Chapter 3: SYSTEMATIC STUDY

3.1. Introduction

Floristic explorations and taxonomic studies can provide efficient and convenient information about the nomenclature, distribution, ecology, utility of various plant species, and thus about an ecosystem. Early plant classification based only on the visible artificial characters gradually turned to obvious morphological and more significant ones. In eighteenth century the term dicotyledons and monocotyledons was used by John Ray and Nehemiah Grew. The term “famille” was used by Pierre Magnol (1715). Carl Linnaeus (1753) classified seeds as monocotyledons and dicotyledons and grouped plants based on sexual characters in 24 classes into 65 natural orders and developed the system of binomial nomenclature. Later Bernard de Jussieu and Antoine de Jussieu in 1789 classified the plant world into Acotyledons, Monocotyledons and Dicotyledons. Dicotyledons include four groups namely Apetalae, Monopetalae, Polypetalae and Declines Irregulares and published Genera plantarum secundum ordines naturales disposita (1789). Jussieu described a total of 28 genera in 5 groups based on fruit characters under the family name Borragineae Juss. (De Jussieu, 1789) In nineteenth century A.P. de Candolle introduced the term ‘taxonomy’ and proposed a system (1819) starting with Ranunculaceae under Dicotyledoneae and published Theorie elementaire de la botanique in 1813 and Prodromus Systematis Naturalis Regni Vegetabilis (1824-1839). Horaninov (1834) and Lindley (1836) used ‘aceae’ as termination for orders. Endlicher in 1840 completed the first comprehensive description of genera and dedicated to Jussieu and used the same title Genera plantarum secundum ordines naturales disposita. Those early system makers grabbed upon arbitrary characters to effectively give the name to plants.

After the publication of Darwin’s “The Origin of Species by means of Natural Selection” (1859) evolutionary approaches became vogue in the classification. Later in 1862-1883 Bentham and Hooker prepared the Genera Plantarum containing main divisions Dicotyledones, Gymnospermae and Monocotyledons. Dicotyledones are divided in to Polypetalae, Gamopetalae and Monochlamydeae. Engler and Prantl
proposed phylogenetic system of plant classification and published *Die natürlichen Pflanzenfamilien*. In 1915, Bessey considered Dicotyledons into two lines Ranunculus series having receptacle an axis and Rosa series with receptacle cup shaped. Since then, several workers modified the classification system till 1940. Different traditional classification systems were popularized in different countries; e.g. the Engler system in continental Europe; the Bentham & Hooker’s system in Britain and its colonial countries; the Takhtajan’s system in the former Soviet Union and countries within its sphere of influence; and the Cronquist system in the United States.

Among the Botanists who worked on the flora of Peninsular India, Robert Wight contributed, *Illustrations of Indian Botany* (1840) and *Icones Plantarum Indiae Orientalis* (1838-1853). Wight and Arnott in 1834 published *Prodromus Florae Peninsulae Indiae Orientalis* in which several new taxa were described. The other prominent contributions during the 19th century were, *The Flora Sylvatica* for Southern India (Beddome 1869-1874), *Icones Plantarum Indiae Orientalis* (Beddome, 1868-1874) and *Flora Indica* (Roxburgh, 1832). J. D. Hooker published *Flora of British India* (1872-1897) in seven volumes described the phanerogams and phytogeography of the British India. Later two remarkable regional floras, *Flora of the Presidency of Bombay* (Cooke, 1901-1908) and *Flora of the Presidency of Madras* (Gamble, 1915-1936) were published.

The Angiosperm Phylogeny Group (APG), an informal international group of systematic botanists who came together to establish a consensus view of the taxonomy of flowering plants (angiosperms) that would reflect new knowledge about their relationship based upon phylogenetic studies. An important motivation for the group was what they viewed as deficiencies in prior angiosperm classifications, which were not based on monophyletic groups (i.e. groups consisting of all the descendants of a common ancestor). According to APG I system (1998) the number of families was 462. As of 2010, two revisions have been published, in 2003 (APG II) and in 2009 (APG III), each superseding the previous system. APG III system contains only 415 families, rather than the 457 of APG II. A significant number of major herbaria, including Kew, are changing the order of their herbarium collections and Kew’s order beds are now organised according to the APG classification (Chase, 2009).
influential World Checklist of Selected Plant Families is being updated to the APG III system. The family name Boraginaceae was conserved in APG system (Chase & Reveal, 2009).

