10. Families GERANIACEAE, OXALIDACEAE and BALSAMINACEAE

The family Geraniaceae (including the Oxalidaceae and Balsaminaceae), consisting of 19 genera and 2250 species, is represented by 6 genera in India. The family is predominantly herbaceous. The stipulate leaves are simple or compound, opposite or alternate. The flowers are bisexual, regular or irregular and are arranged in axillary cymes, umbel or racemes. The sepals and petals are pentamerous, free or united. Torus is either modified into a disk or raised in the center to form a beak. Stamens are 5, 10 or 15, filaments are filiform or dilated. Ovary is tri-or pentacarpellary with carpels united with the axis as far as the insertion of the ovules or sometimes lengthwise into a beak bearing styles or styles free. Stigma capitate, linear or ligulate. Ovules 1, 2 or rarely numerous in pendulous placentation. Fruit is a capsule, 3-5 lobed with one seed in each locule often separating from the axis septicidally or rarely is a berry. The dispersal mechanism is usually forceful.

The Geraniaceae s.l. are divided into three tribes by Edgeworth and Hooker (1875) :

1. Geranieae : Simple or compound leaves, regular flowers, imbricate calyx, glands alternating with petals. **Geranium, Erodium** and **Monsonia.**

2. Oxalideae : Compound leaves, regular flowers, imbricate calyx, glands 0,stigma capitate, ovules 2 or more in each locule. **Oxalis, Biophytum, Averrhoa.**

3. Balsamineae : Simple leaves, irregular flowers, posterior sepal spurred, stamens five, very short, anthers subconnate. **Impatiens.**

The distinguishing characters of these 3 tribes were considered enough to treat them as separate families

: Geraniaceae, Oxalidaceae and Balsaminaceae, by later taxonomists. The Geraniaceae are characterised by pentamerous flowers, beaked or lobed fruits distinctive by its elastic dehiscence, separation of mericarps and the usual absence of endosperm whereas the Oxalidaceae are distinguished by monadelphous stamens, five distinct styles, single quinquilocular pistil, compound leaves and fruit dehiscing characteristically in the members with arillate seeds. The Balsaminaceae are characterised by the spur and peculiar androecial situation especially by the coherence or connation of the anthers about the ovary and stigma, and elastic dehiscence of usually succulent capsule.

Anatomy :

The floral anatomical studies indicate that stamens are obdiplostemonous in all the three families. In **Monsonia** the antipetalous stamens are duplicated and petal and staminal strands originate from a single strand indicating that obdiplostemony is formed by conjoining of the staminal bundles with petal midrib (Narayana and Arora, 1963). The sepals of Oxalidaceae receive three traces each. Loss of antipetalous stamens occur in **Averrhoa.** The carpels receive five traces (three traces in **Averrhoa**). A tendency towards supression of dorsal carpellary trace occurs in the Oxalidaceae. The dorsal trace in **Biophytum** fades away at the level where the bases of the locules appear while it is completely supressed in a species of **Oxalis.** The floral anatomy of the Oxalidaceae is similar to those of the Geraniaceae and Linaceae (Narayana, 1966). The flower of **Impatiens** is highly modified and is quite different from the other two families. The lower sepal is prominantly pouched with a short spur. One pair of sepals is absent in most of the species and is sometimes represented by rudimentary traces. The dorsal lobes of corolla are free but the lateral pair is united. Each petal of a pair has its own main

vascular trace showing that each has orginated as a separate petal (Grey - Wilson, 1980; Simon, 1975).

In wood anatomy these families share a number of characters. They have scanty paratracheal parenchyma, frequent occurence of septate fibres and a tendency towards elimination of rays. The bundles are united to form a ring by the activity of interfascicular cambium. Vessel segments are with simple perforations and imperforate tracheary elements possess simple pits. The nodes are trilacunar and the pericycle is sclerenchymatous in both the Geraniaceae and Oxalidaceae while the Balsaminaceae have unilacunar nodes and parenchymatous pericycle. The Geraniaceae and Balsaminaceae have S-type of sieve element plastids. P-type (PIc') plastids are seen in the sieve tubes of the Oxalidaceae, except in **Biophytum** which has S-type of sieve tube plastids (Behnke, 1982) Calcium oxalate crystals are accumulated in all three families.

