# CHEMOSYSTEMATICS OF THE CHENOPODIACEAE

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## INTRODUCTION

The Chenopodiaceae, the 'Goosefoot' family, consist of about 100 genera and 1500 species (Cronquist, 1981) of cosmopolitan distribution. The family is represented abundantly in desert and semidesert regions. Many members of this family are halophytes.

The Chenopodiaceae members are predominantly herbs. The leaves are alternate, rarely opposite, entire (lobed or toothed in Chenopodium). Flowers are generally small and greenish, 1-many and glomerate in the leaf axils or in bracteate or bractless spikes, panicles or cymes. Flowers are mostly regular, perfect sometimes unisexual. Sepals (1-5) (6), distinct or basally connate, petals absent, stamens of the same number as the sepals and opposite to them, but sometimes fewer, filaments distinct or connate at the base, hypogynous or inserted on an annular disc or adnate to the base of calyx. Anthers are tetrasporangiate and dithecal, opening by longitudinal slits. Ovary is superior but in Beta it is half-inferior, carpels 2-3(-5), united to form compound unilocular ovary with distinct or more or less connate styles. Ovule solitary, basal,

amphitropous to more often campylotropous, bitegmic, crassinucellar. Fruit is generally an urticle or nut. In Beta several fruits ripen together with the calyx forming a multiple fruit. Seeds are lenticular with annular or spirally twisted dicotyledonous embryo. In Dysphania the embryo is only slightly curved.

ECONOMIC IMPORTANCE

Economically the most important plant in this family is Beta vulgaris var. rapa (sugar beet), a source of sugar, which is a substitute for cane sugar. Annual production of sugar beet exceeds 220 million tons, mostly from Soviet Union and Europe. Apart from that, many varities of Beta vulgaris are used as leafy vegetables, they are Beta vulgaris var. cicila (Swisschard), B. vulgaris var. crassa (Mangels) and B. vulgaris var. vulgaris (Garden beet). Other vegetables from this family include Spinacia oleracea (Spinach), Suaeda fruticosa, S. maritima, Salsola bryosma, Chenopodium album and C. murale. A pseudocereal, Chenopodium quinoa (Quinoa) also belongs to this family. Fruits of Chenopodium ambrosioides var. anthelminticum yield a volatile oil containing 'Ascaridol', an anthelmintic.

TAXONOMY

Based on the nature of embryo, Bentham and Hooker (1880)

divided the family Chenopodiaceae into two series, The Cyclobeae and Spirolobeae. The Cyclobeae are characterized by cyclical embryo whereas Spirolobeae has spiral embryo. The Series Cyclobeae are classified into seven tribes viz. The Euchenopodieae, Atripliceae, Camphorosmeae, Corispermeae, Polychemeae, Chenoloceae and Salicornieae. Spirolobeae contains four tribes, Suedeae, Salsoleae, Sarcobatideae and Eubaselleae.

William and Ford (1974) classified the family into 3 subfamilies, the Chenopodieae, Salsoleae and Beteae. The subfamily Chenopodieae one characterized by the presence of cyclical embryo, endosperm in the seeds, superior ovary and absence of operculum in the fruit. Spiral embryo, superior ovary, absence of endosperm and operculum are the distinguishing features of the Salsoleae, whereas Beteae are demarcated by cyclical embryo, operculum in the fruit, endosperm and semiinferior ovary. The subfamily Chenopodieae contain 20 genera, Salsoleae 14 genera and Beteae two i.e. Hablitzia and Beta.

Blackwell (1977) recognized only two subfamilies, the Chenopodioideae and Salsoloideae, the former with cyclical embryo and the latter with spiral embryo.

The existance of these two distinct groups in the family Chenopodiaceae was recognized by many authors like Engler (1964) Iljin (1936) and Ulbrich (1934) also.