### 3.2. Review on the systematics of Boraginaceae

Jussieu (1789) classified *Borragineae* plants under 28 genera in five groups based on the following characteristics; berry-like fruits, one or two-locular capsules and four separate nutlets. Candolle & Candolle (l.c.) divided *Boraginaceae* into four tribes: *Cordieae*, *Ehretieae*, *Heliotropieae* and *Boragineae*, the latter subdivided into six subtribes: *Cerinthinae*, *Echiinae*, *Lithosperminae*, *Cranioperminae*, *Anchusinae* and *Cynoglossinae*. This tribal classification was adopted by Bentham & Hooker’s (1876) but recognizing only four subtribes within *Boragineae*: *Cynoglossinae*, *Eritrichinae* (the *Cranioperminae* of the Candolles), *Anchusinae* and *Lithosperminae*, including here the *Cerinthinae*, *Echiinae* and *Lithosperminae* of the Candolles. *Rotula aquatica* Lour. belongs to the family Boraginaceae as per Benthem and Hooker’s (1876) classification. In 1819, Schrader established a segregate family Heliotropiaceae including the genera Heliotropium and Tournefortia. Gurke (in Engler & Prantl, *Nat. Pflanzenfam.* 4(3a): 71-131. 1893) divided the family into four subfamilies: *Cordioideae*, *Ehretioidae*, *Heliotrophioidae* and *Boraginoideae*, the latter subdivided into seven tribes, which were reduced to four by Johnston according to morphological and palynological characters: *Lithospermeae*, *Anchuseae*, *Eritrichieae* and *Cynoglossaeae*. Further, Airy Shaw (1973) divided the family Boraginaceae into Heliotropioidae and Boraginoideae and accepted a separate family, Ehretiaceae. Many authors such as Hutchinson (1969), Heywood (1993) and Riedl (1997) considered these subfamilies as separate families. Diane et al. (2002) accepted Heliotropiaceae as a separate family based on molecular and morphological study.

The electron microscopic studies especially, the nutlet shape and surface ornamentation of pollen of the members of the family Boraginaceae were studied by several taxonomists (Scheel *et al.*, 1996; Bigazzi & Selvi, 1998; Bigazzi *et al.*, 2006). The nutlet shape and its surface provide valuable taxonomic data for infrageneric
classification in Boraginaceae family (Riedl, 1978). Recently some taxonomists have classified the broadly treated Boraginales, with four traditional subfamilies Cordioideae, Ehretioideae, Heliotropioideae and Boraginoideae to the family level, Cordiaceae, Ehretiaceae, Heliotropiaceae and Boraginaceae with Hydrophyllaceae and Lennoaceae (Miller, 2007). Delimitation of the family as a whole is still controversial. Many authors subdivided the family Boraginaceae into four or five subfamilies. Some of them treated these subfamilies as separate families (Riedl, 1997) and some treated all subfamilies under the family Boraginaceae (Ruengsawang & Chantaranothai, 2009). Based on molecular analyses by ITS1 data and phylogeny assessments, Rotula and Carmona are transferred within Ehretia sensu lato (Gottschling & Hilger, 2001). Gottschling & Hilger treated Boraginales to family status and Rotula was under the family Ehretiaceae.

