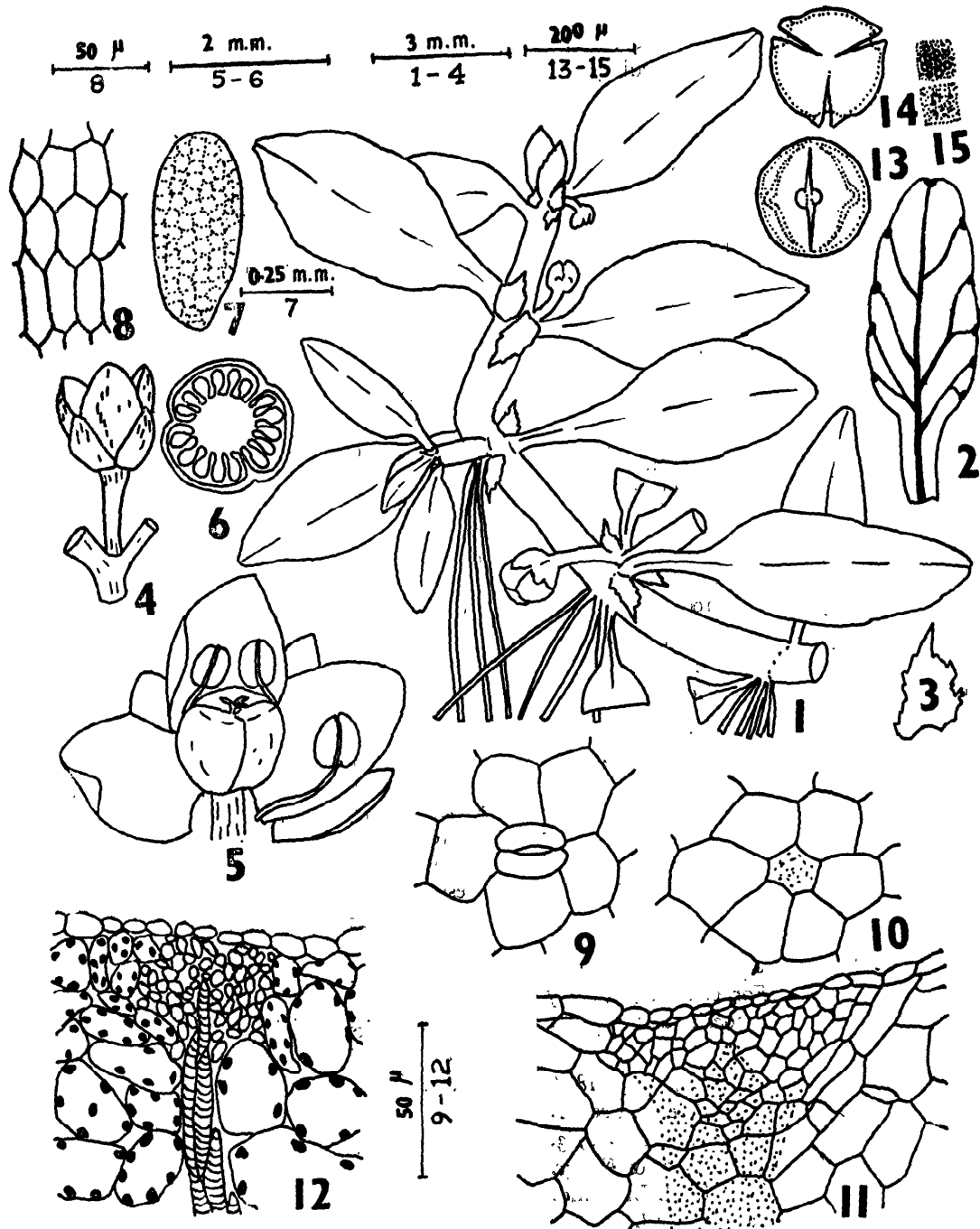
than the sepals, oval, white or pink. Stamens as many as the petals or twice their number. Ovary globose. Styles 2-4, or stigmas sessile. Fruit globose, but somewhat depressed at apex, septicidally dehiscent; wall very thin, transparent. Seeds minute, oblong, slightly curved, hexagonally reticulate.

KEY TO THE INDIAN SPECIES

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| Flowers pedicelled; stamens shorter than the sepals | 1. <i>E. ambigua</i> |
| Flowers $\pm$ sessile, stamens longer than the sepals | 2. <i>E. triandra</i> |

Elatine ambigua Wight in Hook. Bot. Misc. 2: 103. 1831; Dyer in Hook. f. Fl. Brit. Ind. 1: 251. 1874; Gamble, Fl. Madras 1: 68. 1915; Backer in Steenis, Fl. Malesiana 4: 206. 1951; Backer & Bekn. Fl. Java 1: 205. 1963.