Most of the taxonomists do not agree in keeping Eubaselleae, the last tribe (Bentham and Hooker, 1880) along with other members of Chenopodiaceae. Eichler (1876) separated this tribe from the Chenopodiaceae and raised to the status of a family, Basellaceae. This separation is supported by many (Engler 1964; Lawrence, 1951; Cronquist, 1961). The Eubaselleae differs from the rest of the Chenopodiaceae by the biseriate perianth and climbing habit. Palynologically the cuboidal pollen grains of Basella are highly unique in the angiosperms (Nowicke, 1975) and entirely different from the rest of the Chenopodiaceae.

Cytologically also this uniqueness is evident, Basella has X = 12 (Ehrendorfer, 1976) as against X = 9 of the rest of the Chenopodiaceae. But the most important data regarding the separation of Basella come from the ultrastructure of sieve element plastids. The Amaranthaceae and Chenopodiaceae are the two families in Caryophyllales (perhaps in angiosperms) having the P-III sub-type plastids without protein crystalloids. But Basella, like most of the other members of Caryophyllales are with globular protein crystaloids (Behnke, 1976). Moreover, the $C_4$-photosynthetic pathway present in Chenopodiaceae is absent in the Basella which has $C_3$-pathway.

PREVIOUS CHEMICAL WORK

The known chemical data of various Chenopodiaceae members include flavonoids, alkaloids and steroids (Table-4 ). Flavonoids reported in this family are flavonols like kaempferol, gossypetin and flavones such as 7-O-methyl luteolin. Pyridines and quinolizidines are the types of alkaloids reported in this family. The steroids reported in this family include estrogen, β -ecdysone, polypodine-B and sitosterol. The nutritional and phytochemical studies on some edible members of the Chenopodiaceae is presented in the appendix.3

In the present study, 14 members of the Chenopodiaceae have been screened for various chemical markers and data thus obtained have been used to understand the intrafamilial classification.

MATERIALS AND METHODS

The plants were collected from different localities like Kerala (Chenopodium ambrosioides), Gujarat (Salsola brayosma, Chenopodium murale, C.album, Sueda nudiflora, Haloxylon recurvum) and Kashmir (Chenopodium botryodes, Agroglochin persicarioides). All the voucher specimens have been deposited in the Herbarium of M.S. University of Baroda, Baroda, India. Mature leaves were used for the analysis of phenolics and other chemical markers. The

TABLE 4 SOME OF THE FAMILIAR CHEMICAL CONSTITUENTS IN THE CHENOPODIACEAE

| | Name of the plants | Organ | Name of the Compounds | Reference |
|---|---|---|---|---|
| | | | ALKALOIDS | |
| 1. | Anabasis aphylla | - | Pyridine and quinolizidine | Sadykov, A.S. et al. (1965) |
| 2. | Anabasis aphylla | - | isomer of anabasine | Brutko et al. (1968) |
| 3. | Chenopodium botryodes | fruit | $C_{20}H_{52}O_7N$ | Sadykov et.al. (1978) |
| 4. | Haloxyon persicum | - | Anabasine and nicotine | Habib, A.A.K. et.al. (1974) |
| 5. | Haloxylon spp. | | Chloroform soluble alkaloids | Sandberg et.al. (1967) |
| 6. | Salicornia herbacea | | Saliherbine, Salicornine (tertiary base) | Borkowski et.al. (1965) |
| 7. | | | FLAVONOIDS | |
| 1. | Atraphaxis pyrifolia | | 3-Rhamnoside of -7-O-methylgossypetin | Chumbalov, et.al. (1975) |
| 2. | Atraphaxis pyrifolia | | 4'-β-L-rhamnopyranoside-7-O-methyllutcolin | |
| 3. | Atraphaxis spinosa | | 5,6,7,4'-tetrahydroxy flavone | Chumbalov et.al. (1971) |
| | | | 1% -1 rhamnopyranosl-7-O-methylluteolin | |
| | | | 4'-β D-glyconuronosyl 6-β-L-glycopyranoside | ,, |

(Contd....)