Embryology :

The Geraniaceae have glandular tapetum (**Pelargonium** has amoeboidal tapetum) and fibrous endothecium. The ovules are anatropous, pendulous, epitropous, bitegmic, crassinucellate, micropyle directed upward and raphe ventral. Development of embryo sac is Polygonum type. The embryogeny is Asterad (**Erodium** and **Geranium wallichianum**), Solanad (**G. nepalense**) and Onagrad type (**G. molle**) while **Pelargonium** has a mixture of Asterad and Onagrad types. **Monsonia** is peculiar in having a mixture of Myosurus variation of Onagrad and Geum variation of Asterad type (Kumar, 1976; 1977). The endosperm development is nuclear.

The ovule of the Oxalidaceae is similar to that of the Geraniaceae. Allium type of embryo sac development and Oxalis variation of Asterad type of embryogeny occur (Govi-

ndappa and Boriah, 1956; Narayana, 1966). The Balsaminaceae are different from the other two taxa in having apotropous, bitegmic or unitegmic (by fusion), tenuinucellate ovule. The endosperm is cellular. Micropylar and chalazal haustoria are present. The family characteristically produces trabeculae in the anther dividing the anther into lobes. The embryo development is Asterad or Polygonum type and the endothelium is formed from inner integument (Narayana, 1965; Narayana and Sayeeduddin, 1959; Tokao, 1976).

Palynology :

Pollen of the Geraniaceae is eurypalynous, 3-colpate or 3-colporate with a number of variations. The pollen may be polyforate or sometimes non-aperturate, suboblate and prolate. Eloqlab (1983) observed Erodium type of pollen in the genus **Erodium**. The Oxalidaceae have 3-colpate or 3-colporoidate, oblate spherical or prolate pollen and are stenopalynous,while the Balsaminaceae pollen is 3-4-colpate and very flattened. The lumina of reticulum is dotted with short rods (Erdtman, 1952). Binucleate pollen occur in the Balsaminaceae and Oxalidaceae while trinucleate pollen is found in the Geraniaceae.

Taxonomy :

The Geraniaceae and Oxalidaceae are placed in the order Geraniales in all the classifications, though the circumscription of the Geraniales varies with the author. The close affinity existing between the Oxalidaceae and Geraniaceae are generally agreed upon. These two families are interconnected by various small genera such as **Vivia, Ledocarpa** etc., which are either included in the Geraniaceae or each one is placed in unigeneric families (Airshaw, 1973).

The placement of the Balsaminaceae always remained controversial. Thorne (1976) and Cronquist (1981) included

this family in Geraniales. Eventhough Takhtajan (1980) keeps the balsaminaceae in his Geraniales, he groups them in 2 different suborders, Geraniineae containing the Geraniaceae and Oxalidaceae, and Balsaminineae with the Balsaminaceae and Tropaeolaceae. Engler (1931) and Dahlgren (1981) created a new unifamilial order Balsaminales to include the Balsaminaceae while Lawrence (1951) and Wettstein (1935) placed it in their Sapindales (Terebinathales) due to the apotropous nature of the ovules. Cronquist (1969) is of the opinion that the Balsaminales may be grouped either in the Geraniales or in the Polygalales but he prefers to place it in the former order because of its similarities with the Tropaeolaceae (in having spur, irregular flowers and similar pollen). However Lawrence (1951) considers the spur of the Balsaminaceae to be quite distinct from that of the Tropaeolaceae in that the former is a modified sepal whereas the spur in **Tropaeolum** has a receptacular origin and therefore the resemblences to be superficial. Reddy and Narayana (1986) also conclude that the two families share only a distant relationship.

The Geraniaceae and Balsaminaceae, being homogeneous families, are not divided into tribes but each genus is subdivided into a number of sections. But the Oxalidaceae is classified into 4 subfamilies by Takhtajan : (1) Averrhoideae (2) Oxalidoieae, (3) Lepidobotryoideae and (4) Hypseacharitoideae. Hutchinson (1973) excluded **Averrhoa** from the Oxalidaceae giving it a familial status Averrhoaceae. The Averrhoaceae are characterised by imparipinnate leaves, absence of stipules, corolla loosely connivent in the middle, a berry and nude or arillate seeds. This family was grouped in Rutales.