Prostrate, radiately branched, delicate glabrous herb, usually spreading, 10-15 cm long. Stems round, 0.5-1 mm thick, rooting at nodes. Leaves opposite, quite variable being oblong to ovate-oblong, 2.5 $\times$ 1.3 mm, tapering at base, obtuse, rounded or emarginate at tip; lamina entire, penninerved; each lateral nerve ending at the margin into a hydathode, rarely branching except the basal ones. Petiole narrowly winged. Stipules minute, ovately-triangular, acute to acuminate, dentate, at length deciduous. Flowers axillary, solitary, one at each node on alternate sides. Pedicels 1-2.25 mm long. Sepals 3, slightly more than half as long as the petals, obtuse, oblong. Petals broadly oval, greenish-white to white, $\pm$ 1 mm long. Stamens 3, alternipetalous; anthers oblong, opening



Figs. 1-15 : *Elatine ambigua*. 1. Habit. 2. Leaf showing veins which end in the hyathodes occurring at the margin. 3. Stipule. 4. Flower. 5. Flower cut open showing stamens and ovary. 6. T. S. of ovary. 7. Seed. 8. Magnified surface pattern of the seed. 9. Stomata from the upper surface of the leaf. 10. Aborted guard cell mother cell from the lower surface of the leaf. 11. Hydathode in surface view. 12. Paradermal section of the leaf margin showing the internal structure of the hydathode. 13-15. Pollen grain (Fig. 15 diagrammatic).

longitudinally along the sides. Ovary rounded with 3 sessile peg like stigmas which are shorter than the ovary, 3-celled; placentation axile. Capsule $\pm$ globose, 1-1.5 mm in diameter, pendulous on usually a curved stalk, depressed at the apex. Seeds oblong, slightly curved, 0.2-0.35 mm long, light brown in colour; surface hexagonally reticulate; embryo straight (Figs. 1-8).

Pollen: 3-colporate, obloate-spheroidal to spheroidal ($13 \times 14 \mu$). Apocolpium diameter ca. 1μ . Colpi $11.5 \times 1 \mu$ with tapering ends, constricted at equator; membrane more or less granular. Ora circular to lalongate ($4 \times 5 \mu$). Exine about 1μ thick. Sexine about 0.5μ thick, tectate (Figs. 13-15).

Flowers and fruits: October-December.

Near Ramappa temple, Warangal district, Andhra Pradesh: *Ramayya* s.n. (1962) from a moist area; *Rajagopal* 2404 (1967) from a marshy area with about a cm standing water.

Range: Peninsular India; Fiji Islands, Java, 100 m to 1900 m (Backer 1951); Zambesiaca, Polynesia and Eastern Europe (Wild., 1961).

The plant was first spotted near Ramappa temple in moist areas along the road leading to Ramappa lake by the first author in 1962. The second collection was made again from the same place but from a marshy area, about a kilometer away from the place of first collection by the second author in 1967. It is relevant to mention that the habit of the plants of the two collections shows a clear correlation with their habitat conditions. The plants of the first collection are relatively less spread out and bear thicker and crisp leaves while of the second, much spread out and have thin soft leaves. The two forms also show corresponding anatomical differences as described later. For convenience they will be here after referred as mesic and aquatic forms respectively.

Elatine triandra Schkuhr, Bot. Handb. 1: 345. 1808, sensu lato; Backer in Steenis, Fl. Malesiana ser. 1. 4: 206. 1951; Backer & Bken. Fl. Java. 1: 205. 1963. *E. americana* Arn. Edinb. Journ. Nat. & Geogr. Sc. 1: 431. 1830; Dyer in Hook. f. Fl. Brit. Ind. 1: 251. 1874; Gamble, Fl. Madras 1: 68. 1915.

A slender spreading herb, larger than the previous species; stems 0.5-2.5 mm thick. Leaves $3-15 \times 1.5-5$ mm. Flowers $\pm$ sessile. Capsule 1.5-2 mm in diameter. Seeds obliquely erect. In other respects quite similar to *E. ambigua* (Figs. 16-23).

Pollen: Similar to that of *E. ambigua*, but the

material available with us is not sufficient to give the dimensions.

Flowers and fruits: October-December.

Collected from a marshy and shady place in Pakhal forest of Warangal district, Andhra Pradesh: *Rajagopal* 2436 (1967).

