GENERAL DISCUSSION

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In the present study, five major families such as the Amaranthaceae, Chenopodiaceae, Caryophyllaceae, Polygonaceae, Cactaceae and seven smaller families viz. the Nyctaginaceae, Petiveriaceae, Gisekiaceae, Portulacaceae, Phytolaccaceae, Basellaceae, and Illecebraceae have been studied Chemotaxonomically. The distribution of various natural products in these families is presented in the table. 19. Flavonols formed the dominant phenolic pigments of the group as a whole. The Amaranthaceae, Chenopodiaceae, Cactaceae, Illecebraceae, Petiveriaceae, Nyctaginaceae and Polygonaceae are rich in these compounds. Flavones and glycoflavones predominated the Caryophyllaceae. All these groups of flavonoids are present in Basellaceae and Amaranthaceae. In Portulacaceae and Phytolaccaceae flavonoids are absent. Proanthocyanidins are seen in both Polygonaceae and Cactaceae, but their distribution is very less in the latter family. Alkaloids have a very restricted occurrence, obtained from the Phytolaccaceae, Cactaceae and Chenopodiaceae. Quinones and tannins are located only in Polygonaceae. Saponins and steroids are universally present, whereas the iridoids are absent in all the families screened.

The presence of quinones as the dominant phenolic pigments marks Polygonaceae distinct from other families.

TABLE - 19. SHOWING DISTRIBUTION OF VARIOUS NATURAL PRODUCTS AND THEIR PERCENTAGE OF INCIDENCE IN THE FAMILIES STUDIED

Name of the Family	Flavonols	Flavones	Glyco-flavone	Tannins	Proanthocyanidins	Alkaloids	Saponins	Steroids	Quinones
AMARANTHACEAE	Moderate (39.13%)	Rare (4.34%)	Rare (4.34%)	Absent	Absent	Present (39.13%)	Present (100%)	Present (100%)	Absent
CHENOPODIACEAE	Abundant (92.30%)	Absent	Present (7.6%)	Absent	Absent	Present (64.44%)	Present (100%)	Present (100%)	Absent
BASELLACEAE	Present (100%)	Present (100%)	Present (100%)	Absent	Absent	Absent	Present (100%)	Present (100%)	Absent
CACTACEAE	Abundant (100%)	Absent	Absent	Absent	Present	Present (100%)	Present (100%)	Present (100%)	Absent
NYCTAGINACEAE	Moderate (75%)	Absent	Absent	Absent	Absent	Rare (22.22%)	Present (100%)	Present (100%)	Absent
PORTULACACEAE	Absent	Absent	Absent	Absent	Absent	Absent	Present (100%)	Present (100%)	Absent
PHYTOLACCACEAE	Absent	Absent	Rare	Absent	Absent	Present (50%)	Present (100%)	Present (100%)	Absent
ILLECEBRACEAE	Present (100%)	Absent	Absent	Absent	Absent	Absent	Present (100%)	Present (100%)	Absent

(Contd...)

TABLE - 19 (Contd.)

Name of the Family	Flavonols	Flavones	Glyco-flavones	Tannins	Proant-hocyani-dins	Alkaloids	Saponins	Steroids	Quin-ones
PETIVERIACEAE	Present (100%)	Absent	Absent	Absent	Absent	Absent	Present (100%)	Present (100%)	Absent
GISEKIACEAE	Present (100%)	Absent	Absent	Absent	Absent	Absent	Present (100%)	Present (100%)	Absent
CARYOPHYLLACEAE	Rare (12.5%)	Present (25%)	Abemd-ent (87.50%)	Absent	Absent	Absent	Present (100%)	Present (100%)	Absent
POLYGONACEAE	Abund-ent (82.35%)	Rare (23.52%)	Rare (11.76%)	Present (47.05%)	Present (47.05%)	Absent	Present (100%)	Present (100%)	Present

The widespread occurrence of tannins and proanthocyanidins in this family is another significant feature. Such differences are also seen in other characters such as the ultrastructure of sieve-element plastids (Behnke, 1976) and pollen morphological features (Nowicke and Skvarla, 1977). The similarities of the Polygonaceae with other families screened are restricted to the widespread occurrence of flavonols, unilocular ovary, solitary ovule in basal placentation and a more or less curved embryo.