The family Boraginaceae (Forget-me-not family) comprises about 2700 species and was distributed in tropical, subtropical, and temperate regions of the world. The family Boraginaceae is distinguished from the allied families Verbenaceae and Lamiaceae by the presence of alternative leaves and coiled cincinnus inflorescence i.e. scorpoid cyme which is termed “borogoid”, a dorsiventral monopodia, uncoiling as flowers open. Gurke (1893) presented a comprehensive study on Boraginales and recognised four subfamilies of his Boraginaceae: Boraginoideae, Heliotropioideae, Cordioideae, and Ehretioideae. Bentham & Hooker in Genera plantarum (1862-83) placed this family under the order Polemoniales and circumscribed taxa that have close relationship, although their units were recognized as sections. Engler and Prantl (1897) considered the following sub families Boraginoideae, Heliotropioideae, Cordioideae and Ehretioideae. The family Boraginaceae circumscribed and included two subfamilies Boraginoideae and Heliotropioideae, while the family Ehretiaceae includes subtribes Ehretioideae and Cordioideae. Engler considered this under Tubiflorae; while Hutchinson (1969) proposed a separate order Boraginales (Dicotylidones- Herbaceaee- Boraginales) and the phylogeny proposed relates Boraginales to Ranales through Geraniales. Ivan Johnston studied Boraginaceae in detail and considered Rotula, Bourreria and Carmona each as
distinct from *Ehretia*, and *Rotula* is segregated from *Ehretia*, due to its undivided stigma (Johnston, 1950, 1951 & 1956). Lawrence (1937) preferred the subfamily status to the components of Boraginaceae instead of microfamily status. Takhtajan (1959) considered this family under the order Polemoniales. Cronquist (1981) included the family Boraginaceae in the order Lamiales. In families Borginaceae, Verbenaceae and Lamiaceae the presence of gynobasic style and the characteristic four nutlets which develop into a drupaceous fruit, indicates these families may be originated independently from a common ancestor (Cronquist, 1981). The assessment of iridoid compounds (Iridoids are secondary metabolites commonly found in plants and function as defensive compounds) in plant families by Dahlgren led the grouping morphologically, similar iridoid containing families in different groups. Dahlgren (1983) treated the family Boraginaceae in the order Boraginales and further segregated the family Ehretiaceae. On the basis of the presence of iridoid compounds and morphological similarities, Cronquist placed the family Boraginaceae in the order Lamiales.


Sharma et al., (1984) given family status to all sub families of Boraginaceae and genus *Rotula* was placed under the family Ehretiaceae in Flora of Karnataka. Separate family status was given to all sub families of Boraginales by Keshava Murthy & Yoganarasimhan (1990) in Flora of Coorg, Karnataka, India. In Flora of

### 3.3. Materials and methods

For systematic treatment, primary data on the distribution, locality, associated plants and flowering season were collected through literature review, herbarium analysis and floristic studies. Floristic studies were conducted in post monsoon period from September to May when the plants are visible.

#### 3.3.1. Literature studies

Flora of Kerala were investigated to understand the past distribution of the genus *Rotula*. The major flora such as, Flora of British India (Hooker, 1872-97), Flora of the Presidency of Madras (Gamble & Fischer, 1915-1936), Flowering plants of Travencore (Rama Rao, 1914), The families of flowering plants (Hutchinson, 1956), Flowering Plants of Thrissur Forests (Sasidharan & Sivarajan, 1996), Evolution of Flowering plants (Hutchinson, 1969), The Wealth of India, Raw materials Vol. IX Rh-So (CSIR, 1972), Flora of Hassan district Karnataka, India (Saldanha, 1976), Flowering plants origin and dispersal (Takhtajan, 1981), Systematic studies on the Flora of Kottayam District (Antony, 1989), Flora of Silent valley (Manilal, 1988), Flora of Cannanore (Ramachandran & Nair, 1988), Flora of Palghat district (Vajravelu, 1990), Flora of Coorg (Keshava Murthy, 1990) A revised hand book to the Flora of Ceylon (Dassanayake, 1991), Flora of Thiruvananthapuram (Mohanand Henry, 1994), Flora of Nilambur -Western Ghats, Kerala (Sivarajan & Philip, 1997), Flora Malesiana vol. 13 (Riedl, 1997), Flora of Agasthyamala (Mohanand Sivadasan 2002), Flora of Pathanamthitta (Anilkumar et al., 2005), Flowering plants of Kerala (Nayar, 2006) and Biodiversity of flowering plants (Antony et al., 2011) were referred. In addition to this, standard research journals, online information and publications were reviewed for the floristic analysis of *Rotula*. 

