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NUMERICAL TAXONOMIC STUDIES ON SOME MEMBERS OF APOCYNACEAE[1]

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ABSTRACT

The paper deals with numerical taxonomy of 25 taxa, covering 84 characters taken from external morphology, foliar venation and epidermal pattern, palynology, cytology and chlorophyll estimation. With the help of percentage of similarity these have been formulated into five clusters. Affinities based on inter-and intra-cluster variations are discussed.

INTRODUCTION

Apocynaceae comprises about 180 genera and 1500 species mostly occurring in the tropical and subtropical belt (Willis, 1973). In earlier years the family has been classified on the basis of gross morphological characters only. More recently, characters of pollen, chromosomes, tissues (wood, foliar epidermal and flora), embryo sac and embryo development have also been gainfully utilised. Among the classifications based on phenetic relationships, the accepted one is that of Schumann (1895). However, based on the earlier work on morphology (Woodson, 1930), cytology (Roy Tapadar and Sen, 1960; Datta and Maiti, 1972) and wood anatomy (Datta and Maiti, 1971) the systematic positions of *Allamanda, Carissa, Thevetia, Holarrhena* and *Plumeria* do not appear to be justified in Schumann's classification. In the placement of sub-families also there are different views. The systematic position of sub-families, tribes and genera may possibly be more reasonably assessed by numerical taxonomic studies introduced by Anderson and Abbe (1934). In the present investigation, interrelationships among the 25 species of Apocynaceae have been presented, clarifying the taxonomic ambiguities in Schumann's classification.

MATERIAL AND METHODS

For the present study 31 taxa were collected from the Eastern Ghats forests of Srikakulam, Vijayanagaram, East and West Godavari districts of Andhra Pradesh, and 12 cultivated ones from the gardens and surroundings of Visakhapatnam; details are included in Table I. A total of 84 characters (Table II)., 66 qualitative and 18 quantitative, for each of the 25 taxa, have been studied. Percentage of similarity has been estimated from the data tables using the formula:

$$\frac{\text{Number of common attributes}}{\text{Number of total attributes}} \times 100$$

RESULTS

Based on percentage of similarity among the 25 taxa (Table III) these are

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TABLE I

LIST OF THE MATERIALS COLLECTED FROM THE DIFFERENT LOCALITIES

S. No.	Name of the Plant	Locality	Collector	Field No.
*1.	*Allamanda cathartica* L.	A. U. Campus Visakhapatnam	Balamani	4806
*2.	*A. schottii* Pohl.	—do—	—do—	8650
*3.	*A. grandiflora* Lamk.	—do—	—do—	4805
*4.	*A. blanchetii* A. DC.	—do—	—do—	4807
*5.	*A. neriifolia* Hook.	—do—	—do—	4808
6.	*Carissa carandas* L.	Zoological Park, Visakhapatnam	—do—	8638
7.	*C. spinarum* L.	—do—	—do—	8639
8.	*Rauvolfia serpentina* Benth.	Thumbakonda Srikakulam dt.	Seetharamam	2408
9.	*R. tetraphylla* L.	Waltair Uplands Visakhapatnam	Balamani	8649
*10.	*Thevetia peruviana* (Pers.) K. Schum.	A. U. Campus, Visakhapatnam	—do—	4811
11.	*Catharanthus pusillus* (Murr.) G. Don	Chinagora, Srikakulam dt.	Hara-sreeramulu	10265
12.	*C. roseus* (L.) G. Don	Pedapallavapalem, West Godavari	Venkanna	126
*13.	*Plumeria alba* L.	A. U. Campus, Visakhapatnam	Balamani	4812
*14.	*P. rubra* var. *acuminata* (Ait.) Rolla Rao & Balamani *comb. nov.* (=*P. acuminata* Ait. Hort. Kew. 2 : 70. 1789)	—do—	—do—	4813
*15.	*P. rubra* L.	—do—	—do—	4814
16.	*Alstonia venenata* R. Br.	Thonam, Srikakulam dt.	Seetharamam	2001
17.	*Holarrhena antidysenterica* (L.) Wall.	Maredumilli, East Godavari	Sudhakar	421
*18.	*Tabernaemontana divaricata* (L.) R. Br.	A. U. Campus Visakhapatnam	Balamani	8652
*19.	*Vallaris solanacea* (Roth) O. Ktze.	Waltair Uplands, Visakhapatnam	—do—	3030
20.	*Wrightia tinctoria* R. Br.	Veduruvada, Vizianagaram dt.	Venkaiah	4064
21.	*W. tomentosa* Roem. & Sch.	Kottakota, Srikakulam dt.	Seetharamam	1054
**22.	*Nerium indicum* Mill.	A. U. Campus, Visakhapatnam	Balamani	4899
23.	*Strophanthus wallichi* A. DC.	Bhimili, Visakhapatnam dt.	—do—	4810
24.	*Agavosma caryophyllata* G. Don	Somidavalasa, Srikakulam dt.	Hara-sreeramulu	10646
25.	*Ichnocarpus frutescens* R. Br.	Moolavalasa-Duggeru, Srikakulam dt.	Seetharamam	3032