Range: Peninsular India; Java, Sumatra; Australia; New Zealand; Europe and N. America; Senegal, Zambesiaca, 100 m to 300 m (Backer, 1951; Wild., 1961).

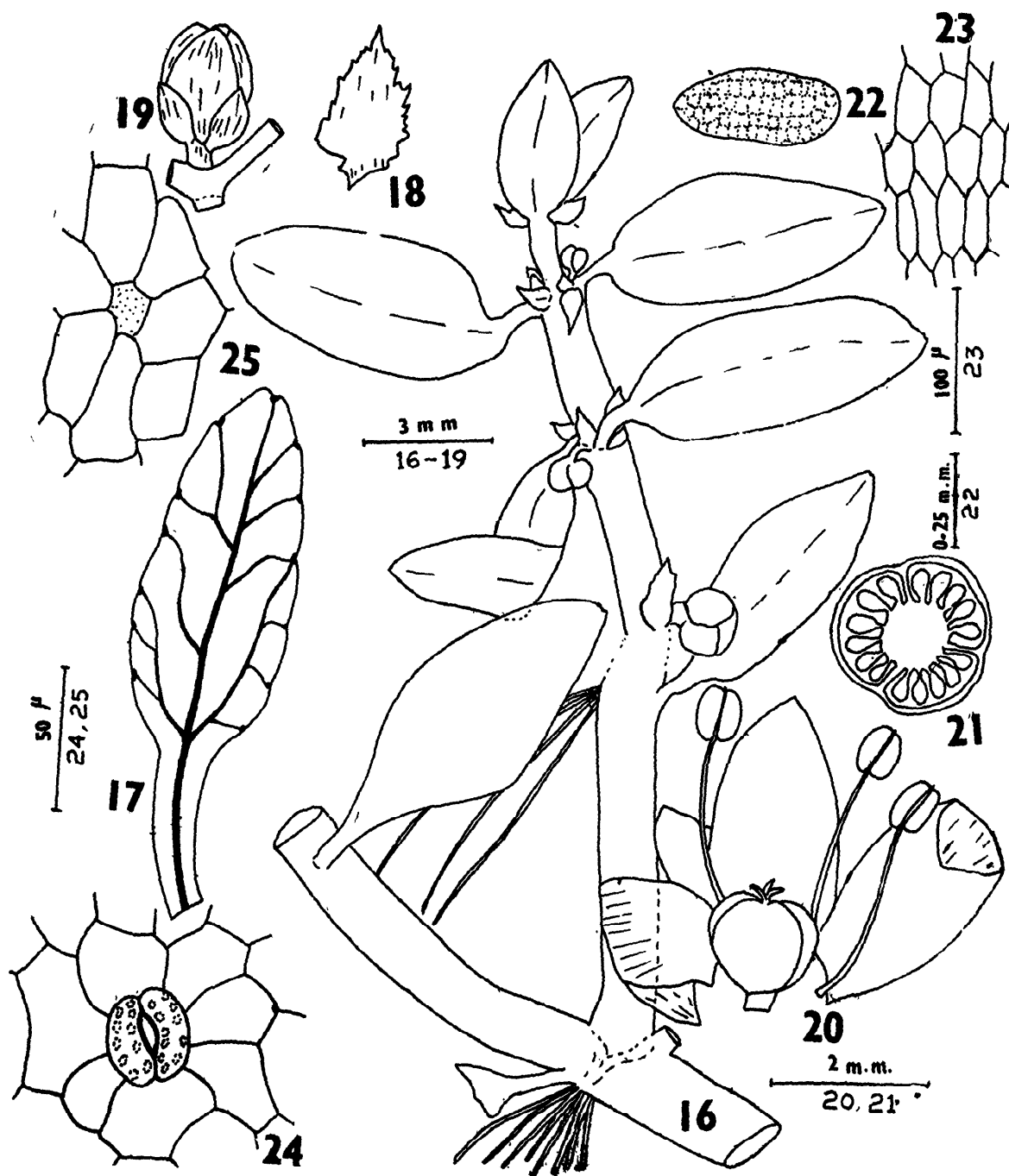
According to Fernald (cf. Backer, 1951) in *E. triandra* the seeds are horizontally divergent and borne on the whole length of the placental axis, whereas in *E. americana*, they are erect and confined to the base of the placenta. Our collection from Pakhal is intermediate to the above two species since the seeds are oblique to $\pm$ vertically oriented and face the apex of the capsule. We, therefore, do not consider this character to be of value in demarcating the two species. Accordingly we have preferred to follow Backer (1951) in treating the species in its wider sense.

