9. Family ZYGOPHYLLACEAE

The family Zygophyllaceae containing 26 genera and 246 species occurs mostly in the arid zones and saline areas of tropical and subtropical regions. Six genera, which are found in India, are more or less equally distributed to the various desert areas.

The Zygophyllaceae are low bushy herbs, shrubs or rarely trees with oppositely arranged simple or compound leaves (hairy fleshy/leathery) having two persistant stipules. Flower is pentamerous, bisexual having persistant free sepals which are imbricate (**Tribulus, Zygophyllum**) or valvate (**Fagonia, Peganum**) in aestivation. Petals are spathulate, imbricate (**Tribulus**), twisted (**Peganum, Fagonia**) or valvate (**Zygophyllum**). Stamens are obdiplostemonous except in **Seetzenia**. Ten stamens occur in two whorls but in **Peganum** there are 15 stamens arranged in three whorls, with a prominant intrastaminal disk. The filaments have a bilobed scale each at the base. Gynoecium is pentacarpellary (tricarpellary in **Peganum** and **Nitraria**) with a single style and capitate or lobed stigmas. Ovary is furrowed, angled or winged, tetra - or pentalocular with one (**Balanites** and **Nitraria**) to numerous ovules (rest of the genera) in axile placentation. Ovules are epitropous, bitegmic, crassinucellate, pendulous and anatropous. Fruit is a loculicidal or septicidal capsule or rarely a drupe.

Anatomy :

Floral anatomical studies (Amalraj, 1986; Narayana and Rao, 1963; Nair and Gupta, 1961; Masand, 1963; Kapil and Ahluwalia, 1963; Shukla, 1955; Porter, 1971) show a basic pattern of vasculature with some variations resulted from the reduction or fusion between the whorl members and their vascular supply. The sepals are usually three-traced as in **Nitraria**. In **Fagonia** the laterals of the adjacent sepals are fused while in **Tribulus** and **Peganum** the commissural strands

are fused with the petal traces. The placentation of the family is axile but the inverted vascular bundles of the ovules in **Peganum** indicate that the placentation is basically of parietal type (Puri, 1951). An intermediate stage is seen in **Zygophyllum** where the placentation of the lower half of the ovary is axile and the upper half is parietal. This type of evolution is similar to that observed in the Meliaceae. Another line of evolution to unilocular condition from plurilocular ovary is seen in **Peganum** In this genus the placenta recede to the periphery in the middle of the ovary thus making it unilocular. Reduction in number of ovules per locules also occurs within the family. Numerous ovules occur in **Peganum** and **Zygophyllum**; **Tribulus** has 4-5 ovules in two rows; **Fagonia** has two collateral ovules and finally **Nitraria** has only one ovule per locule.

The wood is characterised by a distinct storied arrangement of elements, predominance of fusiform apotracheal parenchyma, moderately large vessels and very small intervascular pittings. The family has both specialized (storied structures) and unspecialized (fibres distinctly bordered pitted) tissues. Metcalfe and Chalk (1950, 1983) conclude that the family forms a very distinct natural group and the wood must be regarded as highly advanced.

Embryology :

The anther wall of the Zygophyllaceae is five-layered having fibrous endothecium and glandular tapetum. The middle layer of the wall (except in **Zygophyllum**) is persistant. The pollens are shed at 2 or 3-celled stages. The ovule has well-developed integumentary tapetum. The development of embryo sac is Polygonum type, endosperm is nuclear, the nucellus is scanty (**Peganum** has massive nucellus) and hypostase and obturator are present. The embryogeny is of Solanad type and the embryo has a uniseriate suspensor. In **Peganum** synergid

polyembryony is observed.

Palynology :

The family is very heterogeneous in its pollens. They are 3-colpate (**Seetzenia**), or 3-colporoidate (**Zygophyllum**). Sexine is equal to or thicker than nexine and are oblate (**Seetzenia**) or subprolate (**Peganum, Fagonia**). The exine has reticulate ornamentation. The pollen grains of **Peganum** and **Tribulus** resemble that of the Rutaceae and Polemoniaceae respectively (Erdtman, 1952; Mathur and Bhandari, 1983).