TABLE II

LIST OF THE CHARACTERS STUDIED FOR NUMERICAL TAXONOMY

1. Habit
2. Surface of the plant
3. Latex
4. Phyllotaxy
5. Shape of the leaf
6. Surface of the leaf
7. Base of the leaf
8. Tip of the leaf
9. Margin of the leaf
10. Texture of the leaf
11. l/b ratio of leaf
12. Type of leaf
13. Type of trichomes
14. Type of stomata
15. Stomatal index
16. Length of stomata
17. Width of stomata
18. Length of aperture
19. Width of aperture
20. l/b ratio of stomata
21. l/b ratio of aperture
22. Shape of the upper epidermal cell
23. Shape of the lower epidermal cell
24. Wall nature of the upper epidermal cell
25. Wall nature of the lower epidermal cell
26. Base of trichome
27. Type of venation
28. Sub-type
29. Intra-marginal veins
30. Primary vein size
31. Primary vein course
32. Angle of divergence
33. Variations in angle of divergence
34. Reative thickness of secondary veins
35. Course
36. Tertiary veins arrangement
37. Relationship to mid veins
38. Arrangement
39. Higher order venation
40. Inter secondary veins
41. Quartenary veins size
42. Course
43. Quinternary veins size
44. Course
45. Veinlets
46. Areoles development
47. Arrangement
48. Shape of Areole
49. Size of Areole
50. No of vein islets/Unit area (2 sq. mm.).
51. No. of vein endings/Unit area (2 sq. mm.)
52. Total chlorophyll content
53. Chlorophyll a/ b ratio
54. Type of inflorescence
55. Surface of the inflorescence
56. Sepals condition
57. Aestivation of the sepal
58. Surface of the sepal
59. Shape of the sepal
60. Condition of the petal
61. Surface of the petal
62. Shape of the petal
63. Aestivation of petal
64. Shape of the corolla tube
65. Coronary hairs
66. Stamens position
67. Shape of the anther
68. Base of the anther
69. Fertility of stamen
70. Connate at the stigma or not
71. Type of the pollen grain
72. Shape of the pollen grain
73. Surface of the pollen grain
74. Pollen fertility
75. Length of the pollen grain
76. Width of the pollen grain
77. Chromosome number
78. Carpel condition
79. Style nature
80. Stigma shape
81. No. of locules
82. Placentation
83. Type of fruit
84. Surface of the seed

grouped into five clusters, following Sneath and Sokal (1973). A dendrogram is drawn (Fig. 1), utilising the intra- and inter-cluster values to illustrate the relative sequence and the affinities among all taxa. With the same sequencial arrangement, similarity matrix (Fig. 2) is constructed to demonstrate the close affinity and also the distinct variation together with the wide range of intermediates among the twenty five taxa. The percentage of similarities among the five clusters have been tabulated (Table IV). The chart (Fig. 3) shows the inter-relationships among 25 taxa, utilising the percentage of similarities and the position of each taxa and cluster were given.