The unique chemical characters of the Polygonaceae justify their present placement in the monotypic order, the Polygonales. The presence of unilocular ovary and solitary ovules in basal placentation and the curved embryo validates keeping the Polygonales in the subclass Caryophyllidae, along with the Caryophyllales.

The distribution of various classes of flavonoids demarcate two groups in the Caryophyllales. The first group, containing the Amaranthaceae, Chenopodiaceae, Nyctaginaceae, Illecebraceae, Basellaceae, Petiveriaceae, Phytolaccaceae and Portulacaceae, are characterized by the presence of flavonols as the main phenolic pigments. (Though flavonoids were not detected from the members of Phytolaccaceae and Portulacaceae screened in the present study, the reports of flavonoids from other members of these taxa (Richardson, 1981; Doyle Jeft, 1983) are considered here.) Except for the Illecebraceae, all these families characteristically produce betalains. Apart from this, alkaloids are detected in this group only. The second group containing the Caryophyllaceae and Molluginaceae are characterized by flavones and glycoflavones (Daniel and Sabnis, 1986). Moreover, they produce anthocyanins, instead of betalains.

Though the Illecebraceae is kept in the first group, this family differs from other families of this assemblage in producing anthocyanins. It is therefore logical to assume that this family, in the absence of betalain-synthesising machinery and in containing anthocyanins is similar to the Caryophyllaceae and Molluginaceae. The occurrence of flavonols in some members of Caryophyllaceae brings the Illecebraceae closer to the Caryophyllaceae. The two groups visualised above with in the Caryophyllales correspond to the suborder Chenopodineae and Caryophyllineae proposed by Mabry *et al.* (1977).

Within the suborder Chenopodineae, the families Amaranthaceae, Chenopodiaceae, Basellaceae and Phytolaceaceae appear to be very closely related because of the higher incidence of flavonols and in containing flavones and/or glycoflavones in a few members. The Chenopodiaceae and Phytolaccaceae contained glycoflavones. The Amaranthaceae and Basellaceae possessed both flavones and glycoflavones. None of the members of this group contained proanthocyanidins. In the second group, consisting of the Cactaceae, Aizoaceae, Nyctaginaceae, Portulacaceae, Petiveriaceae and Gisekiaceae, flavonols formed the sole group of flavonoids. Flavones and glycoflavones are not located from this group, and at least two families contained proanthocyanidins.

In the first group of families, the Amaranthaceae and Basellaceae have more or less same pattern of flavonoid distribution and hence they are very close to each other. The presence of flavones and glycoflavones keeps both these families at a higher evolutionary level. Both these families may represent evolutionary lines originating from the flavonol-rich Chenopodiaceae. The Amaranthaceae retain many of the features of Chenopodiaceae such as sieve element plastids devoid of protein Crystaloids (Behnke, 1976), more or less same type of pollen grains (Nowicke and Skvarla, 1977), and the same basic chromosome number (Ehrendorfer, 1976) and are directly evolved from Chenopodiaceae. The Basellaceae is unique in possessing cuboidal pollen grain (Nowicke and Skvarla, 1976) and is also different in having sieve element plastids with globular protein crystaloids, thus representing another line of evolution from the Chenopodiaceae.

