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PHYLETIC VERSUS PHENETIC APPROACH OF CLASSIFICATION: A CASE STUDY FROM FAMILY EUPHORBIACEAE

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ABSTRACT

Phenetic as well as Phyletic, are both objective classifications, but are based on different dicta. One is based on overall similarities and other on evolutionary characters. It is a matter of arguments, which one is more predictive and natural. Some taxa of Euphorbiaceae have been taken as example to see, which one is better.

INTRODUCTION

One of the basic aim of classification is to produce a more natural and predictive classification which is based on more characters. These general purpose classifications are good for most purposes, and they are reasonably represented by the familiar sequences of families, genera and species etc. which appear in Flora.

There are situations when predictivity is not the only requirement, it is the relationship of a group of the taxa. Theoretically Phylogenetic classifications can be considered as less natural than Phenetic ones, since they are based on only few but phylogenetically important characters. From a long time it is a matter of arguments whether phenetic or phyletic classifications are more predictive and natural. What difference lies between classifications erected according to the two stand point, and investigating the reasons for and consequences of any difference found.

Family Euphorbiaceae is considered as heterogeneous assemblage of taxa with ambiguous affinities. Morphologically it shows variety of characters, ranging from primitive to highly advance such as apetalous, unisexual flowers and cyathium inflorescence. It is considered as monophyletic in origin by Hutchinson (1969), and Crozoit (1973), and polyphyletic by Stebbins (1974), Takhatajan (1980), Dahlgren (1980) and Thorne (1992). Variability of the morphological characters and complexity of the relationships within the family has challenged the best efforts of systematists. Main aim of this study is to discover whether it is possible to construct a classification that is both faithfully phylogenetic and maximally predictive by taking an example of some taxa of Euphorbiaceae.

MATERIALS AND METHODS

The taxa considered in this study are collected from surroundings of Nagpur. They are coded by alphabetical codes [Table 1]. A general list of character state [Table 2]

Table 1

OTU / EU	CODE
Euphorbia cyathophora	*A*
E.antiquorum	*B*
E.corrigioides	*C*
E. cotinifolia	*D*
E. cristata	*E*
E. dracunculoides	*F*
E. geniculata	*G*
E. heterophylla	*H*
E. hirta	*I*
E. parviflora / hypericifolia	*J*
E. milii	*K*
E. neriifolia	*L*
E. nivulia	*M*
E. notoptera	*N*
E. perbracteata	*O*
E. prostrata	*P*
E. pulcherrima	*Q*
E. pulcherrima var. alba	*R*
E. rosea	*S*
E. rothiana	*T*
E. thymifolia	*U*
E. tirucalli	*V*
E. tortilis	*W*
Pedilanthus sp.	*X*
Synadenium sp.	*Y*
E. parvifolia	*Z*

is given for Taxometrics and a list of apomorphous and plesiomorphous characters [Table 3] for Cladistics. The polarity of characters is based on the well established dicta of Takhtajan [1980], Cronquist [1981], Goldberg [1986] and Webster [1994].

For Taxometrics, character X taxon matrix is prepared to show the distribution of the characters within different OTU's [Table 4].A similarity matrix is prepared on the basis of common characters between the two OTU's. Out of several clustering techniques, "Weighted pair group method with arithmetic averages" is used. These clusters /groups were then represented in the form of Phenogram, to show degree of relationship and taxonomic distances among the taxa of various groups, as well as among the various groups [Fig.1].

For the Cladistics same set of taxa as Evolutionary Units [EU] has been used with the same code. Character X taxon matrix is prepared to show the distribution of only apomorphous characters within different EU's [Table 5].Of the several methods in vogue,

Table 2 Characters and Character-state employed in the Taxonomatrix.

