CHEMOSYSTEMATICS OF THE AMARANTHACEAE

CHEMOSYSTEMATICS OF THE AMARANTHACEAE

INTRODUCTION

The Amaranthaceae are considered to be a tropical family with tropical America and India as the chief centres of distribution (Rendle, 1938). The dry regions of Africa and Australia also abound in large number of species of this family. The Amaranthaceae consist of 65 genera and 900 species (Cronquist, 1981). The larger genera of this family are Alternanthera Forsk. (170 spp.) and Ptilotus Br. (100 spp.)

Members of the family Amaranthaceae are mostly herbs. Leaves are alternate or opposite (Gomphrena), exstipulate, simple and normally entire. Flowers are small, hypogynous, perfect but unisexual in some Amaranthus species and are arranged in various type of inflorescences such as cymes, racemes, spikes or panicles. Sepals mostly 3-5, generally dry and scarious or membraneous, distinct or connate at the base. Stamens, normally, as many as the sepals and opposite to them. Filaments free or more often connate into a tube at the base. Anthers tetrasporangiate and dithecal. Species like Amaranthus and Allmania are with bisporangiate and unithecal anthers. Gynoecium is of 2-3(4) carpels united to form a compound unilocular ovary with a single, evidently lobed, style. Ovules are usually solitary, basal or apical and pendulous. In Celosia and Deeringia, ovules are several on a basal or less distinctly free central placenta. Fruit is an achene or a small nut. Seeds are with peripheral, annular, dicotyledonous embryo.

TAXONOMY

This family is divided by Bentham and Hooker (1880) into three tribes, the Celosieae, Amaranthcae, and Gomphreneae. The Celosieae contain plants with alternate leaves, 2-celled anthers and bilocular, 2-to many ovuled ovary. This tribe contains five genera. The tribe Amarantheae are characterized by 2-celled anthers, one-ovuled ovary and alternate leaves, whereas the tribe Gomphreneae possess one-celled anthers, one-celled ovary and opposite leaves. The tribe Amarantheae are further divided into two subtribes, the Achyrantheae (with curved seeds) and Euamarantheae (with erect seeds).

In a monograph on the taxonomy of the family Amaranthaceae, Schinz (1934) divided the family into two sub-families, the Amaranthoideae and Gomphrenoideae. The Amaranthoideae included two tribes, the Celosieae and Amarantheae. The Amarantheae are further divided into two subtribes, the Amaranthineae and Achyranthineae. The sub-family Gomphrenoideae are divided into tribes Froelichiineae and Gomphreneae. The concept of two sub-families in the family Amaranthaceae is accepted by many later workers including Thorne (1968) and Cronquist (1981). Kowal (1954), based on the morphological and anatomical features of the seeds, grouped the species of *Amaranthus* into three sections *viz*. *Amaranthotypus* Dumont, *Blitopsis* Dumont and *Puncticulate* Kowal.

ECONOMIC IMPORTANCE

Economically important plants in this family are *Amaranthus tricolour*, *A. viridis*, and *A. paniculatus* which are used as leafy vegetables. Species of *Celosia*, *Alternanthera*, *Gomphrena*, *Iresine* and *Amaranthus* are ornamentals. *Achyranthus aspera* is important medicinally, used against leprosy. *Alternanthera ficoides* var. *bettzickiana* is used as soil binder. Members of the Amaranthaceae, particularly species of *Achyranthus*, are noted for their "ecdysterones" (an insect-moulting hormone) which are known as 'third generation insecticides' because of their insect controlling role in agriculture.

REVIEW OF CHEMICAL LITERATURE

A few genera belonging to this family have been known for their chemical constituents. A great attention has been focussed on insect-moulting hormones from these plants (Hikino *et al*., 1968, 1970; Takemoto, 1967, 1968).