It is significant to note that species *E. triandra* (*E. americana*) was previously collected from Nilgiri Hills at about 2000 m altitude, and *E. ambigua* from Tanjore and Madras, about 100 m above sea-level. Both the places are about 850 km away from the present localities of collection which are situated at an altitude of about 400 m. The long distance between the two areas of collection suggests that the species may have a wider distribution than presently known. Their nonobservance from a wider area in India is perhaps due to their small size. Backer (1951) expresses a similar opinion regarding their occurrence in Malaysia; "the small size and habitat of *Elatine* are probably the major causes for its scarcity in the herbaria. A special search would doubtless reveal many additional localities "

ANATOMY

Both the species investigated have an identical anatomical picture excepting the mesic form of *E. ambigua* which is characterised by few special features. Hence the description given below represents the structure of both the species (including the mesic form). The features by which the last differs are given at appropriate places.

Root: The roots studied are of the adventitious type emerging from the nodes. They are cylindri-



Figs. 16-25: *Elatine triandra*. 16. Habit. 17. Leaf showing veins which end in hydathodes occurring at the margin. 18. Stipule. 19. Flower. 20. Flower cut open showing stamens and ovary. 21. T. S. of ovary. 22. Seed. 23. Magnified surface pattern of the seed. 24. Stomata from the leaf (upper surface). 25. Aborted guard cell mother cell from the leaf (lower surface).

cal and about 1 mm in diameter and 15 cm in length. In transections their structure is as follows:

Circular to ovoid in outline, usually 0.5-1 mm in diameter. Epidermis single layered; cells tabular to radially elongated. Cortex wholly aerenchymatous, consisting of 5-7 radially arranged uniseriate partitions which enclose as many air-cavities; partitions 4-5-celled in radices, meeting the epidermis towards the periphery and the endodermis on the inside. Endodermis 1-layered; cells tabular, occasional ones being tanniferous; walls slightly thickened, radial ones suberised but without the typical casparian thickenings. Pericycle usually 1-layered, cells thin-walled, not quite distinctive from the adjacent phloem tissue. Vascular tissue consisting of a single large central vessel surrounded by the phloem which is usually 1-layered.

The above mentioned characters are shown by the thickest roots available with us. But as seen from the description given, the root has only primary tissues and hence it is doubtful if it develops secondary tissues (Figs. 26 & 27).

Stem: The epidermis is glabrous, nonstomatiferous and consists of rectilinear cells as seen in surface view. In transections the stem structure is as follows:

Epidermis 1-layered, nonstomatiferous; cells radially longer than broad, achlorophyllous, occasional ones tanniferous. Cortex aerenchymatous with 6-13 air-cavities; chlorenchymatous with occasional tanniferous elements, distinguishable into three zones (1) an outer layer consisting of cells isodiametrical to broader than long, (2) partitions with cells radially longer than broad and (3) an inner layer having cells of varied sizes. Endodermis of tabular cells; the latter without casparian thickenings, occasional cells tanniferous. Pericycle 1-layered, indiscrete from phloem. Primary vascular system of four discrete strands each consisting of 1 or 2 vessels, phloem not distinctive. Wood: xylem organised into nearly a cylinder, 2-3 vessels in diameter, but more so at the nodes. Vessels of the protoxylem of the same diameter as others; thickening of the vessels ranges from annular to reticulate type as one passes from the inner margin to the periphery in longitudinal section of the stem; vessels of bizarre forms at the node (Figs. 28-31, 34 & 35).

The node is unilacunar and only a single trace departs into the leaf base. The vessels at the node are often bizarre and quite shortened unlike those observed in the internodes (Fig. 32).

The shoot apex is characterised by a single tunica layer and is about 40μ in diameter above the recently formed leaf primordia (not seen in the mesic form of *E. ambigua*) (Fig. 33).

The mesic form of *E. ambigua* is distinctive by its deeply stained tanniferous cells both in the epidermis and other tissues, unlike in the other two forms.

Leaf: In surface view the epidermal cells appear nearly straight-walled, 4-6-sided and smooth surfaced. Those overlying the veinular areas are usually somewhat longer than others.

