

CYPSELA MORPHOLOGY OF *INULA* L. (S.STR.) AND ITS ALLIED GENERA (INULEAE-COMPOSITAE) FROM PAKISTAN AND KASHMIR

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Abstract

The cypselae morphology of 22 species of *Inula* L. (s.str.) and its allied genera (*Pentanema* Cass., *Duhaldea* DC., *Dittrichia* Greuter and *Iphiona* Cass.) was examined from Pakistan and Kashmir. Micromorphological characters of cypselae in this group also support the taxonomic decision, except that of the genera *Inula* L., and *Duhaldea* DC., which have quite similar type of cypselae and both are placed in one cypselae type which points out the close relationship of both genera as compared to the other genera of this group.

Introduction

The genus *Inula* L. (s.l.) belongs to the tribe Inuleae of the family Compositae. This is assemblage of five different genera viz., *Inula* L. (s.str.), *Pentanema* Cass., *Duhaldea* DC., *Dittrichia* Greuter and *Iphiona* Cass. In all, 5 genera and 22 species are recognized from Pakistan and Kashmir.

Seed morphological studies though closely allied with taxonomic interpretations but have been neglected seriously as a source of stable taxonomic characters till the middle of 20th century. However, during the last five decades most of the workers (Isely, 1947; Chuang & Heckard, 1972; Canne, 1980; Nasir, 1986; Qaiser, 1987; Omer & Qaiser, 1995) utilized seed morphological data with their taxonomic interpretation. Similarly there are various reports on the cypselae morphology used as taxonomic markers for a wide range of Compositae groups (Briquet, 1930; Dittrich, 1968; Haque & Godward, 1984; Matue & Guemes, 1993; Mouradian, 1995). In spite of the fact that considerable attention has been given to cypselae morphological studies of the family Compositae but there are no exclusive reports on the cypselae morphology of the genus *Inula* L. (s.l.) or even of the tribe Inuleae from Pakistan and Kashmir, except some of the investigations of Isely (1947). He emphasized the importance of cypselae size, shape, surface ornamentation, specialized scars and pappus of some members of Inuleae. Likewise, Pandey *et al.*, (1983) studied the cypselae of *Helichrysum bracteatum* and *Vicoa indica* and made distinction between them on the basis of cypselae size and surface hairs.

The present report describes the cypselae morphology of *Inula* L. (s.str.) and its allied genera (Inuleae-Compositae) from Pakistan and Kashmir.

Materials and Methods

Mature cypselae of 22 taxa belonging to *Inula* L. (s.str.), *Pentanema* Cass., *Duhaldea* DC., *Dittrichia* Greuter and *Iphiona* Cass., from the herbarium material were examined. However, in few cases fresh cypselae were also studied. Following characters were studied under stereo (Nikon XN Model)/compound (Nikon Type 102) and scanning electron microscopes (Joel JSM-T200). For scanning microscopic studies, mature cypselae were mounted on a metallic stub with the help of double adhesive tape and coated with gold for a period of 6 minutes in sputtering chamber and observed in SEM. In most of the cases 10 plants/species and 10 cypselae/plant were studied (Appendix-I).

Appendix-1. List of the voucher specimens.

No.	Taxon	Collector, number and herbarium
1.	<i>Dittrichia graveolens</i>	J.L. Stewart 245 (E, K).
2.	<i>Duhaldea cappa</i>	A. Ghafoor & Tahir Ali 4005 (KUH); S.A. Farooqui & M. Qaiser 3172 (KUH); M. Qaiser & A. Ghafoor 4948 (KUH); M. Qaiser 7006 (KUH); Y. Nasir & Rubina Akhtar 10566 (RAW) Y. Nasir, Rubina Akhtar & Hanif 12118 (RAW); R.R. Stewart & I.D. Stewart 3722 (RAW); Shaukat Ali 26129 (RAW); A. Rashid Khan s.n. (RAW); B.L. Burt 1388 (E).
3.	<i>D. cuspidata</i>	S.M.A. Kazmi 284 (KUH); Tahir Ali, M. Qaiser & M. Ajmal 367 (KUH); S.A. Farooqui & M. Qaiser 2439 (KUH); S.I. Ali 1108 (KUH); A. Rashid Khan s.n. (KUH); R.R. Stewart & I.D. Stewart 17399 (RAW); A. Rashid 25728 (RAW); Y. Nasir & Nazir 10519 (RAW); Y. Nasir 9388 (RAW); S.M.A. Kazmi 859 (M).
4.	<i>D. eupatorioides</i>	R.R. Stewart & I.D. Stewart 4145 (RAW); J.R. Drummond 14619 (K).
5.	<i>D. latifolia</i>	Royle 113.2 (LIV).
6.	<i>Inula acuminata</i>	E. Nasir & G.L. Webster 6566 (RAW); R.R. Stewart 26356 (RAW); Stainton 3077 (RAW); J.F. Duthie 13999 (E); S.A. Bowes-Lyon 22 (E).
7.	<i>I. britannica</i>	R.R. Stewart 54 (RAW); R.R. Stewart 19253 (RAW).
8.	<i>I. clarkei</i>	E. Nasir & G.L. Webster 5804 (RAW); E. Nasir & G.L. Webster 5877 (RAW); Hans Hartmann s.n. (RAW).
9.	<i>I. falconeri</i>	R.R. Stewart 20484 (KUH); C.B. Clarke 30027B (K); M.A. Siddiqui, Y. Nasir & Zaffar 4182 (K).
10.	<i>I. grandiflora</i>	RR. Stewart 6687 (RAW); S. Omer & M. Qaiser 2734 (KUH); M. Qaiser & Azmat Ali 5228 (KUH); Jan Mohammad s.n. (RAW); K.W. Vaid s.n. (KUH); R.R. Stewart & I.D. Stewart 19231 (RAW); Tahir Ali, M. Qaiser & M. Ajmal 503 (KUH); J.F. Duthie 13969 (E); O. Polunin 56/487 (E).
11.	<i>I. koelzii</i>	W. Koelz 2818 (RAW); W. Koelz 2900 a (KUH).
12.	<i>I. obtusifolia</i>	R.R. Stewart & I.D. Stewart 21865 (RAW); M.A. Siddiqui & A. Rahman 26817 (RAW); R.R. Stewart 26358 (RAW); R.R. Stewart 18803 (RAW); M. Qaiser, S. Omer & S.Z. Hussain 8414 (KUH); R.R. Stewart 24659 (KUH); S.M.A. Kazmi 3592 (M); S.M.A. Kazmi 5818 (M); Walter Koelz 2778 (E); J.F. Duthie 13694 (E).