TABLE I . SOME OF THE EARLIER CHEMICAL WORKS IN THE AMARANTHACEAE

Name of the plants	Organ	Name of the compounds	Reference
		STERODS AND INSECT MOULTING HORMONES	
1. Amaranthus bidentata	Root	Ecdysterone	Takemoto et.al.(1968)
2. A.rutrofusca	"	Inokosterone	"
3. A. longifolia	"	"	"
4. A. obtusifolia	Terestrial portion		"
5. Amaranthus rutrofusca	-	Rubrostrone	Takemoto et.al.(1968)
6. Amaranthus spp.	-	"	"
7. Cyathula Spp.	-	Ecdysterol	Hikino et.al.(1972)
8. Aerva javanica	-	Hentriacontane, non acosane non acosanol, tritracontane, tetra-triacontane, Sitosterol	Usmanghnik et.al.(1982)
9. Achyranthus japonica			
10. A. longifolia	Lvs and Root	Steroids with Moulting hormone	Takemoto et.al.(1967)
11. A.bidentata			
12. Achyranthus obtusifolia		Ecdysterone	Takemoto et.al.(1968)
13. Achyranthus faurici	Root	Inokosterone	" (1967)
14. Achyranthus aspera	Root	Ecdysterone	Hikino, et.al.(1968)

(contd...)

TABLE-1 (Contd.)

15.	*Achyranthus radix*		β-Sitosterol and Stigmastrol	Takemoto *et.al*.(1968)
16.	*Bosea yervamora*	Root and Lvs	Steroids with moulting hormone	Takemoto *et.al*.(1967)
17.	*Cyathula capitata*	"	"	"
18.	" "		Cyasterone	Hikino, *et.al*.(1968)
19.	" "	-	Seagosterone	" (1970)
20.	*Irisin lindonii*	Lvs and Root	Steroids with moulting hormone	Takemoto *et.al*.(1967)
			FLAVONOIDS	
1.	*Aerva persica*		8-galactosyl-7-4-dihydroxy flavone	Garg (1980)
2.	*Amaranthus Spinosus*			
3.	*A. flavus* (a)	-	Rutin	Bech. *et.al*.(1977)
4.	*Amaranthus retroflexus*	Lvs	Rutin	Bech. T.D. (1963)
5.	*Gomphrena maritima*		5,6-dimethoxy-7-hydroxy flavone 5,7-dihydroxy-6-methoxy flavone	Mansour *et.al*.(1981)
6.	*Gomphrena Maritina*		Isorhamnetin 3-O-robinoside	Buschi *et.al*.(1982)

Flavonoids reported in this family include rutin, isorhamnetin and methylated flavonoids (Table-I). Nutritional and other phytochemical aspects of some of the edible members of this family are discussed elsewhere (see appendix).

Since the known data are not sufficient for a chemotaxonomic assessment, a systematic screening of all the available members of the Amaranthaceae for their leaf phenolics and other chemical markers have been carried out. These data in combination with data from other diciplines have been used to understand the intra-, and interfamilial relationships of the family and to assess the status of each taxon.

MATERIALS AND METHODS

Twenty three members belonging to 11 genera of the Amaranthaceae were screened for various chemical markers like flavonoids, phenolic acids, tannins, iridoids, saponins, alkaloids, steroids, quinones and proanthocyanidins.

The various genera and the number of species studied were as follows: *Celosia*(1), *Amaranthus* (7), *Allmania* (1), *Digera* (1), *Achyranthus* (1), *Aerva* (3), *Cyathula* (1), *Nothosaerva* (1), *Pupalia* (1), *Alternanthera* (3) and *Gomphrena* (3).

Majority of the plants were collected from localities in and around Baroda. The plants procured from other places were *Allmania nodiflora* from Kerala, *Alternanthera nudiflora* from Pachmarhi (M.P.) and *Amaranthus hybridus*, *A. caudatus*, and *A. lividis* from Kashmir. Voucher specimens of all the plants have been deposited in the herbarium of the M.S.University of Baroda, Baroda, India. (Appendix-2)

Mature leaves were analysed for phenolics and other chemical markers. The leaves were separated and dried at 60°C in an electric oven. The dried leaves were ground to powder in a grinder or blender. Powder was stored in air-tight glass containers or sealed plastic bags. Analytical procedures followed for the various groups of compounds are described in Chapter two.