Plant glabrous	Not glabrous
Plant armed	Not armed
Plant succulent	Not succulent
Herb	Shrub/Tree
Erect	Prostrate
Stem Zigzag	Straight
Branches angled	Terete
Branchlets umbellate	Not
Leaf opposite	Alternate/whorled
Leaf sessile	Petiolate
Leaves estipulate	Stipulate
Leaf caducous	Persistent
Leaf acute	Obtuse
Leaf entire	Not
Leaf reddish	Leaf green
Leaf ovate	Not
Venation uni-costate	Multi-costate
Flowering twig leafy	Not
Flower leaves distichous	Not
Cyathia axillary	Terminal
Cyathia peduncled	Sessile
Cyathia Actinomorphic	Not
Involucral gland 5	Not
Gland with petaloid limb	Not
Glands horned	Not horned
Limb of gland	Laciniate Not
Cocci keeled	Not
Seeds furrowed	Not
Seeds carunculate	Not

the Wagner's [1980] Ground Plan Divergence Method was followed for the preparation of Phylogenetic tree [Fig.2], on account of its simplicity. Relative advancement of various taxa is based on the total score, as shown in table [Taxa-character matrix].

Table 3 Characters and Character-state employed in the Cladistic relationship of Taxa of sub-family Euphorbioideae

Plesiomorphic state (Score-0)	Apomorphic state (Score-1)
Plant glabrous	Plant not glabrous
Plant not armed	Plant armed
Plant not succulent	Plant succulent
Shrub or Tree	Herb
Erect	Prostrate
Stem straight	Stem zigzag
Branches terete	Branches angled
Branches not umbellate	Branches umbellate
Leaf alternate or whorled	Leaf opposite
Leaf petiolate	Leaf sessile
Leaves stipulate	Leaf estipulate
Leaf persistent	Leaf caducous
Leaf acute	Leaf obtuse
Leaf entire	Leaf serrate
Leaf green	Leaf reddish
Leaf ovate	Leaf not ovate
Venation unicostate	Venation multicostate
Flowering twig leafy	Flowering twig not leafy
Flower leaves not distichous	Flower leaves distichous
Cyathia terminal	Cyathia axillary
Cyathia sessile	Cyathia peduncled
Cyathia actinomorphic	Cyathia zygomorphic
Involucral glands less than 5	Involucral gland 5
Gland without petaloid limb	Gland with petaloid limb
Glands non horned	Gland horned
Limb or gland not laciniate	Limb of gland laciniate
Cocci not keeled	Cocci keeled
Seeds smooth	Seeds furrowed
Seeds not carunculate	Seeds not carunculate

Table 4 : Characters × Taxon Matrix

OPERATIONAL TAXONOMIC UNITS (OTU)																								
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	1
0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0
1	0	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	0	1
1	1	0	1	0	1	1	1	0	1	1	1	1	1	0	0	1	1	0	1	0	1	1	1	1	1
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	1	0	0	0	0	1	1	0	0
0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0
0	0	1	0	1	0	0	0	1	1	0	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0
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0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1
0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1
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1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	1	0	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	1	0
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0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	1	1	0	0	1	0	0	1	1	0	0	0	1	0	1	0	0	1	0	1	0	1	0	0	1
0	0	0	0	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1	1	0	1	1	0	1
0	1	0	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0