Economic Importance :

The members of the Geraniaceae and Balsaminaceae are showy ornamentals. The volatile oils produced by **Geranium**

are used in the preparation of perfumes. Hydrolysable tannins (1 to 25%) also are obtained from **Geranium. Oxalis** accumulates large amounts of ascorbic acid (vit. C) and therefore used as an effective antiscorbutic agent. The aqueous extract of this plant is found to be antibacterial and is used as astringents, vermifuges, diuretics, emmenagogues and antiseptics. The fresh leaves exhibit cooling effects, cures dyspepsia, piles and anemia. **Oxalis** is an important medicine in homeopathy. A yellow quinonoid pigment, rapanone, is obtained from bulbs. Carambola, the fruit of **Averrhoa** are eaten raw, pickled or used for the preparation of curries. The dried fruits of this tree exert effects similar to **Oxalis.** The wood of **Averrhoa** is used for building purposes, furnitures, turnery articles and in making smaller items such as rulers, toys etc.

Previous Chemical Reports :

Bate-Smith (1973; 1983) analysed the flavonoids of the family Geraniaceae and found that flavonols, quercetin and kaempferol, occurred in high concentrations. Myricetin was rare, located in 8 species of which only one possessed it in high concentrations while in others it was in low concentrations. Luteolin was located in only two species of **Erodium.** Hydrolysable tannins based on ellagic and gallic acids are frequent in the family (Bate-Smith, 1972; 1981; Takuo et al., 1979). Geraniin and mallotusinic acid are reported from Geraniaceae (Takuo et al., 1980). Volatile oils present in **Geranium** and **Pelargonium** consist of α-terpeneol (Berikashivile et al., 1982), d-citronellic acid and l-menthone. The Oxalidaceae contain aurone glycosides (aureusin and ceruoside) in flowers, quinone (rapanone) from bulbs, glycoflavone (orientin) (Shimokariyana and Geissman, 1962, Bohm, 1975) and various organic acids. **Impatiens** contains a quinone (2-hydroxy, 2 -methoxy 1, 4-naphthoquinone), phenolic acids (p-hydroxy benzoic acid, gentisic acid, ferulic acid and caffeic acid) (Bohm

and Towers, 1962) and a coumarin (scopoletin). Kaempferol, quercetin and anthocyanidins are the other polyphenols reported from this genus.

In the present work leaves of 28 plants belonging to the Geraniaceae (10), Oxalidaceae (9) and Balsaminaceae (9) are screened for their various chemical constituents and their significance in the taxonomic treatment of these families is assesed.

Materials And Methods

The leaves were collected from Kashmir, Nainital, Mahabaleshwar, Ooty and Trivandrum. **Averrhoa carambola** and **Oxalis corniculata** are collected from Baroda. For the isolation and identification of phenolics, tannins, saponins and alkaloids standard methods, described in chapter 2, are followed.

Results :

The distribution of phytochemicals in members of the Geraniaceae (10), Oxalidaceae (9) and Balsaminaceae (9) is presented in Table 10.1. With the exception of **Oxalis acetocella** all the plants screened contained various flavonoids in their leaves. Similar to other families flavones, glycoflavones, flavonols and proanthocyanidins are located in these taxa. Within the Geraniaceae flavonols form the single group of phenolic pigments. Kaempferol, quercetin and their methoxylated derivatives are the flavonols identified. **Monsonia** is noteworthy in elaborating aurones.