RESULTS

The distribution of flavonoids, phenolic acids, saponins, and steroids in 23 members of the Amaranthaceae is presented in the Table-2 and 3.

The predominant flavonoids of this family are flavonols. Flavones, as o-glycosides and/or glycoflavones were present in a few species. Twelve out of 23 plants were devoid of the flavonoid system. 11 species gave a positive test for alkaloids. None of the plants contained iridoids, tannins quinones and proanthocyanidins.

TABLE - 2 . Showing distribution of Flavonoids in the family Amaranthaceae*

	AMARANTHACEAE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	TRIBE-I. CELOSIEAE																
1.	*Celosia plumosa* Linn.																
2.	TRIBE-II. AMARANTHEAE																
2.	Subtribe-EUAMARANTHEAE																
2.	*Amaranthus viridis* Linn.																
3.	*A. tricolor* Linn.																
4.	*A. hybridus* Linn.																
5.	*A. caudatus* Linn.												+				
6.	*A. lividus* Linn.																
7.	*A. paniculatus* Linn.																
8.	*A. spinosus* Linn.																
9.	*Allmania nodiflora* Rb.Br.							+									
10.	*Digera muricata* (L.) Mart.											+	+	+			

(Contd....)

TABLE - 2 . (Contd.)

AMARANTHACEAE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<u>Subtribe-ACHYRANTHEAE</u>																
11. <u>Achyranthus</u> <u>aspera</u> Linn.																
12. <u>Aerva</u> <u>javanica</u> Juss.									+		+					
13. <u>A.</u> <u>sanquinolenta</u> (Linn.) Blume.																
14. <u>A.</u> <u>lanata</u> (Linn.) Juss.																
15. <u>Cyathula</u> <u>prostrata</u> Blume																
16. <u>Nothosaerva</u> <u>brachiata</u> (Linn.) Wight								+								
17. <u>Pupalia</u> <u>lappacea</u> (Linn.) Juss.																
18 <u>TRIBE-III.</u> <u>GOMPHRENEAE</u>																
18. <u>Alternanthera</u> <u>nodiflora</u> Linn.																+
19. <u>A.</u> <u>pungens</u> Kunth.						+					+					
20. <u>A.</u> <u>sessilis</u> (Linn.) D.C.	+	+	+	+	+									+	+	
21. <u>Gomphrena</u> <u>decumbens</u> Linn.												+				
22. <u>G.</u> <u>celosioides</u> Mart.												+				
23. <u>G.</u> <u>globosa</u> Linn.										+	+					

1. 4-OMe Apigenin, 2. Luteolin, 3. 3-OMe Luteolin, 4. 4-OMe Luteolin, 5. 3,4-di OMe Luteolin, 6. 3-OMe Kaempferol, 7. 4-OMe Kaempferol, 8. 7,4-di OMe Kaempferol, 9. Quercetin, 10. 3-OMe Quercetin, 11. 3-OMe Quercetin, 12. 3,4-di OMe Quercetin, 13. 4-OMe Quercetin, 14. Vitexin, 15. Isovitexin, 16. 6-C-Glycoside of Acacetin.

* After Bentham and Hooker 1880.