In the second category the Aizoaceae and Cactaceae are very much alike in possessing proanthocyanidins and higher frequency of incidence of flavonols. The prevalence of CAM photosynthetic pathway is another notable similarity between these families. The presence of 6-hydroxy flavonol (Sesuvin) in many members of Aizoaceae (Banerji and Chintalwar, 1971; Daniel and Sabnis, 1986) keep them chemically distinct from Cactaceae. Among the remaining families of this group, only the Phytolaccaceae come closer to these two families in their features. The Phytolaccaceae share a number of characters with the Aizoaceae such as round protein crystaloids in sieve element plastids, alternate leaves, thyrsoid inflorescence, hermophrodite pentamerous flowers with single perianth, two (three) whorls of stamens, tricolpate pollen grains, 5-free or partly fused carpels with axile placentation and numerous ovules. The absence of proanthocyanidins and presence of glycoflavones keep Phytolaccaceae in a relatively advanced position in the evolutionary sequence than Aizoaceae and Cactaceae. If the presence of apocarpous pistil in some members of Phytolaccaceae is considered as of secondary origin (Rohweder, 1965, a,b). The phytolaccaceae may well be derived directly from Aizoaceae.

Among the remaining four families, Nyctaginaceae, Petiveriaceae and Gisekiaceae exhibit some or the other features of similarity with Phytolaccaceae. The Nyctaginaceae and Phytolaccaceae are the only families in Caryophyllales containing starch grains in their sieve element plastids (Behnke, 1976). The Petiveriaceae and Phytolaccaceae are similar in all characters except for the dry and elongate fruit (with 4 reflexed sharp, apical prickles) densely pubscent ovary, hairy stigma and sulphur containing compounds present in the former family. The Gisekiaceae are also closer to the Phytolaccaceae in characters like nature of gynoecium (See the Chapter on the Phytolaccaceae for a detailed discussion of the inter-relationships of the Gisekiaceae). On the other hand, the Portulaccaceae show certain similarities towards Aizoaceae in characters like succulent nature and many stamens and ovules.

The morphological and chemical peculiarities of the Caryophyllales which bind them as an order obviously support the monophyletic origin of this group. These characters are the production of betalains and p-type sieve element plastids, pantoporate type of pollen grains and the peculiar Caryophyllalean embryological syndrome.

Cronquist (1968) and Buxbaum (1961) derive this group from Illiceaceae of the order Illiceales (Magnolidae). Apart from the presence of apocarpous pistil there is nothing in common between the Illiceaceae and Caryophyllales. Chemically these two groups are very dissimilar. Anisatin (a toxic lactone) and scattered ethereal oil cells prevalent in the Illiceaceae are unknown in Caryophyllales.

Similarities between the Dilleniidae and Caryophyllales which were cited in support of the close relationships existing between these two taxa are not reflected in the chemical characters. Mustard oils and iridoids, the characteristic compounds of Dilleniidae are not seen in any member of the Caryophyllales. The presence of sulphides in the Petiveriaceae similar to thiocynates of the Dilleniidae may be considered accidental.

Ranunculales, another possible ancestor of Caryophyllales (Cronquist, 1981) possess benzylisoquinoline and aporphine type of alkaloids, which are not detected in Caryophyllales.

A quest for the roots of Caryophyllales elsewhere will be a lot more easier if one searches for the taxa rich in the precursors of betalains, the characteristic pigments of this group. DOPA (Dihydroxyphenylalanine), the precursor of betalains, has been reported in many members of Fabales such as _Phaseolus_, _Vicia_, _Cicer_, _Baptisia_ and _Mucuna_ (Andrews and Pridham, 1966). Stizolobic acid, formed by the extra-diol cleavage of DOPA, and which is found to be another intermediate in the biosynthesis of betalains, is detected in the young leaves of _Stizolobium hassjoo_ and _Mucuna_ (Fabaceae) along with DOPA. The enzyme responsible for the production of stizolobic acid (4,5-extradiol deoxygenase) is present in the Fabaceae and Caryophyllales. (Ellis, 1976). Sieve-tube plastids containing irregular protein crystaloids, which are more or less similar to the the p-plastids of the Caryophyllales, are located in some members of Fabales (Cronquist, 1981). The occurrence of triterpenoid saponins and indole and quinolizidine alkaloids in Fabales and in Chenopodiaceae provides some more features of similarity. But the Fabales are relatively a far too advanced group for considering ancestral to the Caryophyllales and these similarities evidently point to a common origin. Thus the search narrows down to Rosales, the ancestral group of Fabales. A number of morphological features seen in the Caryophyllales are present in various members of the Rosales. Apart from the apocarpous pistil, apetalous flowers (Cunoniaceae, Davidsoniaceae), curved embryo (Rosaceae, Surinaceae) and free central placentation (Chrysobalanaceae) are the Caryophyllalean features observed in some of the Rosales. CAM phytosynthetic pathway is another feature of similarity between the Rosales (Crassulaceae) and Caryophyllales (Aizoaceae, Cactaceae).

