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NUMERICAL ANALYSIS OF *INULA* L. (s.str.) AND ITS ALLIED GENERA FROM PAKISTAN AND KASHMIR

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Abstract

Numerical analysis of 21 species belonging to the genera *Inula* L. (s.str.), *Pentanema* Cass., *Duhaldea* DC., *Dittrichia* Greuter and *Iphiona* Cass., was carried out to find out the interrelationship of these taxa. Two distinct groups of taxa are formed from which one group comprises of *Dittrichia* and *Pentanema* and other group is represented by *Inula*, *Duhaldea* and *Iphiona*. The grouping of the taxa points out the close affinity and the genus *Inula* L. (s.str.) is further divided into two distinct groups which indicates the heterogenous and paraphyletic nature of the genus.

Introduction

Among the modern systematic methods, the numerical taxonomy is considered to be more comprehensive than others. The numerical taxonomic methods quantify the diversity and phylogenetic relationships in a more objective manner than with the human pattern recognition mode. A biological classification is considered to be good when it shows stability, objectivity and has a high predictive value. All these goals for the classification could easily be achieved simultaneously by using the numerical methods (Sokal & Sneath, 1963; McNeil *et al*., 1969; Sneath & Sokal, 1973).

In the last few years a considerable work has been done on the family Compositae to elucidate the phylogenetic relationships. Bremer (1987) studied the phylogeny of the various tribes of the family Asteraceae. Karis *et al*., (1992) analyzed the relationships within the subfamily Cichorioideae. Similarly, Anderberg (1989-1991) also did cladistic analysis on the different tribes including *Inuleae, Gnaphalieae* and *Plucheeae*. For the tribe *Inuleae* (s.l.), Anderberg (1989) analyzed 37 genera belonging to the tribes *Cichorioideae, Liabeae, Vernonieae* and *Lactuceae* as outgroup and concluded that Inuleae (s.l.) are a paraphyletic assemblage forming the basal part of the subfamily Asteroideae. Likewise, in 1991 he published a generic monograph of *Inuleae* (s.str.), using the *Arctotideae* as functional outgroup. A new genus *Xerolekia* was described and *Mollera* was reduced to the synonymy of *Calostephane*. The genus *Duhaldea* was resurrected, *Anisopappus* was found to be a paraphyletic basal group in the tribe. *Buphthalmum* and *Xerolekia* formed one monophyletic group while *Inula* and other similar genera were found to constitute the ancestral complex of *Pulicaria* group.

Apart from the above work on the tribal level no report is available for the genus *Inula* L. (s.l.). The present study was carried out to determine and trace the phenetic relationships among various taxa belonging to *Inula* L. (s.str.) and its allied genera.

Materials and Methods

Numerical analysis was carried out leading to the recognition of different genera and distinct groups of species and to determine the phenetic relationship between them.

Hierarchical clustering was performed using the Euclidean distance index and group average strategy with the computer package (SPSS) Inc., 1996). Each taxon was treated as operational taxonomic unit (OUT). All the OTUs were represented in the study except that of *Duhaldea latifolia* (DC.) Dawar & Qaiser, as its chemical information is missing.

For the analysis, charactes were used from macro as well as micromorphology (i.e., cypsela morphology and palynology) along with chemical informations. Weightage was given to the key characters which were thought to be more informative than others (Abbott *et al.,* 1985). In most of the cases, the qualitative characters were recorded in binary state and in some cases, multiple state. The binary characters were recorded as 1 and 2. Multiple state characters were recorded as 1, 2, 3, 4, 5, and 6. For quantitative characters their average values were used, while in cases of presence or absence, certain characters were coded as 1 or 0 respectively (Tables 1-2).

Results and Discussion

Dendrogram of *Inula* L. (s.str.) and its related genera (Fig. 1) clearly indicates the presence of two broad groups viz., group A and group B. Detail of characters used is given in Tables 1 and 2.