Table - 5: Apomorphous Characters × Evolutionary Matrix

EVOLUTIONARY UNITS (EU)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0
1	0	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	0	1
0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	1	0	0	0	0	1	1	0	0
0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0
0	0	1	0	1	0	0	0	1	1	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0
0	1	0	0	1	0	0	0	1	1	1	0	1	0	1	0	0	0	0	1	0	1	1	0	0	0
0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0
1	0	1	0	0	1	0	0	1	1	0	1	0	0	1	1	1	0	0	1	0	1	1	1	0	1
1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0
0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1
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1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	1	0	1	1	1	1	1
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0	0	1	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1
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0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	1	0	0	1	0	1	0	1	0	0	1
0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1	1	0	0	0	0	1
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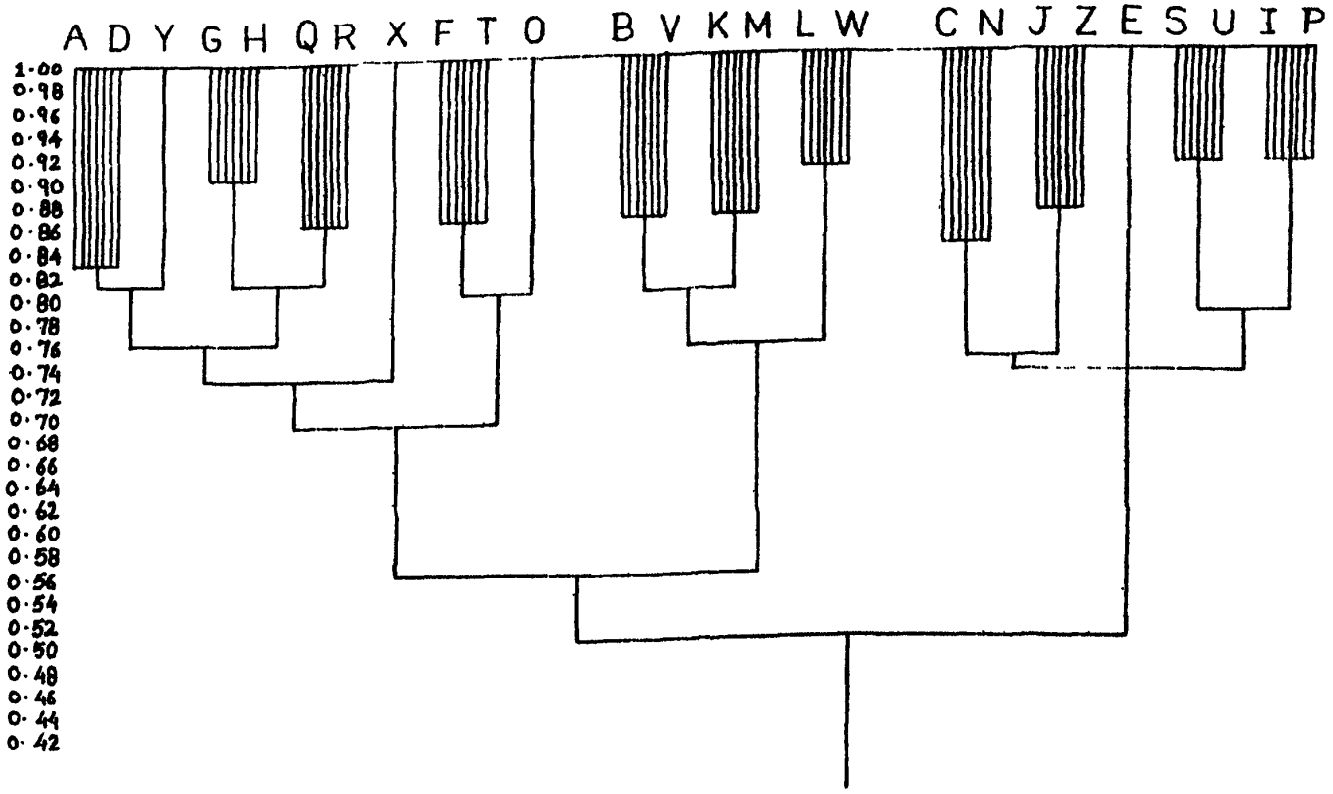

Fig. 1 : Phenogram showing Phenetic Relationship.

