NUMERICAL TAXONOMY OF SOME *IPOMOEA* (LINN.) SPECIES IN SOUTH-WEST NIGERIA.

Folorunso, A. E.*, Illoh, H. C. and Olorungbeja, J. A.

Department of Botany, Obafemi Awolowo University, Ile-Ife 22005, Osun State, Nigeria.
* Corresponding Author E mail: afolorun@oauife.edu.ng
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ABSTRACT

Numerical taxonomic studies were conducted on thirty six species of *Ipomoea* found in Southwestern Nigeria to improve the classification and identification of this relatively poorly known genus. Twenty-three species were collected from natural populations; thirteen species were sourced from herbarium specimens. For the field samples, specimen identification was done at the IFE herbarium, following which voucher specimens were deposited. Qualitative and quantitative characters were recorded from the vegetative and reproductive parts of the specimen. The Principal Components Analysis (PCA) and Single Linkage Cluster Analysis (SLCA) reveal radial distribution of the *Ipomoea* species when the power of variance reduces; at high percentage total variance, they are separated into their phenons. The interrelationships observed among the traditional sections delimited by the quantitative analyses further support the suggestion of monophyly of *Ipomoea*.

Key words: *Ipomoea*, Numerical, Taxonomy, Monophyletic, Sections

INTRODUCTION

Ipomoea is an exceptionally large and diverse genus in the family Convolvulaceae, comprising over 600 species in strict and traditional concepts of the group (Austin and Huáman, 1996) or up to 1000 species in recent phylogenetic conceptions of the group (Wilkin, 1999; Manos *et al*., 2001; Miller *et al*., 2002). Most *Ipomoea* occur in tropical and subtropical climates throughout the world, but representative elements of the genus are in all known biomes (McDonald, 1991; Wilkin, 1999). The genus comprises about five hundred species in the tropical and sub-tropical zones of the world. Thirty-eight species have been reported in West Africa and of these, thirty species are reported in Nigeria (Hutchinson and Dalziel, 1958). They are mostly herbaceous to woody, scrambler, climber, trailer, twinner, shrub or small tree. The presence of milky latex exudates and bicollateral vascular bundles is highly diagnostic (Shukla and Mistra, 1979). Flowers are campanulate, generally bisexual, actinomorphic with variable petal colours ranging from purple to blue, red, pink, scarlet or white (Olorode, 1984). Stamens are five situated alternately with the corolla lobes; ovary is superior with one style, stigma capitate (Austin, 1975). Fruits are capsular, thin walled, globose or ovoid in shape and bearing 4 or rarely 6 seeds per fruit.

Ipomoea are good flagship species and possible good environmental indicators (Gill, 1988). *Ipomoea* species are generally of vital economic importance ranging from ornamental, medicinal to culinary value.

Ipomoea species are highly variable in nature and this has led to the description of intraspecific species. *Ipomoea triloba* Linn. for example has three varieties viz: *genuila* Meissn., *glaberrima* Meissn.; and *eustachiama* Jacq. *Ipomoea obscura* (Linn.) Ker-Gawl has three varieties viz: *ochracea* Lindl, *tricholyx* Schum and *acanthocarpa* Chiosy (Ogunwenmo, 2005). The high variability in *Ipomoea* species has created identification problems. A better system of classification and delimitation of the species using numerical taxonomic studies is therefore desirable.

Previous works in the family revealed that pollen characteristics have been used as important criteria for generic delimitation. Spinose pollen of *Ipomoea* has been used to separate it from related genera like *Meremia* and *Operculina* which have smooth pollen (Olorode, 1984). Shinner (1965) exploited the pollen character together with fruiting materials to dump both *Meremia* and *Operculina* into *Ipomoea*. However, gross similarities in the pollen characteristics of the different species of *Ipomoea* have been reported by Vij *et al.* 1975, thus pollen characteristics cannot be used for species delimitation. Infrageneric

classifications of *Ipomoea* were provided by Choisy (1845), Hallier (1893a, b), and House (1908). Relationships among Old World *Ipomoea* species were further refined by van Ooststroom (1953), who recognized seven infrageneric taxa in his studies on Asian species. Borrowing liberally from van Ooststroom's concepts, Verdcourt (1957; 1963) recognized eight infrageneric taxa in his treatment of African species.

Additional sources of phylogenetic data will provide a better means of understanding the relationships among *Ipomoea* species. An attempt is therefore made in this work to improve the taxonomy of the genus in Nigeria with its consequent delimitations into sections for subsequent revisionary studies. The purpose of the present study is to use Principal Component Analysis (PCA) and Single Linkage Cluster Analysis (SLCA) to determine the classification of the genus *Ipomoea* in Southwestern Nigeria and to delimit the species into their traditional sections. The results obtained from this study will provide information on the taxonomic status of the *Ipomoea* species. This will enhance the classification and delimitation of *Ipomoea* species and, at the end, provide a better understanding of the phylogenetic relationships among the *Ipomoea species* in Southwestern Nigeria.

MATERIALS AND METHODS

Specimens were collected from different sites in southwestern Nigeria (Fig. 1). A total of twenty-three *Ipomoea* species were collected from natural population in Southwestern Nigeria, the remaining thirteen species were sourced from herbarium specimens (Table 1 and 2). Specimen identification was done at the herbarium of Botany (IFE) following which voucher specimens were deposited. Also comparison with the herbarium specimens of Obafemi Awolowo University, Ile - Ife herbarium (IFE), University of Ibadan herbarium (UIH) and Forestry Herbarium Ibadan (FHI) Nigeria were done for authentication. The vegetative parts of the fresh specimen collected were planted in Obafemi Awolowo University, Botanical Garden, Ile-Ife for *ex situ* conservation. Herbaria abbreviations are according to Holmgren and Keuken (1974).
Qualitative characters like the colours of flowers, fruit, sepal and presence or absence of wrinkled leaves were recorded on the field (Table 3). Other qualitative characters such as pubescence of the leaves, stem, fruit, petiole and sepals were noted in laboratory with the aid of hand lens. The information of floral parts such as the numbers of petals, sepals, stamens, number of lateral vein in pairs were determined by counting physically. Other characters like leaf shape, leaf base, leaf apex, leaf margin, fruit type, texture and size together with those of the seed and number of seed per fruit were recorded.