Group-A: This group is characterized by the presence of smooth and unribbed cypselas. It comprises of two subgroups, I and II. Subgroup-I contains *Dittrichia graveolens* (L.) Greuter and *Pentanema* Cass. viz., *P. glanduligerum* (Krasch.) Gorschk., *P. indicum* (L.) Ling, *P. divaricatum* Cass., and *P. vestitum* (Wall. ex DC.) Ling.

Subgroup-I: Is distinguished from other subgroup due to the presence of scale like ridges on receptacle, cupule at the apex of cypsela and by the presence of specific compound, Sakuranetin.Within subgroup- II, *Pentanema vestitum* and *P. divaricatum* are closely related and *P. glauduligerum* is somewhat apart form rest of the species as the difference is found only in their habit.

Group B: It is represented by the genera *Inula* L. (s.str.), *Iphiona* Cass., and *Duhaldea* DC. This is generally characterized by the presence of prominent ribs on cypselas. Group is further divided into two distinct subgroups.

Subgroup-I: It comprises of *Inula koelzii* Dawar & Qaiser, *I. racemosa* Hook. f., *I. royleana* DC., and *I. stewartii* Dawar & Qaiser. The distinction of this subgroup is due to long winged petiolate leaves, 3-4 mm long, 16-24 ribbed and glabrous cypselas. It occupies the basal position amongst all the groups and it is considered most primitive with respect to the presence of usually glabrous cypselas.

Sub group-II: It comprises of *Iphiona aucheri* (Boiss.) A. Anderb., *I. grantiodies* (Boiss.) A. Anderb., *Duhaldea cappa* (Ham.ex D. Don) A. Anderb., *D. eupatorioides* (Wall. ex. DC.) A. Anderb., *D. cuspidata* (Wall. ex. DC.) A. Anderb., and seven species of *Inula* L. (s.str.) viz., *I. acuminata* royle ex DC., *I. falconeri* Hook.f., *I. britannica* L., *I. orientalis* Lam., *I. clarkei* (Hook.f.) Stewart, *I. obtusifolia* Kern., and *I. rhizocephala* Schrenk.

Table 1. List of characters, scored for cluster analysis for the species of *Inula* L. (s.str.) and its related genera.

No.	Character description
1.	Habit: annual herb (1), perennial herb (2)
2.	Stem: absent (0), present (1)
3.	Rosette of leaves: absent (0), present (1)
4.	Leaves: sessile (1), petiolate (2), both (3)
5.	Apex of leaves: not lobed (0), lobed (1)
6.	Receptacle surface: without scale like ridges (0), with scale like ridges (1)
7.	Anther apices: acute -obtuse (1), truncate- emarginate (2)
8.	Endothecial tissues: polar (1), radial (2), transitional (3)
9.	Acute sweeping hairs on style: not reaching to furcation (0), reaching to furcation (1)
10.	Length of cypselas: mm
11.	Surface of cypselas: glabrous (0), pubescent (1)
12.	Ribs on cypselas: absent (0), present (1)
13.	Number of ribs on cypselas
14.	Pappus series: uniseriate (1), biseriate (2), bi-many seriate (3)
15.	Cupule of cypselas:absent (0), present (1)
16.	Apex of spines of pollen grains: acute-acuminate (1),rounded+acute (2)
17.	Spine length (μm)
18.	Mesocolpium (μm)
19.	Colpus length (μm)
20.	Ferulic acid: absent (0), present (1)
21.	O-coumaric acid: absent (0), present (1)
22.	Vitexin: absent (0), present (1)
23.	Iso-orientin: absent (0), present (1)
24.	Sakuranetin: absent (0), present (1)

The two genera *Iphiona* Cass., and *Duhaldea* DC., occupy an intermediate position between the two groups of *Inula* L. (s.str.) and suggests an intermediate evolutionary position of both the genera. On one hand the genera *Iphiona* Cass., and *Duhaldea* DC. show an advancement over the groups of *Inula* L. (s.str.) by the presence of scale-like ridges on receptacle surface and radial endothecial tissues along with leaf lobes at the apex in the former genus and usually petiolate leaves in the latter. At the same time these genera also possess some pleisiomorphic characters viz., polar endothelial tissues in *Duhaldea* DC., and pappus with both bristles and scales in *Iphiona* Cass. Furthermore, the genus *Iphiona C*ass., is also distinct by having neuter marginal florets (when present). Similarly, the ellipsoid cypselas and the presence of tricin 5-glucoside make it distinct from the other genera.

