CHEMISTRY AND TAXONOMY OF SOME MEMBERS OF THE ZINGIBERALES

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ABSTRACT

The leaves of 39 members belonging to the order Zingiberales have been screened for leaf phenolics and iridoids. Flavonols form the major phenolic pigments of this order. Flavones as C-glycosides and proanthocyanins are infrequent. Iridoids are absent in this group. The analysis of rhizomes of 26 members revealed the presence of alkaloids, saponins and tannins to be a common feature. Cronquist's treatment of this order is supported, the evolutionary levels of the families assessed and the various evolutionary lines operating are traced.

INTRODUCTION

THE Zingiberales, a natural taxon consisting of tropical and subtropical families, are generally accepted as a well-knit assemblage of closely related and advanced monocotyledons. This order is of great economic importance because it yields a number of foods, fibres, medicines, spices, dyes and perfumes. All the families included within this order were contained in 4 tribes of one family, Scitamineae[1,2]. These tribes Museae, Zingibereae, Canneae and Maranteae, were elevated to families Musaceae, Zingiberaceae, Cannaceae and Marantaceae in later treatments. Scitamineae of Nakai[3] contained 8 families viz Zingiberaceae, Costaceae, Cannaceae, Marantaceae, Lowiaceae, Musaceae, Heliconiaceae and Strelitziaceae. Tomlinson[4] supported this classification but recognized four natural groups within, the first containing Heliconiaceae, Musaceae and Strelitziaceae, the second with Costaceae, Zingiberaceae and Marantaceae and the third and fourth groups with Cannaceae and Lowiaceae respectively.

The families Musaceae, Lowiaceae (*Orchidantha* and *Lowia*) Strelitziaceae (*Ravenala*, *Phenakospermum* and *Strelitzia*) and Heliconiaceae (unigeneric) have been derived from the tribe Museae of Scitamineae. The family Strelitziaceae contains 3 subfamilies: Strelitzoideae, Ravenaloideae and Phenakospermoideae. The subfamily Zingiberaceae is subdivided into three tribes: Globbeae, Hedychieae and Zingibereae[5-8].

The aromatic rhizomes of *Zingiber*, *Curcuma* and fruits of *Elettaria* are extensively worked out for their volatile oils. The flower and seed pigments of *Alpinia*, *Musa* and *Canna*[9-12] as well as the saponins of *Costus*[13-15] are also studied in detail. Reports on leaf flavonoids of some temperate (mainly European) members of Zingiberales are also available[16]. However no systematic study aimed at better taxonomic judgement and evolutionary phylogeny was done involving members of this continent.

In the present work, 39 members belonging to 20 genera of Zingiberales have been analyzed for phenolics like flavonoids, proanthocynin-derived anthocynidins, glycoflavones and phenolic acids. All of them have been tested for iridoids also. The 39 plants screened are Zingiberaceae 22 (8 genera), Costaceae 1 (1), Cannaceae 2 (1), Musaceae 2 (2), Strelitziaceae 3 (2), Heliconiaceae 2 (1), and Marantaceae 7 (5). Rhizomes of 26 members (Zingiberaceae 19 (8), Costaceae 1 (1), Cannaceae 2 (1), Musaceae 2 (2) and Marantaceae 2 (2)) have been screened for alkaloids, saponins and tannins. Using chemical characters the extent of evolutionary advancement achieved by each family is assessed.

MATERIALS AND METHODS

The plants were collected from different localities in India and from the New York Botanical Garden. Most of the screening was done using fresh materials. In their absence, unpoisoned herbarium specimens were used. Voucher specimens of all the plants have been deposited in The Herbarium of the M. S. University of Baroda, Baroda, India.

The analytical methods employed for flavonoids and phenolic acids have been described elsewhere[17]. Iridoids were tested following Weiffering[18]. Anthocynidins were analyzed using standard procedures[19]. The compounds were confirmed by co-chromatography with authentic samples. Alkaloids, saponins and tannins were tested using procedures described elsewhere[20].