The quantitative attributes of the vegetative and reproductive parts were measured and scored (Table 4). The length and breadth of the stem, leaves and flowers together with the length of petiole, style and stamen were measured to the nearest centimeter using metric ruler. Principal Component Analysis (PCA) was carried out on the data using Palaeontological Statistics (PAST), ver. 1.75. The basic data matrixes of 81 × 36 were prepared by coding for presence or absence of the attributes of characters involved. A combination of two-state and multistate codings were employed (Sokal and Sneath, 1963). Single Linkage Cluster Analysis (SCLA) was performed for the estimation of resemblance among the groups of OTUs and the affinities of different OTUs are determined.

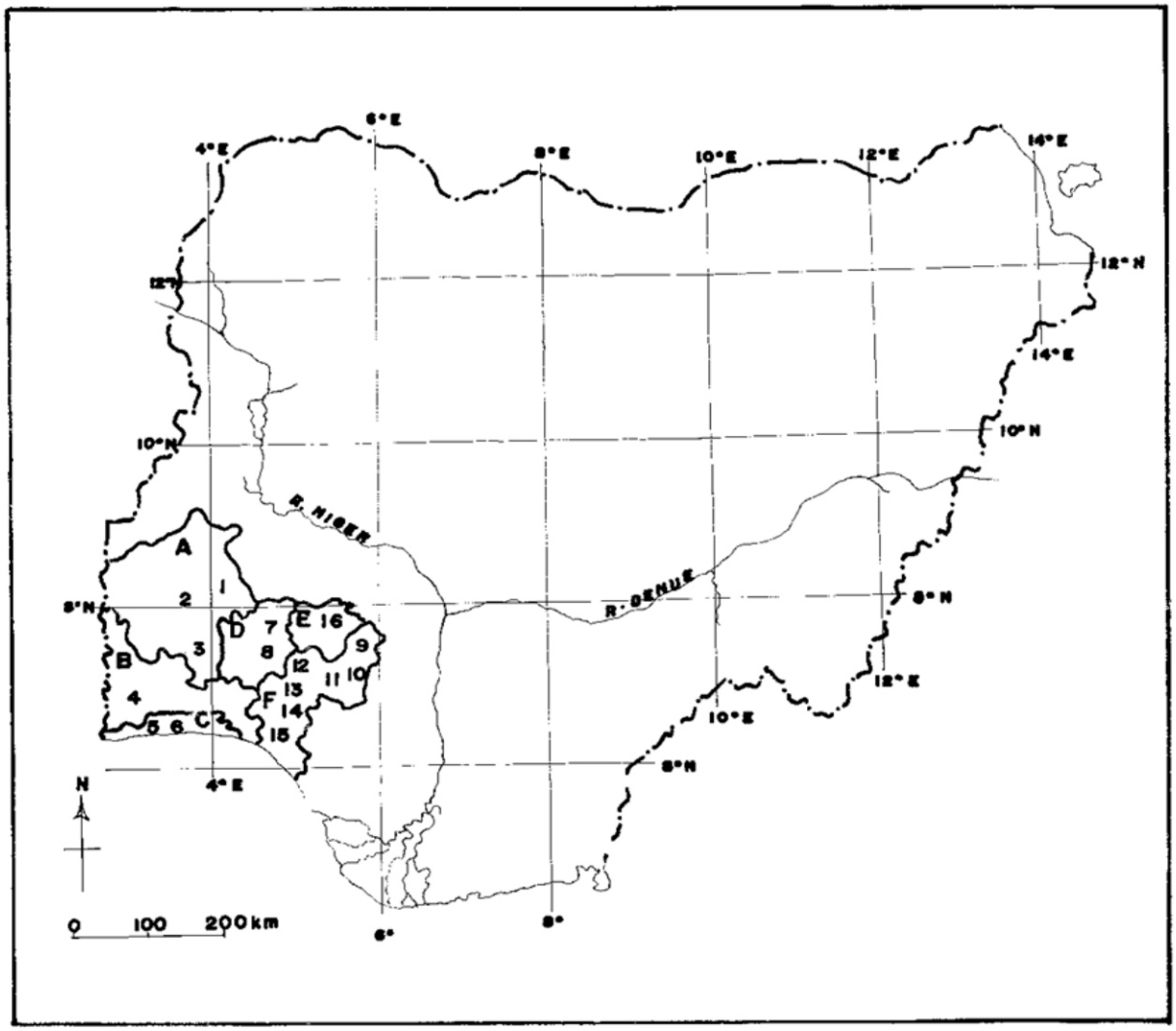

Fig. 1: Areas of collection of *Ipomoea* Species Used for the Study in Southwestern Nigeria. A - Oyo State, B - Ogun State, C - Lagos State, D - Osun State, E - Ekiti State and F - Ondo. 1= Ogbomoso, 2= Iseyin, 3= Ibadan, 4= Ewekoro, 5= Victoria Island, 6= Tarkwa Bay, 7= Ikirun, 8= Ile- Ife, 9= Akunnu Akoko, 10= Ipe Akoko,11= Owo, 12=