Flavones and glycoflavones formed the dominant phenolic pigments in the family Oxalidaceae. Apigenin and its derivatives are more common than luteolin. **O.acetocella** and **O. pubescence** are distinct because the former does not elaborate

flavonoids and the latter in its ability to synthesise flavonols. Glycoflavones based on methoxylated apigenin and luteolin i.e. 4'-OMe vitexin, 4'-OMe isovitexin, 3', 4'-diOMe orientin and 3', 4'-diOMe isoorientin are produced by **Averrhoa**, **Biophytum** and **Oxalis**. Proanthocyanidins are restricted to two species of **Averrhoa**. **Oxalis** shows a high frequency of p-hydroxybenzoic and melilotic acids also. Tannins are seen in both the members of **Averrhoa** while alkaloids are located in **A. bilimbi** only.

The Balsaminaceae are similar to the Geraniaceae in containing flavonols. Almost all the plants screened contained flavonols in their leaves. However, the amount of flavonoids in the leaves is much lesser when compared to the members of Geraniaceae and in **I. scabriuscula** these compounds occur in traces. Quinones, especially naphthoquinones, are noticed in a number of species. Syringic acid is comparatively rare in this family while tannins are omnipresent though in very less concentrations. Saponins are fairly common.

Discussion :

The three families screened in the present work are chemically distinct from each other. The chemical features which isolate the families are :-

1. Flavones in the Oxalidaceae

2. Flavonols in high concentration, volatile oils and hydrolysable tannins in the Geraniaceae.

3. Quinones and low concentration of flavonols in the Balsaminaceae.

The widespread occurence of flavones, syringic, p-coumaric and melilotic acids keep the members of the Oxalida-

ceae together and distinct from the other two families. **Averrhoa** is different from **Oxalis** and **Biophytum** in producing proanthocyanidins and tannins. The presence of alkaloids in **A. bilimbi** is also significant. The predominance of flavones and glycoflavones in **Averrhoa**, which are the characteristic phenolic pigments of the Oxalidaceae, illustrates very well that the affinities of the former are with the latter. Therefore, this restrains us from making any comment on the separate identity of **Averrhoa** as a family Averrhoaceae as practised by Hutchinson (1973). The retention of proanthocyanidins and tannins in **Averrhoa** may be associated with the woody habit of this genus. **Averrhoa** and **O. pubescens** (containing flavonols) remain the primitive members of this family while the rest of the group are advanced.

The Geraniaceae also form a chemically homogeneous family due to the uniform presence of flavonols, particularly quercetin and keampferol, volatile oils, and gallic acid and in the absence of flavones, glycoflavones, syringic acid and gentisic acid. **Monsonia** is distinct in containing aurones. Incidentally a few aurones are reported from the Oxalidaceae also, and therefore **Monsonia** may be considered as a close ally of the Oxalidaceae.

The Balsaminaceae are similar to the Geraniaceae in producing flavonols and in not containing flavones and proanthocyanidins. But the family specialises in synthesising naphthoquinones. They also eliminate trihydroxy systems (gallic and ellagic acids). The presence of glycoflavones in some members of the **Impatiens** bring them close to the Oxalidaceae. These evidences (presence of quinones, low concentration flavonols and absence of hydrolysable tannins) alongwith morphological (irregular flower, sepaloid spur, reduction of perianth, special condition of anthers and fruit dehiscence) and embryological (cellular endosperm, tendency towards unitegmy, dorsal

raphe, endotheliun and haustoria) characters focus our attention to the concept of a separate order Balsaminales containing Balsaminaceae only. These advanced characters achieved by the Balsminaceae bring this family to a high level of evolution necessitating the recognition of a separate taxon to include the Balsaminaceae. The grouping of the Balsaminaceae with Tropaeolaceae in a separate suborder Balsaminineae away from Geraniaceae of the order Geraniales by Thorne deserves a special mention. Though these two families possess irregular flowers, the origin and nature of the spur is of much dispute (Lawrence, 1951) and therefore the grouping is taxonomically unsound. Chemically also the Tropaeolaceae differ from the Balsaminaceae in containing high concentration of flavonols, proanthocyanidins and in the absence of quinones (unpublished data). The unifamilial order Balsaminales appears to be a taxonomically viable climax group.

It appears that the Geraniaceae form the basic stock from which two lines of evolution occurred. First line (Oxalidaceae) specilizes in compound leaves and flavones and in eliminating tannins. The second line (Balsaminales) resorts to irregular flowers, quinones and partial elimination of flavonols.