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3.3.2. Herbarium analysis

The herbarium studies help to identify the locality and distribution of the species *Rotula aquatica* in Kerala. National, regional and university herbaria such as Central National Herbarium (CAL) Kolkata, Madras Herbarium (MH) Coimbatore, Jawaharlal Nehru Tropical Botanical Garden and Research Institute Herbarium (TBGT) Thiruvananthapuram, Kerala Forest Research Institute Herbarium (KFRI) Thrissur, Regional Herbarium Kerala (RHK) at St. Berchmans College, Changanassery, Calicut University Herbarium (CALI) at Calicut, Fischer Herbarium (FRC) at Institute of Forest Genetics and Tree Breeding Coimbatore and Center for Medicinal Plant Research Herbarium (CMPR) Kottakal Malappuram, holding specimens collected from the different parts of Kerala were visited and investigated in detail. These herbaria contain many species which were collected from different areas of Kerala State as part of floristic surveys undertaken by these institutes. These herbaria helped in finding out the range of variation and also contain the details of localities and previous distribution of *Rotula aquatica* before the field studies. Detailed analysis of those specimens were done on herbarium data sheet (Appendix 1) and photographs of relevant specimens were also recorded. The image specimen of *Rotula aquatica* housed at British Museum (BM) and at Kew (K) could be studied.

3.3.3. Floristic exploration

Field studies conducted extensively throughout Kerala, especially in the riverbeds in Western Ghats region of the State. Floristic surveys were in such a way so as to cover all the seasons to record the phenology. Several field trips were conducted and repeated visits were made to same site till full data on the species have been obtained. Usually specimens were collected in flowering stage. Passport data of each collection like date and season, locality, habit, habitat, adaptations, morphological characters, distribution were recorded. Floral examinations were done at fields and also later on preserved specimens. For collection, preservation drying and preparation of herbarium, standard protocols were followed (Singh, 2008). Illustrations of relevant specimens were made from fresh specimens. For observing minute details, magnifying lens, dissection microscope (Weswox optik, OM-4) and compound microscope (ERMA, Tokyo) and photographs were taken by CanonSX50.
digital camera. Voucher specimens were deposited to the Regional Herbarium Kerala (RHK) situated at St. Berchmans College Changanassery, Kerala.

The systematic treatment begins with the family description, generic treatment, which is followed by citation, type species, and detailed description of genus. Artificial keys were provided for the identification of taxa. Genus and species description was followed by flowering and fruiting periods, vernacular names, habitat and distribution. All herbarium specimens studied were cited under specimens examined. The details of specimens cited were given in the following sequence: country, state, district, collection locality, date of collection, collector/collectors name, collection number, and acronym of the depository was given in parenthesis. Data regarding flowering and fruiting, vernacular names, distribution were given. Illustrations and relevant photographs were also prepared. Nomenclature is updated based on ICN codes adopted by the Eighteenth International Botanical Congress Melbourne, Australia, (ICN, 2011).

3.4. Results

3.4.1. Systematic treatment

BORAGINACEAE Juss.

A. L. de Jussieu, Gen. pl.: 128. 1789

Perennial, or annual, less often lianas, shrubs, or trees, usually bristly or scabrous pubescent. Leaves simple, exstipulate, alternate, rarely opposite, entire or serrate at margin. Inflorescences often double scorioid cymes, terminal or axial, rarely solitary; bracts present or absent. Flowers bisexual, actinomorphic, rarely zygomorphic. Calyx usually 5 lobed, mostly persistent. Corolla tubular, campanulate, rotate, funnelform, or salverform; tube appendages 5, rarely more or absent, sometimes a ring of hairs present; limb usually 5-parted; lobes overlapping, rarely twisted in bud. Stamens 5, inserted on corolla tube or rarely at throat, included or rarely exserted; anthers latrorse, 2-loculed, usually dorsifixed at base, less often medifixed, dehiscence longitudinal. Nectaries at base of corolla tube or on disc below
ovary. Ovary superior, bicarpellate; locules 2 and each with 2 ovules, or 4 and each
with 1 ovule; ovules nearly atropous, semianatropous, or anatropous. Style terminal or
gynobasic, branched or not. Gynobase flat, fastigiate, or subulate. Fruit 1–4 seeded
drupes or nutlets (mericarps); nutlets mostly dry, often ornamented with wings,
prickles and/or glochids (stiff bristles with barbed or anchor like tips). Seeds vertical
or oblique, coat membranous; embryo straight, less often curved; cotyledons flat,
fleshy.


1951; Nowicke & Miller in Dassan. & Fosberg, Fl. Ceyl. 7: 7. 1991; Riedl, Fl.

Type: *Rotula aquatica* Lour., Vietnam, Cochinchina (BM!).

