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Research Article

TAXONOMIC RELATIONSHIPS AND ETHNOBOTANY OF FAMILY CONVOLVULACEAE

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ABSTRACT

Convolvulaceae is also known as the morning glory family and has 55 genera and 1650 species. Convolvulaceae show affinities towards a number of other families with which they have been associated in different systems of classification. The family has been sometimes classified into sub-families, tribes and has a very fluid state of boundaries separating adjoining genera resulting in generic synonymies.

A phytochemical screening of 19 genera and 59 species showed the presence of flavonoids, quinones, phenolic acids, seed fats, glycolipids, saponins and ergolines based on which phylogenetic interpretations have been made on tribes and genera of Convolvulaceae. Ethnobotanical uses of the family are rich and varied - from tonics to analgesics, aphrodisiacs, diuretics, antiflatulents and preparations for the treatment of diphtheria.

Key Words: *Convolvulaceae, Taxonomy, Phytochemistry, Flavonoids, Phylogeny, Ethnobotanical uses*

INTRODUCTION

Convolvulaceae, the morning glory family consists of twiners, bearing showy flowers with plaited corolla and often containing milky juice. The presence of bicollateral vascular strands, the erect sessile ovules in axile placentation and the folded cotyledons are other diagnostic features of the family.

This family was first constituted by N.J. de Necker in 1770 with *Convolvulus*. The type genus of the family is *Convolvulus* Linn., and the type species is *C.arvensis* Linn. (Hutchinson, 1969).

The habit of the constituent members varies from erect or prostrate, twining or creeping herbs to shrubs. *Humbertia madagascariensis* is exceptional being a tall tree and *Cuscuta* because of its parasitic habit. *Hildebrandtia* (endemic to North-East Tropical Africa) is a slender much branched shrub with rigid, woody branches that often end in spines.

Leaves are usually petiolate, exstipulate, sometimes with peudostipules which are leaves of axillary shoot and arranged in a spiral phyllotaxy. Leaves are absent in parasitic species.

Inflorescences are mostly cymose (rarely racemose – *Porana* and *Erycibe*). Typically, they are dichasial cymes passing into monochasia in the ultimate branches as in *Ipomoea*, *Convolvulus* and *Argyreia*.

The flowers are generally bracteate, bisexual, actinomorphic, pentamerous, hypogynous and in various sizes and colours. *Hildebrandtia* has dioecious and tetramerous flowers and those of *Dichondra* are cleistogamous. The flowers generally conform to the floral formula, + , ð , K_5, $C_{(5)}$, A_5, $G_{(2)}$.

Calyx consists of five free sepals in characteristic imbricate – quincuncial aestivation. The sepals are often persistent and sometimes accrescent in fruit. Often the outer sepals are larger than the inner ones.

The sympetalous corolla has various shapes. They are frequently funnel-shaped (*Ipomoea*) or campanulate (*Argyreia*), rarely hypocrateriform (*Rivea*), or salver-form (*Quamoclit pinnata*) or tubular to subglobose (*Cuscuta*). The corolla has five strong longitudinal areas tapering from base to apex, corresponding to the middle of the petals and characterized by well-marked longitudinal vascular bundles, alternating with five non-striated weaker triangular areas, which in the bud are folded inwards. The stronger areas are exposed and show a twist towards the right, affording a useful generic character (Rendle, 1925). The limb of the corolla is nearly entire or deeply lobed. The aestivation is distinctively induplicate – valvate except in *Cressa* and *Wilsonia* which possess imbricate corolla lobes. In *Cuscuta*, there is a whorl of scales on the inside of the corolla tube in alternipetalous positions and these are of controversial morphological nature (Tiagi and Kshetrapal, 1976-1977).

The androecium comprises five epipetalous stamens with heterodynamous filaments and with dithecous, introrse and longitudinally dehiscing anthers. In *Cuscuta*, the anthers are attached to the throat of the corolla tube. In *Lepistemon* (Tropical Africa and Asia), the filaments of the stamens are dilated at the base into papillous scales over the ovary. The pollen may be smooth or spinulose.

Gynoecium is bicarpellary syncarpous (rarely 3-5 carpels as in some *Ipomoea* and *Erycibe*). The ovary has as many chambers as carpels and one to two ovules per carpel in axile placentation. This superior ovary has one (*Ipomoea, Convolvulus*) or two (*Evolvulus, Dichondra*) or numerous (*Polymeria* R. Br. of Australia) styles. The style is usually simple and filiform, but sometimes forked (*Evolvulus*). The stigmas vary in number from 204 and are of diverse shapes. They may be globular, ellipsoid, filiform or flattened. In *Erycibe*, the stigma is large and subsessile. There may be a single bi- to trilobed stigma as in *Ipomoea*, or two stigmatic lobes as in *Convolvulus*, or four lobes as in *Evolvulus*. In *Dichondra*, the ovary is deeply divided and the two styles are prominently gynobasic. In *Cuscuta* and *Erycibe*, the style is rather short or practically lacking.

The capsular fruit dehisces regularly by halves (*Ipomoea*). Dehiscence is sometimes irregular or circumsessile. Indehiscent, fleshy fruits are found in *Argyreia* spp. A one-seeded achene with a membranous pericarp occurs in *Porana*. The pericarp is thick in *Erycibe*. A schizocarp is seen in *Dichondra*. The fruit is 1-seeded and matures below the surface of the soil in *Nephrophyllum* (Ethiopia). In *Calycolobus africanus* (G. Don) Heine (tropical Africa), the fruits are enclosed by two enlarged, unequal outer sepals. Seeds may be spherical, hemispherical or shaped like the quadrant of a sphere depending upon the number of ovules that develop into seeds in an ovary. They may be smooth or hairy. The seeds possess a cartilaginous endosperm. Cotyledons are generally folded, sometimes obscure or absent (*Cuscuta*). *Nephrophyllum* has linear and persistent cotyledons above ground.

The family contains about 55 genera and 1650 species (Airy Shaw, 1973). Being primarily a tropical and sub-tropical taxon, it is well represented in India with 15 genera and 150 species (Clarke, 1883). *Ipomoea* is the largest genus of the family with 400 species, mostly lianous, distributed throughout the tropics; *Convolvulus* of more temperature distribution, has about 200 species and *Cuscuta*, the third largest genus is found both in warm and temperate regions with about 100 species (Rendle, 1925). Several new plants have been discovered in recent years and new records have been established in different parts of the world. *Neuropeltopsis alba* from Borneo (Van Ooststroom, 1964), is a new monotypic genus allied to *Neuropeltis* Wall with conspicuous white bracts in lax inflorescences during anthesis. *Dactylostigma* is another new genus from Madagascar (Austin, 1973).

TAXONOMY AND RELATIONSHIPS

The placing of the Convolvulaceae has been variously placed in different schemes of classification. Bentham and Hooker (1865), Bessey (1915), Benson (1970), and Takhatajan (1980) assigned Convolvulaceae to order Polemoniales along with families such as Polemoniaceae, Hydrophyllaceae and Boraginaceae.

Peter (1897) placed this family in order Tubiflorae, which is equivalent to the Gamopetalae of Bentham and Hooker, along with 21 other families. Engler and Diels (1936), followed by Melchior (1964), kept Convolvulaceae in Tubiflorae under a suborder Convolvulinae.

Rendle (1925) segregated the Convolvulaceae from the Tubiflorae as a separate unifamiliar order, the Convolvulales (group – Tetracyclicae; subseries- Superae). According to him, the family Convolvulaceae is distinguished from the Tubiflorae in the placentation of the ovules, presence of latex and the large embryo with folded cotyledons. Wettstein (1935) suggested that the Convolvulales may have had a separate origin from the dialypetalous dicotyledons which gave rise to the Tubiflorae. He regarded them as phylogenetically allied to the Malvales or Geraniales.

Thorne (1968) included this family in his order Solanales (Superorder – Malviiflorae) along with Polemoniaceae and Fouquieriaceae. Hutchinson (1973), who separated Cuscutaceae from Convolvulaceae, also housed the family in Solanales along with Solanaceae, Retziaceae and Nolanaceae. In his opinion, the Convolvulaceae are a climax family of this order, the phylogeny of which is remote and far-removed from Ranales and has perhaps evolved via Saxifragales to Solanales. The Cuscutaceae was kept by him in the Polemoniales along with Polemoniaceae and Hydrophyllaceae. The Cuscutaceae was shown as derived from Ranales, through Caryophyllales, to Polemoniales. Cronquist (1981) brings the Convolvulaceae and Cuscutaceae together as the fourth and fifth families of his order Solanales (subclass – Asteridae).

Convolvulaceae show affinities towards a number of other families with which they have been associated in different systems of classification (Figure 1). The inter-familial relationships are aptly summed up in the statement "it has been widely agreed in the past that the Nolanaceae, Solanaceae and Convolvulaceae are closely related *inter se* that the Polemoniaceae and Hydrophyllaceae form a pair and that these two groups are related to each other. The relationship of the Cuscutaceae to the Convolvulaceae is also generally admitted; indeed the Cuscutaceae have often been submerged in the Convolvulaceae (Cronquist, 1981)".