DISCUSSION

The common qualitative characters of the 25 taxa are (1) paracytic stomata (except in *Catharanthus*), (2) Craspidodromous venation, (3) Vein orders distinct with reticulate arrangement of veins except in *Catharanthus* (where horizontal arrangement is seen), (4) Gamosepalous condition except in *Allamanda blanchetii*, (5) Gamopetalous condition, (6) twisted aestivation of petals, (7) Psilate exine pattern of pollen grain. The four quantitative characters, viz., (i) width of aperture, (2) L/b ratio of stoma, (3) L/b ratio of aperture, (4) chlorophyll a/b ratio (except in the genus *Catharanthus*) among the eighteen characters studied, are not statistically significant in all pair-wise comparisons of the twenty five taxa.

Among the five clusters, the first (or the primitive cluster) representing the members of Echitoideae with the evidences as worked out in the present study, supports the work of Woodson (1930) in contrast to that of Schumann and thus such primitive cluster forms the base of the phylogenetic scheme proposed now (Fig.3). This cluster represents two groups (1) *Ichnocarpus frutescens-Aganosma caryophyllata-Strophanthus wallichii-Nerium indicum* and (2) *Wrightia tinctoria-Wrightia tomentosa-Vallaris solanacea*, which are linked by *Nerium indicum* with 66% of similarity to *Strophanthus wallichii* and 55% of similarity to *Wrightia tinctoria*. The common chracters of the first group are opposite, thick and leathery leaves with acute tip and epidermal cells penta-or hexa-gonal. The second group has the common characters like thin leaves, acuminate or apiculate leaf lip and prolate-spheroidal pollen grains. *Nerium indicum* is connected with *Strophanthus wallichii* on one side by obovate, sagittate anthers with rounded base, oblate-spheroidal pollen grains and on the other with *Wrightia tinctoria* by small tree habit, acute leaf tip. The fourth and second clusters exhibit close affinity to *Ichnocarpus frutescens* with 57% of similarity to *Thevetia peruviana* and *Allamanda schottii* of the fourth cluster and with 64% of similarity to *Carissa carardas* of the second cluster. The advanced character of these two clusters over the first one is the syncarpous condition.

The fourth cluster includes only two genera *Thevetia* and *Allamanda* which are closely related by all morphological characters such as shape of flowers, anther arrangement, coronary hairs, ovary condition and seeds, but differs in the habit of the plant, phyllotaxy, number of locules, placentation and fruit characters. The placement of *Thevetia* along with the species of *Allamanda* is supported by many characters as suggested by earlier workers also (Roy Tapadar, 1960; Roy Tapadar and Sen, 1964). From *Allamanda schottii* two different lines are evolved with *A. grandiflora* followed by *A. cathartica* in one line and with *A. neriifolia* followed by *A. blanchetii* in another (Fig. 3).