Shrubs erect or trailing. *Leaves* alternate, crowded on short branches; lamina
oblanceolate to oblong, pubescent. *Inflorescence* terminal or axillary. *Flowers*
subsessile. *Calyx* green, 5-lobed, persistent, pubescent. *Corolla* pink to purplish or
white, campanulate, 5-lobed, tube shorter than lobes. *Stamens* 5, free, exserted,
filaments attached to mouth of corolla tube; anthers oblong, dehiscent, glabrous.
*Ovary* glabrous; style terminal; stigma subcapitate or bifid. *Fruit* 4-lobed drupe,
splitting into 4 pyrenes.

Distribution: Pantropical. Borneo, China, Celebes, India, Malesia, Myanmar
New Guinea, Philippines, Laos, Sri Lanka, Thailand, Tropical Africa and
Vietnam.KERALA: Througout.

**Key to the species**

1. Stem pinkish. Corolla pink. Filaments and style pinkish; anther basifixed;
   style protruded, stigma bifid, angled. Fruits reddish; seeds more than 2mm x1.5mm
   size. Trichomes not glandular………………………………………………………….*R. aquatica*
2. Stem greenish. Corolla white. Filaments and style white; anther dorsifixed; style not protruded, stigma bifid, flattened. Fruits creamish yellow; seeds size less than 1.5 mm x 1 mm. Trichomes glandular .................. R. henryi


A rheophytic woody under shrub, with trailing branches, usually pinkish when young, 50-150 cm long with numerous short lateral arrested branchlets, often rooting. Leaves simple, alternate, nearly sessile, oblanceolate or spatulate, acuminate at apex, cuneate at base, more or less hairy, crowded on the branches. Flowers solitary or in few on axillary cymes, 5-merous, bisexual, sessile, shortly pedicellate. Bracts lanceolate, up to 4 mm long. Calyx lobes 5, free, lanceolate, pubescent, up to 2 mm long. Corolla pink or purple, 5 lobed, oblone, up to 8 mm long, campanulate, spreading. Stamens 5, exserted beyond the corolla tube, anthers sagittate at base; style protruded, filiform, up to 6 mm long, stigma purple, capitate, slightly bifid. Ovary 4 locular, ovule 1 per locule. Fruits globoid, drupe orange red with persistent style, lobes 4 and 4 seeded, splitting into 4 pyrenes (Fig. 12).

Fl. & Fr.: November- March. 
Vernacular Names: Sanskrit: Pasanabhedah; Malayalam: Kallurvanchi, Puzha manjal; Tamil: Cheppunerinjal, Karnatic: Pasanabheda; Telungu: Pasanabheda.

Distribution: Throughout most rivers in Kerala. Districts: Idukki, Kannur Kasaragod, Kollam, Kottayam, Kozhikode, Malapuram, Palakkad, Pathanamthitta, Thrissur and Waynad.

Specimen examined


Kasaragod district, Parappa, 24.1.1979, V. J. Nair, 59832, MH, CAL; Parappa, 24.1.1979, V. S Ramachandran, 59193, MH; Malom Kasaba-Thejaswini tributary, Kariangode river, 23.5.2013, Jaison Joseph, 6597 RHK; Cheerkayam-Thejaswini tributary- Kariangode river, 23.5.2013, Jaison Joseph, 6598 RHK; Udayapuram-
Chandragiri river, 23.5.2013, Jaison Joseph, 6599 RHK; Eranjipuzha bridge-Chandragiri river, 23.5.2013, Jaison Joseph, 6600, RHK.


Waynad district, Mananthavady river, Malabar North, 13.11.1907, C. E. C. Fischer, no collection date, FRC; Thirunelly banks of river, 13.2.1987, T. Balakrishnan, 42769, CAL.


ASSAM, Ponga R.F, 23.11.1957, G. Panigrahi, 11510, CAL.


TAMILNADU, Coimbatore district, Aanamalays, 1864, Beddome, no collection No., Accession No. 39980, MH; Eroad district, Kavery river, Eroad, no date, Det. By J.S Gamble in 1912, Wight, no Collection No., MH; Thirunelveli district, Mundanthurai, 16.3.1917, No collector, 14632, MH.

UTHARAKHAND, Chamoli dist, Khandura, 13.1.1889, *J. F. Dathu*, 8345, CAL.

WEST BENGAL, Samnarong, Gau hills, Nov. 1921, *K.G Pani*, 1077, CAL.