Appendix-1 (Cont'd.)

No.	Taxon	Collector, number and herbarium
13.	<i>I. racemosa</i>	R.R. Stewart 14052 (KUH); J.F. Duthie 25657/a (RAW); R.R. Stewart 19550 (RAW); Bowes Lyon 160 (BM); G.A. Gammie s.n. (K).
14.	<i>I. rhizocephala</i>	S. Omer & M. Qaiser 2391 (KUH); A. Rashid 1088 (KUH); M. Qaiser, S. Omer & S.Z. Hussain 8420 (KUH); Kamal A. Malik & S. Nazimuddin 1691 (KUH); Hakim Khan s.n. (RAW); S. Schmid s.n. (RAW); R.R. Stewart 18859 (RAW); R.R. Stewart 26365 (RAW); Lloyd & Megaw 11 (BM); Stainton 2783 (BM).
15.	<i>I. royleana</i>	R.R. Stewart & I.D. Stewart 4302 (RAW); M. Qaiser & Rizwan Y. Hashmi 7868 (KUH); M. Qaiser & A. Ghafoor 5904 (KUH); Y. Nasir & Khan 9663 (RAW); E. Nasir s.n. (RAW); S.M.A. Kazmi 2212 (M); J.F. Duthie 13528 (E); J.F. Duthie 12569 (E); J.F. Duthie 25657 (RAW); Shanti Sarup s.n. (KUH).
16.	<i>I. stewartii</i>	R.R. Stewart s.n. (RAW); R.R. Stewart s.n. (K).
17.	<i>Iphiona aucheri</i>	Abrar Hussain & Abedin 6050 (KUH); Tahir Ali 1478 (KUH); Tahir Ali 737 (KUH); S.I. Ali, S.A. Farooqui & S. Abedin 147 (B).
18.	<i>I. grantioides</i>	A. Ghafoor & Steve M. Goodman 4916 (KUH); S. Omer & Rizwan Y. Hashmi 2003 (KUH); S. Abedin & M. Qaiser 9816 (KUH); A. Ghafoor & S. Omer 1825 (KUH); Gulzar Khan s.n. (KUH); S.M.A. Kazmi 6408 (M).
19.	<i>Pentanema divaricatum</i>	A. Ghafoor & M. Qaiser 292 (KUH); A. Ghafoor & M. Qaiser 298 (KUH); S. Abedin & Abrar Hussain 6232 (KUH); S. Abedin 1849 (KUH); S.M.H. Jafri 2854 (KUH); S.I. Ali, S.A. Farooqui & S. Abedin 1634* (KUH); W.A. Dick-Peddie 43 (RAW); W.A. Dick-Peddie 60 (RAW).
20.	<i>P. glanduligerum</i>	Stainton 2944 (RAW); Stainton 2591 (E).
21.	<i>P. indicum</i>	Farrukh Hussain s.n. (RAW); R.R. Stewart 28570 (RAW); A. Rashid 26985 (RAW).
22.	<i>P. vestium</i>	Y. Nasir 37 (KUH); S. Abedin 2659 (KUH); M. Liang s.n. (KUH); S. Abedin 2410 (KUH); S. Abedin & Abrar Hussain 6152 (KUH); Y. Nasir & Rubina Akhtar 11863 (RAW); M. Qaiser & S. Abedin 5633 (RAW); Mohindar Nath 68 (RAW); S.M.A. Kazmi 3084 (M); D. Podlech 10145 (M).

Cypselae

The following characters were studied under light microscope:

(i) Shape (ii) Colour (iii) Size (iv) Hairs and (v) Number of ribs

Pappus

The following characters of Pappus were studied under light microscope:

(i) Series (ii) Form (iii) Number (iv) Colour (v) Cupule formation and (vi) Length of the longest bristle

Carpopodium

Shape and position of carpopodium were studied by SEM. For diameter of carpopodium and its foramen, carpopodium was detached and measurements were recorded in μm under compound microscope.

Observations

General characters of *Inula* (s.str.) and its allied genera

Cypselae narrowly obovate-oblong, oblong-oblancheolate oblong, elliptic-narrowly obovate, oblancheolate-elliptic and ellipsoid, 1-4 x 0.25-1.0 mm. Basic colour is brown, however variation from dark brown to yellowish brown and reddish brown is present. Surface thin or thick walled, non ribbed or 8-24 ribbed. Different types of pubescence ranging from pubescent to dense sericeous, villous, hirsute, glandular or even glabrous condition is found. Pappus monomorphic (with bristles only) or dimorphic (with both bristles and scales), vary from 1-3-seriate. Colour of pappus varies from golden yellow, cream-golden, white-dirty white and reddish brown, bristles 3-52 in number and 3-8 mm long. Carpopodium indistinct or distinct, U-V-shaped, angular, narrow circular or broad disc like, with or without any interruption, basal-subbasal in position, 118-463 μm in diameter. Foramen of carpopodium 35-275 μm in diameter (Table 1).