Table 1 *Distribution of flavones/-ols, glycoflavones, anthocyanidins phenolic acids, alkaloids, saponins and tannins in members of the Zingiberales*

Sl. No.	Name of the plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Family ZINGIBERACEAE																											
	Tribe: Globbeae																											
*	1. *Globba bulbifera* Roxb												+	+	+		+			+								
	2. *G. ophioglossa* Wight																									+	+	
	Tribe: Zingiberceae																											
	3. *Curcuma amada* Roxb																									+		+
	4. *C. longa* Linn												+	+		+			+							+		+
*	5. *C. inodora* Blatter												+	+		+	+		+									
	6. *C. aromatica* Salisb							+					+	+		+				+						+	+	+
	7. *C. angustifolia* Roxb			+									+				+									+	+	
	8. *Hedychium coronarium* Koenig		+				+	+					+	+		+				+								+
	9. *H. cocceinium* Hamilt		+		+			+					+	+			+			+						+	+	
*10.	*H. longicornatum* Griff		+		+								+	+			+			+								
	11. *Kaempferia galanga* Linn												+				+	+								+		
	12. *K. rotunda* Linn												+	+		+												
	13. *Zingiber zerumbet* Roscoe					+		+						+	+			+								+	+	
	14. *Z. rubens* Roxb																									+	+	+
	15. *Z. darceyi* Roxb			+				+					+	+			+			+						+	+	
	Tribe: Alpineae																									+	+	+
	16. *Alpinia nutans* Roscoe	+						+					+	+	+													
	17. *A. calcarata* Roscoe								+				+	+		+										+		
	18. *A. bracteata* Roxb								+				+	+		+	+									+		+
	19. *A. allhugas* Roscoe												+				+	+								+		
	20. *Elatteria cardemomum* Maton												+				+			+	+			+				
	21. *Amomum involucratum* Benth							+					+	+		+	+								+	+		
	22. *A. hypoleucum* Thw							+					+	+		+	+									+		
	Family COSTACEAE																									+	+	+
	23. *Costus speciosus* Smith												+															
	Family CANNACEAE																										+	+
	24. *Canna indica* Linn												+	+		+	+										+	+
	25. *C. flaccida* Roscoe												+		+		+	+		+		+	+					
	Family MUSACEAE																									+	+	
	26. *Ensete superbum* Roxb						+						+	+		+	+											
	27. *Musa paradisiaca* Linn												+	+												+		

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Family STRELITZIACEAE																											
*28. *Ravenala madagascariensis* Sonnersat		+			+			+			+					+						+					
*29. *R. nikolai* Linn		+			+	+		+			+		+	+		+	+		+				+				
*30. *Strelitzia regalis* Salisb					+						+	+	+			+			+								
Family HELICONIACEAE																											
31. *Heliconia angustifolia* Hook					+		+				+	+				+						+	+		+		+
*32. *H. aureo-striata* Hort				+							+	+				+			+								
Family MARANTACEAE																											
33. *Maranta arundinacea* Linn								+			+	+				+	+	+						+		+	+
*34. *M. bicolor* Vell					+		+				+	+						+					+				
*35. *Schumanianthes dichotomus* Linn						+		+				+		+	+					+		+				+	
*36. *S. virgatus* Roxb											+	+	+			+			+								
*37. *Montagma densiflorum* K. Schum											+	+			+	+			+								
*38. *Stromanthe spectabilis* Lam	+							+	+		+	+			+												
*39. *Pleiostachya purinosa* Linn		+			+						+	+			+												

1. Iridoids, 2. Peonidin, 3. Pelargonidin, 4. Cyanidin, 5. Delphinidin, 6. Rosinidin, 7. Quercetin, 8. 4′-OMe Quercetin, 9. Kaempferol, 10. 6-C-glycoside of 3′-OMe luteolin, 11. Vitexin, 12. Vanillic acid, 13. Syringic acid, 14. Ferulic acid, 15. Protocatechuic acid, 16. p-OH-Benzoic acid, 17. Chlorogenic acid, 18. o-Coumaric acid, 19. p-Coumaric acid, 20. Sinapic acid, 21. Gentisic acid, 22. Melilotic acid, 23. Phloretic acid, 24. α-Resorcilic acid, 25. Alkaloids, 26. Saponins, 27. Tannins.
*Not screened for alkaloids, saponins and tannins.