Table 1: A list of *Ipomoea* Species Collected Indicating their Locations

Species Number	Species	Collector	Location
1	*I.hederifolia* Linn.	Olorungbeja J.A. IFE 16607	Near New Bukataria O. A. U. Ile-Ife
2	*I.heterotricha* F. Didr.	Olorungbeja J.A. IFE 16614	Top of Hill 3 Rocky soil, O. A. U. Ile-Ife
3	*I. involucrata* P. Beauv.	Olorungbeja J.A. IFE 16602	Along Students Residence Roadside, O. A. U. Ile-Ife
4	*I. triloba* Linn.	Olorungbeja J.A. IFE 16421	No 02 Anu-Oluwapo St. Idanre Rd. Oke-Aro, Akure. Ondo State.
5	*I. asarifolia* (Desr) Roem & Schult	Olorungbeja J.A. IFE 16605	Opp. St John's RCM Roadside Ipe Akoko, Ondo State.
6	*I. alba* Linn.	Olorungbeja J.A. IFE 16608	Under overhead bridge Oyo Road, Ojoo, Ibadan, Oyo State.
7	*I. batatas* (Linn.) Lam.	Olorungbeja J.A. IFE 16611	Behind G. block, Pg Hall, Ife campus O.A.U.
8	*I. argentaurata* Hallier. F.	Olorunfemi IFE 6942	Roadside IITA Ibadan, Oyo State.
9	*I. quamoclit* Linn.	Olorungbeja J.A. IFE 16615	Front of Hezekiah O. Library, O. A. U. Ile-Ife
10	*I. carnea* Jacq.	Olorungbeja J.A. IFE 16612	Behind Moremi Hall opp. Fajuyi Hall, O. A. U. Ile-Ife
11	*I. aquatica* Forsk	Olorungbeja J.A. IFE 16603	Water bank, IITA Road Ojoo Ibadan.
12	*I. eriocarpa* R. Br. Prod	Olorungbeja J.A. IFE 16606	Roadside, Polytechnic campus, Ibadan, Oyo State.
13	*I. mauritiana* Jacq.	Olorungbeja J.A. IFE 16617	Agric farm O. A. U. campus, Ile-Ife Osun State
14	*I. vagans* Bak.	M. G. Latilo FHI 6	Akure Road, Ilesa, Osun State
15	*I. blepharophylla* Hallier	Olorungbeja J.A. IFE 16613	Top of Hill 3 summit O.A.U. campus Ile - Ife.
16	*I. cairica* (Linn.) Sweet Hort	G. Ibhanesebhor FHI 65208 Ibhanesebhor & Oke IFE 16018	Ewekoro Cement Plc Premises, Ogun State. Border of Mangrove Swamp, Lagos.
17	*I. coptica* (Linn.) Roth ex Roem & Schult.	Olorungbeja J.A. IFE 16618	Akure Road, Ilesa, Osun State
18	*I. intrapilosa* Rose	Olorungbeja J.A. IFE 16610	In front of Postgraduate Hall, O.A.U campus
19	*I. nil* (Linn.) Roth Cat.	Olorungbeja J.A. IFE 16604 J. Lowe UIH 13135	In front of ETF Hostel, New Market Road, O.A.U. Ile Ife, Nigeria.
20	*I. muricata* (Linn.) Jacq.	Olorungbeja J.A. IFE 16616	Omuaran-Oro Ago road junction, Ilorin, Kwara State.
21	*I. pes - caprae* (Linn.) Sweet	B. I. Asuquo UIH	Roadside Badagary, Lagos.
22	*I. pileata* Roxb.	Daramola/ Okoro/ Akin FHI 98976	Around Forestry Nursery Numan Town, Gongola.
23	*I. obscura* (Linn.) Ker-Gawl.	Olorungbeja J.A. IFE 16609 H. G. Sadory UIH 1463	Near O.A.U main gate, Ede Rd Ile-Ife, Osun State. Roadside in Idanre, Ondo State.

Table 2: Herbarium Materials of *Ipomoea* Species Used for the Study.

Species Number	Species	Collector	Location
1	*I. barteri* Bak.	Soladoye, Ekwuno FHI 83528	Rocky Slope Ppanshanu Pass, Bauchi, Bauchi State
2	*I. coscinosperma* Hochst.	Onyeachusim & Daramola FHI 46962	Bamngelzarma F. R. S. N. 8. Savanna Zaga Bornu State.
3	*I. alpina* Rendle	B. O. Daramola FHI 62746	Yelwa, Maiduguri, Benue State
4	*I. aitonii* Lindl	G.Ibhanesebhor FHI 31586	Akindele Forest Reserve, Ibadan, Oyo State.
5	*I. stenobasis* Brenan	J. Lowe FHI 10145506 W. W. Sanford IFE 7032	Olere farm Hill, Iba Ipe, Akoko, Ondo State. Idanre Hill, Idanre, Ondo State.
6	*I. rubens* choisy	B. O. Daramola FHI 61917 W. W. Sanford IFE 7030	At the Bank of River Niger, Bida, Niger State. Open grassland along mountain summit Bauna at 4545 pt 9^0 8 Plateau State.
7	*I. stolonifera* (Cyrill) J. F. Gmel	J. K. Morton FHI 56726 W. W. Stanford IFE 7034 A.M.I. Salaam UIH 22152	Victoria Sea - Shores Badagry, Lagos State Bata, 8km toward Airport along the sea Cotonu, Republic of Benin. Oginibiri Ocean Akassa, River State.
8	*I. tenvirostris* Choisy.	G. Ibhanesebhor FHI 77834 W. W. Sanford IFE 7037	Kakara Afforestation scheme, Plateau top. Mambilla, Plateau State. Dschang Dist, Bafang Bamenda, Cameroon 5^0 10
9	*I. verbascoidea* Choisy	V. Bojnansky FHI 102380 W.W.Sanford IFE 7040	Jos stony Hill behind Hill station Hotel, University of Jos (Makurdi campus) Makurdi. Magama F.R. 11^0, 9 Bauchi State.
10	*I. velutipes* Welw ex Rendle.	Gbile, Olorunfemi FHI 20545	Ayika Lawole street, Ipetu road, Ile - Oluji, Ondo State
11	*I. orchracea* (Lindl) G. Don.	Enwiogbon, C. FHI 73127	Iva Forest Reserve Juju groove, East Central, Enugu, Enugu State
12	*I. pes- tigridis* Linn.	Ekwuno/Fagbemi FHI 93878	Zaga F. R. Mungonu, Borno State.
13	*I. pyrophila* A. Chev.	Soladoye, Ekwumi FHI & Ihe 83651 W.W.Sanford IFE 7041 J.Lowe UIH 3354	Dogon Daura F. R. Brinin Gwari, Kaduna State Tanelsa - Kaba, Kogi State. Afaka Zaria, Kaduna State.

RESULTS

The result obtained by using Single Linkage Cluster Analysis (SCLA) is shown in Figure 2 while Figure 3 and 4 show the relationship obtained by Principal Components Analysis (PCA). In both cases, 36 OTUs by 81 characters were employed. The qualitative and quantitative characters together with their states are shown in Tables 3 and 4 respectively. A line at 65% creates eight phenons which are *I. asarifolia, I. stenobasis, I. blepharophylla, I. rubens, I. vagans, I. coscinosperma, I. pyrophila, I. intrapilosa, I. carnea, I. mauritiana, I. cairica, I. quamoclit, I. heterotricha, I. muricata, I. aitonii, I. stolonifera, I. pes-carprae, I. argentaurata, I. verbascoidea, I. eriocarpa, I, tenvirostris, I. involucrata, I. pileata, I. aquatica, I. batatas, I. velutipes, I. ochracea* and *I. obscura; I. alba; I. barteri; I. coptica* and *I. pes-tigridis; I. nil; I. hederifolia; I.alpina; I. triloba.* At 68% phenon line, seventeen phenons are observable: *I. asarifolia, I. stenobasis, I. blepharophylla, I. rubens, I. vagans, I. coscinosperma, I. pyrophila, I. intrapilosa, I. carnea, I. mauritiana, I. cairica, I. quamoclit, I. heterotricha, I. muricata, I. aitonii, I. stolonifera; I. pes-carprae; I. argentaurata; I. verbascoidea; I. eriocarpa* and