TABLE

PERCENTAGE OF SIMILARILY

	25	24	23	19	20	22	21	6	7	9	8	16
25.	100											
24.	77.38	100										
23.	70.24	63.09	100									
19.	64.29	55.95	60.71	100								
20.	63.09	61.90	63.09	65.48	100							
22.	59.21	59.21	65.79	52.63	55.26	100						
21.	54.76	60.71	52.38	55.95	61.90	51.32	100					
6.	64.29	59.52	54.76	57.14	58.33	55.73	50.00	100				
7.	64.24	63.09	59.52	57.14	55.95	48.68	58.33	92.86	100			
9.	53.57	50.00	57.14	48.81	50.00	55.26	51.19	69.45	69.05	100		
8.	63.09	55.95	61.90	58.33	51.19	57.89	44.05	65.48	66.67	73.81	100	
16.	57.14	51.19	53.57	53.57	52.38	59.21	57.14	58.33	60.71	65.48	60.71	100
17.	58.33	60.71	60.71	57.14	58.33	39.47	50.00	58.33	60.71	57.146	0.71	57.14
18.	55.95	50.00	58.33	58.33	57.14	48.68	45.24	57.14	53.57	58.33	67.86	59.52
15.	55.95	54.76	61.90	52.38	58.33	51.32	38.09	54.76	54.76	58.33	60.71	48.81
14.	54.76	47.62	57.14	50.00	58.33	47.37	35.71	52.38	52.38	54.76	58.33	51.19
13.	52.38	47.62	58.33	58.76	57.14	48.68	40.48	48.81	57.14	54.76	59.52	52.38
1.	53.57	48.81	48.81	47.62	40.48	47.37	48.81	55.95	58.33	59.52	59.52	52.38
3.	53.57	47.62	53.57	46.43	52.38	48.68	47.62	55.95	55.95	60.71	61.90	51.19
2.	57.14	48.81	55.95	51.19	53.87	47.37	48.81	53.57	54.76	60.71	61.90	48.81
5.	46.43	50.00	51.19	42.86	47.62	51.32	51.19	46.43	51.19	60.71	48.81	52.38
4.	46.43	50.00	51.19	42.86	47.62	51.38	51.19	46.43	51.19	60.71	48.81	52.38
10.	57.14	52.38	55.95	51.19	55.95	55.26	51.19	59.52	61.91	53.57	54.76	45.24
11.	45.24	44.05	47.62	44.05	48.81	43.42	36.90	45.24	46.43	53.57	54.76	50.00
12.	42.86	38.09	45.24	39.29	47.62	39.47	36.90	46.43	51.19	47.62	52.38	45.24

III

AMONG TWENTY FIVE TAXA

17	18	15	14	13	1	3	2	5	10	11	12
100											
57.14	100										
55.95	58.33	100									
55.95	54.76	90.48	100								
48.81	58.33	77.38	76.19	100							
40.48	44.05	45.24	45.24	45.24	100						
44.05	44.05	50.00	51.19	44.05	85.71	100					
46.43	54.76	59.52	51.19	58.33	73.81	76.19	100				
45.24	42.86	52.38	51.19	47.62	73.81	72.62	79.76	100			
45.23	42.86	52.38	51.19	47.62	70.24	75.00	65.48	61.90	100		
57.14	48.81	61.90	53.57	51.19	54.76	53.57	57.14	55.95	55.95	100	
47.62	52.38	54.76	53.57	46.43	36.90	41.67	47.62	35.71	35.71	44.05	100
42.86	52.38	51.19	52.38	57.14	34.52	40.48	46.43	33.33	33.33	48.81	78.57	100

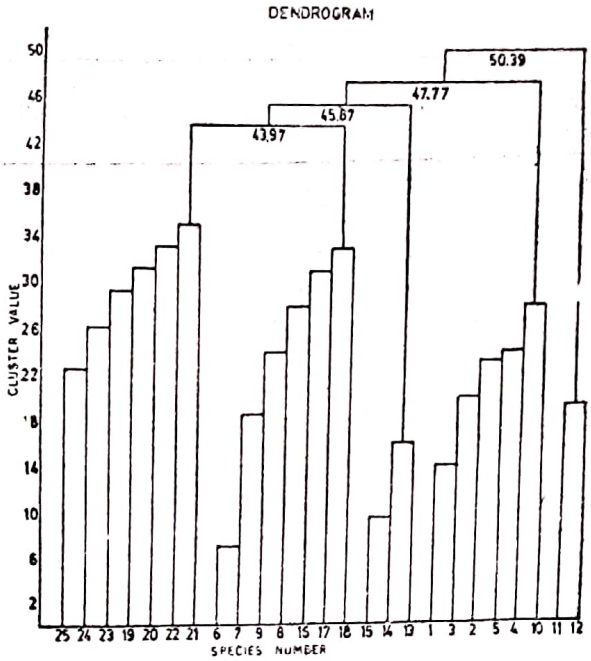

Fig. 1. Dendrogram constructed from cluster and intercluster values showing the arrangement of the twenty five taxa.