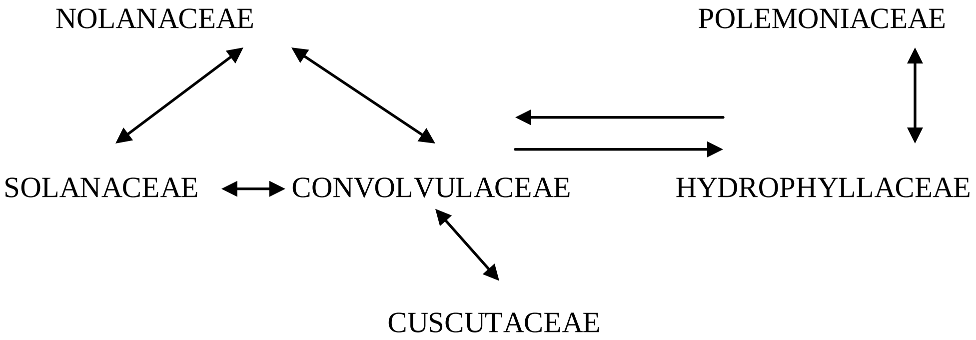

Figure 1: Diagram showing interrelationships of Convolvulaceae with other families

Though considered to be a very homogeneous and therefore a natural taxon by many, diverse opinions have been expressed in relation to the delimitations of the broader subdivision within the Convolvulaceae. Hallier (1893) classified the family into two subfamilies based mainly on the nature of the exine. The subfamily Psiloconiae contained plants having smooth pollen grains whereas the other subfamily Echinoconiae included plants with spiny pollen grains. Peter's (1897) recognition of two subfamilies was based on morphological features such as habit (parasitic/ autotrophic), presence or absence of infrastaminal scales and the presence or absence of cotyledons. Van Ooststroom (1953) and Hegnauer (1964) also recognized the subfamilies Convolvuloideae and Cuscutoideae. Takhtajan (1980) separates Cuscutaceae as a family co-ordinate with Convolvulaceae and perceived three subfamilies, viz., Humbertioideae, Dichondroideae and Convolvuloideae under Convolvulaceae.

Bentham and Hooker (1965) did not group the Convolvulaceae members into subfamilies; instead, they classified the family directly into five tribes, viz., Convolvuleae, Dichondreae, Nolaneae, Cresseae and Cuscuteae based on habit, aestivation of corolla, structure of ovary and style, the type of fruits and their dehiscence. Airy Shaw (1973) preferred to have Cuscutaceae as a distinct family and split the family Convolvulaceae into eight tribes based on corolla (plicae), gynoecium, fruit and pollen characters.

The tribe Convolvuleae of Bentham and Hooker has been subjected to a great deal of shuffling and rearrangement which has resulted in the production of smaller tribes and shifting of some genera to other tribes.. Hallier (1893), Hegnauer (1964) and Airy Shaw (1973) distributed the genera of Convolvuleae over six tribes (belonging to both the subfamilies in the first author's classification)-- the Dicranostyleae, Convolvuleae, Poraneae, Erycibeae, Ipomoeae and Argyreieae. Peter (1897) restricted them to three tribes, viz., Dicranostyleae, Convolvuleae and Erycibeae of his subfamily Convolvuloideae; and Van Ooststroom (1953) included them in just two tribes (but under separate subtribes) of his subfamily Convolvuloideae. Tribes Convolvuleae and Ipomoeae of Van Ooststroom's classification are equivalent to Hallier's subfamilies Psiloconiae and Echinoconiae respectively.

The tribe Dichondreae is maintained by most authors either with both *Dichondra* and *Falkia* or with *Dichondra*, *Falkia* and *Hygrocharis*. But, Van Ooststroom (1953) included *Dichondra* under subtribe Dichondrinae of Convolvuleae. Takhtajan (1980) elevates *Dichondra* to a subfamilial level as Dichondroideae. Dumortier (1829) erected family Dichondraceae including *Dichondra* and *Falkia*. Cronquist (1981) regards *Dichondra* and *Falkia* as two of the three (the third being *Humbertia*) aberrant genera in Convolvulaceae. According to him, the taxonomic rank at which the Dichondraceae should be received is debatable, but its relationships are not in dispute.

Tribe Nolaneae of Bentham and Hooker was excluded from the Convolvulaceae by Hallier, Peter, Van Ooststroom, Hegnauer and Airy Shaw. Dumortier (1829) conceived Nolanaceae with a single genus *Nolana* and included the family in his order Boraginaceae. Many taxonomists incorporate *Alona* also in Nolanaceae and keep this family in the Tubiflorae or related orders, always associating it with the Convolvulaceae and Solanaceae. Thorne (1968) included it in his Solanaceae.

Wilsonia and *Cressa*, two members of the tribe Cresseae of Bentham and Hooker were separated and kept in two distinct tribes of *Psiloconiae* by Hallier (1893). *Wilsonia* was placed in tribe Wilsonieae whereas *Cressa* was in Dicranostyleae along with *Evolvulus* and *Seddera*. Peter (1897) included both the genera in the same tribe Dicranostyleae under subfamily Convolvuloideae along with *Breweria* and *Evolvulus*. Van Ooststroom created a subtribe Wilsoniinae under tribe Convolvuleae.

The tribe Cuscuteae has often been raised to a subfamilial level (Peter, 1897); Van Ooststroom, 1953; Hegnauer, (1964), or to a familial level (Airy Shaw, 1973; Hutchinson, 1973; Takhtajan, 1980; Cronquist, 1981). As a distinct family it is kept under the same order as that of Convolvulaceae or a related one." It is generally agreed that *Cuscuta* is related to and derived from the Convolvulaceae, and many authors include the genus in that family. The differences seem as significant, however, as those separating other recognized families of the order (Cronquist, 1981)". Mukherjee and Bhattacharya (1972) assigned the family Cuscutaceae to a unifamilial order Cuscutales.

One of the most striking features of the family Convolvulaceae is the very fluid state of boundaries or limits separating adjoining genera. These generic delimitations in an otherwise very natural family are ambiguous and often single characters which are relatively irrelevant by other standards have been used for their circumscription. Contradictory views have been held with regard to the position, circumscription and subdivision of many genera (Table 2).

Bentham and Hooker (1865) classified *Ipomoea* into fourteen sections, viz., Calonyction, Exogonium, Quamoclit, Marcellia, Operculina, Pharbitis, Aniseia, Batatas, Spiranthera, Ipomoea, Skinneria, Calycanthemum, Bombycosperma *and* Erythrostamna. The section Ipomoea consisted of the series Orthipomoea, Erpipomoea and Strophipomoea. Clarke (1883) raised five of these sections, viz., Calonyction, Quamoclit, Pharbitis, Aniseia, and Batatas to the subgeneric status and designed a sixth subgenus Euipomoea to include all the species of *Ipomoea* not distinctly referable to any of his five preceding subgenera. These subgenera were segregated based on shape, size and colour of corolla, size of sepals, the inserted or exserted nature of stamens and the number of locules in the ovary. According to him, Aniseia is not very distinct from Euipomoea in that both of them have larger outer sepals. Hallier (1893) raised the subgenera Aniseia, Operculina, Calonyction, and Quamoclit to the generic rank along with *Ipomoea*.

Peter (1897) raised Exogonium and Pharbitis along with the above four sections, as distinct genera. He subdivided Quamoclit into Euquamoclit and Calboa; and Ipomoea into Orthoipomoea, Erpipomoea, and Strophipomoea. Van Oostsroom (1953) recognized only seven sections under *Ipomoea*, viz., Calycanthemum, Pharbitis, Batatas, Leiocalyx, Calonyction, Quamoclit, and Eriospermum on the basis of habit, leaf, calyx and corolla traits. Aniseia and Operculina were raised to the generic status and kept in subtribe Convolvuleae while Ipomoea was in tribe Ipomoeeae.

The genus *Merremia* was recognized by Hallier (1893). He separated it from *Ipomoea* almost entirely on the basis of its non-spinulose pollen grains and the five distinct mid-petaline bands of corolla. *Merremia* was grouped in Psiloconieae, away from *Ipomoea* which was kept in Echinoconieae. He recognized several sections of *Merremia*, namely Skinneria, Xanthips, Streptandra and Hailale. Van Ooststroom (1953) replaced the name Skinneria by EuMerremia and established a fifth section Wavula. The sections were separated based on shape of flower buds, size of flowers, presence or absence of five dark lines in the mid-petaline bands, the habit and inflorescence characters. Roberty (1952) maintained the genus *Merremia* and recognized three sub-genera EuMerremia, Spiranthera and Operculina in it. Both in Hallier's initial concept of *Merremia* and in Roberty's classification also, the delimitation of *Merremia* from *Operculina* was not clear. In Van Ooststroom's opinion, the name *Operculina* could be retained for those species having a very characteristic fruit where the epicarp splits around the middle, the lid separates from the lower part and the endocarp bursts irregularly. Two species formerly considered members of *Merremia* have recently been found to fall outside an acceptable range of variations for the genus and a new genus *Xenostegia* has been proposed for these two species — *X. tridentata* comb.nov. and *X. medium*.comb.nov (Austin and Staples, 1980).

The genus *Argyreia* was formulated by Loureiro in 1790. Clarke (1883) classified *Argyreia* (in Bentham and Hooker's Convolvuleae) into sections Pomifera and Euargyreia based mainly on features of size and shape of sepals. Peter (1897) also placed it in Convolvuleae recognizing Orthargyreia and Strophargyreia on the basis of the upright or twining nature of the stalks or branches. Hallier (1893) separated the genus *Stictocardia* from *Argyreia* (both in tribe Argyreieae) because of its habit, the winged fruit which is completely enclosed by the much expanded calyx and the leaves which are strewn with minute glands. Van Ooststroom (1953) also recognized *Stictocardia* while dividing *Argyreia* (*Lettsomia* and *Moorcroftia* included) into sections Ptyxanthus and Schizanthus based on the corolla lobes and the included or exserted stamens and style.

Choisy (1833) established the genus *Rivea* from the species of *Lettsomia* with linear oblong stigmas and with indehiscent dry fruit. Later he added several American species of *Ipomoea* to it all with big lobular stigmas) and the natural limits of *Rivea* became blurred. The genus *Rivea* is distinct from *Argyreia* by its linear to oblong stigmas and from *Ipomoea* by the same character and the indehiscent fruit (Van Ooststroom, 1943).

Convolvulus, *Hewittia* and *Jacquemontia* are maintained by all in Convolvuleae. Bentham and Hooker divided *Convolvulus* into Rhodorhiza and Pantocsekia on the characters of the capsular fruit. Peter divided *Convolvulus* into Orthocaulos and Strophocaulos on the basis of the upright or twining nature of the plants. A new genus *Odonellia* has been described from tropical America to accommodate two species previously included within *Jacquemontia* (Robertson, 1982).