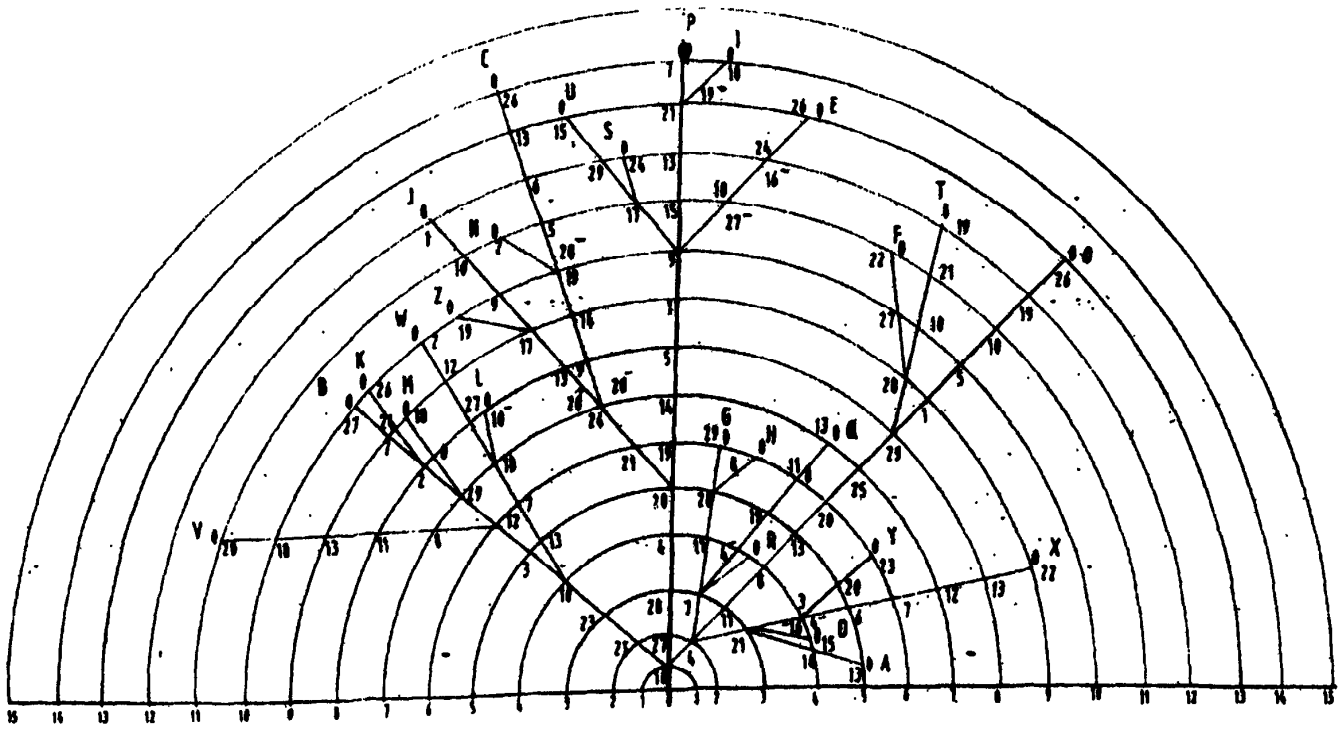

Fig. 2 : Cladogram showing Phylogenetic Relationship.

OBSERVATIONS

Phenogram reveals three groups among the considered OTU's. The OTU's fall under each group are as follows-

Group 1 OTU's A D F G H O Q R T X Y

Group 2 OTU's B K L M V W

Group 3 OTU's C E I J N P S U Z

Group 1 is rather big and contained 11 OTU's ie. OTU A [*Euphorbia cyathophora*], OTU D [*E. cotinifolia*], OTU F[*E. dracunculoides*], OTU G [*E. geniculata*], OTU H [*E. heterophylla*], OTU O [*E. perbracteata*], OTU Q [*E. pulcherrima*], OTU R [*E. pulcherrima var. alba*], OTU T [*E.rothiana]*, OTU X *[Pedilanthus* species] and OTU Y *[Synadenium* species].Of this cluster OTU G and H are showing highest degree of similarity *i.e.* 90% followed by pair QR and FT, both are having 86% similarity, and AD with 83%. Y is closely related with AD [81%], And O with FT [80%]. GH and QR by 81% and with ADY by 76% of similarity.