TABLE - 3!. Showing distribution of phenolic acids, saponins, steroids, and alkaloids in the family Amaranthaceae *

	AMARANTHACEAE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	TRIBE-I. <u>CELOSIEAE</u>														
1.	*Celosia plumosa* Linn.	+	+	+						+			+	+	+
	<u>TRIBE-II. AMARANTHEAE</u>														
	Subtribe-<u>EUAMARANTHEAE</u>														
2.	*Amaranthus viridis* Linn.	+		+	+			+					+	+	
3.	*A. tricolor* Linn.	+		+				+					+	+	
4.	*A. hybridus* Linn.	+	+	+		+			+				+	+	+
5.	*A. caudatus* Linn.	+	+	+							+		+	+	+
6.	*A. lividus* Linn.	+	+										+	+	+
7.	*A. paniculatus* Linn.		+										+	+	+
8.	*A. spinosus* Linn.	+	+					+					+	+	
9.	*All?mania nodiflora* Rb.Br.	+	+										+	+	
10.	*Digera muricata* (L.) Mart.	+	+										+	+	

(Contd....)

TABLE - 3 (Contd.)

AMARANTHACEAE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Subtribe - ACHYRANTHEAE														
11. Achyranthus aspera Linn.	+	+										+	+	+
12. Aerva javanica Juss.	+	+								+		+	+	
13. A. sanquinolenta (Linn.) Blume	+	+					+				+			
14. A. lanata (Linn.) Juss.	+	+										+	+	
15. Cyathula prostrata Blume	+	+	+									+	+	+
16. Nothosaerva brachiata (Linn.)Wight.	+	+										+	+	
17. Pupalia lappacea (Linn.) Juss.	+	+										+	+	
TRIBE-III. GOMPHRENEAE														
18. Alternanthera nodiflora Linn.	+		+	+								+	+	+
19. A. pungens Kunth.	+		+		+	+	+					+	+	+
20. A. sessilis (Linn.) D.C.	+	+										+	+	+
21. Gomphrena decumbens Linn.	+	+										+	+	+
22. G. celosioides Mart.	+	+										+	+	
23. G. globosa Linn.	+	+										+	+	

1. Vanillic acid, 2. Syringic acid, 3. p-OH Benzoic acid, 4. Melilotic, 5. Gentisic, 6. p-Coumaric, 7. Ferulic, 8. Phloretic, 9. Chlorogenic, 10. Resorcylic, 11. o-Coumaric, 12. Saponins, 13. Steroids, 14. Alkaloids.

Flavonoids have been located in 11 members of which 6 contained only flavonols as the sole flavonoid pigments. Quercetin is located in *Aerva javanica*. 3-OMe, Quercetin is detected in *Gomphrena globosa* and 3'-OMe quercetin (isorhamnetin) in *Alternanthera pungens* and *Gomphrena globosa*. 4'-OMe Quercetin (Tamarixetin) is located in one species, *Digera muricata*. *Amaranthus caudatus*, *Gomphrena decumbens*, *Gomphrena celosioides* and *Digera muricata* contained 3',4'-diOMe quercetin.

Mono, and dimethylated kaempferols were present in three members. *Allmania nudiflora* contained 4'-OMe kaempferol. 3-OMe Kaempferol have been located in *Alternanthera pungens* and 7,4'-diOMe kaempferol is found to occur in *Nothosaerva brachiata*.

Flavones as O-glycosides have been located only in *Alternanthera sessilis*. The different flavones encountered in this species are 4'-OMe apigenin, luteolin, 3'-OMe luteolin, 4'-OMe luteolin add 3',4'-diOMe luteolin.

Alternanthera nodiflora and *A. sessilis*, contained glycoflavones in the leaves. Isovitexin was located in both the plants while its isomer vitexin was identified only in the latter plant.

Altogether 11 phenolic acids have been located in this family, of which vanillic, and syringic acids showed a very high percentage of incidence i.e. 100% and 82% respectively. p-OH Benzoic acid was present in about 50% of the plants. Melilotic, gentisic, p-Coumaric, cis- and trans-ferulic, phloretic, chlorogenic,β-resorcylic and o-coumaric acids were having a very low frequency of distribution.