TABLE-4 (Contd.)

| | | | | |
|---|---|---|---|---|
| 4 8. | Chenopodium botrytis | | Hispidulin, Salvigenin<br>5-Methylsalvigenin, 7-Methyleupalcilin<br>Sinensentin | ...e Vascuni et.al.(1981) |
| 5 4. | Chenopodium ambrosioides | | Kaempferol-7-rhamnoside<br>kaempferol-7-rhamnoside with one mol each of glucose and Rhamnose | Ariesna et.al.(1971) |
| 6. 7. | Chenopodium atrovirensis | | | |
| | C. desiccatum | | 3-O-glycoside of quercetin | Crawford et.al.(1975) |
| | C. incognitum | | iso rhamnetin | |
| | C. hians | | | |
| 7. 8. | Chenopodium graveolens | | Flavonoids | ...achalmata et.al.(1986) |

SAPONINS AND RELATED COMPOUNDS

| | | | | |
|---|---|---|---|---|
| 1. | Beta vulgaris | | 3-O-(β-D glucopyranoside of oleanolic acid and its methyl ester | ...afetau et.al.(1970) |
| 2. | Chenopodium ambrosoides | | Triterpenoid glycoside | ...Bogacheva, et.al.(1972) |
| 3. | Kochia tricophylla | | Oleanolic acid saponin | ...moon et.al.(1966) |
| 4. | Kochia scoparia | fruit | Triterpenoid Saponin | ...Souto, Jesus (1957) |
| 5. | Salsola micranthera | | Triterepenoid glycosides<br>3-(O-β-D-xylopyranoside(1 4)-O- D-glycopyranosyl(1-2) or - L- β-glucopyranoside<br>28-O- -glucopyranoside of oleanic acid | ...mmaev, et.al.(1984) |

(Contd....)

TABLE- 4 (contd.)

| | | | | |
|---|---|---|---|---|
| 6. | Spinacea oleraceae | | spinosaponins A & B | [illegible]aenesche et.al.(1969) |
| 7. | Beta vulgaris | leaves | C-24 alkylated $\Delta^5$ sterols | |
| | | | $\Delta^5$ sterols | [illegible]ler et.al. (1983) |
| 8. | Chenopodium rubrum | | Steroidal estrogen | van hompuy et.al. (1972) |
| 9. | Chenopodium rubrum | | Estrogen | [illegible]pendiez et.al. (1972) |
| 10. | C. quinoa | | Sitosterol | Burnouf-Radosevich et.al.(1984) |
| 11. | Chenopodium bonus-hendricus | | 20-hydroxy-24-methylecdysone | [illegible]athory [illegible] (1984) |
| 12. | Spinaceae oleraceae | | 20-hydroxy 24 Methyl ecdysone | [illegible]athory (1984) |
| 13. | Spinaceae oleraceae | leaves | Sterols | [illegible]chenberger et.al. (1966) |
| 14. | Salsola transcaucica | | Triterpene glycoside | [illegible]nacv et.al.(1984) |

procedures followed in the extraction, isolation and identification of these compounds are described in Chapter-2.

RESULTS

The distribution of flavonoids, phenolic acids, alkaloids, saponins and steroids from leaves of 14 members of Chenopodiaceae is presented in the table. 5 and 6.

All the members screened contained flavonols. Beta vulgaris var. rapa and Basella rubra were the members containing glycoflavones. Flavones were located in Basella only, which incidentally contained flavonols and glycoflavones.

The subfamily Chenopodioideae in which 9 species were analysed showed the dominance of flavonols. The different type of flavonols identified in this subfamily were mono-, or dimethoxy derivatives of kaempferol and quercetin. Kaempferol was detected in 4 members, Agroglochin persicaroides, Chenopodium murale, C. botryodes, C. hydridum and Kochia indica. Agroglochin persicarioides, Chenopodium murale, Kochia indica and Salicornia brachiata contained quercetin. 4'-OMe Kaempferol was present in Agroglochin persicarioides, Chenopodium botryodes and Kochia indica whereas 3'-OMe quercetin was detected in Beta vulgaris var. Rapa and Chenopodium album. 7-OMe Quercetin was located in Chenopodium hybridum. Salicornea brachiata contained