A rheophytic woody under shrub, profusely branching with arrested short branchlets on trailing branches, young stem greenish yellow, hairy, 1-1.5 m long with often rooting at tip. Leaves simple, alternate, nearly sessile, eliectic-oblong, acute at apex, cuneate at base, pubescent, crowded on branches. Flowers solitary or in few on axillary or terminal cymes, pentameresous, hermaphrodite, sub sessile, shortly pedicellate. Bracts lanceolate, up to 4 mm long. Calyx lobes 5, free, lanceolate, pubescent, up to 2 mm long. Corolla white, 5 lobed, oblong, up to 8 mm long, campanulate, spreading. Stamens 5, exerted beyond the corolla tube, filaments white, anthers reniform, dorsifixed, extrose; style creamy white, filiform, up to 4 mm long,
stigma creamy white, slightly bifid and flattened, stigma and anthers on the same level. Ovary 4 locular, 1 ovule per locule. Fruits globoid, creamish yellow, drupes with persistent style, lobes 4 and 4 seeded, splitting into 4 pyrenes up to 1.5mm x 1mm size.

Table 4: Comparison of *Rotula aquatica* and *Rotula henryi*.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th><em>Rotula aquatica</em></th>
<th><em>Rotula henryi</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Habitat</td>
<td>Riparian</td>
<td>Riparian</td>
</tr>
<tr>
<td>2.</td>
<td>Habit</td>
<td>Trailing woody perennial shrub</td>
<td>Trailing woody perennial shrub</td>
</tr>
<tr>
<td>3.</td>
<td>Stem</td>
<td>Pink</td>
<td>Greenish yellow</td>
</tr>
<tr>
<td>4.</td>
<td>Leaf</td>
<td>Not crowded</td>
<td>Crowded on stem</td>
</tr>
<tr>
<td>5.</td>
<td>Leaf tip</td>
<td>Acute</td>
<td>Accuminate</td>
</tr>
<tr>
<td>6.</td>
<td>Corolla</td>
<td>Petals Pink</td>
<td>Petals White</td>
</tr>
<tr>
<td>7.</td>
<td>Filament length</td>
<td>4 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>8.</td>
<td>Filament colour</td>
<td>Pink</td>
<td>White</td>
</tr>
<tr>
<td>9.</td>
<td>Pistil</td>
<td>Up to 6 mm long, stigma protruded than anther level</td>
<td>Up to 5 mm long, stigma and anther on same level</td>
</tr>
<tr>
<td>10.</td>
<td>Style colour</td>
<td>Pink</td>
<td>White</td>
</tr>
<tr>
<td>11.</td>
<td>Style length</td>
<td>Up to 5 mm</td>
<td>Up to 4 mm</td>
</tr>
<tr>
<td>12.</td>
<td>Anther adnation</td>
<td>Basifixed</td>
<td>Dorsifixed</td>
</tr>
<tr>
<td>13.</td>
<td>Stigma colour</td>
<td>Pink</td>
<td>Creamish yellow</td>
</tr>
<tr>
<td>14.</td>
<td>Shape of stigma</td>
<td>Bifid, angled</td>
<td>Bifid, not angled</td>
</tr>
<tr>
<td>15.</td>
<td>Fruit colour</td>
<td>Reddish orange</td>
<td>Creamish yellow</td>
</tr>
<tr>
<td>16.</td>
<td>Seed size</td>
<td>Up to 2mm x 1.5mm</td>
<td>Up 1.5mm x 1mm</td>
</tr>
<tr>
<td>17.</td>
<td>Hair/trichome</td>
<td>Simple, not glandular</td>
<td>Simple, glandular</td>
</tr>
</tbody>
</table>
Figure 11: Diagnostic characters of *Rotula aquatica* & *Rotula henryi*.

Legend: Left side *R. aquatica* & right side *R. henryi*. a & b stem colour, c & d style length, e & f stigma type, g & h fruit colour, i & k anther adhesion, j & l seed size.
Diagnosis

*Rotula henryi* Jaison Joseph and V. T. Antony, *sp. nov.* differs from typical *Rotula aquatica* Lour. by having greenish yellow stem (versus purplish), corolla white (versus pink) anthers dorsifixed (versus basifixed), bifid flattened stigma (versus bifid capitate angled), anthers and stigma on same level (versus protruded style), filaments and style white (versus pinkish), fruit creamish yellow (versus reddish orange) seed size up to 1.5mm x 1mm (versus 2mm x 1.5mm). The diagnostic features are compared in the Table (4) and Figure (10.a-l). Illustration of *Rotula henryi* is given in the fig. (13).