I, tenvirostris; I. involucrata and *I. pileata; I. aquatic; I. batatas; I. velutipes; I. ochracea* and *I. obscura; I. alba; I. barteri; I. coptica* and *I. pes-tigridis; I. nil; I. hederifolia; I.alpina; I. triloba.* At 70% phenon line, twenty-one phenons are recognized; they are *I. asarifolia, I. stenobasis, I. blepharophylla, I. rubens, I. vagans, I. coscinosperma, I. pyrophila, I. intrapilosa, I. carnea, I. mauritiana, I. cairica, I. quamoclit, I. heterotricha; I. muricata, I. aitonii* and *I. stolonifera; I. pes-carprae; I. argentaurata; I. verbascoidea; I. eriocarpa* and *I, tenvirostris; I. involucrata; I. pileata; I. aquatica; I. batatas; I. velutipes; I. ochracea; I. obscura; I. alba; I. barteri; I. coptica; I. pes-tigridis; I. nil; I. hederifolia; I.alpina; I. triloba.*

A line at 75% creates twenty-seven phenons which are *I. asarifolia, I. stenobasis, I. blepharophylla, I. rubens, I. vagans, I. coscinosperma, I. pyrophila, I. intrapilosa; I. carnea; I. mauritiana* and *I. cairica; I. quamoclit, I. heterotricha, I. muricata, I. aitonii, I. stolonifera, I. pes-carprae, I. argentaurata, I. verbascoidea; I. eriocarpa* and *I, tenvirostris; I. involucrata; I. pileata; I. aquatica; I. batatas; I. velutipes; I. ochracea; I. obscura; I. alba; I. barteri; I. coptica; I. pes-tigridis; I. nil; I. hederifolia; I.alpina; I. triloba.* The percentage of total variation, cumulative percentage and the eigen-value are as shown in Table 5.

In Figure 3, component 1 is heavily loaded because it has the highest % total variance (35.10%). Four major groups are recognized in this component. The first group comprises of *I. quamoclit, I. barteri, I. eriocarpa, I. verbascoidea, I. carnea, I. stolonifera, I. tenvirostris, I. aitonii, I. heterotricha, I. argentaurata, I. pileata, I. muricata, I. ochracea, I. alpina, I. pes-caprae, I. obscura, I. involucrata* and *I. velutipes.* The second group comprises of *I. rubens, I. intrapilosa, I. vagans, I. stenobasis, I. pyrophila, I. asarifolia, I. alba* and *I. coscinosperma.* The third group comprises of *I. nil, I. hederifolia* and *I. triloba* while the fourth group include *I. mauritiana* and *I. cairica.* The second component has 13.27% total variance (Table 5) and comprises *I. batatas, I. coptica,* with *I. pes-tigridis* as an outlier. The % total variance in Figure 4 is 13.27% plus 7.58%, this is relatively low and so there is radial distribution of the *Ipomoea* species.

Table 3: A List of Qualitative Characters and Character States Used for the Numerical Analysis

Character Number	Character	States
1	Stem surface: Glabrous/ Pubescent	2
2	Presence of Root at leaf node: Present/Absent	2
3	Structure of Stem: Thick/Slender	2
4	Presence of Hollow stem: Present/Absent	2
5	Presence of Scalelike structure on stem: Present/Absent	2
6	Stem becomes reddish at leaf node at maturity : Present/Absent	2
7	Habit of plant: Twinner/Trailer/Scrambler/Creeper/Climber/Erect	6
8	Type of stem: Woody/Herbaceous	2
9	Presence of milky latex: Present/Absent	2
10	Nature of stem: Weak/Erect	2
11	Habit of growth: Herb/Shrub	2
12	Colour of stem: Green/Greenish brown/Brown/Whitish	4
13	Type of growth: Annual/Perennial	2
14	Leaf adaxial surface: Glabrous/Pubescent	2
15	Leaf abaxial surface: Smooth/ Glabrous/Pubescent	3
16	Types of hairs on leaf surface: Peltate/Microhairs/Wooly hairs	3
17	Leaf with silky surface: Present/Absent	2
18	Leaf shape: Cordate/Lanceolate/Hastate/Ovate/Acicular/Oblong-lanceolate/Palmate/Linear-oblong/Sub-orbicular	9
19	Leaf base: Cordate/Attenuate/Acute/Obtuse/Retuse/Ovate	6
20	Leaf apex: Mucronate/Acuminate/Acute/Obtuse/Retuse/Ovate/Linear/	7
21	Leaf margin: Entire/Serrated	2
22	Leaf type: Simple/Compound	2
23	Presence of variable leaf shape: Present/Absent	2
24	Presence of parted leaf: Present/Absent	2
25	Leaf pinnately parted into linear segments: Present/Absent	2
26	Leaf lobe shape: Orbicular/Lanceolate/Ovate/Sagitate/Aciculate/Palmate	6
27	Presence of leaf lobed shape: Present/Absent	2
28	Leaf bilobed at the apex: Present/Absent	2

Table 3 contd: A List of Qualitative Characters and Character States Used for the Numerical Analysis