The genus *Duhaldea* DC., differs from all the other genera due to the presence of truncate- emarginate anther apices and the presence of vitexin. On the other hand, cypselas of *Duhaldea* DC., are more or less similar to *Inula* L. (s.str.) so *Duhaldea* shows close affinity to *Inula*. It is interesting to note that when different characters are taken together into consideration not only the five genera separate out quite clearly but grouping with in the genus *Inula* (s.str.) is also evident which points out the heterogenous and paraphyletic nature of this genus. The present studies are based on 11 species of *Inula* (s.str.) therefore, at present no attempt has been made to recognize these subgroups as separate taxonomic entities, as this genus is a fairly large genus with about 100 species (Anderberg, 1991) and complete information about rest of the species is not available so the acceptance of these groups as distinct taxa is kept abeyance.

Table 2. Data matrix of *Inula L.* (s.str.) scored for 24 characters presented in Table 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Inula koelzii	2	1	0	3	0	0	1	3	0	3.5	3	1	16-20	2	0	1	4.7	27	24	1	0	0	1	0
I. royleana	2	1	0	3	0	0	1	3	0	3.5	3	1	16-24	1	0	1	4.62	22.5	25.5	0	0	0	1	0
I. racemosa	2	1	0	3	0	0	1	3	0	3.5	3	1	16-24	1	0	1	4.15	22.25	21.85	0	0	0	1	0
I. stewartii	2	1	0	3	0	0	1	3	0	3.5	1	1	16-20	2	0	1	4.5	23.12	22.5	0	0	0	1	0
I. orientalis	2	1	0	2	0	0	1	2	0	1.5	2	1	8-10	1	0	1	4.75	20.3	20.3	0	0	0	0	0
I. clarkei	2	1	0	1	0	0	1	2	0	2.5	2	1	10-12	1	0	1	4.35	22.8	21.55	1	0	0	1	0
I. obtusifolia	2	1	0	1	0	0	1	2	0	2.5	2	1	10-12	1	0	1	4.37	24.25	22.5	1	0	0	0	0
I. britannica	2	1	0	1	0	0	1	2	0	1.5	2	1	8	1	0	1	4.5	20.27	20	0	0	0	0	0
I. acuminata	2	1	0	1	0	0	1	2	0	1.25	2	1	8	1	0	1	3	18.75	16.25	0	0	0	0	0
I. falconeri	2	1	0	1	0	0	1	2	0	1.25	2	1	8	1	0	1	4.77	19.25	19.57	0	0	0	0	0
I. rhizocephala	2	0	1	2	0	0	1	2	0	1.75	1	1	10-12	3	0	2	4.15	21.87	21.25	0	0	0	0	0
Pentanema glanduligerum	2	1	0	1	0	0	1	2	0	1.75	2	0	0	1	0	1	3.75	16.25	16.5	0	0	0	0	0
P. indicum	1	1	0	1	0	0	1	2	0	1.25	2	0	0	1	0	1	3.15	12.5	9.35	0	0	0	0	0
P. divaricatum	1	1	0	1	0	0	1	2	0	1.25	2	0	0	1	0	1	2.75	14.7	14.7	0	0	0	0	0
P. vestitum	1	1	0	1	0	0	1	2	0	1.25	2	0	0	1	0	1	2.75	13.75	13.75	0	0	0	0	0
Duhaldea cappa	2	1	0	2	0	1	2	1	0	1.75	2	1	8-10	1	0	1	3.12	19.15	19.42	0	0	1	1	0
D. eupatorioides	2	1	0	2	0	1	2	1	0	1.75	2	1	8-10	1	0	1	3.75	19.57	21.65	0	0	1	0	0
D. cuspidata	2	1	0	2	0	1	2	1	0	1.75	2	1	8-10	1	0	1	4.15	19.57	21.25	0	0	1	1	0
Dittrichia graveolens	1	1	0	1	0	1	1	2	1	2.5	2	0	0	1	1	1	4.25	17	16.5	0	0	0	0	1
Iphiona aucheri	2	1	0	1	1	1	1	2	1	3	2	1	10-12	2	0	1	3.52	18.75	21.55	0	1	0	0	0
I. grantioides	2	1	0	1	1	1	1	2	1	3	2	1	10-12	3	0	1	4.25	19.5	22	0	1	0	0	0