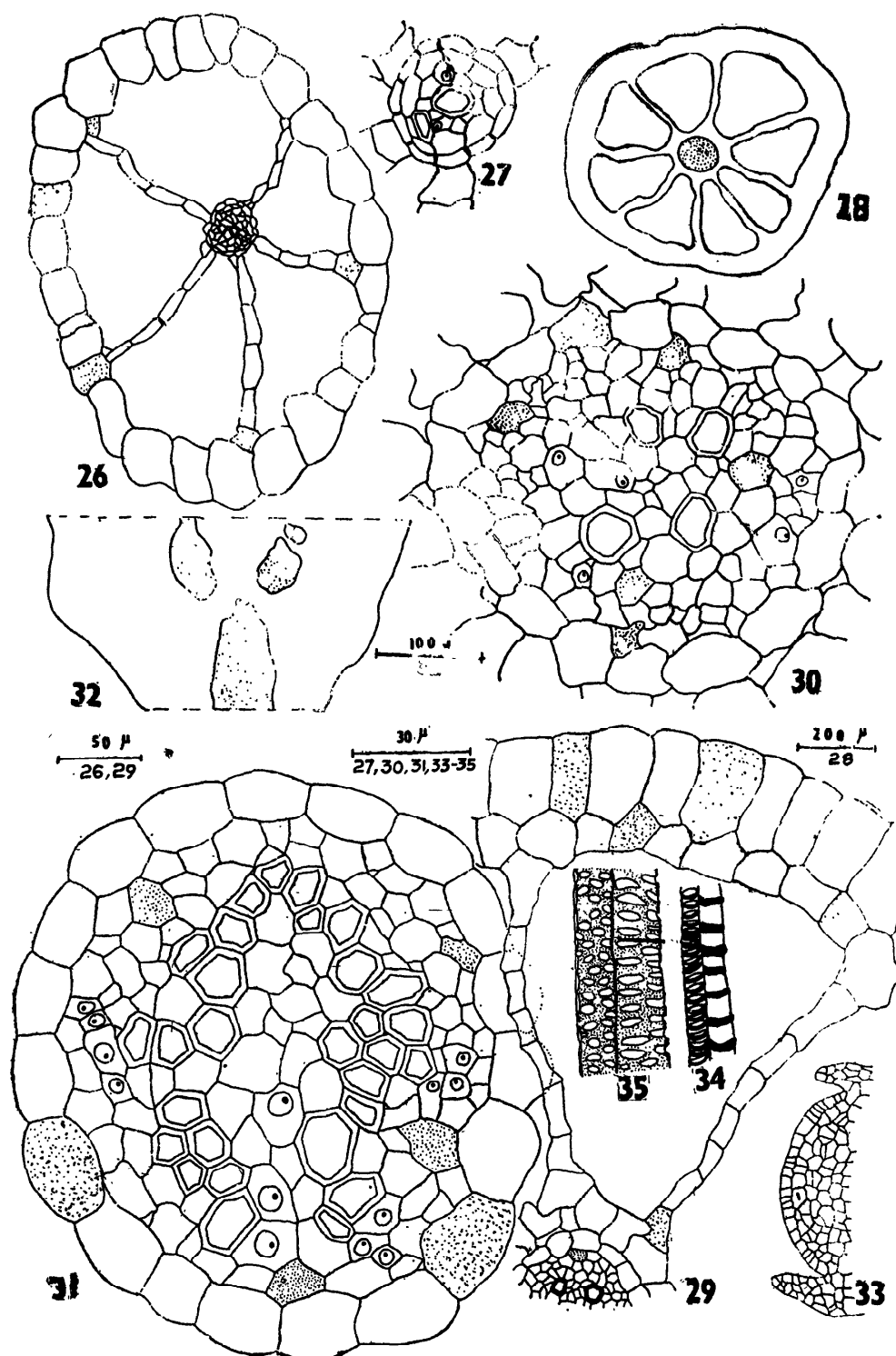
The stomata are anomocytic being surrounded by 4-7 epidermal cells similar to the adjacent ones. Only the upper epidermis is wholly stomatiferous; the stomata are confined to only the lamina margin towards the lower surface, while the rest of the area shows mere aborted guard cell mother cells. The mesic form, however, differs in having stomata all over its lower surface. The frequencies of stomata for both the species are given in the Table I (Figs. 9, 10, 24 & 25).

TABLE 1: Stomatal frequency per mm²

Sur face	Spec-ies	<i>E. ambigua</i>		<i>E. triandra</i>
		Rajagopal 2404	Ramayya s.n.	Rajagopal 2436
Upper		65	58	63
Lower		very few on the margin	50	very few on the margin

The stomata are diffuse in their origin. A given stomatal meristemoid is distinguished by its hexagonal to round outline and denser contents. It divides directly into the guard cells through a median wall, indicating that the stomata are haplocheilic or perigenous in their development as defined by Pant (1965) (Figs. 43-46).