TABLE - 5. DISTRIBUTION OF FLAVONOIDS IN THE FAMILY CHENOPODIOCEAE*

| Sl.No. | Name of the Plants | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | SERIES CYCLOBEAE | | | | | | | | | | | |
| | TRIBE I EUCHENOPODIAE | | | | | | | | | | | |
| 1. | Agroglochin persicarioides Linn. | + | + | | + | | | | | | | |
| 2. | Beta vulgaris var rapa Linn. | | | | | + | | | | | + | |
| 3. | Chenopodium album Linn. | | | | | + | | | | | | |
| 4. | Chenopodium murale Linn. | + | | | + | | | | | | | |
| 5. | C.botryodes Sm. | + | + | | | | | | | | | |
| 6. | C.hybridum Linn. | + | | | | | | + | | | | |
| 7. | C.ambrosioides Linn. | | | | | | | | | | | |
| | TRIBE CHENOLEAE | | | | | | | | | | | |
| 8. | Kochia indica Wight. | + | + | | + | | | | | | | |
| | TRIBE - SALICORNIEAE | | | | | | | | | | | |
| 9. | Salicornia brachiata Roxb. | | | | + | | + | | + | | | |

(Contd....)

TABLE - 5 . (Contd.)

| Sr. No. | Name of the Plants | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SERIES - SPIROLOBEAE | | | | | | | | | | | |
| | TRIBE - SUAEDEAE | | | | | | | | | | | |
| 10. | Suaeda fruticosa (L.) Forsk. | | | | + | + | | | | + | | |
| 11. | Suaeda nudiflora (Wild) Moq. | | | | + | | + | | + | | | |
| 12 | TRIBE-SALSOLAE | | | | | | | | | | | |
| 12. | Salsola baryosma (R.& S.) Dandy. | | | | | + | | | | | | |
| 13. | Haloxylon recurrum (Moq.)Bunge ex Bioss. | | | | | + | | | + | | | |
| 14. | Basella rubra Linn. | | | + | | | | | | | | + |

1. Kaempferol 2. 4'-OMe Kaempferol, 3. 7,4'-diOMe Kaempferol, 4. Quercetin,
5. 3' OMe-Quercetin . . 6. 4'-OMe Quercetin, 7. 7,OMe Quercetin
8. 3',4'-diOMe Quercetin 9. 7,4'-diOMe Quercetin, 10. 4'-OMe Vitexin,
11. 6-Glycosylated acacetin.

* Bentham and Hooker (1880).

TABLE - 6 . DISTRIBUTION OF PHENOLIC ACIDS, SAPONINS, STEROIDS AND ALKALOIDS IN THE FAMILY CHENOPODIACEAE*

| Sr.No. | Name of the Plants | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SERIES - CYCLOBEAE | | | | | | | | | | | | |
| | TRIBE - I EUCHENOPODIAE | | | | | | | | | | | | |
| 1. | Agroglochin persicarioides Linn. | + | | + | | | | | | | + | + | |
| 2. | Beta vulgaris var rapa Linn. | + | + | + | + | + | | | | | + | + | + |
| 3. | Chenopodium album Linn. | + | + | | | | | | | | + | + | + |
| 4. | Chenopodium murale Linn. | + | | + | | | | | | | + | + | + |
| 5. | C.botryodes Sm. | + | | + | | | | | | | + | + | + |
| 6. | C.hybridum Linn. | + | + | + | | | | | | | + | + | + |
| 7. | C.ambrosioides Linn. | + | + | | | | | | | | + | | |
| | TRIBE - CHENOLEAE | | | | | | | | | | | | |
| 8. | Kochia indica Wight | + | | + | | | | + | | | + | + | |
| | TRIBE - SALICORNEAE | | | | | | | | | | | | |
| 9. | Salicornia brachiata Roxb. | + | + | | | | | | + | | + | + | |

(Contd...)