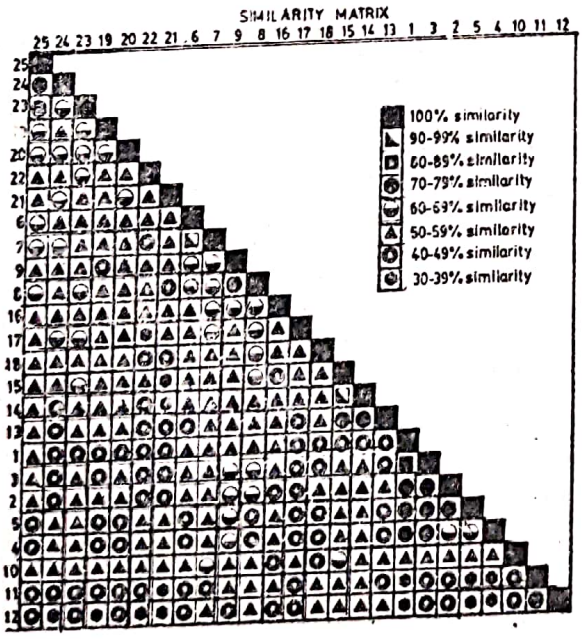

Fig. 2. Similarity matrix based on the cluster analysis showing the percentage of similarities among the twenty five taxa.

TABLE IV

PERCENTAGE OF SIMILARITY AMONG THE FIVE CLUSTERS OF APOCYNACEAE

	I	II	III	IV	V
I	100.00				
II	23.81	100.00			
III	21.43	32.14	100.00		
IV	26.19	29.76	29.76	100.00	
V	15.48	23.81	26.19	25.00	100.00

The other cluster related to *Ichnocarpus frutescens* namely the second cluster comprises five genera and seven species of the present study. Among the five clusters, this one is considered to be the least homogeneous. Based on the qualitative characters it is divided into two groups (1) *Carissa carandas-C. spinarum-Rauvolfia serpentina-R. tetraphylla* and (2) *Tabernaemontana divaricata-Alstonia venenata-Holarrhena antidysenterica.* The common characters of the first group are the lanceolate sepals, connate carpels, axile placentation and fruit a drupe. Those of the second group are the oblong or oblong-lanceolate sepals, distinct carpels, marginal placentation, and fruit a pair of follicles. Both the groups are connected with each other by *Tabernaemontana divaricata.* The character of naked seeds is common to both *Tabernaemontana* and *Rauvolfia* but characters like distinct carpels, marginal placentation and paired follicles are common for *Tabernaemontana* and *Alstonia.*

The other two monogeneric clusters are derived in a similar pattern from the genus *Strophanthus* of the first cluster. *Plumeria rubra* is derived from *Strophanthus wallichii* the percentage of similarity between the two being 62%. *Plumeria*