Gray (1862) suggested the fusion of the genus *Breweria* with *Bonamia*, the older name *Bonamia* being retained for the combined genus. Bentham and Hooker (1865), Clarke (1883) and Peter (1897) did not accept this fusion and kept the two genera separate. Hallier (1893), Merrill (1923-1926) and Van Ooststroom (1953) followed Asa Gray in lumping together the two genera. Bentham and Hooker divided *Breweria* into five sections viz., Seddera, Stylisma, Duforea, Trichantha and Codonanthus with the help of habit and sepal characters. Peter accepted three sub-genera under *Breweria*, namely Stylisma, Eubreweria and Seddera, raising thereby two of Bentham and Hooker's sub-sections to the sub-generic level. While Bentham and Hooker made *Seddera* a section of *Breweria* and Peter had it as a sub-genus, O.Kuntze (1891-1898) placed all the species of *Seddera* under *Convolvulus* and both Van Ooststroom (1938) and Santapau (1947) combined *Breweria* and *Seddera* under *Bonamia*.

The difficulties in separating the various genera in Convolvulaceae prompted some of the Kew botanists to suggest a practical working idea of grouping together of most of the Convolvulaceae under *Ipomoea* and *Convolvulus* as Linnaeus did in his *Species Plantarum*. From the point of the practical systematist,

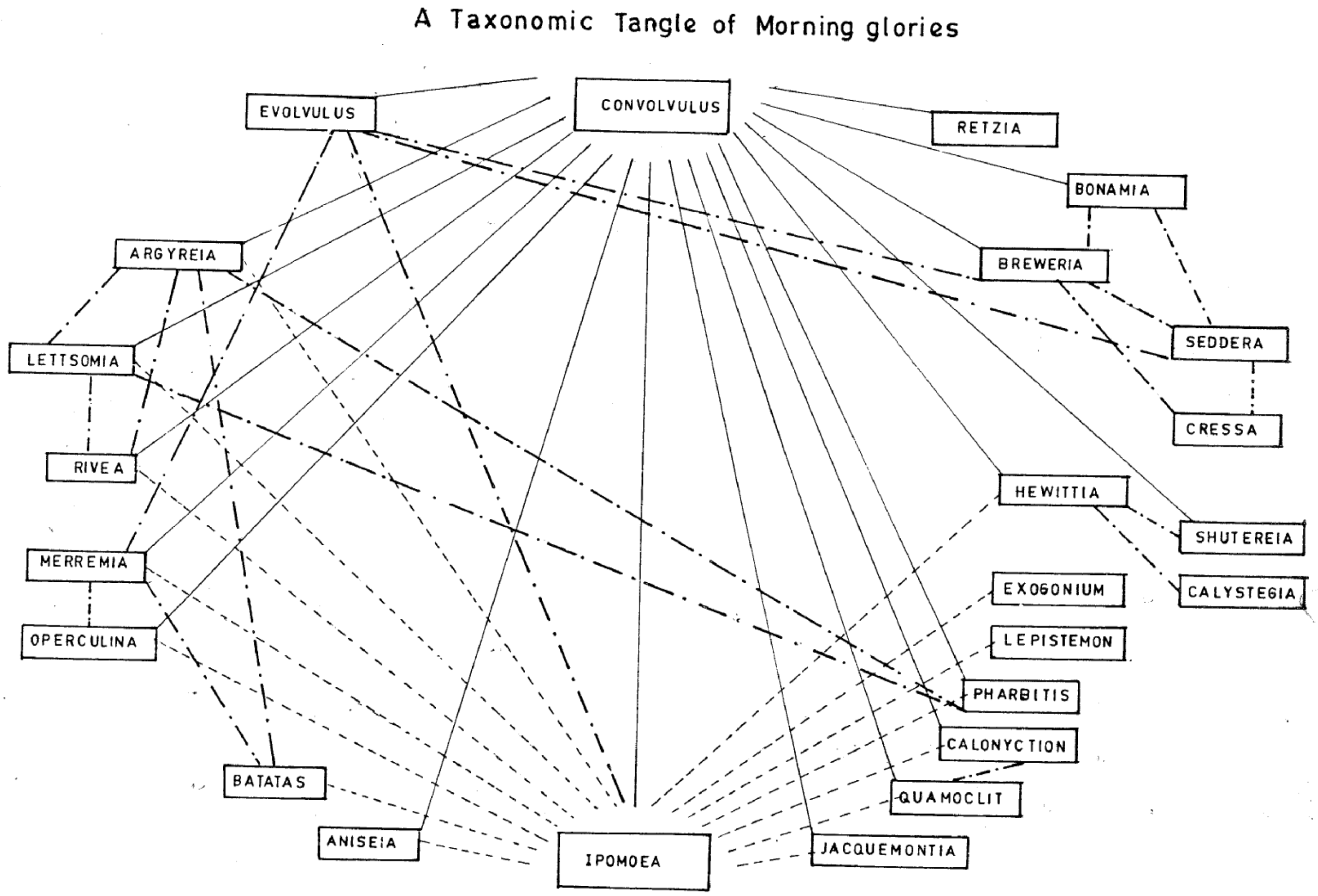

Figure 2: Generic synonymies in the Convolvulaceae

the result of this confusion is that there is scarcely a genus of the Indian Convolvulaceae that has not been placed at one time or another under a number of different genera(cf. Santapau, 1947). Variable synonyms have been inevitable due both to the ill-defined generic limits as well as intraspecific polymorphism (Also see Van Oosstroom, 1963; Skinners, 1965; Myint and Daniel, 1968; Powell *et al*., 1978; Austin, 1970, 1971, 1977; Brummit, 1980). These synonymies complicate the problem of nomenclature almost to limits of endurance for the systematist. The generic synonymies in the Convolvulaceae are graphically represented in Figure 2.

Subspecies and varieties are very common in this natural family. This is particularly so in the genera *Ipomoea* and *Merremia*.

MATERIALS AND METHODS

Fifty nine members belonging to eighteen genera of the Convolvulaceae were surveyed for chemical markers such as flavonoids, quinones, phenolic acids, tannins, iridoids, saponins and alkaloids. The various genera and the number of species studied under each were as flows: *Aniseia* (1), *Argyreia* (4), *Breweria* (1), *Convolvulus* (2), *Cressa* (1), *Cuscuta* (2), *Dichondra* (1), *Erycibe* (1), *Evolvulus* (2), *Hewittia* (1), *Ipomoea* (25), *Jacquemontia* (2), *Merremia* (9), *Operculina* (1), *Porana* (3), *Rivea* (1), *Seddera* (1) and *Stictocardia* (1),

Most of the plants were procured from localities in and around Baroda. The plants procured from other places were *Argyreia cuneata* and a white-flowered variety of *Ipomoea cairica* (from Waghai Botanical Gardens); *Argyreia cymosa* (from Aurangabad); *Porana paniculata* (from Mahabaleswar); *Seddera latifolia* (from Kutchh); *Aniseia*, *Breweria*, *Erycibe*, *Hewittia*, *Stictocardia* and a few *Merremia* species (from Kerala); and *Dichondra repens* (from West Bengal). Voucher specimen of all the plants have been deposited in the Herbarium of the M.S.University of Baroda, Baroda.

Mature leaves were analysed for phenolics and other chemical markers, the stem parts for alkaloids, and the ripened seeds were used for screening and estimation of ergolines and lipids.

The various plant parts were separated and dried. Mature fruits were collected and the seeds separated. All the dried plant parts were ground to a fine powder in a grinder or blender. Powders were stored in air-tight glass containers or in sealed plastic bags. Analytical procedures for the various groups of compounds followed were as given by Harborne *et al* (1984).

Ethnobotanical data were collected through literature survey and discrete queries at the time of plant collection.

RESULTS

The available chemical data were sporadic and were insufficient for chemotaxonomic assessment. Therefore, in the present work, a systematic screening of all available members of Convolvulaceae for leaf phenolics and other chemical markers has been carried out. These data in combination with evidences from a number of other disciplines have been used to understand the inter- and intra-familial relationships of the family and to assess its taxonomic status.

The data gathered from the phytochemical and literature survey have been utilized to make a chemotaxonomical assessment of the family and of genera and species within family (Tables 1-3). New sources of flavonoids, quinones, saponins, lipids and alkaloids have been unearthed (Table 4). 10-15 plants of ethnobotanical interest also are recorded from surrounding localities.

Table 1: Comparative account of the embryology, anatomy and palynology and chemistry of the convolvulaceae and cuscutaceae

Convolvulaceae	**Cuscutaceae**
I. Embryology	
1. Parietal cell present or absent in the nucellus. 2. Development of embryo-sac is monosporic and Polygonum type. 3. Development of embryo Caryophyllad, Solanad or Onagrad type. 4. Mature embryo well developed with folded cotyledons.	Parietal cell absent Mono or bisporic and Allium type origin of the embryo-sac. Development of embryo is Solanad type. Filiform, spirally coiled embryo without differentiation into cotyledons.
II. Anatomy	
1. Bicollateral vascular bundles with intraxylary phloem. 2. 'gaine nourriciere' absent	Simple collateral vascular bundles showing absence of intraxylary phloem. 'gaine nourriciere' or a peculiar sheath of cells with abundant protoplasmic contents develop as a

	complete envelope to the individual vascular bundles.
3. Glandular and non-glandular hairs present.	Glandular hairs absent.
4. Clothing hairs simple, or 2-armed, or Y-shaped, or T-shaped.	Clothing hairs simple and with one or two cells
5. Stomata widely distributed, mostly rubiaceous, some times cruciferous or ranunculaceous.	Stomata lesser in number. They are invariably perigynous.
6. Seed-coat exotestal with a pad-like structure.	Seed-coat exotestal without a pad-like structure.
7. Seed-coat is thick.	Thin seed-coat.
III. Palynology	
1. Pollen pantoporate/spinous/smooth walled zonicolpate.	Pollen smooth walled and zonicolpate.
2. Pollen shed at 2-celled or 3-celled stage.	Pollen shed at 2-celled stage.
IV. Karyology	
1. Smaller chromosomes with 15 as the basic chromosome number. Polyploidy observed in many taxa.	Exceptionally large-sized chromosomes with 7 or 15 as the basic chromosome numbers.
V. Chemistry	
1. Flavonols, proanthocyanins, flavanones, glycoflavones and flavones.	Flavonols only.
2. Seeds rich in fat content.	Seed fats in traces
3. *Glycolipids present	Glycolipids absent
4. Both benzo and naphthoquinones	Naphthoquinones only
5. Uncommon phenolic acids common.	Uncommon phenolic acids rare or absent
6. Ergolines yellow and blue fluorescing.	Ergolines blue fluorescing.