Apparently, there is no doubt about the antiquity of the Rosales. Cronquist (1981) opines that "if other orders of Rosidae are wiped out of existence the order Rosales could be accommodated without great difficulty as a somewhat isolated order of Magnolidae". All these evidences tempt anybody to assume that Caryophyllales represent one line of evolution from Rosales (or a prerosalian group) parallel to the line of evolution culminating in Fabales. When this proposal was referred to Cronquist, (Senior Scientist, The New York Botanical Garden) it elicited the following comments......" the possible ancestry of the Caryophyllales in or just antecedent to the Rosales has enough plausibility to warrant further consideration" (Personal communication dated 2nd Oct. 1987). The probable scheme of evolution of this taxon is summarised in Fig.

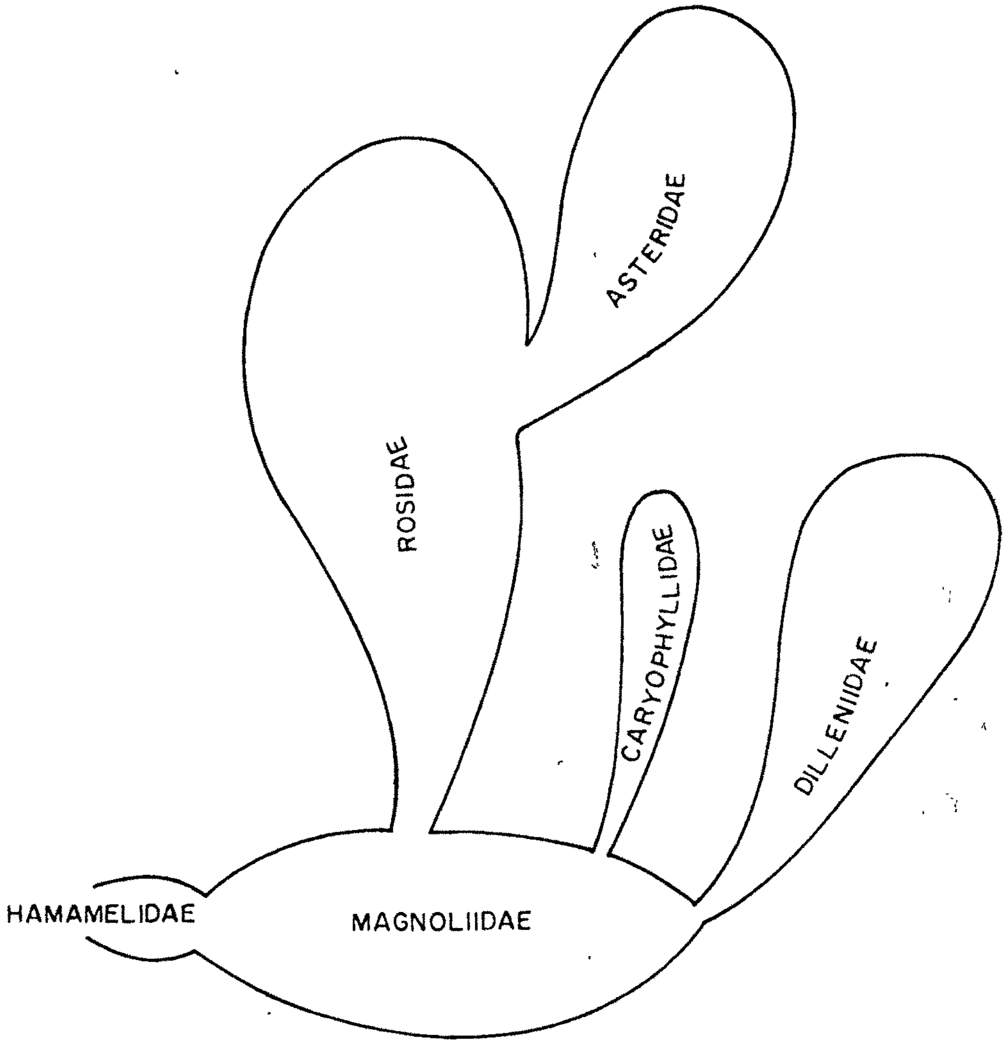

FIG.3. PROBABLE RELATIONSHIPS AMONG THE SUB CLASSES OF MAGNOLIOPSIDA (CRONQUIST, 1968)

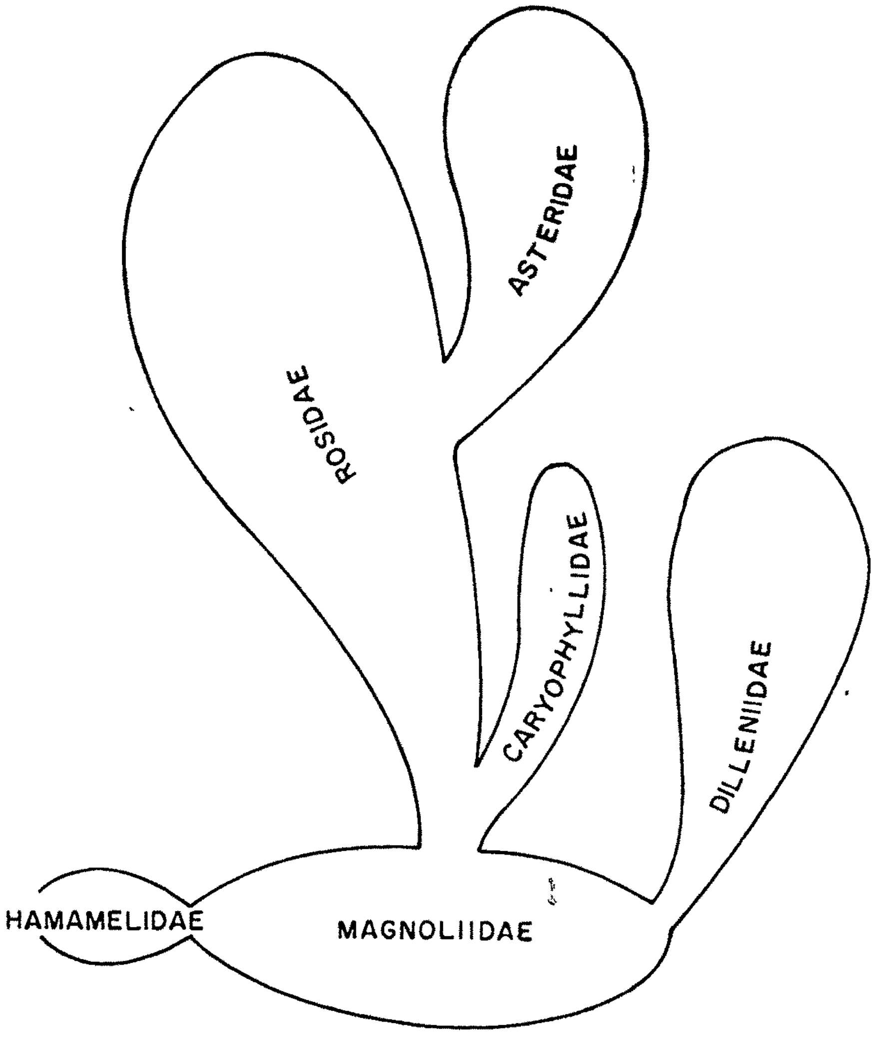

FIG.-4 MODIFIED DIAGRAM SHOWING PROBABLE RELATIONSHIPS OF CARYOPHYLLIDAE TO ROSIDAE