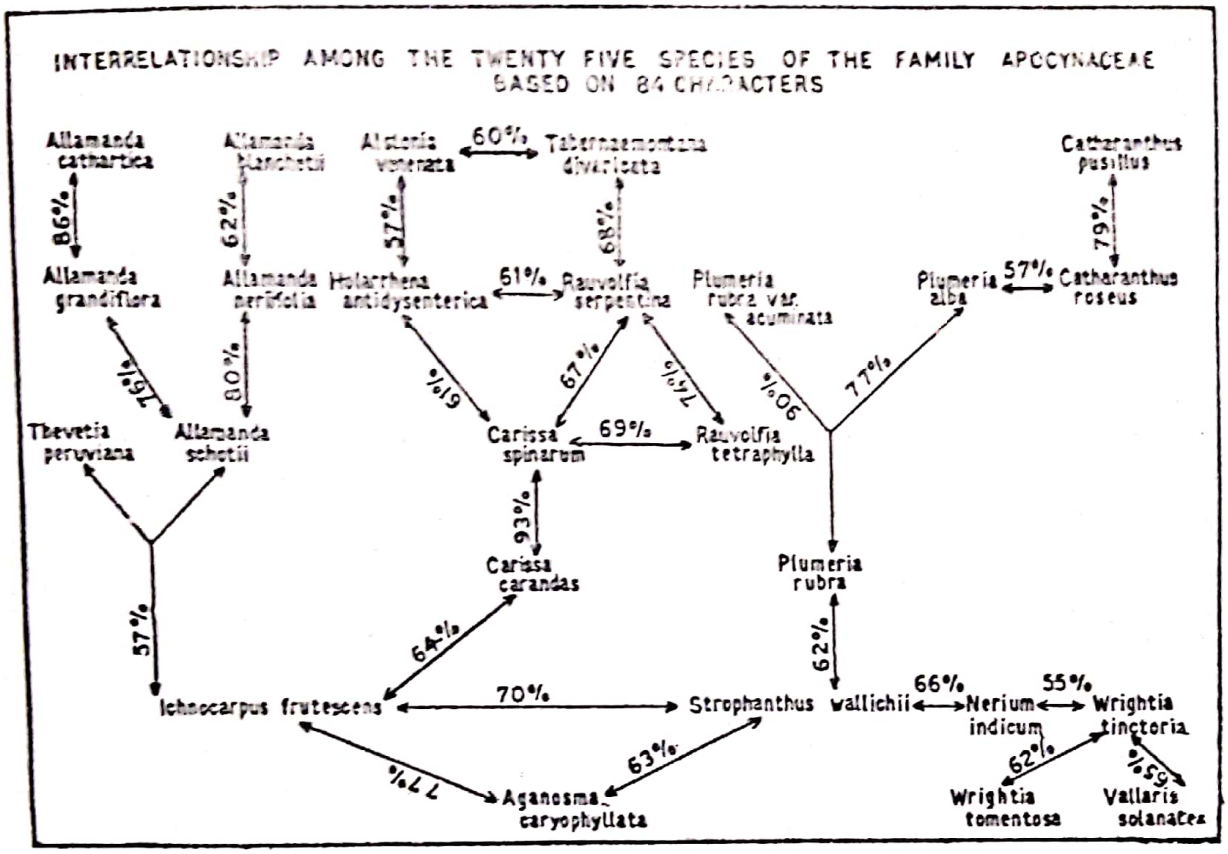

Fig. 3. Graph showing the relation between chromosome number and habit of the plant.

SERIAL NUMBERS & ACRONYMS FOR THE PLANTS USEDIN THE STUDY

(Numbers as in Table-III; Figs. 1 & 2.)

1 — AC — *Allamanda cathartica* L.
2 — AS — *A. schottii* Pohl.
3 — AG — *A. grandiflora* Lamk.
4 — AB — *A. blanchetii* A. DC.
5— AN — *A. neriifolia* Hook.
6 — CC — *Carissa carandas* L.
7 — CS — *C. spinarum* L.
8 — RS — *Rauvolfia serpentina* Beath.
9 — RT — *R. tetraphylla* L.
10 — TP — *Thevetia peruviana* (Pers.) K. Schum.
11 — CP — *Catharanthus pusillus* (Murr.) G. Don
12 — CR — *C. roseus* (L.) G. Don
13 — PA — *Plumeria alba* L.
14 — PRA— *P. rubra* L. var. *acuminata* (Ait.) Rolla Rao & Balamani *comb. nov.*
15 — PR — *P. rubra* L.
16 — AV — *Alstonia venenata* R. Br
17 — HA — *Holarrhena antidysenterica* (L.) Wall
18 — TD — *Tabernaemontana divaricata* (L.) R.Br.
19 — VS — *Vallaris solanacea* (Roth) O. Ktze.
20 — WTi— *Wrightia tinctoria* R. Br.
21 — WTo— *W. tomentosa* Roem. & Sch.
22 — NI — *Nerium indicum* Mill.
23 — SW — *Strophanthus wallichii* A. DC.
24 — ACA— *Aganosma caryophyllata* G. Don
25 — IF — *Ichnocarpus frutescens* R. Br.