Classification :

The Zygophyllaceae were first concieved by Brown (1814). De Jussieu (1825) and Baillon (1887) treated it as a subfamily of Rutaceae. The Zygophyllaceae are generally grouped in the order Geraniales (Bentham and Hooker, 1862; Hallier, 1912; Rendle, 1950; Gunderson, 1950; Thorne, 1980; Dahlgren, 1981), Rutales (Takhtajan 1980) or in Sapindales (Cronquist, 1981). But Hutchinson (1973) includes it in the order Malpighiales. Based on the nature of leaves and fruits Engler (1931) divided the Zygophyllaceae into 7-subfamilies: (1) Peganoideae (2) Chitonioideae (3) Tetradiclidoideae (4) Augeoideae (5) Zygophylloideae (6) Nitrarioideae and (7) Balanitoideae. A number of disputes on the levels of hierarchy and the circumscription of the subfamilies prevail even today. Most of these subfamilies are raised to families by various authors. Takhtajan (1980) considers the family would become homogeneous after the separation of drupaceous fruit producing Nitrariaceae and Balanitaceae. El-Hadidi (1977), based on the character of fruit and leaves (pinnate leaves, fruit splitting into cocci and seeds non-endospermic) and ably supported by the chemical data (quercetin and kaempferol gentiobiosides or closely related galactosides) favours the separation of

the tribe Tribuloideae to a new family Tribulaceae. Thorne (1976) accepts the family status of the Balanitaceae but includes the subfamily Augeoideae in Zygophylloideae. Dahlgren's (1980) treatment of the family is similar to that of Takhtajan except for having **Peganum** in a unigeneric family, Peganaceae.

The taxonomic position of two genera, **Balanites** and **Peganum** remained controversial. The genus **Balanites** which was placed in Simaroubaceae by Bentham and Hooker (1862), Cronquist (1981) and Dahlgren (1980), is now generally included in the Zygophyllaceae (Thorne, 1981; Takhtajan, 1980). **Balanites** shares a number of characters such as tree habit, massive disk, pentacarpellary ovary, single ovule per locule, and tricolporate pollen, with the Simaroubaceae. But it is also similar to the Zygophyllaceae in having bisexual flowers, ten stamens, syncarpous ovary, vasicentric tracheids, small vessels, pitted fibres and fusiform parenchyma. Parvathi and Narayana (1978) included **Balanites** in the Zygophyllaceae after considering the sum overall characters. Hutchinson (1969) elevated this genus to a unigeneric family the Balanitaceae, a concept followed by Dahlgren, Takhtajan and Thorne.

In the same way **Peganum harmala** also is variously placed in the Rutaceae (Hooker 1875) or in Zygophyllaceae. Though **Peganum harmala** resembles **Nitraria** of Zygophyllaceae in floral anatomical characters it differs from the Zygophyllaceae in some of the characters such as **in situ** germination of pollen, absence of integumentary tapetum and massive nucellus (Masand, 1963). Pollen characters of the genus is similar to both Zygophyllaceae and Rutaceae. It is elevated to a unigeneric family Peganaceae by Soueges (1953) and Dahlgren (1975).

Bhandari and Sharma (1977) recognised a new species **Tribulus rajasthaniensis** from **T. terrestris**. The former taxon differs from the latter in having hirsuted cocci, more prono-

unced and stouter secondary spines and in absence of lower pair of secondary spines.

The Zygophyllaceae are peculiar in having both primitive and advanced characters co-occuring. The primitive characters of the family are the bisexual flowers, more than ten stamens, numerous ovules in a single locule and bordered pits whereas the advanced characters are perennial herbaceous habit, stipulate compound leaves, furrowed or winged ovary, spiny septicidal or loculicidal capsule, feebly developed nucellus and storied tissues in the wood. The family is closely related to the Simaroubaceae, Rutaceae and Meliaceae.

Economic Importance :

The Zygophyllaceae contain a number of medicinal plants. The bark of **Balanites** is used as purgative, anthelmintic and fish poison. The seeds are used against cough and colic. **Balanites** containing 4.9% diosgenin is one of the important commercial sources of this saponin. Other plants containing diosgenin and their related compounds are **Tribulus** and **Fagonia**. The fruits of **Tribulus** are used as diuretic, aphrodisiacs and against urinary discharge and kidney diseases. It is also known to produce vasodepression (Chakraborty and Neogi, 1978) and induces hypnosis. **Fagonia**, being bitter, is used as astrigent, tonic, febrifuge and against small pox. **Peganum harmala** is considered one of the important narcotic plants of India. The seeds of this plant are used as astringent, tonic and for fever while its leaves are employed against rheumatism. Most of the medicinal properties are attributed to the indole alkaloids found in these plants. The resins of the **Guaiacum** are used in venereal desease, gout and rheumatism.