***cf. Wagner. 1974*

Table 2: Chemistry of Convolvulaceae and related families (Harborne, 1967; Gibbs, 1974)

Compounds	**Polemoniaceae**	**Fouquieriaceae**	**Hydrophyllaceae**	**Boraginaceae**	**Nolanaceae**	**Solanaceae**	**Convolvulaceae**	**Saxifragaceae**
Flavones/-ols	*-ols	-ols	-ols	-ols	-ols	-ols	-ols	-ols
Proanthocyanins	-	-	-	-	-	-	+	+
Tannins	-	+	+(?)	+	-	+	-	+
Quinones	-	●	-	+	●	-	+	+
Ellagic acid	●	+	●	●	●	●	●	●
Caffeic acid	●	+	+	+	+	+	+	+
Sinapic acid	+	●	●	+	●	+	+	+
Ferulic acid	+	+	+	+	●	+	+	+
p-coumaric acid	●	+	●	+	●	+	+	+
Gentisic acid	●	●	●	+	●	+	+	+
p-OH benzoic acid	●	●	●	●	●	+	+	+
Coumarins	+(?)	+(?)	●	●	●	+	+	+

Orobanchin	●	●	●	●	●	-	●	●
Saponins	+	+	+	+	●	+	+	-
Iridoids	-	+	-	-	-	-	-	+
Alkaloids	●	●	●	+	●	+	+	+

** -ols - Flavonols; ● - No reports; + - Present; - - Absent*

Table 2a: Distribution of flavonoids in different sub-genera of *Ipomoea*

Subgenus 1. Calonyction
I. turbinata - Flavonols

Subgenus 2. Quamoclit
I. hederifolia - Flavonols; proanthocyanins
I. quamoclit - Flavones

Subgenus 3. *Pharbitis*
I. nil - flavones
I. diversifolia - flavonols

Subgenus 4. *Aniseia*
Aniseia martinicensis - flavonoids absent
I. sinensis - flavonoids absent

Subgenus 5. *Batatas*
I. mauritiana - flavonols
I. batatas - flavonols
Merremia aegyptia - flavonols; flavones (C-glyco.)

Subgenus 6. *Euipomoea*
I. pestigridis (lobed & unlobed) - flavanones

I. obscura - flavonols
I. sepiaria var. sepiaria - flavonols; Proanthocyanins
I. sepiaria var. stipulacea - flavonols
I. aquatica - flavonols
I. pes-caprae s.sp.pes-caprae - flavonols
I. pes-caprae s.sp.brasiliensis - flavonoids absent
I. arachnosperma - flavones
I. cairica (pink-flowered type) - flavonols
I. cairica (white-flowered type) - flavonoids absent
Merremia hederacea - flavonols
M. tridentata s.sp.tridentata - flavones (O-and C-glyco); Proanthocyanins
M. dissecta - flavonols; flavones (C-glyco)
M. gangetica - flavonols; proanthocyanins
Operculina turpethum - flavones

Table 2b: Categorisation of species of *Ipomoea* into phylogenetic groups based on flavonoid chemistry

1. The primitive group with both flavonols and proanthocyanins
   - *I. hederifolia*
   - *I. carnea s.sp.fistulosa*
   - *I. sepiaria var.sepiaria*
   - *I. sindica*

2. The intermediate group with either flavanones or flavonols
   - *I. pes-caprae s.sp.pes-caprae*
   - *I. obscura*
   - *I. indica*
   - *I. pes-tigridis* (lobed & unlobed)
   - *I. aquatica*
   - *I. batatas*
   - *I. cairica* (pink-flowered type)
   - *I. mauritiana*
   - *I. sepiaria var. stipulacea*
   - *I. diversifolia*
   - *I. turbinata*

3. Advanced group with only flavones
   - *I. arachnosperma*
   - *I. nil*
   - *I. quamoclit*

4. The highly advanced group with the total lack of flavonoid system
   - *I. sinensis*
   - *I. triloba*
   - *I. cairica* (white-flowered type)
   - *I. pes-caprae s.sp. brasiliensis*
   - *I. pulchella*

The *Merremia* species studied during this investigation belong to two sections.

Table 2c: Flavonoid constitution of *Merremia* spp.

Section 1.	Eu-Merremia		
	M. gangetica	-	flavonols; proanthocyanins
	M. hederacea	-	flavonols
Section 2.	Streptandra		
	M. tuberosa	-	flavonols
	M. aegyptia	-	flavonols; glycoflavones
	M. dissecta	-	flavonols; glycoflavones
	M. tridentata s.sp.*hastata*	-	flavones; proanthocyanins
	M. tridentata s.sp.*tridentata*	-	flavones; glycoflavones; Proanthocyanins
	M.quinquefolia	-	flavonoids absent

Table 3: A synoptical key to the genera of CONVOLVULACEAE and CUSCUTACEAE based on the present study

Parasitic leafless plants containing flavonols, quinones, abundant saponins and seed ergolines; flavanones, proanthocyanins, flavones (0- and C-glycosides), and glycolipids absent; basic chromosome number n=7; embryo coiled like a watch-spring and without cotyledons; 'gaine nourriciere' present and intraxylary phloem absent.

………. 1. *Cuscuta*

Non-parasitic plants, leaves present; a variety of flavonoids ranging from proanthocyanin and flavanones to flavonols and flavones (0- and C-glycosides), saponins, quinones, glycolipids, ergolines, tropanes, hexahydroindolizines and protoberberines present; basic chromosome number n=15; embryo with folded and well-developed cotyledons; 'gaine nourriciere' absent and intraxylary phloem present.

a. Fruits indehiscent.
  b. Style 0, stigma 5-10 ridged; proanthocyanins, flavonols and quinones present; saponins absent.
………. 2. *Erycibe*
  b. Style present, filiform.
  c. Flavonoids and saponins present.
    Corolla infundibuliform or tubular, hirsute externally, rose-purple in colour, globose stigmas; n=14 and 15; pollen with spines having straight bases and pointed tips.
………. 3. *Argyreia*

  c. Flavonoids and saponins absent; quinones present.
    d. Corolla hypocrateriform, white or creamy white, stigmas elliptic-oblong; n=15; pollen wih spines having bulbuous bases and swollen tips.
………. 4. *Rivea*
    d. Corolla widely infundibuliform, fruit characteristic and enclosed by sepals; large, external glands on the lower side of leaf.
………. 5. *Stictocardia*

a. Fruits dehiscent.
  e. Stems winged, dehiscence opercular; only flavones present.
……….. 6. *Operculina*

  e. Stems not winged, fruit dehiscence valvular; a variety of flavonoids seen or flavonoids absent.
    f. Style 1; habit usually twining.
      g. Stigma 1
        h. Flavonoids absent.
          i. Sepals ovate, outer sepals larger than inner and enlarged in fruit; saponins present.
……….7. *Aniseia*
          i. Sepals acute, outer ovate and inner lanceolate, enlarged in fruit; saponins absent.
………. 8. *Hewittia*
        h. Flavonoids present.
          j. Sepals ovate; presence of flavanones; proantho

cyanins/flavonols/flavones (0-glycosides); glycoflavones absent; pollen spiny.
………. 9. *Ipomoea*

J. Sepals acuminate; presence of proanthocyanins/flavonols/flavones (0-glycosides), and glyco-flavones; flavanones absent; pollen smooth.
  k. Co-occurrence of flavonols and flavones (0- and C-glycosides); pollen colpate or rugate; 2 veins running parallel to each other in the cotyledons and the presence of basal sinus.
………..10. *Merremia*

  k. Co-occurrence of proanthocyanins and flavones (0- and C-gylcosides); pollen pantoporate; cotyledonary leaves with one vein in each leaf and without a basal sinus.
…….11. *Xenostegia*

g. Stigmas 2, distinct.
  1. Shape of stigmas flattened and elliptic, or linear or oblong; saponins absent.
    m. Presence of flavonols and seed-ergolines; other flavonoids and quinones absent; n=9; pollen pantoporate and sub-prolate.
……...12.*Jacquemontia*

m. Presence of flavonols, proanthocyanins and quinones; other flavonoids and seed ergolines absent; a graded series of basic chromosome numbers; subprolate spheroidal pollen with reticulate exine.
…13 *Convolvulus*

  1. Stigmas capitate; saponins present, or absent.
    n. Fruit 1-seeded; quinones present, Rarely absent; n=13 and 14.
……….14. *Porana*

n. Fruit 4-seeded; quinones absent; n=14 and 15.
………15. *Breweria*

f. styles 2; prostrate to semi-erect and erect habit.

o. Origin of styles from between the lobes of the ovary; presence of laticiferous vessels.

…….16. *Dichondra*

o. Origin of styles from the apex of the ovary; absence of laticiferous vessels

p. Flavonoids present.

q. stigmas subclavate; presence of proanthocyanins and glycoflavones.