Key to the genera

- 1 + Pappus monomorphic (with bristles only) or dimorphic (with both scales and bristles), 2-3-seriate. Cypselae 10-12 ribbed *Iphiaona*
 - Pappus monomorphic (with bristles only), 1-2-seriate. If pappus 2-seriate then cypselae 16-24-ribbed 2
- 2 + Pappus 1-seriate, basally connate in a minute cupule *Dittrichia*
 - Pappus 1-2 seriate, basally not connate in a minute cupule 3
- 3 + Cypselae ribbed, thick-walled. Pappus 1-2 seriate, 20-52 in number *Inula* type (*Inula* and *Duhaldea*)
 - Cypselae non-ribbed, thin-walled. Pappus 1-seriate, 3-18 (-20) in number *Pentanema*

Table 1. Cypselae characters of *Inula* L. (s.str.) and its related genera.

Name of taxa	Cypselae					
	Mean weight of 50 cypselae (gms)	Shape	Surface (hairs)	No. of ribs	Colour	Size (mm)
<i>Dittrichia graveolens</i>	0.225	Oblanceolate – elliptic	Pubescent + glandular	0	Yellowish brown	2.5 x 0.5-1.0
<i>Duhaldea cappa</i>	0.022	Narrowly obovate-oblong	Dense sericeous	8-10	Yellowish brown	1.5-2.0 x 0.25-0.5
<i>D. cuspidata</i>	0.015	Narrowly obovate-oblong	Sparsely white pubescent	8-10	Reddish brown	1.5-2.0 x 0.25-0.5
<i>D. eupatorioides</i>	0.025	Narrowly obovate-oblong	Sparsely white pubescent	8-10	Yellowish brown	1.5-2.0 x 0.25-0.5
<i>D. latifolia</i>	0.210	Oblong – oblanceolate	Dense sericeous	8-10	Yellowish brown	2-3.0 x 0.5
<i>Inula acuminata</i>	0.025	Narrowly obovate-oblong	Sparsely golden-brown hirsute	8	Yellowish brown	1-1.5 x 0.5
<i>I. britannica</i>	0.03	Narrowly obovate-oblong	Sparsely golden-brown hirsute	8	Reddish brown	1-2 x 0.5
<i>I. clarkei</i>	0.125	Oblong	Dense sericeous	10-12	Yellowish brown	2-3 x 0.5-0.75
<i>I. falconeri</i>	0.032	Narrowly obovate-oblong	Sparsely golden-brown hirsute	8	Yellowish brown	1-1.5 x 0.5
<i>I. grandiflora</i>	0.011	Oblong – oblanceolate	Sparsely golden-brown hirsute	8-10	Dark brown	1.5 x 0.5
<i>I. koelzii</i>	0.325	Oblong	Glabrous	16-20	Yellowish brown	3-4 x 0.5-0.75
<i>I. obtusifolia</i>	0.11	Oblong	Sericeous – villous	10-12	Yellowish brown	2-3 x 0.5-0.75
<i>I. racemosa</i>	0.275	Oblong	Glabrous	16-24	Dark brown	3-4 x 0.5-0.75
<i>I. rhizocephala</i>	0.025	Oblong – oblanceolate	Glabrous – pubescent	10-12	Dark brown	1.5-2.0 x 0.5
<i>I. royleana</i>	0.225	Oblong	Glabrous	16-24	Yellowish brown	3-4 x 0.75-1.0
<i>I. stewartii</i>	0.195	Oblong	1/3 Portion pubescent	16-20	Yellowish brown	3-4 x 0.75-1.0
<i>Iphiona aucheri</i>	0.390	Ellipsoid	Pubescent + apically glandular	10-12	Yellowish brown	3-3.5 x 0.75-1.0
<i>I. grantioides</i>	0.285	Ellipsoid	Pubescent + apically glandular	10-12	Yellowish brown	2-3.5 x 0.75-1.0
<i>Pentanema divaricatum</i>	0.035	Elliptic-narrowly obovate	Sparsely golden-brown hirsute	0	Dark brown	1-1.5 x 0.5
<i>P. glanduligerum</i>	0.106	Oblong	Sparsely golden-brown hirsute	0	Yellowish brown	1.5-2.0 x 0.25-0.5
<i>P. indicum</i>	0.065	Narrowly obovate-oblong	Sparsely golden-brown hirsute	0	Yellowish brown	1.0-1.5 x 0.25
<i>P. vestium</i>	0.05	Elliptic-narrowly obovate	Sparsely golden-brown hirsute	0	Dark brown	1-1.5 x 0.5

Table 1 (Contd.)

Name of taxa	Pappus					
	Series		Number	Size (mm)	Colour	Cupule
	Bristles	Scales				
<i>Dittrichia graveolens</i>	1	0	22-24	4-5	Reddish-brown	+
<i>Duhaldea cappa</i>	1	0	22-24	5-6	Dirty white	-
<i>D. cuspidata</i>	1	0	22-25	4-5	Cream-golden	-
<i>D. eupatorioides</i>	1	0	22-24	4-5	Cream-golden	-
<i>D. latifolia</i>	1	0	22-28	5	White-dirty white	-
<i>Inula acuminata</i>	1	0	22-28	5	Golden yellow	-
<i>I. britannica</i>	1	0	20-24	5-6	Reddish brown-golden	-
<i>I. clarkei</i>	1	0	20-24	6-7	Golden yellow	-
<i>I. falconeri</i>	1	0	22-36	5	Golden yellow	-
<i>I. grandiflora</i>	1	0	20-24	6-7	Golden yellow	-
<i>I. koelzii</i>	2	0	30-42	5	Golden yellow	-
<i>I. obtusifolia</i>	1	0	20-22	5-6	Golden yellow	-
<i>I. racemosa</i>	1	0	30-48	7-8	Reddish-brown	-
<i>I. rhizocephala</i>	2-3	0	20-38	6-8	Reddish brown-golden	-
<i>I. royleana</i>	1	0	22-38	7-8	Golden yellow	-
<i>I. stewartii</i>	2	0	36-52	5	Golden yellow	-
<i>Iphiaea aucheri</i>	1	1	8-12	8-10	Golden yellow	-
			Scales: 7-8	Scales: 0.5		
<i>I. grantioides</i>	2-3	0	22-72	6-8	Golden yellow	-
<i>Pentanema divaricatum</i>	1	0	3-6	3-4	White-dirty white	-
<i>P. glanduligerum</i>	1	0	16-20	3-4	Dirty white	-
<i>P. indicum</i>	1	0	8-18	3	White-dirty white	-
<i>P. vestitum</i>	1	0	6-12	3-4	White-dirty white	-

Table 1 (Contd.)