Character Number	Character	States
29	Leaf arrangement: Alternate/Opposite	2
30	Vein type: Pinnate simple/Palmate simple/Palmate compound	3
31	Presence of stipule: Present/Absent	2
32	Presence of wrinkled leaves: Present/Absent	2
33	Presence of glandular dotting on leaf: Present/Absent	2
34	Presence of marked venation on the leaf abaxial surface: Present/Absent	2
35	Petiole pubescent: Present/Absent	2
36	Flower surface: Glabrous/Pubescent	2
37	Flower size: Large/Small	2
38	Flower with differentially coloured throat: Present/Absent	2
39	Type of Inflorescence: Cyme/Cymose/Solitary/Panicle	4
40	Time of opening of flowers: Morning/Afternoon/Evening	3
41	Colour of petals: White/Yellow/Pink/Red/Purple/Blue	6
42	Shape of petals: Tubular/Funnel-form	2
43	Presence of variable flower colour: Present/Absent	2
44	Materials of propagation: Seed and vegetative stem/Vegetative stem alone/Underground materials/Seed and vegetative materials	4
45	Nature of sepals: Foliaceous/Linear shape	2
46	Colour of sepals: Green/White	2
47	Shape of sepals: Ovate/Lanceolate/Oblong/Cordate/Acuminate/Obtuse	6
48	Hairiness of sepals: Glabrous/Pubescent	2
49	Environmental Importance: Weed/Ornamental/Food/Medicinal	4
50	Size of sepals: Large/Small	2
51	Calyx segment unequal: Present/Absent	2
52	Surface of pollen grain: Spinose/Smooth	2
53	Presence of pedicel: Present/Absent	2
54	Presence of flower bract: Present/Absent	2
55	Flower bract united: Present/Absent	2
56	Flower bract modified into involucre: Present/Absent	2
57	Stem originating from woody base: Present/Absent	2
58	Fruit size: Large/Small	2
59	Fruit type: Capsular/Syncarpous	2
60	Shape of fruit: Ovoid/Orbicular/Cordate/Globose/Ovate	5
61	Hairiness of fruit: Glabrous/Pubescent	2
62	Fruit apex: Acuminate/Acute/Obtuse/Ovate/Ovoid	5
63	Fruit colour when ripe: Brown/Deep Brown/Green	3
64	Fruit colour when unripe: Green/Brown	2
65	Shape of seed: Rhombate/Ovoid/Deltoid	3
66	Hairiness of seed: Glabrous/Pubescent	2
67	Hairs on seed modified into wool: Present/Absent	2
68	Anther Arrangement: Versatile/Basifixed	2

Table 4: A List of Qualitative Characters and Character States Used for the Numerical Analysis

Character number	Characters	Number of State
1	Average length of leaf petiole (cm): 0.0 5.0 = 1; 5.1 10.0 = 2; 10.1 15.0 = 3; 15.1 20.0 = 4; 20.1 25.0 = 5	5
2	Lateral nerve number in pair per leaf: 0.0 5.0 = 1; 5.1 10.0 = 2; 10.1 15.0 = 3; 15.1 20.0 = 4; 20.1 25.0 = 5	5
3	Average leaf length (cm): 0.0 10.0 = 1; 10.1 20.0 = 2; 20.1 30.0 = 3	3
4	Average leaf breadth (cm): 0.0 5.0 = 1; 5.1 10.0 = 2; 10.1 15.0 = 3	3
5	Leaf length to breadth ratio (cm): 0.0 3.0 = 1; 3.1 6.0 = 2; 6.1 9.0 = 3; 9.1 12.0 = 4	4
6	Number of leaf lobe: 0, 3, 4, 5, 7, 9	6
7	Average flower length (cm): 0.0 5.0 = 1; 5.1 10.0 = 2; 10.1 15.0 = 3; 15.1 20.0 = 4; 20.1 25.0 = 5; 25.1 30.0 = 6	6
8	Average flower breadth (cm): 0.0 5.0 = 1; 5.1 10.0 = 2; 10.1 15.0 = 3	3
9	Flower length to breadth ratio (cm): 0.0 2.0 =1; 2.1 4.0 = 2; 4.1 6.0 = 3	3
10	Length of styles (cm): 0.0 2.0 =1; 2.1 4.0 = 2; 4.1 6.0 = 3	3
11	Average length of stamen (cm): 0.0 1.0 = 1; 1.1 2.0 = 2; 2.1 3.0 = 3	3
12	Average length pedicel (cm): 0.0 5.0 = 1; 5.1 10.0 = 2; 10.1 15.0 = 3	3
13	Number of seed: 1; 2; 3; 4	4