………. 17. *Evolvulus*

q. stigmas orbicular; presence of only proanthocyanins

………..18. *Seddera*

p. Flavonoids absent

………..19. *Cressa*

Table 4: New chemical reports

Sl.No.	**Type of compound**	**Name of compound**	**Source plant, genus and species**
1	Flavonoids	Apigenin	*Argyreia sericea, Operculina turpethum*
2	Flavonoids	4'OMe Apigenin (acacetin)	*Ipomoea nil, Merremia tridentata s.sp. hastata*
3	Flavonoids	5-OMe Apigenin	*Ipomoea quamoclit*
4	Flavonoids	7-OMe Apigenin (genkwanin)	*Merremia tridentata s.sp. tridentata*
5	Flavonoids	Luteolin	*Ipomoea arachnosperma, Merremia tridentata s.sp. tridentata, Operculina turpethum*
6	Flavonoids	3'-OMe Luteolin (chrysoeriol)	*Argyreia sericea, Ipomoea arachnosperma*
7	Flavonoids	4'-OMe Luteolin (diosmetin)	*Merremia tridentata s.sp. hastata*
8	Flavonoids	7-OMe Luteolin	*Ipomoea nil*
9	Flavonoids	3',4'-DiOMe Luteolin	*Operculina turpethum*
10	Flavonoids	Kaempferol	*Ipomoea diversifolia, Ipomoea turbinata, Merremia gangetica*
11	Flavonoids	4'-OMe Kaempferol (kaempferide)	*Convolvulus prostratus, Erycibe paniculata var. wightiana, Ipomoea diversifolia, Ipomoea turbinata, Merremia gangetica*
12	Flavonoids	7-OMe Kaempferol (rhamnocitrin)	*Ipomoea turbinata*
13	Flavonoids	Quercetin	*Argyreia cuneata, Argyreia nervosa, Breweria cordata, Erycibe paniculata var. wightiana, Ipomoea hederifolia, Ipomoea indica, Ipomoea obscura, Jacquemontia paniculata, Merremia aegyptia, Merremia tuberosa, Porana volubilis*
14	Flavonoids	3'-OMe	*Argyreia cymosa, Convolvulus arvensis, Ipomoea sepiaria var.*

		Quercetin (isorhamnetin)	*stipulacea, Ipomoea carnea s.sp. fistulosa, Merremia aegyptia, Merremia gangetica*
15	Flavonoids	4'-OMe Quercetin (tamarixetin)	*Convolvulus arvensis, Ipomoea aquatica, Ipomoea hederifolia, Ipomoea mauritiana, Ipomoea sepiaria var. sepiaria, Ipomoea carnea s.sp. fistulosa, Jacquemontia paniculata, Jacquemontia pentantha*
16	Flavonoids	7-OMe Quercetin (rhamnetin)	*Convolvulus prostratus, Cuscuta chinensis*
17	Flavonoids	3',4'-DiOMe Quercetin	*Argyreia cymosa, Breweria cordata, Erycibe paniculata var. wightiana, Ipomoea batatas, Ipomoea cairica* (pink-flowered type), *Ipomoea hederifolia, Ipomoea indica, Ipomoea mauritiana, Ipomoea obscura, Ipomoea pes-caprae s.sp. pes-caprae, Ipomoea sepiaria var. sepiaria, Ipomoea sindica, Merremia dissecta, Merremia hederacea, Porana volubilis, Dichondra repens, Cuscuta chinensis*
18	Flavonoids	7,3',4'-triOMe Quercetin	*Ipomoea cairica* (pink-flowered type), *Merremia dissecta*
19	Flavonoids	3,3',4'-triOMe Quercetin	*Merremia hederacea*
20	Flavonoids	6- and /8-glucosyl acacetin (flavone-C-glycosides)	*Evolvulus alsinoides, Evolvulus nummularius, Merremia aegyptia, Merremia dissecta, Merremia tridentata s.sp. tridentata*
21	Flavonoids	Flavanones	*Ipomoea pes-tigridis* (lobed and unlobed types)
22	Flavonoids	Proanthocyanins	*Erycibe paniculata var. wightiana, Evolvulus nummularius, Ipomoea hederifolia, Ipomoea sepiaria var. sepiaria, Ipomoea sindica, Merremia sp., Merremia gangetica, Merremia tridentata s.sp. hastata, Merremia tridentata s.sp. tridentata, Seddera latifolia*

Sl.No.	**Type of compound**	**Name of compound**	**Source plant, genus and species**
23	Quinones	-	*Aniseia martinicensis, Argyreia cuneata, Argyreia cymosa, Convolvulus arvensis, Convolvulus prostratus, Erycibe paniculata var. wightiana, Evolvulus alsinoides, Evolvulus nummularius, Hewittia sublobata, Ipomoea aquatica, Ipomoea batatas, Ipomoea cairica* (white-flowered type), *Ipomoea clarkei, Ipomoea hederifolia, Ipomoea obscura, Ipomoea pes-caprae s.sp. pes-caprae, Ipomoea pes-trigridis* (lobed type), *Ipomoea pulchella, Ipomoea sepiaria var. sepiaria, Ipomoea sepiaria var. stipulacea, Ipomoea sinensis, Merremia tuberosa, Merremia gangetica, Porana sp., Porana paniculata, Rivea hypocrateriformis, Seddera latifolia, Stictocardia tiliaefolia, Dichondra repens, Cressa cretica, Cuscuta chinensis, Cuscuta reflexa*
24	Saponins	-	*Evolvulus alsinoides, Ipomoea diversifolia, Cuscuta reflexa* *Argyreia sericea, Evolvulus nummularius, Ipomoea aquatica,*

			Ipomoea cairica (pink-flowered type), *Ipomoea pes-caprae s.sp. brasiliensis, Ipomoea sepiaria var. stipulacea, Merremia gangetica, Operculina turpethum, Porana volubilis, Cuscuta chinensis* *Aniseia martinicensis, Ipomoea batatas, Ipomoea carnea s.sp. fistulosa, Ipomoea pes-tigridis* (unlobed), *Ipomoea triloba, Merremia tuberosa, Merremia dissecta, Merremia hederacea*
25	Phenolic acids	Caffeic acid Phloretic acid o-Coumaric acid trans-p-Coumaric acid 2-OH, 4-OCH$_3$ benzoic acid trans-Ferulic acid Chlorogenic acid β-Resorcylic acid α-Resorcylic acid 3-OH, 5-OCH$_3$ Benzoic acid Sinapic acid	*Dichondra repens* *Aniseia martinicensis, Merremia tridentata s.sp. tridentata* *Convolvulus arvensis, Merremia quinquefolia* *Ipomoea hederifolia, Ipomoea sepiaria var. stipulacea* *Ipomoea quamoclit. Ipomoea sinensis, Ipomoea indica, Ipomoea nil, Merremia tridentata s.sp. tridentata* *Ipomoea pes-caprae s.sp. pes-caprae* *Ipomoea sindica, Ipomoea indica, Ipomoea nil, Merremia tridentata s.sp. tridentata* *Ipomoea turbinata* *Merremia dissecta* *Merremia dissecta* *Merremia quinquefolia*
26	Seed fats	-	*Ipomoea sindica, Ipomoea pes-tigridis, Ipomoea nil, Ipomoea aquatica, Ipomoea turbinata* *Ipomoea hederifolia, Ipomoea sepiaria var. stipulacea, Jacquemontia paniculata, Evolvulus nummularius, Ipomoea sepiaria var. sepiaria, Argyreia nervosa, Ipomoea obscura, Convolvulus prostratus, Rivea hypocrateriformis, Cuscuta chinensis, Ipomoea cairica*
27	Alkaloids		Stem of *Aniseia martinicensis, Ipomoea hederifolia, Ipomoea aquatica, Ipomoea carnea s.sp. fistulosa, Ipomoea pes-tigridis* (lobed), *Ipomoea sinensis, Evolvulus alsinoides, Evolvulus nummularius, Jacquemontia paniculata, Jacquemontia pentantha, Merremia sp., Merremia quinquefolia, Operculina turpethum, Porana paniculata, Rivea hypocrateriformis.* *Seeds of Ipomoea turbinata, Ipomoea obscura, Ipomoea pes-trigridis, Argyreia nervosa, Jacquemontia paniculata, Ipomoea turbinata.*
28	Amino acids	Tryptophan	*Evolvulus nummularius*

Table 5: Plants of Ethnobotanical interest in Convolvulaceae

	Botanical Name	**Local Name**	**Locality**	**Uses**
1.	*Argyreia speciosa* Sweet	Samudrashosh	Piprol Dharampur	Seeds are used as tonics. The silvery hairy lower part of the leaf is applied for opening boils and the upper part is used for healing wounds.
2.	*Convolvulus microphyllus* Sieb.ex.Spreng.	Safedsankhavali	Surpaneswar Nalsarowar	The plant and flower decoction are used as brain tonic
3.	*Cressa cretica* L.	Bothi	Daman	Plant powder in water is given internally to cure cough.
4.	*Cuscuta reflexa* Roxb.	Maragvel Amarvel Jivarakhu	Dhamni Dharampur Athal Bardipada (Dangs)	Plant juice is used to cure poultry diseases; plant paste is made warm and applied on the stomach to relieve pain.
5.	*Evolvulus alsinoides* Linn.	Fudardi	Dikthali forests near Khedbrahma (N. Gujarat)	Root paste is taken with sugar to work as an aphrodisiac. Leaf juice is applied on ulcers caused by worms.
6.	*Ipomoea aquatica* Forsk.	Velanalo	Veerpur tank and Vijayanagar (N. Gujarat)	Leaves used as vegetable; warm leaf juice is applied in obstructed urine and kidney troubles.
7.	*Ipomoea calycina* C.B.Cl.	Mankaliyu Bhamaradi	Ambadungar Padhara	Leaves are used as vegetables. Leaves cooked in boiling water are applied on boils especially during monsoon.
8.	*Ipomoea fistulosa* Mart.	Phulvel	Poshina Attarsuba	Young leaves are used as vegetables. Leaves after boiling are applied on wounds to remove guinea worms.
9.	*Ipomoea obscura* Ker.Gawl.	Phudadiyo	Poshina (N. Gujarat) Bindrabin	The leaf juice is mixed with pure ghee and taken internally for the treatment of diphtheria.
10.	*Ipomoea petaloidea* Chois.	Nevoto	Neenwada (Songadh)	Leaves, mixed with pulses, form a food supplement. Root paste in water is given internally to cure vomiting.
11.	*Ipomoea sepiaria* Koen.	Ratavo Fudadiya	Mankadbandh Dharampur (S. Gujarat) Athal	Root paste used to cure boils. Root juice is added to country liquor to remove flatulence or gases.
12.	*Jacquemontia paniculata* Wall.	Kaliudadi	Pavagadh	Leaf juice mixed with water is given internally as an antipyretic – also used to relieve stomach ache.
13.	*Merremia emarginata* Hallier.f.	Underkani	Lunawada	Leaves are used as vegetables.