RESULTS

The distribution of various flavonoids, phenolic acids, alkaloids, saponins and tannins is presented in table 1. None of the plants showed presence of iridoids.

Flavones are found to be completely absent from this order. Flavonols occur as O-glycosides (as evidenced by the presence of aglycones in hydrolyzed extracts) in 46% of the plants screened. The various flavonols encountered are quercetin, 4' OMe-quercetin and kaempferol. They are absent from Cannaceae, Musaceae and Costaceae. In plants where kaempferol is located, it co-occurs with quercetin. In two spp of *Alpinia*, i.e. *A. calcarata* and *A. bracteata*, quercetin is replaced by its 4'-methyl ether. The distribution of flavonols is 45% in Zingiberaceae, 66% in Strelitziaceae, 50% in Heliconiaceae and 42% in Marantaceae.

Of the various phenolic acids identified, vanillic acid is omnipresent. Syringic and *p*-hydroxy benzoic acid have a high frequency of distribution viz 72% and 62%. The distribution of other phenolic acids such as protocatechuic, *p*-coumaric, ferulic and chlorogenic acids are 43%, 40%, 21% and 18% respectively. The rest of the phenolic acids have a low frequency of incidence. The Marantaceae, Strelitziaceae, Heliconiaceae and Cannaceae show more phenolic acids quantitatively and qualitatively. o-Coumaric and sinapic acids are confined to Zingiberaceae whereas gentisic acid is absent from this family as well as Musaceae. α-Resorcilic acid is located only in Marantaceae.

Thirteen plants (33%) contained proanthocyanins in leaves. These compounds are more frequent in Zingiberaceae and Strelitziaceae but are absent in Costaceae and Cannaceae. The most common proanthocyanidin is leucopeonidin (in 7 members). Leucopelargonidin (3), leucocynidin (1) and leucodelphinidin (1) are the other proanthocynins detected. Leucopelargonidin and leucocynidin co-occur in *Hedychium coccineum* and *H. longicornatum*. The anthocyanidins of *Hedychium coronarium*, *Ensete superbum and Heliconia aureo-striata* and one spot of *Ravenala nikolai* could not be identified due to the trace amounts present.

Alkaloids are present in all the families except Cannaceae. Saponins are not located in Heliconiaceae and so also tannins in Musaceae.

From an assessment of incidence of various primitive and advanced characters, the Costaceae evidently appears to be the most advanced family in the group whereas Strelitziaceae is the most primitive. Musaceae, Marantaceae and Heliconiaceae occupy the same level in chemical evolution while Cannaceae and Zingiberaceae form more advanced groups.

DISCUSSION

The order Zingiberales presents a picture of homogeneity in the assemblage of families. Almost uniform presence of alkaloids, saponins and tannins in the plants screened indicates the chemical closeness these taxa enjoy. Strelitziaceae form the basic stock from which various other families have evolved. The families Musaceae, Heliconiaceae, Zingiberaceae and Marantaceae form independent evolutionary lines which have attained the same level of chemical advancement. Cannaceae and Costaceae represent two further evolutionary lines arising from Zingiberaceae. The various lines of evolution and the relative level of advancement of various families are presented in figure 1.

The higher incidence of flavonols, leucoanthocynins and glycoflavones suggests chemical primitiveness of