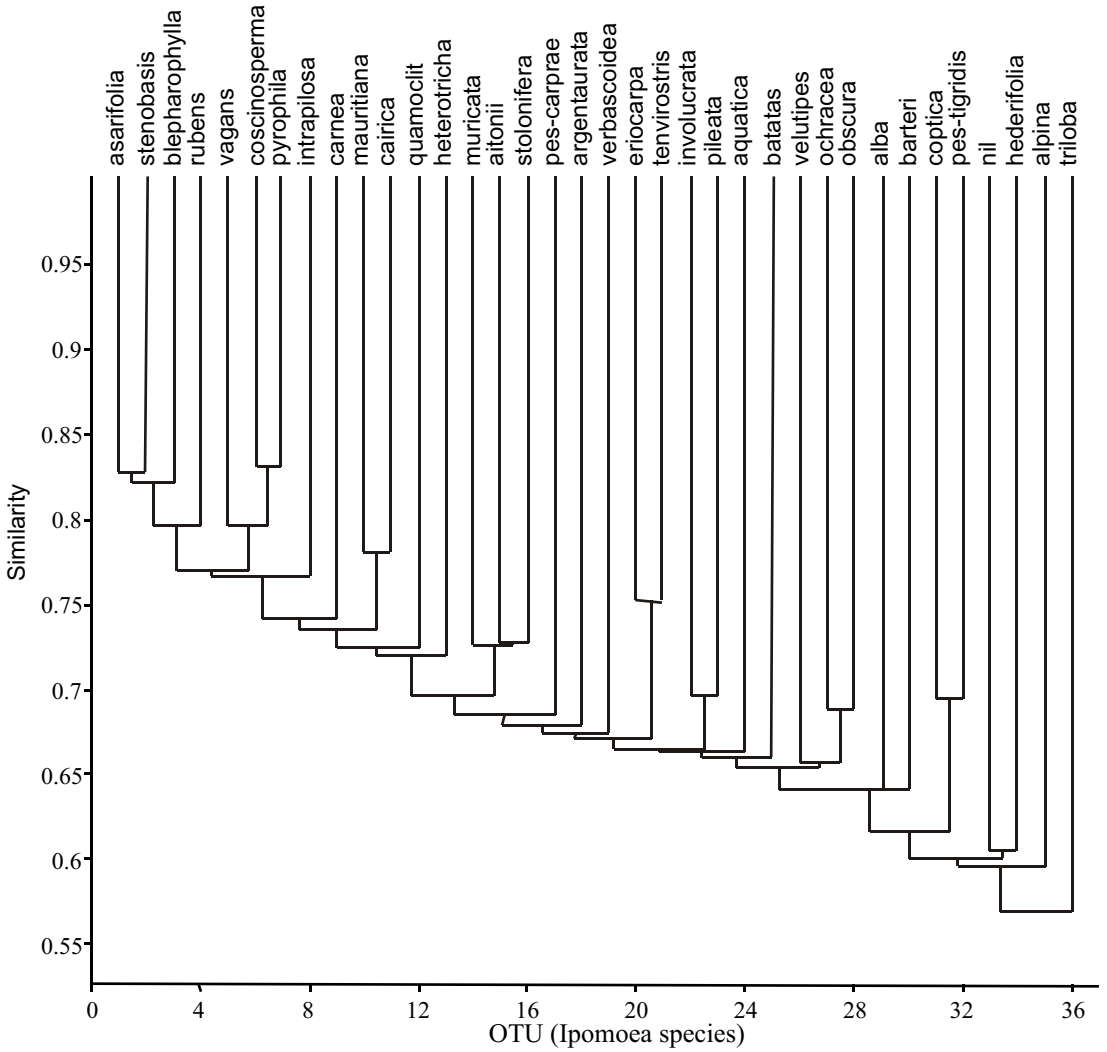

Fig. 2: Cluster Analysis of *Ipomoea* Species Based on Characters.

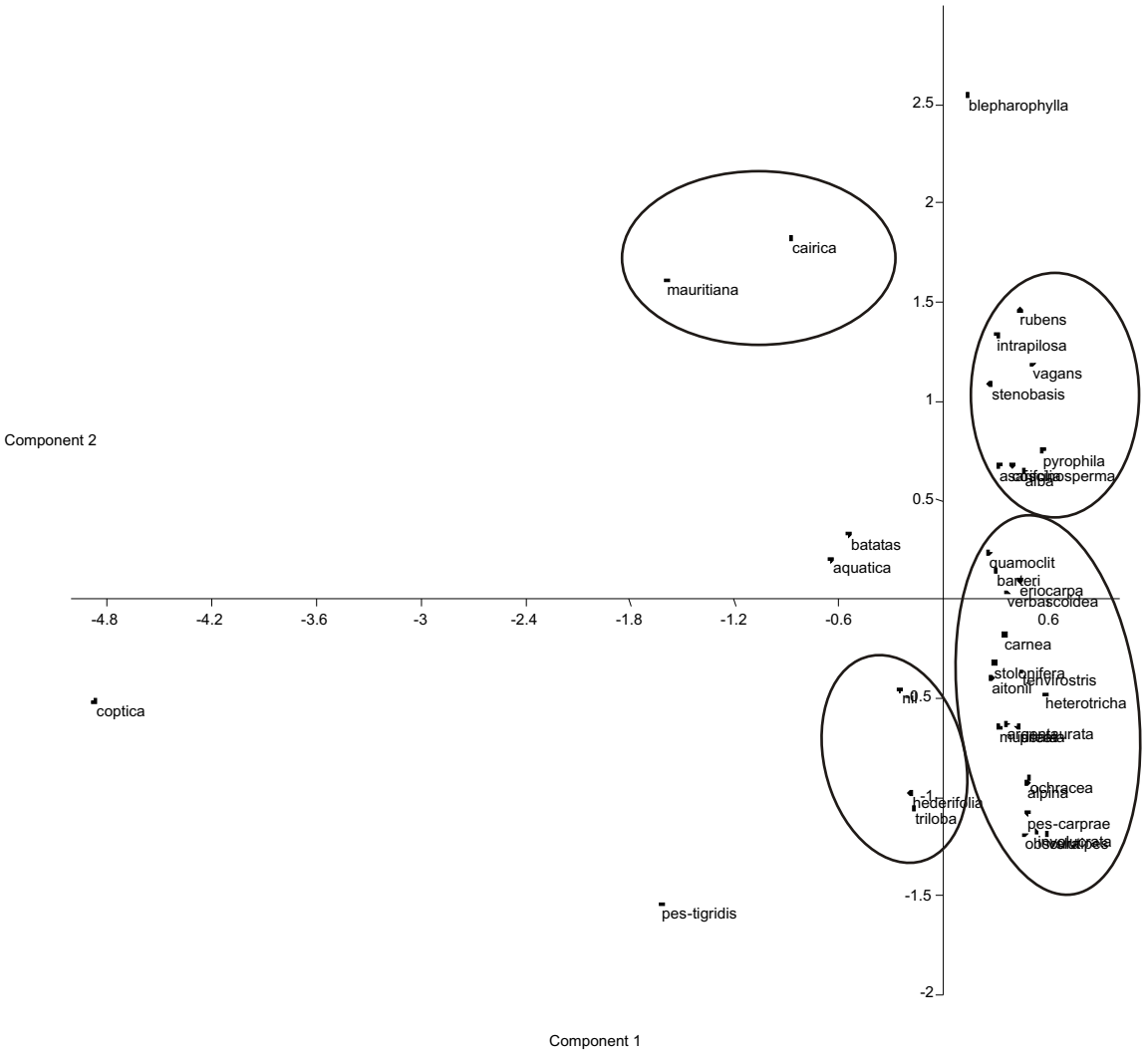

Fig. 3: Scatter Diagram of Components I and II from Principal Components Analysis Based on Characters.