In both the species the leaves show hydathodes at the termination of their lateral veins. In fixed material, the hydathodes appear as dense triangular areas when examined under low magnification; the epidermis here consists of comparatively small cells which are polygonal in outline and straight-sided. The epithem consists of cells which are rounded, achlorophyllous, densely protoplasmic and less interspaced as compared to the adjacent ones. The veins end up just close to the epithem and hence the latter has direct water-supply. Neither stomata nor any pores are observed over them. (Figs. 2, 11, 12 & 17).



Figs. 26-35 : 26 & 27. T. S. of root and magnified vascular bundle of *Elatine triandra* respectively. 28. T. S. stem & 29. Enlarged portion of a sector of the stem showing chlorophyllous and tanniferous (stippled) cells of *E. ambigua* (mesic form). 30. Enlarged view of vascular portion of a young stem of *E. triandra*. 31. Enlarged view of an older stem's vascular portion of *E. ambigua* (mesic form) (in 30 & 31 tanniferous cells stippled). 32. Portion of node of *E. triandra*. 33. L. S. of apical meristem of *E. ambigua* (aquatic form). 34 & 35. Annular, spiral, reticulate thickenings and simple pits of vessel in L. S. stem of *E. ambigua* (mesic form).

The structure of the leaf in transverse sections is as follows:

Petiole in T. S.: Semi-lunar in outline. Epidermis uniseriate, nonstomatiferous; cells longer than broad; achlorophyllous. Mesophyll 1-layered in the form of a hypodermal layer except at the mid-rib where it is continuous with both the epidermises as seen in the Fig. 48, lacunate with an air-canal on either side of the mid-rib; cells rounded, chlorophyllous. Vascular system of a single collateral strand enclosed by the endodermis.

Lamina in T. S.: Epidermis 1-layered; thinly cuticularised; cells isodiametrical to radially longer than broad, occasional ones tanniferous, of the lower epidermis somewhat larger than those of the upper one. Stomata at the same level as the epidermis; outer wall of each guard cells has a ledge which arches over the stomatal aperture. Mesophyll 3-5-layered, but becoming 1-layered towards the margin, chlorophyllous. Palisade 1-layered; cells only shortly longer than broad to nearly circular in outline. Spongy tissue with cells slightly lobed to circular in outline; intercellular spaces moderate. Vascular system of the mid-rib consisting of a collateral vascular strand surrounded by the endodermis (Figs. 36-38 & 47).

The mesic form of *E. ambigua* in general shows darkly stained tanniferous cells both in the epidermis and mesophyll of the petiole and lamina. Further, the mesophyll is up to 4-5-layered even at the margin of the lamina unlike in the other forms (Figs. 39-41).

DISCUSSION

Previous literature on the anatomy of the family has been reviewed by Metcalfe and Chalk (1950) following which as far as the authors know, no work has been published. Since systematic position of the family is doubtful, anatomical study has been emphasized by the above authors. We have, therefore, considered it desirable to compare in detail the anatomical characters of the present species with those previously reported for the genus. Though a number of them have been presently confirmed, quite a few are at variance; further, some new characters have also been noted. The following features of the genus are confirmed in the species investigated.

Root: Cortex of mere radially elongated cells enclosing air-cavities; pericycle and phloem indistinctive from each other; vascular system much

reduced which in the present species is represented merely by a single vessel.

Stem: Cortex aerenchymatous and chlorophyllous; distinctive endodermis; vessels in radial rows.

Leaf: Absence of hairs; presence of stomata on both sides (seen only in the mesic form of *E. ambigua*); loose mesophyll with palisade cells relatively shortened or almost circular in outline.