Group II & III are more homogenous groups. They are showing higher similarity index. Taxon B is related with the Taxon V, and Taxon K with Taxon M, by 86% similarity index. While Taxon L &W are showing 90% closeness. In Group III pair SV and IP are showing 90% intra pair similarity and 79% similarity with each other. JZ are related by 86% and CN by 83% of characters. This entire group along with E is having 73% common attributes.

Group I is related to Group II by 56 % characters & both of these with the group III by 50%.

Cladogram of all of these taxa is also showing three broad lines of evolutions. All these lines of lineage's diverging from a single point. 1st side line shows VB KM LW evolutionary unites [EU]. II side line is having GH QR FT AD and OXY. Main line of evolution is having less number of lateral branches. It is having SU PI CN JZ and E evolutionary units.

Habit of the plant [character state 4], position of cyathia [character state 21] and nature of the cocci [character state 27] are major characters which are showing divergence from the base, in the cladogram constitute first two semi circles. EU's VB KM LW are united by apomorphic character states peduncled cyathia, and involucral glands 5 in number. At circle number 4, there is divergence on account of nature of leaf, that is petiolate. With the apomorphic character states 2,7,12,13,18,& 27, EU W [*E. tortilis*] and L. [*E. nerifolia*] get de linked from the main line. W differs from L only in absence of petiolate leaf. Main line shows apomorphic character states 3 & 12. Other taxa branched out due to a series of dichotomies at successive level.

II side line of evolution shows trichotomy at the very base. One of the side branch with character number 7 as basic character shows apomorphic character states 11, 28

29, it culminates in EU G [*E. geniculata*]. This line shows repeated dichotomy, one in the form of R[*E. pulcherrima var. alba*] and Q *[E. pulcherrima*] with apomorphic character states 4,11,13,19 & H *[E. heterophylla*] with character number 8.This side line shows reverting back of character state 7 and parallel evolution of character no. 11 in G&Q. Other side line with base character 21 shows reversal of the attribute number 4 in the main branch and 4& 16 to the side branch which leads to D[*E.cotinifolia*] & A [*E.cyathophora*]. Here main line with apomorphic character states 3 6 7 12 13 22 leads to X [*Pedilanthus* sp.] and dichotomy at 3 with 20 & 23 leads to Y[*Synadenium* sp.]. Main line of this side along with character states 1 5 8 10 11 13 19 20 25 26 29 leads to O *[E.perbracteata*]. At 29 it branched off to F *[E.dracunculoides*] and T[*E.rothiana*], here F differs from T in having zygomorphic cyathia [char. State 22] & keeled cocci [char.state 27]. While T is showing re -appearance of character states 10,19,21.

Main [central] line of evolution with apomorphic character states 1, 4,5, 7,9,13 ,14,15,19.20,21,27,28 culminates in P[*E.prostrata*]. It shows dichotomy at various points. One of the side branch from character state 20 , shows double dichotomy, one at no. 24 and other at 17 and 19.Both these dichotomies show paraphyletic evolution of character states 9,13,19, while elimination of character states 20 &28.With apomorphic characters 13,17,19,21 & 24, it forms Z [*E.parvifolia*].Side branch at 17 leads to J [*E. hypericifolia*] with apomorphies 1,9,10.Line C [*E. corrigioides]* bifurcate from N[*E. notoptera*] by prostrate state, zigzag stem, & Latinate limb of gland. Two lines come out from character state 9, i.e. Leaf opposite; one line with elimination of character 16,27 leads to E [*E. dracunculoides*].This line posses laminated petaloid limb in the gland and sessile leaves. U [*E. thymifolia*] line shows presence of reddish leaves and ecarunculate seeds. S [*E. rosea*] divert from character state 17, with multicostate venation and petaloid limb of gland. Main line shows last dichotomy at character state 21, along with character 10 it forms I[*E.hirta*].