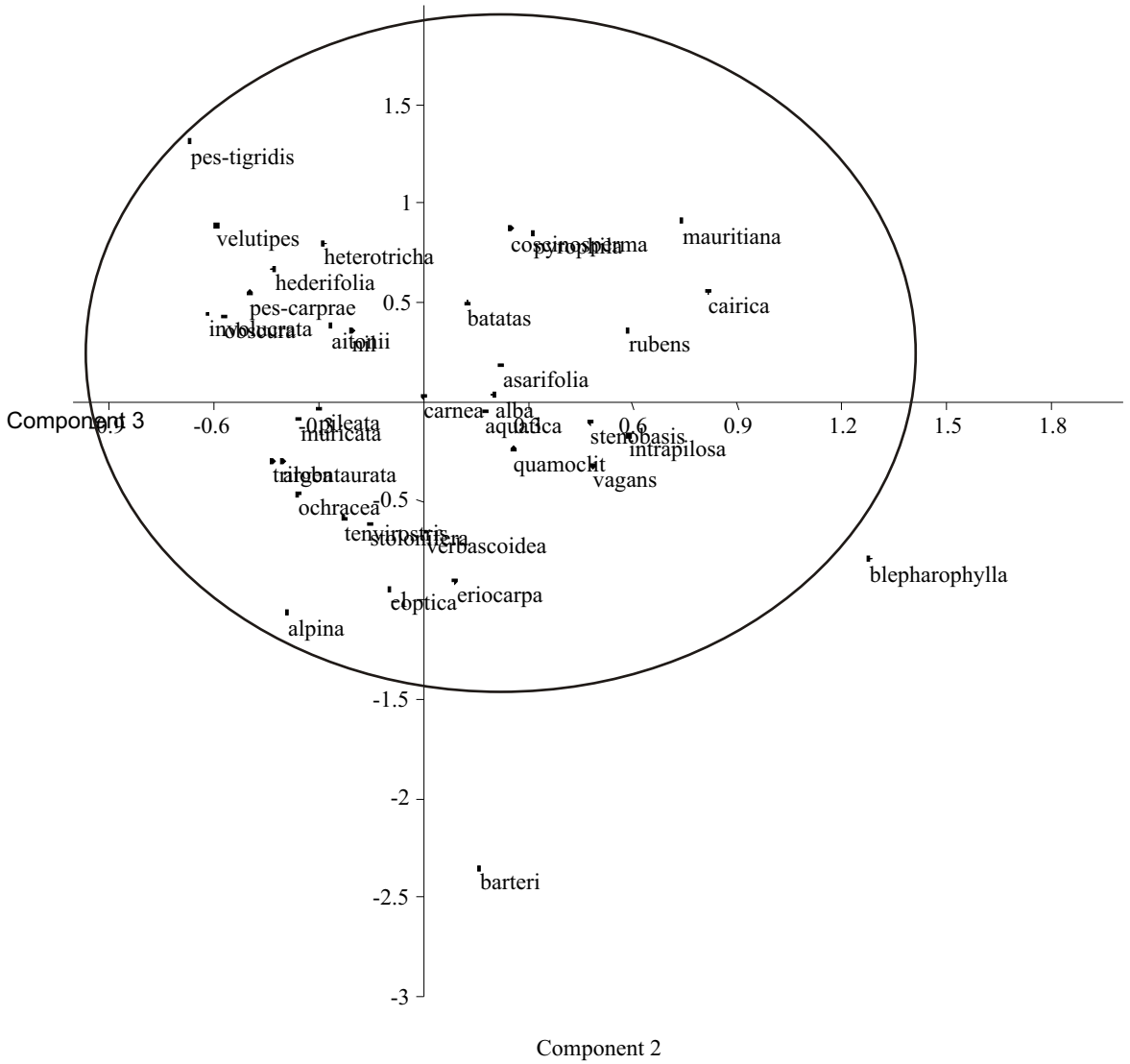

Fig. 4: Scatter Diagram of Components II and III from Principal Component Analysis Based on Characters.

Table 5: Eigen-value and Percent of Total Variation Accounted for the First Three Principal Component Axes of the Ordination of Species of *Ipomoea*.

Principal Component Axis	Eigen-Value	Percentage of Total variation. (%)	Cumulative Percent.
1	22.50	35.10	35.10
2	8.50	13.27	48.37
3	4.86	7.58	56.95

DISCUSSION

The Single Linkage Cluster Analysis revealed interspecific relationships within the genus *Ipomoea*. At lower similarity coefficients below 58%, there is no separation of species. Several clusters or phenons are formed at higher similarity coefficients value based on the affinities of the species. Two clades are produced; the first clade consists of *Ipomoea triloba* only, and this was reported by Austin and Huaman (1996) as belonging to the Section Eriospermum. Other members of this section are *I. heterotricha* and *I. carnea* which belong to the second clade in this study. In the second clade, at 0.72 similarity index, there are infrageneric relations: *I. heterotricha* and *I. carnea* have a close relationship with *I. cairica, I. quamoclit* and *I. mauritiana*. These three species are also considered to belong to the Section

Eriospermum in the present study. Choisy (1845), Hallier (1893b), and House (1908) provided early treatments recognizing subgenera and additional infrageneric subdivisions within *Ipomoea*. Moreover, the relationships among Old World *Ipomoea* species were further refined by van Ooststroom (1953), who recognized seven infrageneric taxa in his studies on Asian species.

At 0.61 similarity level, *I. nil* and *I. hederifolia* are closely related; they belong to the section Pharbitis. Similarly, *I. alpina, I. pes-tigridis, I. coptica, I. barteri* and *I. alba* have close relationship with *I. nil* and *I. hederifolia;* they are in Section Pharbitis. Choisy (1845) had earlier reported the plant in Section Pharbitis to have the most primitive characteristics in subgenus *Ipomoea* and most species have three carpella pistils. Other workers had grouped *I. alba* and *I. muricata* into the Section Calonyction. At 0.66 similarity level, three sections are closely related. *I. aquatica* (Section Mina), *I. batatas* (Section Batatas), *I. ochracea, I. obscura* and *I. velutipes* (Section Leiocalyx); the first and second sections were reported by Austin while the third section was reported by Hallier, 1893. Hallier (1893) proposed and amended Section Leiocalyx, and placed *I. cairica*, *I. obscura* and *I. ochracea* with *I. aquatica* and *I. pes-caprae*. The statement made by Das and Mukherjee (1997), that "exactly what other species are related to *I. aquatica* is problematic as there were no thorough morphological study made" has been resolved in the present study. *I. pileata* and *I. involucrata* are closely related, they form a sub-cluster. *I. tenvirostris* and *I. eriocarpa* are similarly closely related, they also form a sub-cluster. The members of these two sub-clusters are related to *I. aquatica* in this study. The phenon which consists of *I. verbascoidea, I. argentaurata* and *I. pes-caprae, I. stolonifera, I. aitonii* and *I. muricata* belongs to the Section Erpipomoea as reported by Austin (1997).