Eight of the 11 phenolic acids were seen in the tribe Amarantheae. Phloretic, β-resorcylic and o-coumaric acids were confined to the tribe Amarantheae, p-coumaric acid to Gomphreneae and chlorogenic acid to Celosieae.

DISCUSSION

The predominance of flavonols such as quercetin, kaempferol and their derivatives binds all the members screened in this family. The presence of alkaloids as well as the absence of tannins, proanthocyanidins, iridoids are the other distinguishing characters of this family.

Chemical data deleneate all the three tribes of Bentham & Hooker (1880). The tribe Celosieae is without flavonols, flavones or glycoflavones; the tribe Amarantheae is with flavonol only and that tribe Gomphreneae with all the three types of flavonoids, i.e. flavonols, flavones and glycoflavones.

The absence of flavonoid system keeps the Celosieae quite distinct from all other tribes. Morphological features like multiovuled ovary, cytological peculiarities like stability of diploid chromosome number (Behero and Patnaik, 1972; Grant, 1954) and palaynological data like pore membrane devoid of any granules (Livingestone et al., 1974; Vishnu-mittre, 1963) also support the separate identity of this tribe.

Flavonols are the only flavonoids in the tribe Amarantheae. The existence of two sub-tribes Euamarantheae and Achyrantheae does not get any support from the chemical data gathered here. However, chemical data can be used for the regrouping of the members into two groups one with flavonols and other without flavonols.

The concept of two sub-families of Schinz (1934) does not gain any support from the present study. The sub-family Amaranthoideae is evidently hetrogeneous in having flavonoid-rich Amarantheae and flavonoid-free Celosieae, which in turn are two distinct groups comparable to the Gomphreneae. The existence of 3 distinct groups in this family Amaranthaceae, which was already recognised by Bentham and Hooker is chemically sound. Whether these taxa are to be given the status of a tribe or sub-family is a matter of taste. However the quanta of differences existing among the three taxa do warrant a sub-familial status to these groups.

Of the three sub-families, the Amaranthoideae are more primitive than the remaining two sub-families, because of the predominance of flavonols, which is considered to be a primitive character. The sub-family Celosioideae, though considered primitive on morphological grounds, show advanced chemical features like absence of the flavonoid system. The principle of hetrobathamy is very much evident in this case, in that the evolution of chemical characters occurred much faster than the other features. The sub-family Gomphrenoideae have a combination of characters i.e. advanced flavones and primitive flavonols and therefore occupy an intermediate position in the evolutionary sequence (Fig-17).

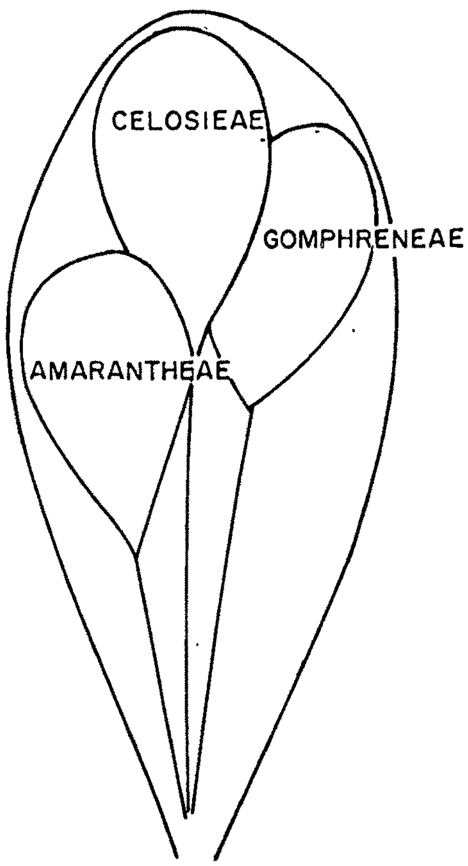

FIG.-I EVOLUTIONARY STATUS ACHIEVED BY VARIOUS
TRIBES WITHIN THE AMARANTHACEAE