Type: Kottiyur, Kannur district, 09.03.2013, Jaison Joseph & V.T Antony, 6592 (holo & iso in RHK)

Fl. & Fr.: November- March.

Vernacular Names: Malayalam: Vella Kallurvanchi, Vella Puzhamanjal

Distribution: In rivers of Malapuram and Kannur districts in Kerala.

Legend: A-Habit, B-Bract & Sepal, C-Corolla, D-Pistil, E-Fruit, F-Seed.

Figure 12: Illustration of *Rotula aquatica* Lour.
Legend: A-Habit, B- Corolla, C- Sepal, D-Pistil, E- Seed, F- Fruit

Figure 13: Illustration of *Rotula henryi* Jaison Joseph and V. T. Antony *sp. nov.*
3.5. Discussion

After the studies the systematic position of Rotula was ascertained and ascribed to as Kingdom: Plantae, Phylum: Tracheophyta, Class: Magnoliopsida, Order: Boraginales, Family: Boraginaceae, Genus: Rotula, Species: Rotula aquatica Lour. and Rotula henryi Jaison Joseph & V.T. Antony. Because the genus Rotula cannot be considered under the genus Ehretia until more precise phylogenetic data were obtained. Gottschling in 2001 transferred Rotula to Ehretia based on ITS1 (First Internal Transcribed Spacer) sequences and fruit structure. According to Gottschling, Ehretiaceae had been the only taxon of Boraginales, for which monophyly is doubtful in the absence of apomorphic characters and high variation in the ITS1 sequences created difficulties and a well resolved molecular phylogeny of Ehretiaceae become unclear. The relationships of the taxa and circumscription were not completely resolved till.

As on traditional classification, the differences in stamen number, structure of style, type of stigma and difference in habitat shows more difference than similarities between Ehretia and Rotula. In Rotula stigma is bifid, capitate and born on a terminal style. The gynoecium is composed of superior bicarpellary ovary which later becomes incompletely four celled, with a single ovule in each locule. The trichome types on the epidermis have played an important role in the modern re-classification of the family. Many studies have recognized and reported the unmistakable taxonomic importance of epidermal characteristics such as the shape and the size of the epidermal cells, the type of trichomes and the type of stomata (Taia, 2006). The polyphyly of Ehretiaceae in their traditional circumscription (Gurke 1893, Miller 1988 & 2003) was based on a heterogeneous morphology of the members with no known apomorphy. A phylogenetic analysis based on morphological data is still lacking in Boraginales.

Ehretia species comprise two clades, one having endocarps that separate into two 2-seeded dispersal units as in Ehretia tinifolia L. and the other endocarp separate into four pyrenes at maturity as in Ehretia cymosa Thonn. The later type exists in Rotula aquatica. But some floral features are similar in members of these two clades. There is similarity in the case of ovule which is anatropous in Rotula and Ehretia
(Nagaraj & Fathima, 1967, Khaleel, 1985). This indicates the close phylogenetic relationship between genera *Rotula* and *Ehretia*. *Rotula* differs from *Ehretia* in habit, leaves, style structure and fruit structure. *Rotula* is segregated from *Ehretia* due to its undivided stigma (Johnston, 1951) and *Ehretia* has divided stigma and forked style. The pollen of *Ehretia* and *Rotula* are totally different (Ruengsawang & Chantaranothai, 2009). Moreover the style is not forked in *Rotula* as that of *Ehretia*. Therefore, the genera *Rotula* is accepted here as separate taxa.

### 3.6. Conclusion

The genus *Rotula* is having riparian endemism and reproductive isolation shows much morphological variations in plants of same habitat and locality in a river. This clearly indicates that these variations are not of ecotypic or edaphic. These two distinct species *Rotula aquatica* and *Rotula henryi* are found in same habitat, locality and each of them having distinguishing vegetative, floral, fruit and seed characters. This shows that these two species are segregated from the genus *Rotula*. The distinguishing morphological characters were found to be stable through generations and therefore these two are treated as separate species.