Name of taxa	Carpodium			
	Shape	Position	Diameter of carpodium (μm)	Diameter of foramen of carpodium (μm)
<i>Dittrichia graveolens</i>	Narrow circular ring without any interruption	Basal	76.60	35.00
<i>Duhaldea cappa</i>	Narrow circular ring without any interruption	Basal-subbasal	222.34	124.16
<i>D. cuspidata</i>	Narrow circular ring without any interruption	Basal-subbasal	192.60	96.28
<i>D. eupatorioides</i>	Narrow circular ring without any interruption	Basal-subbasal	229.83	108.24
<i>D. latifolia</i>	Broad disc like ring without any interruption	Basal-subbasal	325.00	200.00
<i>Inula acuminata</i>	Narrow circular ring without interruption	Basal	219.21	142.12
<i>I. britannica</i>	Indistinct	Basal	118.22	83.82
<i>I. clarkei</i>	Broad discs like ring without any interruption	Basal-subbasal	311.24	85.98
<i>I. falconeri</i>	Narrow circular ring without any interruption	Basal	187.24	121.00
<i>I. grandiflora</i>	Angular without any interruption	Subbasal	154.98	66.76
<i>I. koelzii</i>	U-V-shaped or narrow circular ring with an interruption	Basal-subbasal	251.66	143.33
<i>I. obtusifolia</i>	Broad discs like ring without any interruption	Basal-subbasal	298.21	102.29
<i>I. racemosa</i>	Slightly angular-narrow circular ring without any interruption	Basal-subbasal	463.62	275.75
<i>I. rhizocephala</i>	Slightly angular-narrow circular ring without any interruption	Basal-subbasal	229.00	138.40
<i>I. royleana</i>	Slightly angular-narrow circular ring without any interruption	Basal-subbasal	414.59	253.23
<i>I. stewartii</i>	Narrow circular ring without any interruption	Basal-subbasal	236.65	125.00
<i>Iphiaona aucheri</i>	U-V-shaped or circular with an interruption	Basal-subbasal	219.15	86.50
<i>I. grantioides</i>	U-V-shaped or circular with an interruption	Basal-subbasal	267.65	139.28
<i>Pentanema divaricatum</i>	Broad disc like ring without any interruption	Basal-subbasal	191.62	58.32
<i>P. glanduligerum</i>	\pm angular without any interruption	Basal-subbasal	229.22	74.42
<i>P. indicum</i>	Narrow circular ring without any interruption	Basal-subbasal	152.83	85.20
<i>P. vestitum</i>	Broad disc like ring without any interruption	Basal-subbasal	132.39	49.33

***Inula* type:** As on the bases of cypselae features, the genus *Duhaldea* DC., could not be segregated from the genus *Inula* L. (s.str.) so both the genera are placed here within *Inula* complex.

Cypselae narrowly obovate-oblong, oblong-oblancoate and oblong, 1-4 x 0.25-1.0 mm. Basic colour is brown, however, dark brown to yellowish brown and reddish brown colour is also found. Surface thick walled, 8-24 ribbed. The indumentum varies from pubescent to dense sericeous, villous, hirsute and even glabrous condition is also found in few cases. Pappus bristles 1-2-seriate, colours of pappus are golden yellow, cream-golden, white-dirty white and reddish brown, 20-52 in number and 4-8 mm long. Carpopodium indistinct or distinct, angular, narrow circular or broad disc like, with or without any interruption, basal-subbasal in position, c.118-463 μm in diameter. Foramen of carpopodium c.83-275 μm in diameter (Table 1; Fig.1 a-h; Fig.2 a-h; Fig.3 a-h; Fig.4 a-e). *Inula* L. (s.str.) is represented by 11 species (Table 1; Fig.1 a-h; Fig.2 a-h; Fig.3 a-f).

Key to the species and species groups of *Inula* (s.str.)

- 1 + Pappus bristles 2-3-seriate. Cypselae 1.5-2.0mm long, 10-12 ribbed *I. rhizocephala*
- Pappus bristles 1 or 2-seriate. If pappus 2-seriate then cypselae 3-4 mm long, 16-24-ribbed 2
- 2 + Pappus bristles 2-seriate 3
- Pappus bristles 1-seriate 4
- 3 + Cypselae glabrous. Carpopodium u-v-shaped or circular with an interruption *I. koelzii*
- Cypselae with atleast 1/4 upper part pubescent. Carpopodium circular without any interruption *I. stewartii*
- 4 + Cypselae glabrous, 3-4 mm long, 16-24-ribbed Group I (*I. racemosa*, *I. royleana*)
- Cypselae pubescent, 1-3 mm long, 8-12-ribbed 5
- 5 + Carpopodium indistinct *I. britannica*
- Carpopodium distinct 6
- 6 + Carpopodium angular *I. grandiflora*
- Carpopodium circular 7
- 7 + Cypselae 1-1.5 mm long, 8-ribbed. Carpopodium narrow ring like, basal in position Group II (*I. acutiflora*, *I. falconeri*)
- Cypselae 2-3 mm long, 10-12-ribbed. Carpopodium broad disc like, basal-subbasal in position Group III (*I. obtusifolia*, *I. clarkei*)

The genus *Duhaldea* DC., is another representative of *Inula* type. It comprises of 4 species (Table 1; Fig.3 g-h; Fig.4a-e).