TABLE - 6 (Contd.)

| Sr.No. | Name of the Plants | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SERIES - SPIROLOBEAE | | | | | | | | | | | | |
| | TRIBE - SUAEDEAE | | | | | | | | | | | | |
| 10. | Suaeda fruticosa (L.) Forsk | + | + | | | | | | + | | + | + | + |
| 11. | Suaeda nudiflora (Wild) Moq. | + | + | | | + | | + | | | + | + | + |
| | TRIBE - SALSOLEAE | | | | | | | | | | | | |
| 12. | Salsola baryosma (R. & S.) Dandy. | + | + | + | + | + | | + | | | + | + | + |
| 13. | Haloxylon recurvum (Moq.) Bunge ex Boss. | + | + | + | + | + | | + | | + | + | + | + |
| 14. | Basella rubra Linn. | + | + | | | | | + | | | + | + | |

1. Vanillic, 2. Syringic 3. p-OH Benzoic, 4. Melilotic, 5. Gentisic,
6. p-Coumaric, 7. Ferulic, 8. Resorcylic, 9. Protocatachuic, 10. Saponins,
11. Steroids, 12. Alkaloids.

* After Bentham and Hooker (1880)

3,4'-diOMe quercetin. 4'-OMe Vitexin was the glycoflavone isolated from Beta vulgaris var. rapa.

Four members of the subfamily Salsoloideae contained quercetin and its various methoxylated derivatives. Quercetin was located in Suaeda fruticosa and S.nudiflora. 3'-OMe Quercetin was present in Suaeda fruticosa, Salsola brevoana and Haloxylon recurvum. Suaeda nudiflora was the only member with 4'-OMe quercetin. 3',4'-diOMe quercetin was located in two species, Suaeda nudiflora and Haloxylon recurvum and 7',4'-diOMe quercetin was present in Suaeda fruticosa.

Basella rubra was distinct in containing a flavone (acacetin), a flavonol (7,4'-diOMe kaempferol) and a glycoflavone (4'-OMe isovitexin).

Nine phenolic acids have been detected in this family, of which, vanillic, Syringic, p-OH benzoic, melilotic, gentisic, ferulic and resorcylic acids were common to both subfamilies. Protocatechuic acid was confined to the subfamily Salsoloideae.

Saponins and steroids were universally present. Nine out of 14 plants showed positive test for alkaloids. Iridoids, tannins, quinones and proanthocyanidins were absent in all the members screened.

DISCUSSION

Basella differs from all other plants screened here in possessing all the three types of flavonoids i.e. flavonol (7,4'-di-OMe kaempferol), flavone (acacetin) and glycoflavone (4'-OMe isovitexin). This peculiar combination of flavonol, flavone, glycoflavone is found nowhere in the Chenopodiaceae. This uniqueness of Basella validates the separation of the Eubaselleae to a separate family Basellaceae as practised by many taxonomists (Eichler, 1876; Tahktajan, 1980; Cronquist, 1981).

With the removal of Basella the family Chenopodiaceae becomes a homogenous cluster of genera characterised by the predominance of flavonols, absence of iridoids, tannins and proanthocyanidins.

Beta vulagaris var. rapa is chemically very distinct from all other plants screened is containing glycoflavone along with flavonols. This chemical identity warrant a separate status for this genus. The creation of a separate subfamily Betiodeae to incorporate this genus as done by William and Ford (1974) is thus supported.

The two subfamilies of (Blackwell, 1977) Chenopodiaceae showed more or less same flavonoid distribution pattern, eventhough the methoxylation pattern is different in some

cases (7,4'-diOMe quercetin is present only in the Salsoloideae). The 5 tribes (3 and H) represented in the present study did not show any chemical identities among themselves. The absence of chemical distinctiveness in the various tribes of the Chenopodiaceae is indicative of the homogenous nature of this family, which is also evident from palynological and cytological studies. Palynologically the pollen grains are characterized by thick tectum with few spines and a thin foot layer (Nowicke, 1975). Cytologically the basic chromosome number X = 9 is present uniformly almost throughout the family (Ehrendorfer, 1976).