Austin (1997), classified *I. quamoclit* into the Section Orthipomoea. But in this study, *I. heterotricha, I. cairica, I. mauritiana, I. carnea* (which belong to the Section Eriospermum as reported by Austin and Huaman, 1996) and *I. quamoclit* are altogether in the same cluster. This suggests a close relationship between the Section Eriospermum and Section Orthipomoea. The last cluster in this study comprises of four sub-clusters; the first sub-cluster consists of *I. asarifolia, I. stenobasis* and *I. blepharophylla*. The second sub-cluster consists of *I. rubens*. The third sub-cluster encompasses *I. pyrophylla, I. coscinosperma* and *I. vagans*. The fourth sub-cluster includes *I. intrapilosa*. *I. asarifolia* a member of the section Leiocalyx (Austin, 2005), is closely related to *I. blepharophylla* and *I. stenobasis* in this study. This therefore suggests that *I. blepharophylla* and *I. stenobasis* are also in the Section Leiocalyx proposed by Austin, 2005.

There is correlation between the SCLA and the PCA of the *Ipomoea* species. At lower % variance, the level of similarity is so high that *Ipomoea* species could hardly be separated and this is the reason for the overlapping and clustering of the species. The PCA discloses the behavior of the *Ipomoea* species at 7.58, 13.2 and 35.10 % variance. There is radial distribution of the *Ipomoea* species at lower % variance of 7.58% and 13.27% which are on components 3 and 2 respectively. When the power of variance reduces, radial distribution takes over to strengthen the monophyly hypothesis of *Ipomoea* species. McDonald and Mabry (1992) carried out phylogenetic analysis of chloroplast DNA and RFLPs for 31 New World *Ipomoea* species, and their study supported monophyly of several traditionally recognized taxa of *Ipomoea*. The level of similarity is so high that they could hardly be separated and hence the overlapping. Axes 1 and 2 of the Principal Component Analysis show how the *Ipomoea* species are delimited into their sections and how the sections are interrelated. Component I is heavily loaded because the % variance is high. Although the *Ipomoea* species are delimited into their sections, they still show interrelationships among sections. This finding corroborates the reports of Wilkin, (1999) that *Ipomoea* is monophyletic.

REFERENCES

Austin, D.F. 1975. Typification of the New World subdivisions of *Ipomoea*. *Taxon* 24: 107-110.

Austin, D.F. 1997. Dissolution of *Ipomoea* series Anisomerae (Convolvulaceae). *Taxon* 28: 359-361.

Austin, D.F. 2005. The enigmatic salsa da rua (*Ipomoea asarifolia*, Convolvulaceae).

Ethnobotany 17: 41-48.

Austin, D.F. and Huáman, Z. 1996. A synopsis of *Ipomoea* (Convolvulaceae) in the Americas. *Taxon* 29: 501-502.

Choisy, J.D. 1845. Convolvulaceae. In A. P. DeCandolle [ed.], *Prodromus systematis naturalis regni vegetabilis*, 9: 323462. Paris, France.

Das, S. and Mukherjee, K. K. 1997. Morphological and biochemical investigations on *Ipomoea* seedlings and their species interrelationships. *Annals of Botany* 79: 565 - 571.

Gill, L.S. 1988. *Taxonomy of Flowering Plants.* Africana-Fep Publishers Limited, 116-119p.

Hallier, H. 1893a. Versuch einer natuerlichen Gliederung der Convolvulaceen auf morphologischer und anatomischer Grundlage. *Botanische Jahrbucher fur Systematik* 16: 453-591.

Hallier, H. 1893b. Convolvulaceae Africanae. *Botanische Jahrbucher fur Systematik* 18: 81-160.

Holmgren, P.K. and Keuken, W. 1974. *Index Herbarium.* Part 1. The herbaria of the World. Utrecht.

House, H. D. 1908. Studies in the North American Convolvulaceae DIV. The genus *Exogonium. Bull. Torrey Bot. Club* 35: 97-107.

Hutchinson, J. and Dalziel, J.M. 1958. *Flora of West Tropical Africa.* 2nd ed. By F.N. Hepper (ed.) Vol. II: 344 - 352.

Manos, P.S., Miller, R.E. and Wilkin, P. 2001. Phylogenetic analysis of *Ipomoea*, *Argyreia*, *Stictocardia* and *Turbina* suggests a generalized model of morphological evolution in morning glories. *Systematic Botany* 26: 585-602.

McDonald, J.A. 1991. Origin and diversity of Mexican Convolvulaceae. *Anales del Instituto de Biologia Universidad Nacional Autonoma de Mexico Serie Botanica* 62: 65-82.

McDonald, J.A. and Mabry, T.J. 1992. Phylogenetic systematics of New World *Ipomoea* (Convolvulaceae). *Plant Systematics and Evolution* 180: 243-259.

Miller, R.E., Buckley, T.R. and Manos, P.S. 2002. An examination of the monophyly of morning glory taxa using Bayesian phylogenetic inference. *Systematic Biology* 51: 740-753.

Ogunwenmo, K.O. 2005. Cytology and hybridization in *Ipomoea triloba* L. complex (Convolvulaceae) and its taxonomic consequences. *Acta Satech* 2(1): 19-23.

Olorode, O. 1984. *Taxonomy of West African Flowering Plants*. Longman Group Ltd, London. 88 - 89.

Shinner, L.H. 1965. Untypification for *Ipomoea nil* (L.) *Taxon* 14: 231-234pp.

Shukla, P. and Mistra, S.P. 1979. *An Introduction to the Taxonomy of Angiosperms*. New Delhii Vikas, 447 - 448pp.

Sokal, R. R. 1958. Qualitification of systematic relationship and of phylogenetic trend. *Proc. Xth Intern. Cong. Entomol.* 1: 409 - 415.

Sokal, R. R. and Sneath, P. H. A. 1963. *Principles of Numerical Taxonomy*. W.H.Freeman and Co. San Francisco, Publishers.1 - 51p.

Van Ooststroom, S. J. 1953. Convolvulaceae. In C. G. G. J. van Steenis [ed.] *Flora Malesiana* 458489. Woltors-Nordhoff, Groningen, Netherlands.

Verdcourt, B. 1957. Typification of the subdivisions of *Ipomoea* L. (Convolvulaceae) with particular regard to the East African species. *Taxon* 6: 150-152.

Verdcourt, B. 1963. Convolvulaceae. In C. E. Hubbard and E. Milne-Redhead [eds.], *Flora of Tropical East Africa*, 1161. Whitefriars Press, London, UK.

Vij, S. P., Singh, S. and Sachdeva, V. P. 1975. Pollen grain studies in some North Indian Convolvulaceae. *Journal of Palynology* 10 (2): 133- 143.

Wilkin, P. 1999. A morphological cladistic analysis of the Ipomoeae (Convolvulaceae). *Kew Bulletin* 54: 853-876.