rubra is related with *P. rubra* var. *acuminata* on one side and *P. alba* on another, indicating its relationship with 90% and 77% of similarity respectively. The closer resemblance of *Catharanthus roseus* with *Plumeria alba* than with the other twenty two species, is clearly indicated by 57% of similarity.

The earlier inclusion of the genera *Tabernaemontana, Alstonia, Holarrhena, Catharanthus* along with *Plumeria* under different subtribes, all treated under the tribe Plumerieae, was considered as an undoubtedly heterogeneous assemblage and different workers Tapadar and Sen (1960), Datta and Maiti (1972) on cytological characters, Datta and Maiti (1971) on wood anatomical characters and Lakshminarayana (1978) on embryological characters suggested the separation of these genera from the dominant and most characteristic genus *Plumeria*. The data worked out in the present study interestingly support such views for isolating the genus *Plumeria* from the other genera with the percentage of similarities and thus the cluster III with this genus only, is formed. The distinct position of the genus *Plumeria* is also indicated by its chromosome number.

The genus *Catharanthus* has been found to be somewhat isolated from the remaining 14 genera, presenting the percentage of similarity in the range of 33.3%—57.14% in comparison to the rest whose range is 35.71%—77.4% (Fig. 2 & Table III). The isolated characters of *Catharanthus* are (1) undershrubs, (2) presence of anomycytic stomata, (3) horizontal arrangement of veins, (4) presence of the alkaloid vincistrin and (5) the least chromosome number as n=8 among all the taxa now studied (Fig. 4). The isolated position of the genus is clearly seen in the Dendrogram (Fig. 1).

Based on the data on numerical taxonomic studies as worked out in the present study, the family Apocynaceae is divided into two subfamilies Echitoideae and Plumerioideae (after Schumann, 1895), but with an altered interpretation supporting Woodson (1930) in treating the subfamily Echitoideae as more premitive than the subfamily Plumerioidieae. Schumann's division of the subfamily Echiotoideae into two tribes (1) Echitideae, (2) Parsonsieae together with the genera as given by him in the two tribes are supported and followed in the present study, only with a slightly altered position of the genus *Nerium* considering it as an interesting linking genus between the genera under the two tribes. Thus the components of the two tribes of the subfamily Echitoideae form a homogeneous cluster I as worked out in this study.

The other subfamily Plumeroideae is however subjected to considerable change in its division into tribes and sub-tribes based on the present study, while maintaining, however, generic components of Plumerioideae of Schuman (1895). The main aspects of such changes based on the data of the present and earlier studies are the treating of the conspicuous and interesting genus *Allamanda* under a distinct tribe Allamandeae along with the closely related genus *Thevetia*, thus removing it from its earlier uncompromising position as given by Schumann (1895) under the tribe Plumerieae. The tribe Carisseae is now dividided into two subtribes Rauvolfinae and Alstoniinae, thus establishing now a close affinity of the two genera *Carissa* and *Rauvolfia* now properly treated under one subtribe Rauvolfinae while separating the three genera *Tabernaemontana, Alstonia* and *Holarrhena* from their earlier heterogeneous assemblage under the tribe Plumericae (Schumann, 1895) into the

present subtribe Alstoniinae. The dominant and most characteristic genus *Plumeria* is considered exclusively under the tribe Plumerieae (incidentally the nomenclature of *P. rubra* var. *acuminata* is also corrected (vide no. 14, under Table I), while treating *Catharanthus* under a separate tribe Catharantheae newly designated by us which, however, has affinity with the tribe Plumerieae.

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