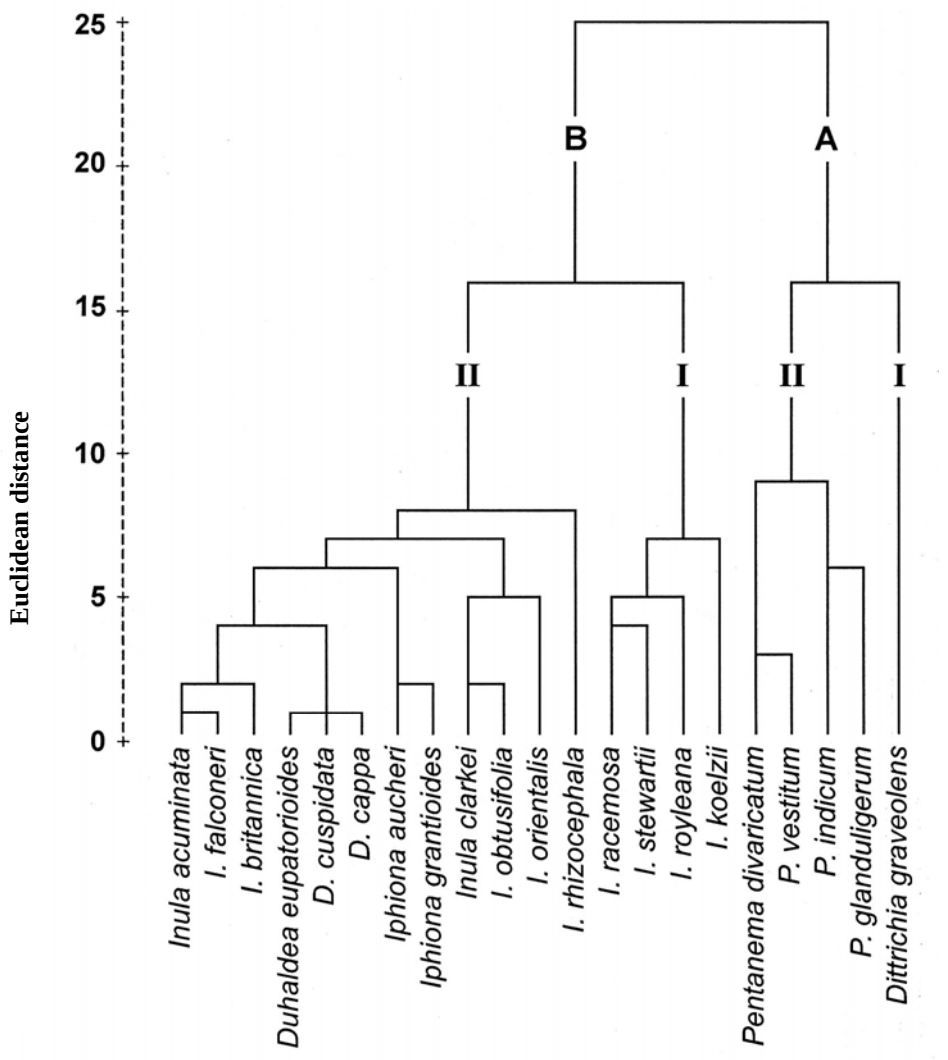

Fig. 1. Dendrogram showing the relationships of the species of *Inula* L. (s.str.) and its related genera.

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