14.	*Merremia turpethum* (L.) Shah & Bhatt	Nasotar Ratuva	Songadh Kaprada	Root paste is given in constipation. The stem pieces are tied around the neck in ulcers and boils of feet and hands.
15.	*Rivea hypocrateriformis* Choisy	Faangu Faang Bhangbhaji Odbhaji	Lunawada Visavadar Hill (Saurashtra) Athal	Leaves are used as vegetables.

DISCUSSIONS

The predominance of flavonols, quinones, benzoic acids, and ergolines reflects the close chemical affinity existing among various members of the Convolvulaceae. Glycolipids form another group of compounds prevalent in the family but for the genus *Cuscuta*. The uniform absence of 6-hydroxylated flavones, chalcones, aurones, iridoids and tannins gives additional evidences linking the members of this large family together

The genus *Cuscuta* strikes a discordant note in the family in having no glycolipids, a group of compounds characteristic of this family. Apparently, one may not attach much weightage to this exception. However, when coupled with the overwhelming differences this genus exhibits in its morphology, embryology, anatomy, karyology and palynology from other Convolvulaceae members, it definitely plays a major role in deciding various relationships of various members in question.

Glycolipids may be considered to be the end products of a special biosynthetic pathway developed late in evolution in the family Convolvulaceae where aberrant pathways like those of ergolines operate. The absence of these compounds definitely denotes a deviation in the genetic machinery of *Cuscuta* from that of the remaining Convolvulaceae members.

Cuscuteae, the unigeneric tribe, is elevated to a family status on morphological grounds such as the mode of nutrition, lack of chlorophyll, the markedly different imbricate aestivation of corolla, the presence of scale leaves instead of foliage leaves, and the presence of scales at the base of the stamens. Data from various other disciplines which are presented in a tabular form (Table 1) also are strongly in favour of the creation of a separate family for the genus *Cuscuta*.

All the mentioned characters in Table 1 further edify the concept of Cuscutaceae. The unique occurrence of ergolines in Convolvulaceae and their presence in Cuscutaceae as well suggests that these two families are very closely related and that they may have evolved from a common ancestor. The abundance of saponins and the absence of iridoids and tannins further bind them together under a common taxonomic category. The creation of a separate order containing only the two families Convolvulaceae and Cuscutaceae, as practised by Takhtajan (1980), seems logical and is thus supported.

The Convolvulaceae exhibit a closer chemical affinity with the Boraginaceae, Solanaceae and Polemoniaceae (Table 2). The similarities between these families are evident in the presence of flavonols as the dominant flavonoids, the occurrence of caffeic acid, and the absence of iridoids.

The Saxifragaceae of Saxifragales, an order which is considered by Hutchinson as the taxon from which the Convolvulaceae have been derived, resemble the Convolvulaceae chemically in the occurrence of flavonols, proanthocyanins, caffeic, sinapic, ferulic, p-coumaric, gentisic and p-hydroxy benzoic acids, coumarins (especially the isocoumarin bergenin) and alkaloids (cf. Gibbs, 1974). Thus the derivation of the Convolvulaceae from the Saxifragales, a concept put forward by Hutchinson, finds support from chemical evidences.

The absence of saponins and the occurrence of caffeic acid (not found in any of the other member of the Convolvulaceae) delineate *Dichondra* from the Convolvuleae and the Cuscuteae. It is distinct from Cresseae in showing the presence of 3’-4’ diOMe flavonol. The chemical data thus comply with the concept of Dichondreae. Unusual basic chromosome numbers of n=12 and n=15 (Vij *et al.*, 1977) and the occurrence of laticiferous vessels as compared to only secretory cells in the rest of the family (Solereder, 1908b) also justify the tribal status accorded to *Dichondra*. The presence of caffeic acid is significant in that it forms the aglycone part of orobanchin, a glycoside characteristic of Scrophulariaceae. The occurrence of caffeic acid, flavonols and of naphthoquinones, brings *Dichondra* closer to Boraginaceae where these compounds are predominant. Coupled with the presence of a gynobasic style, these features point to the possibility of deriving Boraginaceae from the Convolvulaceae through Dichondreae.

Cresseae is characterised by the total absence of the flavonoid system and is quite distinct from all the other tribes. *Cressa cretica* lacks the saponins and stem alkaloids seen in Convolvuleae and Cuscuteae. The elevation of this genus to the tribal level is thus validated. Morphological features like the unique habit; cytological
characteristics such as the uniform occurrence of n = 14, and the stability of the taxon at the diploid level (Baquar and Hussain, 1965; Murin and Chaudhari,1970; Vij *et al.*, 1977); the tricolpate and elliptic pollen grains (Vij and Sachdeva, 1974; Sampathkumar and Ayyangar, 1981); and the linear and sessile cotyledonary leaves with no forking, lobing or basal sinus (Sampathkumar, 1982) also lend support to the tribal status of the genus. The absence of flavonoids makes this tribe the most evolved taxon within the family.

The tribe Convolvuleae exhibits a striking chemical heterogeneity among its various genera. The chemical diversity is at its maximum among the *Ipomoea*s and *Merremia*s in that they include species having a large variety of flavonoids and also of species devoid of the flavonoid system.

Ipomoea, the largest genus belonging to the family, represents chemically the most heterogeneous assemblage of individuals. This genus is characterised by an abundance of primitive features such as the presence of proanthocyanins and flavanones, and the predominance of flavonols. Flavones, through present, are rare in the genus. The division of *Ipomoea* into subgenera (Clarke, 1883) cannot be supported due to the gross chemical similarity among the various subgenera.

The various species of *Ipomoea* can be chemically characterised into seven categories, viz., those containing only flavanones, species with only flavonols, with both flavonols and proanthocyanins, species with flavonols and flavones (C-glyco.), those with flavones (O-glyco.), with both flavones (0- and C-glyco.) and proanthocyanins, and species showing total absence of flavonoids. These flavonoidal groupings are randomly distributed under different subgenera. The various flavonoidal types, viz., flavonols, proanthocyanins, and flavones (O-glycosldes and C-glycosides) also are indeterminately distributed under the various subgenera. For example, amongst the seven *flavonoidal* groupings, flavone-containing species are observed in Quamoclit, Pharbitis and Euipomoea; flavone and flavonol-containing species are seen in Batatas and Euipomoea; flavonol- and proanthocyanin containing species in Quamoclit and Euipomoea; species showing total absence of flavonoids are located in Aniseia and Euipomoea; while flavonol-containing species are present in Calonyction, Pharbitis, Batatas and Euipomoea. Flavonols are found distributed in all subgenera except one.

The chemical heterogeneity characteristic of *Ipomoea* is reflected in equal measure within the different subgenera making them chemically ill-defined and thus invalidating their elevation to the generic level (*Aniseia* being an exception).

Karyological and palynological studies also support these contentions. Chromosome numbers of Calonyction, Quamoclit, Pharbitis, Aniseia, Batatas and Euipomoea show a marked similarity (Sharma and Datta, 1958; Sampathkumar, 1979; Sampathkumar and Ayyangar, 1981). Echinate, pantoporate and foveolate pollen grains form a characteristic feature of *Ipomoea*. Though the different species show variations in pollen grain size, exine characteristics such as thickness, length and shape of the spines, no distinct line of demarcation may be made among the species belonging to the different subgenera (Vij and Sachdeva, 1974).

The smooth pollen, the vertically placed femur-like cells of spongy tissue in the leaf, the rows of secretory cells running parallel to the mid-rib of the leaf as well as freely in the mesophyll (unlike other *Ipomoea*s – see Solereder, 1908a), the longer outer sepals, included stamens, the 2-celled ovary, absence of flavonoids, presence of phloretic acid, and of considerable amounts of alkaloids in the stem, keep *Aniseia martinicensis* distinct from *Ipomoea*.

The assortment of different flavonoids demarcates subspecies/varieties of all species except those of *Ipomoea pes-tigridis*. Both the lobed and unlobed varieties of this species possess flavanones. However, other chemical characteristics such as absence of quinones and presence of trace amounts of saponins in the unlobed variety distinguish it from the lobed variety which contains quinones and lacks saponins.

Ipomoea sepiaria var. *sepiaria* possesses tamarixetin (4'-OMe quercetin), 3',4'-diOMe quercetin and proanthocyanins, while *I. sepiaria* var. *stipulacea* contains isorhamnetin (3'-OMe quercetin) only. Besides this, the occurrence of appreciable quantities of saponins in the latter which is absent in the former species, also help in delineating the two varieties.

The differences in the chemistry of the two varieties in conjunction with the morphological differences such as the lobing of the leaves, presence of stipules, size of flowers and the presence of hairs on the seeds confer distinct identities on these varieties. This would warrant an elevation of these two varieties to the species level.

The morphological differences between the two subspecies of *Ipomoea pescaprae* are supplemented by chemical data. *I.pescaprae s.sp. pes-caprae* possesses flavonols (and quinones) while *I. pes-caprae* s.sp. *brasiliensis* shows absence of all flavonoids (and quinones). The two subspecies are also distinguished by the presence of saponins in the latter and its absence in the former. The differences are of a magnitude equal to those existing among the various species of *Ipomoea*, and therefore it would be appropriate to raise these subspecies to the specific level as has been done by Roth. (Nov. Pl.Sp.109) for ssp. pes-caprae and G.F.W.Mey. (Frim.Fl.Esseq.97) for ssp. *brasiliensis*.

Ipomoea cairica has been mentioned by several authors under the name of *I. pulchella*, which is another species differing by its smaller corolla (cf.Van Ooststroom, 1953; See Clarke, 1883; Cooke, 1905). The chemical study reveals the absence of flavonoids and saponins in *I. pulchella*, whereas *I. cairica* (pink-flowered type) possesses flavonols and saponins. The white-flowered type of *I. cairica* differs chemically from the pink-flowered type in the absence of flavonoids and saponins. No comments on the separate taxonomic identities of the two *I. cairica* types would be feasible at this stage in view of their identical morphology in all respects except flower colour. This morphological variability has been correlated with cytological features (Vij *et al.*, 1977).