The wood of **Guaiacum officinale**, 'lignum vitae',

is one of the heaviest and hardest woods in the world and is extremely resistant to abrasion, wear and tear. The resins present in the fibres and other tissues are responsible for the lubricant property and therefore best used for building underwater structures such as the bearing or bushing blocks for lining stern tubes of propellor shafts of steamships. The wood is also used in bowling balls, mallets and pulley sheaves.

Previous Chemical Reports :

The family is a rich storehouse of steroidal saponins. These saponins are based on diosgenin and its derivatives like tigogenin, kryptogenin, nahogenin, neohecogenin and neotigogenin. **Guaiacum officinale** is known to contain lignans such as guaiaretic acid, **meso**-6-dihydroguaiaretic acid and sesquiterpenes, guaianolides. A number of nortriterpenes also are isolated from the stem bark of **Guaiacum**. Almost all the plants contain alkaloids. β - Carbolines such as harmine, harmaline, harmalol, ruine, dihydroruine are widespread within this family. Quinazoline alkaloids such as peganine and vasicine are located in **Peganum harmala**. The reports of flavonoids from this family include flavonols such as quercetin, isorhamnetin, kaempferol and herbacetin and their glycosides and acetylated derivatives (Saleh and El Hadidi, 1977). Tricin and acacetin are the two flavones isolated. Larreantin is the naphthoquinone identified from **Larrea**. Coumarins are rare in this family and are reported from **Zygophyllum** (scopoletin) and **Balanites** (bergaptene and marmesin). The chemical reports from the Zygophyllaceae are summarised in Table-9.1.

In the present work seven members belonging to six genera have been analysed for their leaf constituents.

Materials And Methods :

Table : 9.1 Chemical Reports From the Family Zygophyllaceae

Name of the Plant	Compound	Ref:
1. **Balanites aegyptiaca**	Diosgenin	Marker(1943); Ghanin *et al.*(1980)
	Coumarins	Dawidar and Fayez (1969)
	Quercetin glycosides, isorhamnetin	Maksoud and El Hadidi (1988)
2. **Fagonia cretica**	Diosgenin, kryptogenin	Nag and Harsh (1982)
	Herbacetin, herbacetin 8-methy-lether isorhamnetin and glycosides	El Negoumy *et al.* (1986)
3. **Guaiacum officinale**	Kaempferol, quercetin glycoside	Maksoud and El Hadidi (1987)
	Nortriterpenes	Ahmed *et al.* (1986)
4. **Larrea tridentata**	Triterpenes and flavonoids	Hui - Zhenz *et al.*, 1980 Luo *et al.*, 1988.
5. **Nitraria sibiriea**	Sibirin	Osmanov *et al.*, (1982). Tulyaganov *et al.*, (1981).
6. **Peganum harmala**	Isoquinoline alkaloids	Nettleship and staylor (1971) Ahmed and Saleh (1987)

Table : 9.1 (Contd.)

Name of the Plant	Compound	Ref :
7. **Tribulus terrestris**	Steroids	Tomova et al., (1977); Mahato et al., (1981).
	Flavonols	Saleh et al., (1982)
8. **Tribulus** species	Steroids	Bhutani et al., (1969)

The leaf materials used for the analysis were collected from Kutch, (**Fagonia cretica, Tribulus rajasthaniensis, Zygophyllum simplex**), Baroda, (**Balanites aegyptiaca, Guaiacum officinale, T.terrestris**) and Srinagar (**Peganum harmala**). Standard methods described in Chapter 2 were followed for the isolation and identification of various markers.

Results :

The results obtained are presented in Table-9.2. Except **Peganum harmala**, all the plants screened contained flavonols in their leaves. Flavones were located in **Balanites** and **Peganum**. The various flavonols encountered are kaempferol, 4'-OMe Kaempferol, quercetin, isorhamnetin, 3',4'-diOMe quercetin and herbacetin. Of these flavonols, isorhamnetin is located in four plants and 4'-OMe kaempferol is identified in 3. Herbacetin-8-hydroxy kaempferol-is restricted to **Fagonia**. The two flavones identified are 7-OMe apigenin and acacetin, both from **Peganum** and the latter from **Balanites**. **T. rajasthaniensis** and **Fagonia** contained quinones in their leaves. Among the 7 phenolic acids identified, p-hydroxybenzoic, vanillic, syringic and ferulic acids were frequent. Proanthocyanidins, tannins and iridoids were absent from all the plants screened; while saponins and alkaloids occured in all the seven plants.