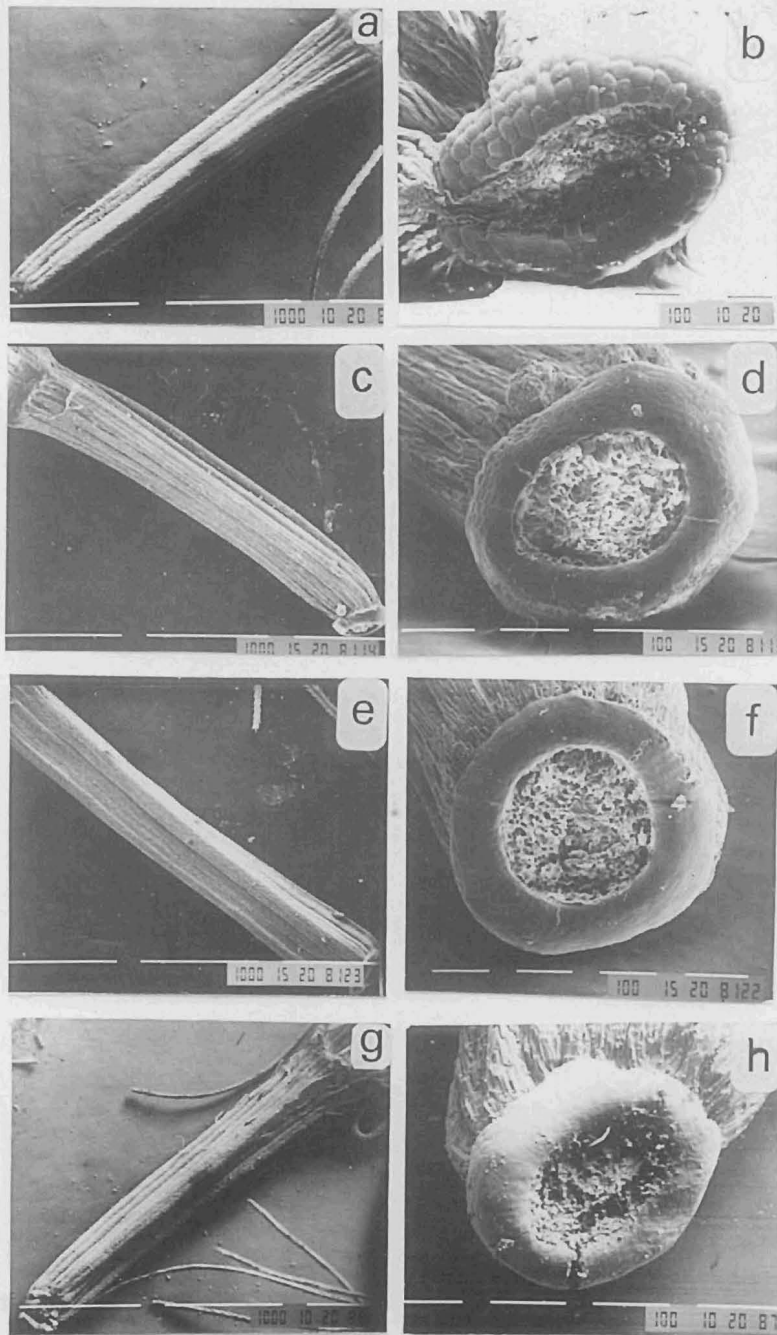


Fig. 1. Scanning Electron micrographs. *Inula koelzii*: a, cypselum; b, carpopodium. *I. royleana*: c, cypselum; d, carpopodium. *I. racemosa*: e, cypselum; f, carpopodium. *I. stewartii*: g, cypselum; h, carpopodium (Scale bar: a,c,e,g=1000 μ m; b,d,f,h=100 μ m).