Thus, in this cladogram all three basic lines of evolution show only apomorphic characters. However, there branches show elimination and re-appearance of characters many times. Character 4,7,16,20,28 are showing reversal in their state various times.

DISCUSSIONS

Modern systematic methodologies are gaining acceptance ever since the publication of Hennings [1966] book " Phylogenetic Systematics" and number of treaties on Numerical Taxonomy. It has been realized that these methodologies will prove helpful in preparation of much talked about Adansonian Classification and in phylogeny of less understood taxa of Angiosperm. Donoghue and Cantino [1988] and Humphries and Chapill [1988] defended the Cladism as a means to unravel the precise lineage of a taxon.

Only one comprehensive phylogenetic analysis of Euphorbiaceae using both phenetic and cladistic methods has been made by Levin [1986 a, b], who classified the genera of sub-family Phyllanthoideae primarily on the basis of leaf anatomy data. Levin and Simpson [1994] have completed a cladistic study of Oldfieldioideae based on pollen characters.

Subfamily of Webster (1994) and tribe Euphorbieae of Hooker (1885) is a very large group with more than 600 species. It is very specific in the characteristics of its taxa. In addition to uniform presence of unisexual, reduced flowers in cyathia and milky juice, taxa of this group show wide variety in habitat, arrangement of leaves, stipules, number and structure of involucral glands, fruits and seeds.

Hooker (*l.c.*) classified these taxa into numbers of sections and sub-sections. Species of section Anisophyllum of genus *Euphorbia* have been indefinitely multiplied and require revision with the view of testing the constancy of the characters by which so many of New World species differ from Old World ones. Important difference do occur in the sculpturing of the seeds, in size and form of the limb of the involucral glands, but at the same time these characters are variable.

Placement of *E. neriifolia, E. nivulia, E. antiquorum, E. tortilis* and *E. millii* in section II Euphorbium and sub section Dichanthium is justified by phenogram as well a cladogram. But *E. tirucally* of sub-section Tirucally shows more similarity with the *E. antiquorum* [86%] than other species of this sub-section.

Similarily II compact group of Phenogram and Cladogram show distribution of taxa in different sub-sections of Section I Anisophyllum. Here *E.notoptera* of Elegantes is closer to *E. corrigioides* of Hypericifolia by 83% of characters, while *E. cristata* of the same sub-section is having only 73% similarity. *E. hypericifolia* and *E. parvifolia* of same section have only 86% similarity. *E.rosea* and *E. hirta* of Hypercifoliae show 90% corelation with *E. thymifolia* and *E. prostrata* of Chamaesyceae ,respectively. All taxa of this section shows 73% of similarity index.

III block of Phenogram and main line of Cladogram show taxa belonging to sub-section of section II Euphorbium and Section III Tithymalus. *E. pulcherrima* and *E. pulcherrima var alba* are related by only 86% characters. On this ground *var alba* can be raised to a new species within same genus. Inclusion of taxa *E. dracunculoides, E. rothiana, E. perbracteata* in a sub-section Esula is justified as these taxa show 80 % of similarity and are forming a single clad. *E. cyathophora* of sub-section Galarheus, section Tithymalus shows 80% similarity with *E. cotinifolia* of section Euphorbium ,sub-section Tirucally. Taxa like *E. geniculata* and *E.heterophylla* with 90% similarity index and *E. cyathophora* by 76% of similarity index are considered as doubtful cases by Hooker. *Pedilanthus* and *Synadenium* are isolated taxa, which are clubbed with this major block by 73% & 81% similarity index respectively.

Thus overall comparison of Phenogram, Cladogram and placement of taxa by Hooker (*l.c.*) in Flora of British India suggests that although number of species are rightly placed in Flora, but some require revision and re-arrangement. Taxa of different sections and sub-sections show similarity index ranging from 50-90%. They are monophyletic in origin..

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