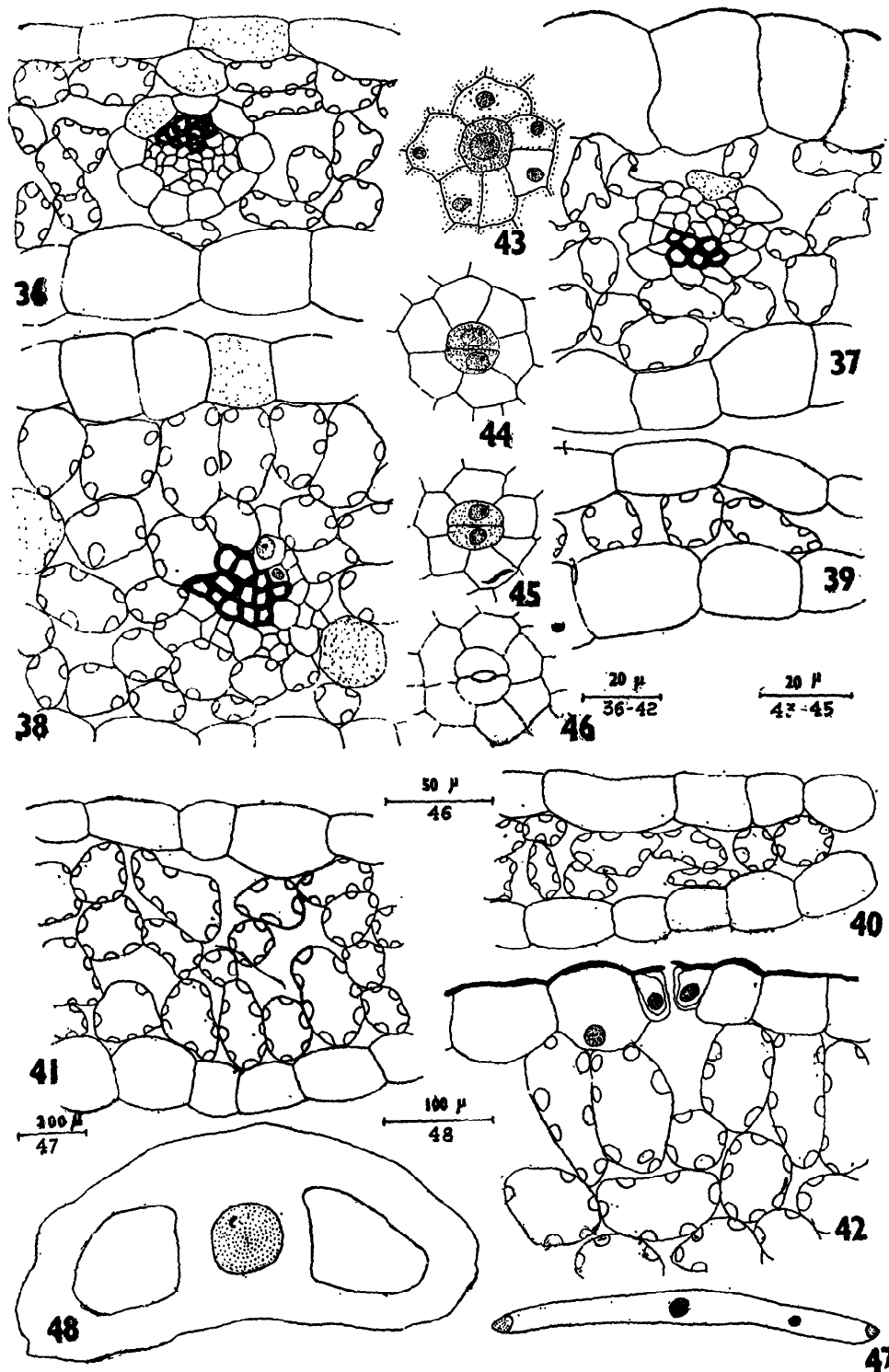
As shown below several characters of the species studied are at variance from those reported in the literature.

Characters reviewed in Metcalf & Chalk (1950)	As presently observed
<i>Root</i> Endodermis indistinctive.	Endodermis fairly distinctive due to larger size and suberised radial walls of its cells.
<i>Stem</i> Epidermis with hair-like cells; cortical air cavities constant in their number and hence of taxonomic value; vessels with annular to horizontal pits; pith absent.	Epidermis glabrous; cortical air-cavities variable from internode to internode and hence taxonomically valueless; vessels of circular pits only; pith present.
<i>Leaf</i> Stomata surrounded by two polar cells and two paracytic cells, though anomocytic in appearance; epidermal cells with wavy walls as seen in surface-view.	Stomata perfectly anomocytic being surrounded by unspecialised subsidiaries; epidermal cells with straight walls in surface view.

The features newly observed are as follows:

Stem protoxylem in T.S., not distinctive from the metaxylem; node unilacunar and supplying a single trace to the leaf; nodal vessels shorter and of bizarre forms; petiole with two air canals one on each side of its vascular strand; leaf lower surface with aborted guard cell mother cells in *E. triandra* and the aquatic form of the *E. ambigua*; stem and leaf epidermal cells achlorophyllous; tanniferous cells in the epidermal, ground and vascular tissues of the root, stem and leaves.