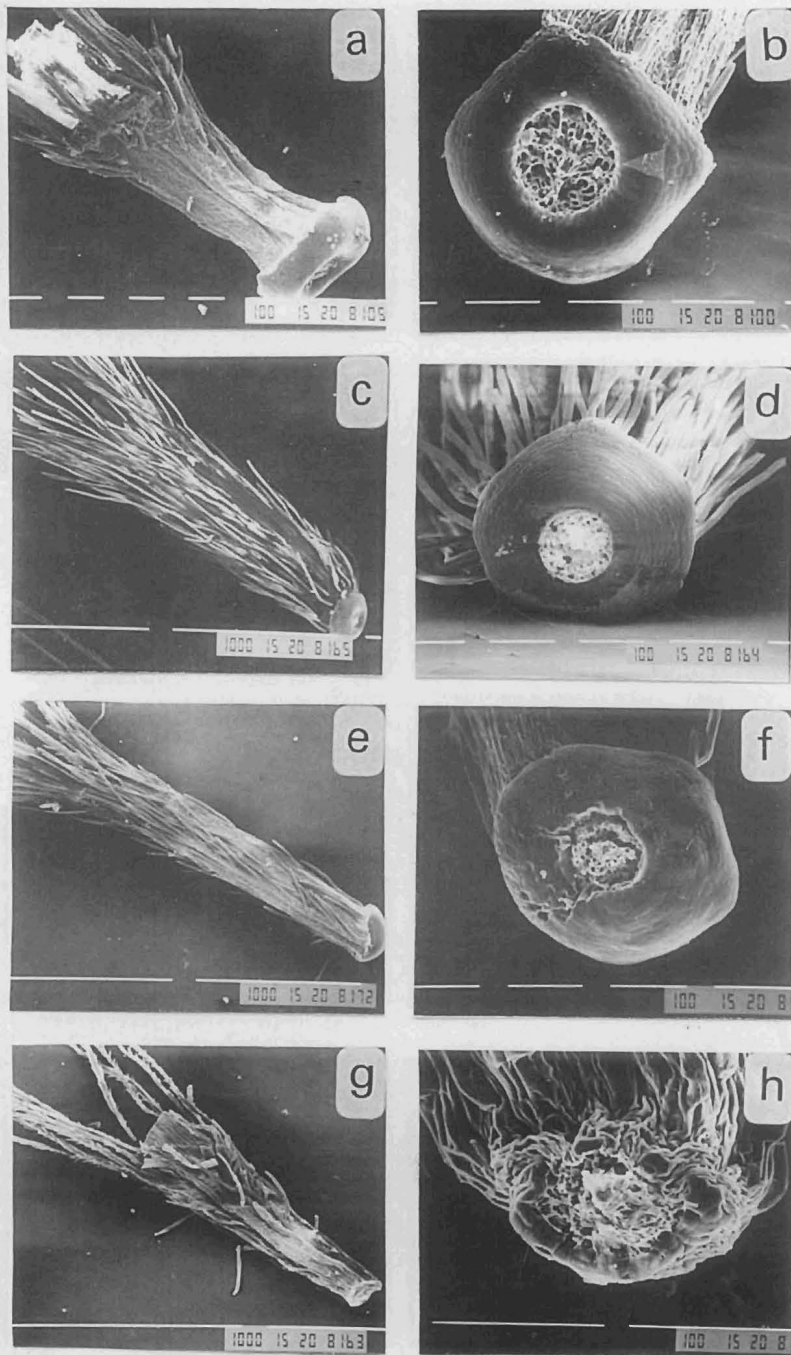


Fig. 2. Scanning Electron micrographs. *Inula grandiflora*: a, cypselas; b, carpopodium. *I. clarkei*: c, cypselas; d, carpopodium. *I. obtusifolia*: e, cypselas; f, carpopodium. *I. britannica*: g, cypselas; h, carpopodium (Scale bar: a, b, d, f, h=100 μ m; c, e, g=1000 μ m).

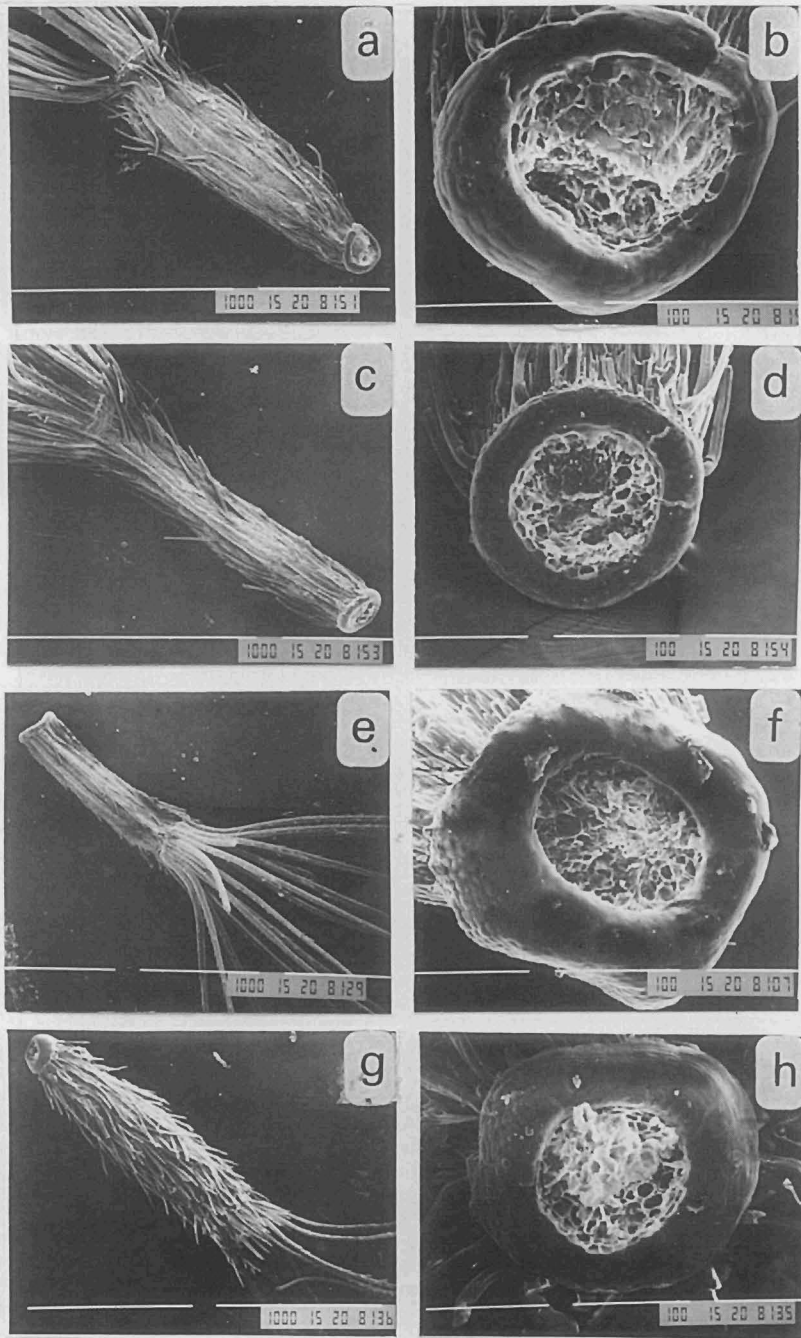


Fig. 3. Scanning Electron micrographs. *Inula acuminata*: a, cypselas; b, carpopodium. *I. falconeri*: c, cypselas; d, carpopodium. *I. rhizocephala*: e, cypselas; f, carpopodium. *Duhaldea cappa*: g, cypselas; h, carpopodium. (Scale bar: a,c,e,g=1000 μ m; b,d,f,h=100 μ m).