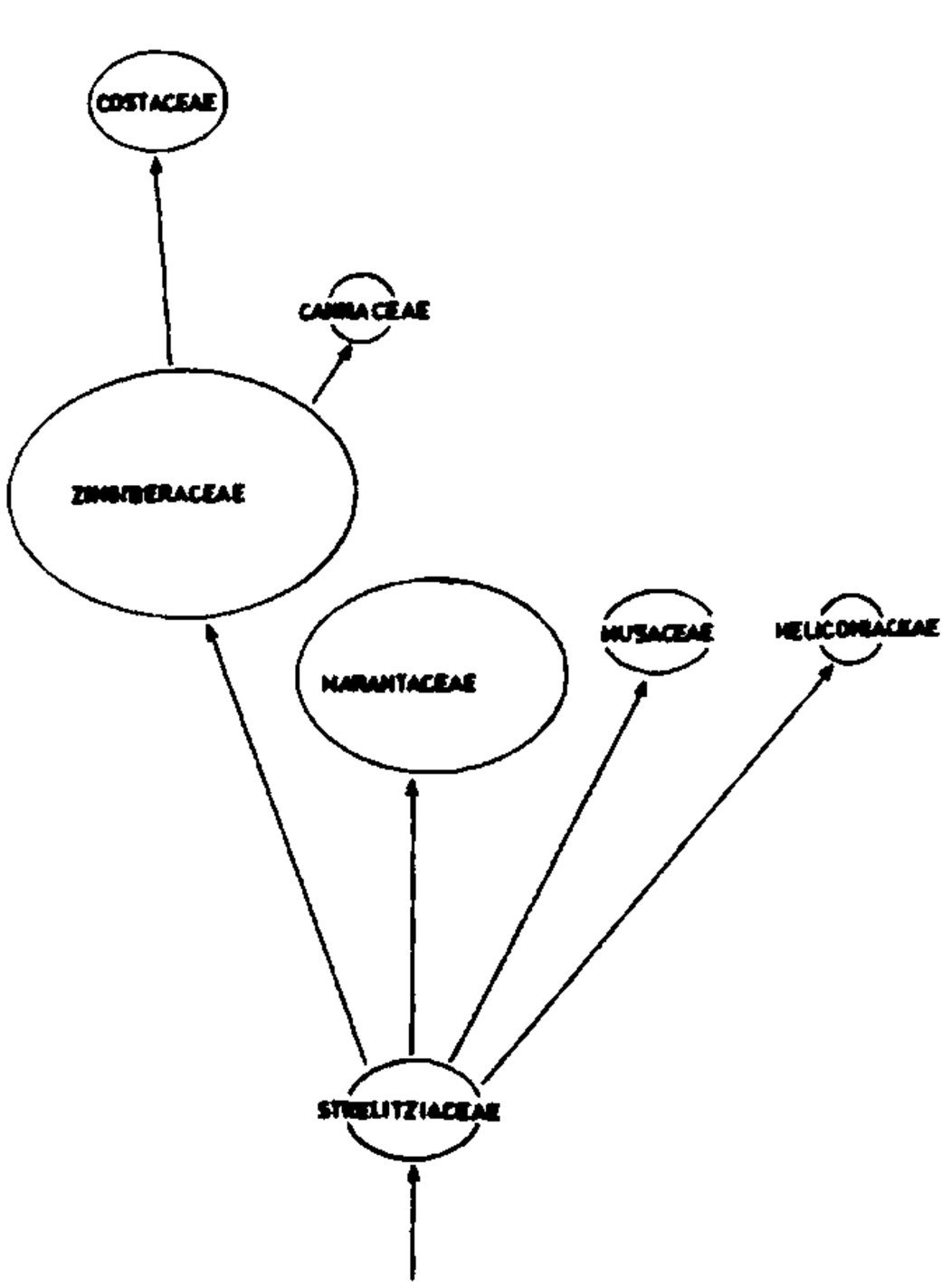

Figure 1. The various lines of evolution and the relative levels of advancement of families in Zingiberales.

the order which is otherwise considered as fairly advanced. The genus *Ravenala* is undoubtedly the most primitive genus of the order, a contention supported by cytological evidence[21]. The grouping of *Ravenala* with *Strelitzia* finds support from chemistry. The Similarities of these two genera with *Heliconia* cast doubts on the separate family status given to the Heliconiaceae. Musaceae is different from them in the absence of flavonols.

It is indeed surprising to find that the family Marantaceae with the highly advanced morphological characters possesses primitive flavonoids in the leaves. The principle of 'heterobathmy' proposed by Takhtajan[7] is probably operative here in that the morphological advancement has proceeded at a faster pace as compared to chemical evolution. In this family, *Montagma* represents the most advanced genus.

Within Zingiberaceae, *Hedychium* is the most primitive genus. The absence of flavonoids keeps the genera *Globba*, *Kaempferia* and *Elettaria* as the highly advanced genera of the group. Evidently Globbeae is the advanced tribe in this family but a clear-cut demarcation among the tribes Globbeae, Hedychieae and Zingibereae does not exist.

The Cannaceae and Costaceae are two families which are the most evolved and homogenous groups within this order.

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