Discussion :

Peganum harmala is distinct from the other genera of the family in containing flavones and in eliminating flavonols from leaves. In addition, this genus contains quinazoline alkaloids which were not located in the other genera of Zygophyllaceae. In these characters **Peganum** is similar to the Rutaceae. However the presence of saponins, β - carbolines and the absence of proanthocyanidins and tannins relate this genus to the Zygophyllaceae. The present chemical data corro-

Table : 9.2 The Distribution of Various Phenolics, Saponins and Alkaloids among 7 Members of the Zygophyllaceae.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
S.f. Zygophylloideae																		
1. **Fagonia Cretica** L.			+	+		+		+	+	+		+	+		+	+	+	+
2. **Guaiacum officinale** L.				+		+					+	+	+				+	+
3. **Tribulus rajasthaniensis** Bhandari et Sharma					+	+			+	+	+	+	+	+	+	+	+	+
4. **T. terrestris** L.			+			+						+	+	+		+	+	+
5. **Zygophyllum simplex** L.				+						+		+					+	
S.f. Balanitoideae																		
6. **Balanites aegyptiaca** Delile		+					+			+		+	+			+	+	+
S.f. Peganoideae																		
7. **Peganum harmala** L.	+	+								+			+		+	+	+	+

1) 7-OMe Apigenin, 2) Acacetin, 3) Kaempferol, 4) 4'-OMe kaempferol, 5) Quercetin, 6) Isorhamnetin, 7) 3',4' -OMe Quercetin, 8) Herbacetin, 9) Quinone, 10) p-Hydroxy benzoic acid, 11) Gentisic acid, 12) Vanillic acid, 13) Syringic acid, 14) Melilotic, 15) p-Coumaric acid, 16) Ferulic acid, 17) Saponins, 18) Alkaloids.

borate the available embryological (Soueges 1953) and palynological evidences and support the placement of **Peganum** in a separate family Peganaceae having close relationships with both the Zygophyllaceae and Rutaceae.

The Zygophyllaceae (excluding Peganaceae) is a homogeneous taxon producing flavonols especially kaempferol, quercetin and their derivatives, as dominant phenolic pigments. Steroidal sapogenins, alkaloids and ferulic acid are present in almost all the plants. In containing herbacetin, **Fagonia cretica**, is distinct from the other genera of the family.

Balanites aegyptiaca possessing flavones, similar type of phenolic acids, steroidal sapogenins and alkaloids is chemically very much at home in the family. Maksaud and El Hadidi (1988) came to a similar conclusion when they compared the data of flavonoid glycosides of **Balanites** with the other Zygophyllaceae members. They found that all the flavonoid glycosides of **Balanites** are identified from the various members of the Zygophyllaceae. Inspite of these, on the strength of the data from leaf vasculature, floral morphology and pollen structure, the same authors recommended a very isolated position for the genus. It is to be recalled that the close affinity of the genus with the Zygophyllaceae than the Simaroubaceae is identified based on epidermal structure and stomatal ontogeny (Inamdar, 1969, see also the discussion on the Simaroubaceae). **Tribulus rajasthaniensis**, a new species created by Bhandari and Sarma (1977) differs from the related species **T.terrestris** in containing quinones, gentisic acid and in absence of kaempferol and quercetin. These characters defend the specific status given to **T. rajasthaniensis**.

The Zygophyllaceae have a number of characters common with the Meliaceae (flavonols, guaianolides), Rutaceae (herbacetin, flavones, lignans) and Simaroubaceae (β - carbolines).

It is also close to the Sapindaceae in containing saponins. However it differs from all these families in not containing proanthocyanidins and tannins. The family has an unusual combination of primitive (flavonols) and advanced (flavones) characters. The absence of other primitive characters like proanthocyanidins and tannins also keep the family fairly advanced. Such a combination of primitive and advanced characters are observed in morphological and anatomical charcters also. Therefore the Zygophyllaceae may be considered as one of the advanced families of Sapindales which somehow retain some of the primitive characters.