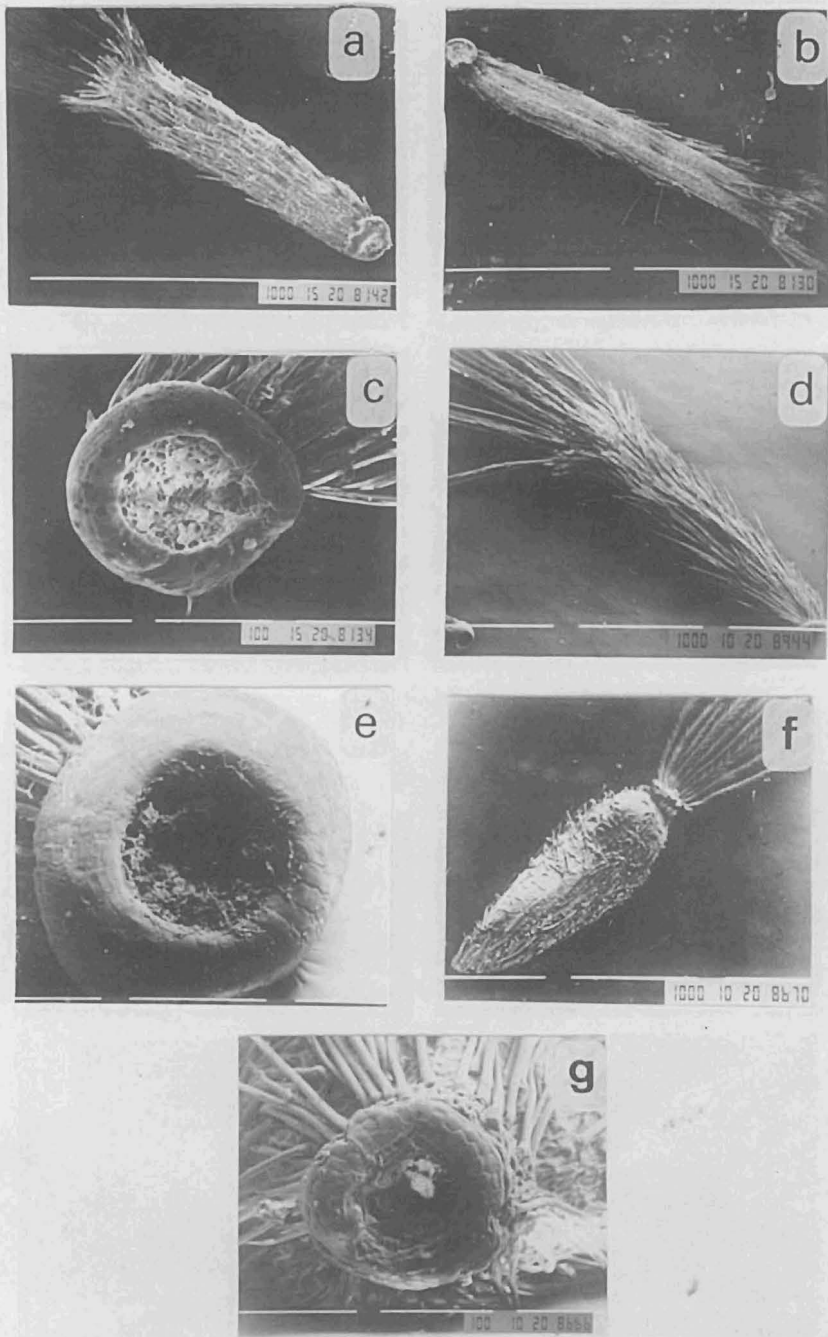


Fig. 4. Scanning Electron micrographs. *Duhaldea eupatorioides*: a, cypselum. *D. cuspidata*: b, cypselum; c, carpodium. *D. latifolia*: d, cypselum; e, carpodium. *Dittrichia graveolens*: f, cypselum; g, carpodium (Scale bar: a,b,d,f=1000 μ m; c,e,g=100 μ m).

Key to the species of *Duhaldea*

- 1 + Cypselae densely sericeous. Pappus white-dirty white 2
 - Cypselae sparsely pubescent. Pappus cream-golden 3
- 2 + Carpopodium broad disc like, c.325 μm in diameter. Foramen of carpopodium c.200 μm in diameter *D. latifolia*
 - Carpopodium narrow ring like, c.222 μm in diameter. Foramen of carpopodium c.124 μm in diameter *D. cappa*
- 3 + Cypselae reddish-brown. Carpopodium c.192 μm in diameter. Foramen of carpopodium c.96 μm in diameter *D. cuspidata*
 - Cypselae yellowish-brown. Carpopodium c.230 μm in diameter. Foramen of carpopodium c.110 μm in diameter *D. eupatorioides*

***Pentanema* Cass.:** It comprises of 4 species.

Cypselae oblong, narrowly obovate-oblong and elliptic-narrowly obovate, 1-2.0 x 0.25-0.5 mm. Colour varies from yellowish brown to dark brown, ribs absent thin-walled, hairs golden-brown, sparsely hirsute. Pappus bristles 1-seriate, similar throughout the whole length or widened towards the apex, 3-18 (-20) in number, 3-4 mm long, white-dirty white. Carpopodium narrow or broad disc like circle or slightly angular without any interruption, basal-subbasal in position, c.132-229 μm in diameter. Foramen of carpopodium c.49-85 μm in diameter (Table 1; Fig. 5 a-h).