Based on the distribution of flavonoids, all the species belonging to the genus *Ipomoea* may be arranged in four groups showing distinct evolutionary tendencies. A graded series of evolutionary stages are also observed within each group.

The *Merremia* species studied during this investigation belong to two sections. The flavonoid constitution of the species belonging to these sections is as given in Table 2c.

No close relationship is seen between the distribution of flavonoids and the existing classification within the genus. A similar inference has been drawn from pollen morphological studies also (Ferguson *et al.*, 1977). Species apparently closely related (belonging to the same section or subgenus) have been found to possess diverse pollen grains making the sectional classification unsubstantial.

The *Merremia*s resemble the *Ipomoea*s in gross external morphology, in size and the absolute length of chromosomes (Sampathkumar and Ayyangar, 1981); the cotyledonary leaf characteristics which show two veins running almost parallel to each other and converging at the tip (Sampathkumar, 1982); and the chemical features such as the predominance of flavonols and the occurrence of proanthocyanins. However, three species viz., *M. aegyptia*, *M. dissecta*, and *M. tridentata* s.sp. *tridentata* are distinct from the others in possessing glycoflavones in leaves. Glycoflavones have been tound to be absent in all the species of *Ipomoea* screened. A more clear and homogeneous picture of the genus *Merremia* would emerge if the species lacking glycoflavones are transferred to *Ipomoea* and the glycoflavone-containing species retained in the genus *Merremia*.

M. tridentata s.sp. *tridentata* is peculiar in that it is the only species among the *Merremia*s and *Ipomoea*s studied here which shows the co-occurrence of the flavone-O-glycosides, glycoflavones and proanthocyanins. *M. tridentata* has also been found to possess pantoporate pollen unlike the colpate or rugate ones in the rest of the *Merremia*s (Fergusen *et al.*, 1977). According to Sampathkumar and Ayyangar (1980), *M. tridentata* presents pollen features which are intermediate between the typical *Ipomoea* and *Convolvulus* type and thus appears to be a palynological liaison between these major categories. The cotyledonary leaves in this species are different in having only one vein in each leaf and in the absence of a basal sinus (Sampathkumar, 1982). A combination of all these features supports the elevation of the species *M. tridentata* s.sp. *tridentata* to a new genus *Xenostegia*, as *Xenostegia tridentata* (L.) Austin and Staples III (as proposed by Austin and Staples, 1980).

Operculina turpethum has been found to contain flavones and glycolipids. Clarke included *Operculina* within *Ipomoea*, and the former genus does resemble some of the *Ipomoea* species such as *I. nil* and *I. quamoclit* which also contain flavones and glycolipids. Karyomorphological studies also have shown a general similarity in the karyotype of *Operculina* to that of *Ipomoea* (Sampathkumar, 1979). Though some of the pollen features suggest a close similarity between *Operculina* and *Merremia* (Ferguson *et al.*, 1977), another genus within which *Operculina* has been merged, it is different from *Merremia* in having glycolipids and no glycoflavones. The distinct morphological features such as the winged stem, and peculiar opercular dehiscence of the fruit warrant a separate identity for *Operculina*.

Argyreia is similar to *Ipomoea* in the predominance of flavonols but is different from the latter in containing both flavonols and flavones and in the absence of proanthocyanins. This genus has been synonymous with both *Ipomoea* and *Rivea*. *Rivea*, however, lacks the entire flavonoid system and therefore, a merger of *Rivea* with *Argyreia* as suggested through karyomorphological studies (Sampathkumar & Ayyangar, 1981) and cotyledonary leaf studies (Sampathkumar, 1982) does not find any support from chemistry. Moreover, *Rivea* differs from *Argyreia* in flower shape and colour, shape of stigmas, the basic chromosome numbers and the nature of the spines on the exine (Darlington and Wylie, 1955; Sampathkumar and Ayyangar,1981; Parveen and Bhandari, 1982). The similarities in absolute chromosome, length, seed morphoanatomy and the characteristic mealy pulp surrounding the seeds is perhaps suggestive of a common ancestor for both the genera.

Among the four species studied under *Argyreia*, *A. cuneata* and *A. nervosa* may be considered primitive because of the presence of quercetin. *A. sericea* is advanced due to the replacement of flavonols by flavones. *A. cymosa* with methoxylated flavonols occupies an intermediate position.

The absence of the flavonoid system in *Stictocardia* defends its generic status as separate from *Argyreia*. The base number n=15, morphological features such as the characteristic fruit enclosed by sepals, and the presence of large external glands on the lower side of the leaf (Solereder, 1908b), lend additional evidences in support of this contention.

The genus *Convolvulus* is characterised by the presence of monomethoxylated quercetin and kaempferol derivatives and the presence of proanthocyanins. The two species *Convolvulus arvensis* and *C. prostratus* have distinct identities in that the former contains the monomethoxylated derivatives of quercetin (3'- and 4'-ONe quercetin derivatives) and proanthocyanins, while the latter possesses, 4'-OMe kaempferol, and 7-OMe quercetin. The absence of proanthocyanins makes *C.prostratus* the more advanced of the two species. However, the two species show a very close chemical affinity in the presence of quinones in leaves and the absence of stem alkaloids and saponins. The presence of tropanes and the absence of ergolines, relates the genus *Convolvulus* to the Solanaceae where the tropanes form a family character.

Hewittia has been considered synonymous with both *Ipomoea* and *Convolvulus*. Besides the absence of flavonoidal compounds, the presence of saponins, the base number of n = 15, and the long to medium sized chromosomes (Sampathkumar,1979; Sampathkumar and Ayyangar, 1981), the anomalous extrafascicular formation of vascular bundles (Solereder,1908 a), the white or yellow flowers with a purple eye, and the short to oblong stigmas give *Hewittia* a distinct identity of its own.

The two species of *Jacquemontia* are chemically similar in having the 4'-methoxylated derivative of quercetin and stem alkaloids, and in the absence of' quinones and saponins. The occurrence of quercetin in *J. paniculata* distinguishes the two species while keeping this species as the more primitive of the two.

Jacquemontia, which has often been considered synonymous with *Convolvulus*, is delineated from it in the absence of proanthocyanins, kaempferol derivatives and quinones, and the presence of stem alkaloids and seed ergolines. The usually twining habit of *Jacquemontia* as against the seldom twining nature of *Convolvulus*, and the unusual chromosome number of 2n=18 in the former as contrasted to the graded series in the latter, lend further evidences in support of the distinction of the two genera. The palynological features also differ between the two genera in that the pollen are pantoporate and subprolate in *Jacquemontia* and 3-zonicolpate and prolate to subprolate-spheroidal with reticulate exine in *Convolvulus* (Vij and Sachdeva, 1974).

Jacquemontia is distinct from *Ipomoea*, another genus with which it is often included, in the absence of many of the flavonoids found in the latter genus, and in the absence of saponins and quinones. The unusual chromosome number of 2n=18 in *Jacquemontia*, the larger size of the chromosomes, and the psilate pollen give additional support to its separate identity (Sampathkumar,loc.cit., Vij and Sachdeva, 1974).

Breweria cordata, containing quercetin and its dimethoxylated derivative, differs from *Convolvulus* in the absence of proanthocyanins and the kaempferol derivative. The base number of n=14 and 15 in *Breweria* as against the series of base -numbers of 0=9, 10, 11, 12,14, 15, 18, 20, 22, 23, 24, 25 and 30 in *Convolvulus* justify these conclusions (Sampathkumar & Ayyangar, 1981). *Breweria* has been synonymous with *Evolvulus* also, but can be differentiated from the latter due to the absence of proanthocyanins and glycoflavones.

Seddera, which was grouped in *Breweria* (as a subgenus) and *Convolvulus*, stands apart from these two genera in having proanthocyanins only. This, along with other chemical characteristics such as the occurrence of quinones and absence of saponins, supports the generic status assigned to the taxon by Hallier (1893). Such a status is also supported on morphological grounds such as habit, inflorescence, gynoecium, fruit and absence of secretory cells (Metcalfe and Chalk, 1950).

Though *Evolvulus* is not very different from the rest of the tribe Convolvuleae, its prostrate or semi-erect (never-twining) habit, distinct styles, the four clavate stigmas; small chromosomes with the discordant basic numbers n=12 and 13 (Sampathkumar and Ayyangar,loc.cit.); the rotund (unlobed) and stalked cotyledonary leaves (Sampathkumar, 1982); and the 5-6-colpate, mostly spheroidal pollen with faintly reticulate exine (Parveen and Bhandari, 1982) keep it apart from the rest of the members of this tribe. In addition to the above features, the particular combination of glycoflavones and proanthocyanins in this genus, coupled with the complete absence of flavones and flavonols, support its separation and elevation from Convolvuleae to a distinct monogeneric tribe Evolvuleae. The presence of quinones, saponins and stem alkaloids in both the species studied makes the genus chemically homogeneous. *Evolvulus nummularius* may be considered more primitive because of proanthocyanins which are lacking in *E. alsinoides*. An excess of saponins and the presence of both benzo- and naphthoquinones in .the latter in contrast to the moderate amount of saponins and occurrence of only naphthoquinones in the former species, differentiates the two species. The genus *Evolvulus* is advanced over *Convolvulus*, *Breweria*, *Jacquemontia*, *Seddera*, and *Erycibe* due to the introduction of flavones as their C-glycosides (glycoflavones).

Porana volubilis contains quercetin and its dimethoxylated derivative, whereas in *Porana paniculata* the flavonoids are replaced by quinones. This genus has been found to be karyologically (n=13, 14) close to *Evolvulus* (Sampathkumar and Ayyangar, 1981). On the basis of chemical data, however, *Evolvulus* is primitive to *Porana* which is quite advanced. *Porana* can be distinguished from most other genera of Convolvulaceae because of the scarious sepals and a 1-seeded capsule.

Erycibe is unique in that a wide variety of flavonoids, viz., proanthocyanins, quercetin, dimethoxylated quercetin and monomethoxylated kaempferol are observed within a single species. Primitive traits as well as trends of advancement in the reduction of hydroxyl groups and increase in methoxyl groups are observed in the genus. In combination with the suppressed style, which is not found in any of the other genera of Convolvulaceae, this taxon is singularly distinctive in the family.