The elatines investigated being aquatics are significant both from the morphologic and ecologic viewpoint. Since plant structure bears a close relation to its habitat an assessment of the nature and degree of adaptation of the elatines studied on the basis of their anatomical characters is called for. Aquatic plants are generally recognised into five morphoecologic categories (1) floating, (2) suspended, (3) submerged anchored, (4) floating-leaved anchored and (5) emergent anchored (Daubenmire, 1959). In the light of our field observations *E. triandra* and the aquatic form of *E. ambigua* come very close to



Figs. 36-48 : 36. T. S. leaf *Elatine ambigua* (aquatic form). 37. T. S. leaf *E. triandra*. 38. T. S. leaf *E. ambigua* (mesic form) (36-38 from middle region of the leaf; the tanniferous cells stippled). 39-41. T. S. leaf margin of *E. ambigua* (mesic form), *E. triandra* and *E. ambigua* (aquatic form) respectively. 42. T. S. leaf showing stomata with ledges in *E. ambigua* (aquatic form). 43-46. Different stages of development of stomata from the leaf (upper surface) in *E. ambigua* (aquatic form). 47. T. S. leaf (hyathodes on the margins stippled) of *E. ambigua* (mesic form). 48. T. S. petiole showing two air-canal canals of *E. ambigua* (mesic form), epidermis densely stippled.

the category of floating-leaved anchored plants. That these plants are specialised to hydric conditions is doubtless indicated by their numerous anatomical characters discussed earlier. The significance of these characters, however, lies in the fact that some of them clearly indicate the grouping of these plants into the category of the floating-leaved anchored plants. Such characters are: the absence of stomata from a larger area of the leaf lower surface; presence of large air-canals in the petiole; and possession of hydathodes. These characters signify the degree of harmony of these plants in relation to the particular habitat stratum they occupy. For instance the biological value of the lack of stomata from the leaf lower surface of the plants can be understood by the fact that since their leaves remain at the water-level (floating or submerged condition), they cannot any more transpire from the surface. The air-cavities of the petiole can be taken as required in maintaining the leaves at water level, since the lamina by itself does not possess any air-chambers. The hydathodes can be considered to be helpful in expelling the excess water.

The mesic form of *E. ambigua* which is found in exposed areas unlike the aquatic form, also possesses specific features in tune with its habitat preference. Its leaf lower surface unlike in the other form is stomatiferous, which could be related to its exposed habit for it can transpire from the lower surface also. The palisade is relatively distinctive, indicating its response to the differential exposure to sunlight.

It is pertinent to point out here that two of the characters observed are such that they do not seem to be adaptive of these plants to their habitat. In both the species the leaves and the stem epidermal cells are achlorophyllous; secondly the guard cells of the leaves are ledged at their exterior edges (Fig. 42). It is well known that epidermis of aquatic plants is particularly chlorophyllous and similarly the ledged guard cells form a feature usually of xerophytes (Warming, 1909). Therefore, occurrence of these characters in the elatines studied cannot be understood in terms of adaptive significance. At the most they may be regarded as vestigial characters which could not be dispensed with.

The present observations are equally significant in throwing light on the relationship of the aquatic and mesic forms of *E. ambigua*. Though the two differ from each other in few characters (as discussed above), there is no doubt that they are related forms

as they are similar in almost all of their anatomical and morphological features. Since they have been located from areas close to each other, it is very likely that they represent mere ecoadaptive forms or ecads of one and the same species rather than two different genetic races.

Taxonomically the family's position has been doubtful. It has been related to different taxa by different authors viz., to Guttiferales (Bentham & Hooker, 1862-1893; Hallier, 1912), to Caryophyllaceae and its related families like Frankeniaceae, Tamaricaceae (cf. Bessey, 1915; Engler and Prantl, 1925; Hutchinson, 1964) and also to Hippuridaceae, Haloragidaceae, Lythraceae etc. (cf. Willis & Shaw, 1966). We have examined the available anatomical characters (see Solereder, 1908; Metcalfe & Chalk, 1950) pertaining to the above taxa and carefully compared with those of Elatinaceae including the data presented in this paper. It has, however, been not possible to correlate the Elatinaceae with any of the above taxa. The characters to which we paid particular attention in comparing with the above taxa are: (1) hydathodes, (2) two air-canals in the petiole, (3) unilacunar node, (4) tanniferous cells, (5) anomocytic stomata, (6) clustered crystals. The above combination of characters or of a few of them are not shown by any of the taxa suggested to be related. In this context the situation cannot be explained better than what has been observed by Metcalfe & Chalk (1950) that the anatomical characters of the family are too simplified to be "an index of taxonomic affinity".

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