A synoptical key to the genera of Convolvulaceae and Cuscutaceae incorporating all the available characters is shown in Table 3.

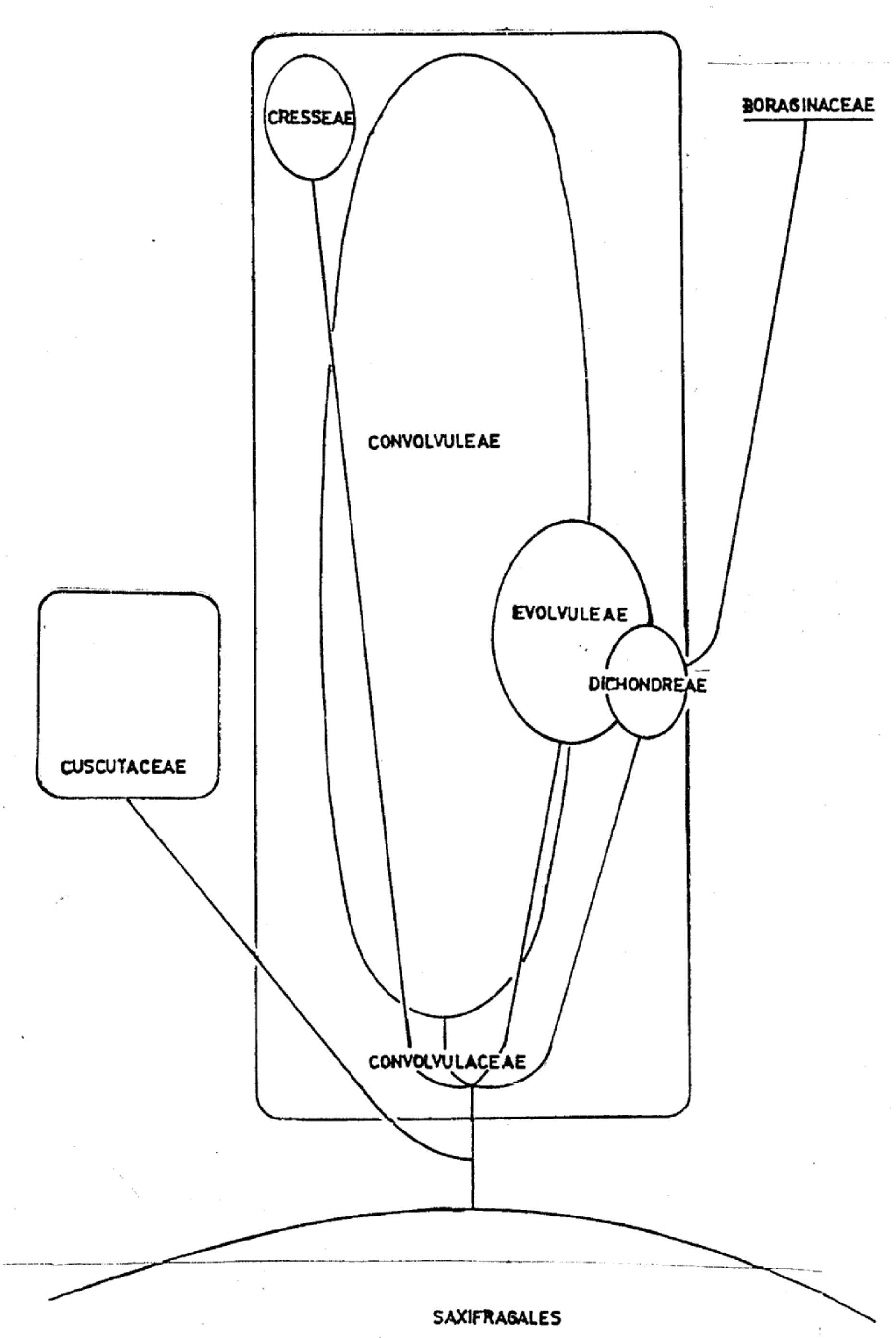

Figure 3: Phylogeny of Cuscutaceae and Convolvulaceae

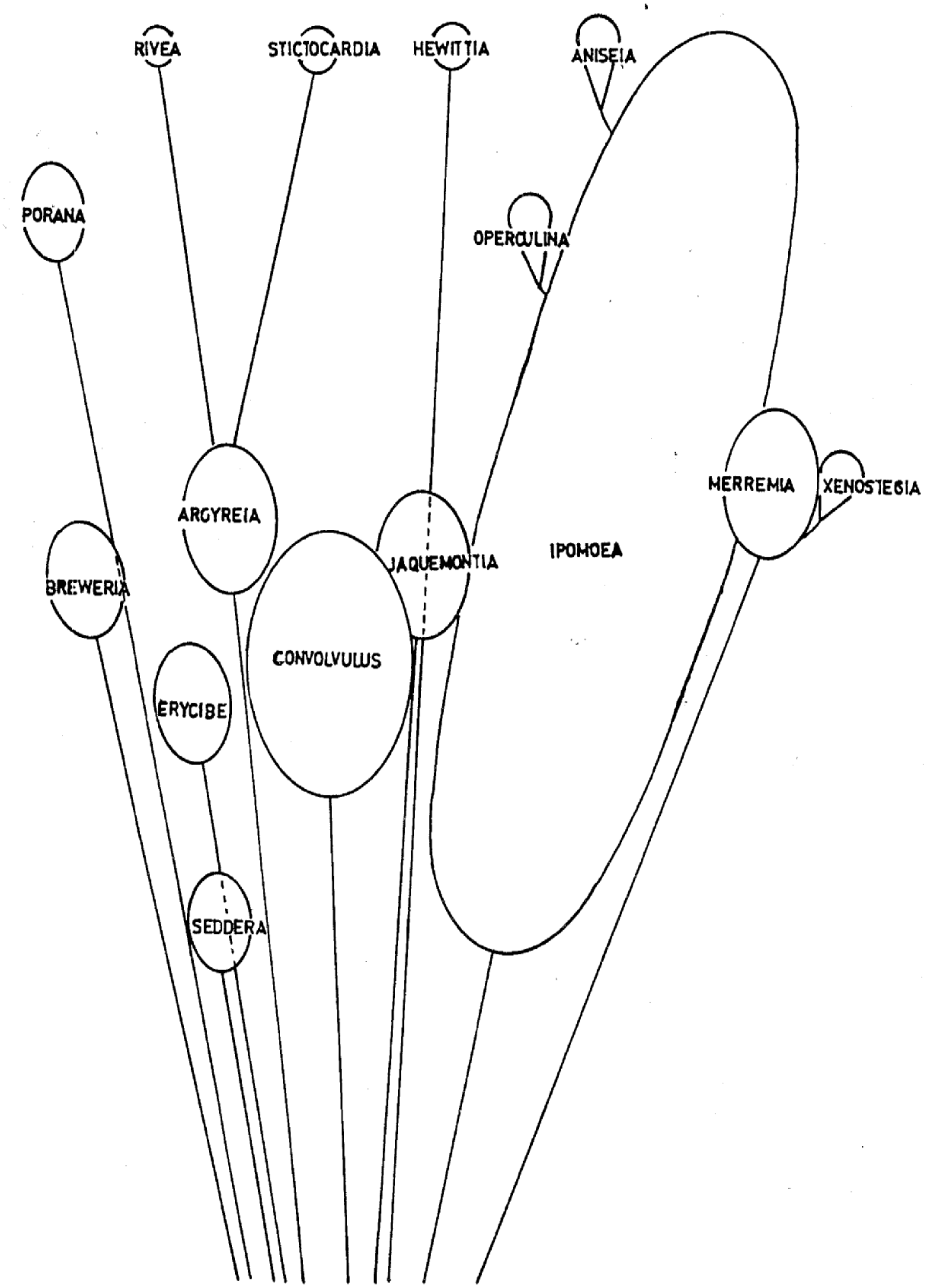

Figure 4: Evolutionary levels attained by various genera within the tribe Convolvuleae

Phylogenetic interpretations on the taxa

Among the families of gamopetalous angiosperms, the Convolvulaceae do not seem to be a highly advanced taxon chemically. The family retains a number of primitive characters like the predominance of flavonols and proanthocyanins. Cuscutaceae, however, is advanced over Convolvulaceae due to the presence of only methoxylated flavonols and the absence of proanthocyanins and glycoflavones. Trends in evolution of both these taxa seem to be on the progressive reduction of flavonoids culminating in their complete loss and replacement by quinones. The presence of ergolines relates the two families closely and represents an isolated character which has reappeared in the plant kingdom at a higher stratum of phylogenetic progress. Both the families seem to be two end lines specialising in complex natural products.

Among the tribes within the family, Convolvuleae is the most primitive tribe. Cresseae is the most advanced tribe of the family in which the entire flavonoid system is lost. Between Dichondreae and Evolvuleae, the latter tribe shows more primitive characters than the former. The levels of evolution achieved by the Cuscutaceae, and the various tribes of Convolvulaceae are represented in Figure 3.

Though the tribe Convolvuleae shows a number of primitive features, varying levels of evolutionary advancement are observed among the genera and their constituent species. *Seddera*, *Erycibe*, *Convolvulus*, *Breweria* and *Jacquemontia* are primitive due to proanthocyanins and flavonols. The co-occurrence of flavonols, flavanones, proanthocyanins, flavone-C-glycosides and flavone-O-glycosides and the complete absence of flavonoids in some species brings *Ipomoea*, *Merremia* and *Argyreia* to the intermediary level of evolution in the tribe Convolvuleae. *Operculina* and *Porana* are advanced due to the presence of only flavones or due to the lack of flavonoids. *Rivea*, *Stictocardia*, *Aniseia* and *Hewittia* are the most highly evolved genera of the tribe Convolvuleae in which the entire flavonoid system is lost. The evolutionary level attained by these genera is at par with *Cressa* of tribe Cresseae. The evolutionary levels attained by the various genera of tribe Convolvuleae are represented diagrammatically in Figure 4.

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