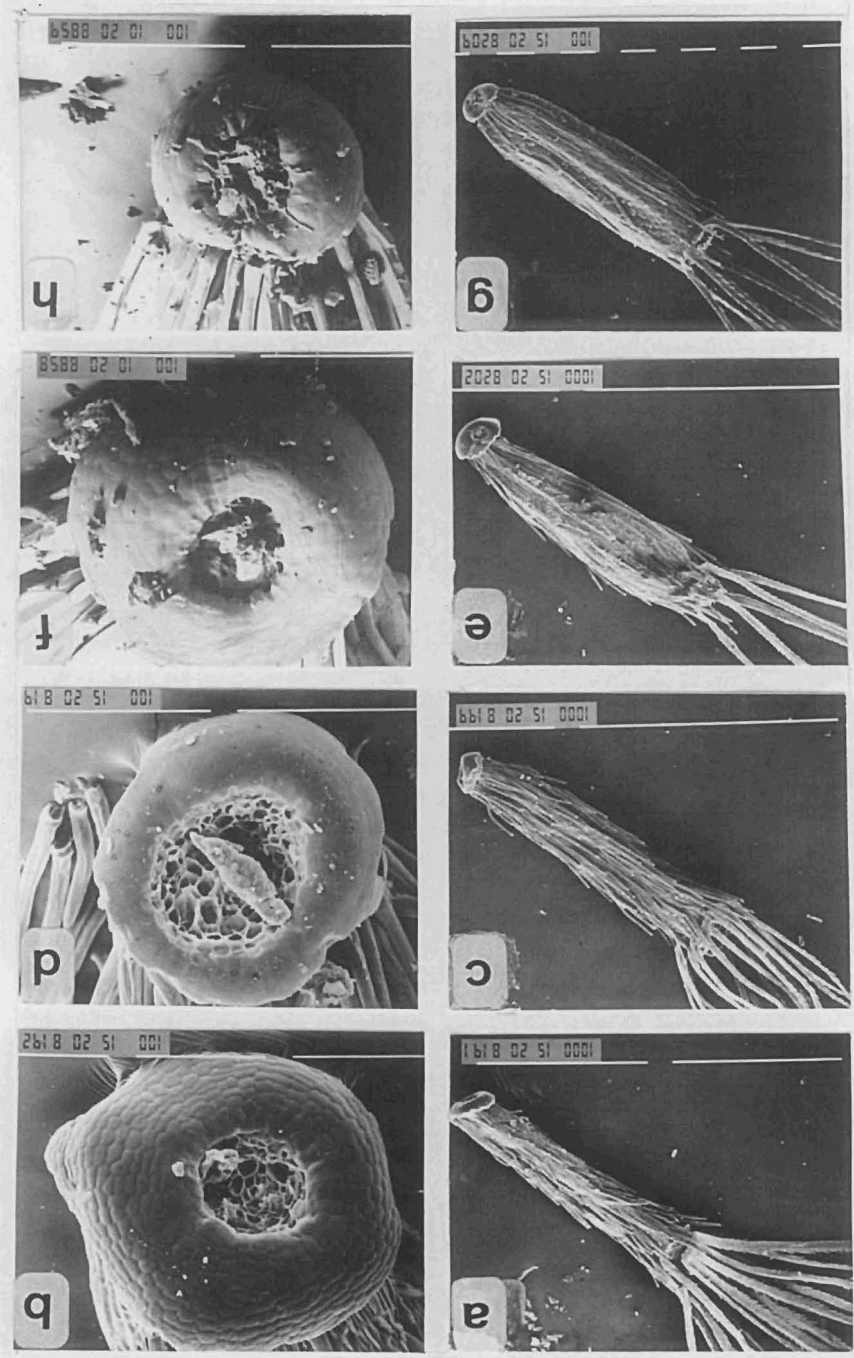
Key to the species of *Pentanema*

- 1 + Carpopodium \pm angular. Bristles widened towards the apex *P. glanduligerum*
 - Carpopodium circular. Bristles not widened towards the apex 2
- 2 + Cypselae yellowish brown. Foramen of carpopodium c.85 μm in diameter *P. indicum*
 - Cypselae dark brown. Foramen of carpopodium upto 59 μm in diameter 3
- 3 + Bristles 3-6 in number. Carpopodium c.191 μm in diameter. Foramen of carpopodium c.58 μm in diameter *P. divaricatum*
 - Bristles 6-12 in number. Carpopodium c.132 μm in diameter. Foramen of carpopodium c.49 μm in diameter *P. vestitum*

***Dittrichia* Greuter:** It is represented by the single species.

Cypselae oblanceolate-elliptic, shortly attenuate towards the apex, 2.5 x 0.5-1.0 mm, yellowish brown, ribs absent, thin-walled, pubescent and glandular. Pappus bristles 1-seriate, 4-5 mm long, 22-24 in number, basally connate in a minute cupule, reddish brown. Carpopodium narrow circular without any interruption, basal in position, c.76 μm in diameter. Foramen of carpopodium c.35 μm in diameter (Table 1; Fig. 4 f-g).

Fig. 5. Scanning Electron Micrographs. *Pentanea glanduligerum*: a, cypselia; b, carpopodium. *P. indicum*: c, cypselia; d, carpopodium. *P. divaricatum*: e, cypselia; f, carpopodium. *P. vestitum*: g, cypselia; h, carpopodium (Scale bar: a,c,e=100µm; b,d,f,g,h=10µm).



***Iphiona* Cass.:** It is represented by 2 species.

Cypselae ellipsoid, 2-3.5 x 0.75-1.0 mm, yellowish brown, 10-12-ribbed, thick-walled, pubescent and apically glandular. Pappus 2-3-seriate, monomorphic (with bristles only) as well as dimorphic (with both scales and bristles); in case of dimorphic outer scales 0.5 mm long, 7-8 in number, inner bristles, 8-10 mm long, 8-12 in number; in monomorphic condition bristles 6-8 mm long, 22-72 in number, golden yellow (in both conditions). Carpopodium u-v-shaped or circular with an interruption, basal-subbasal in position, c.219-267 μ m in diameter. Foramen of carpopodium c.86-139 μ m (Table 1; Fig. 6 a-d).

Key to the species of *Iphiona*

- 1 + Pappus monomorphic (with bristles only), 22-72 in number *I. grantioides*
- Pappus dimorphic (with both bristles and scales), bristles 8-12 in number, scales 7-8 in number *I. aucheri*

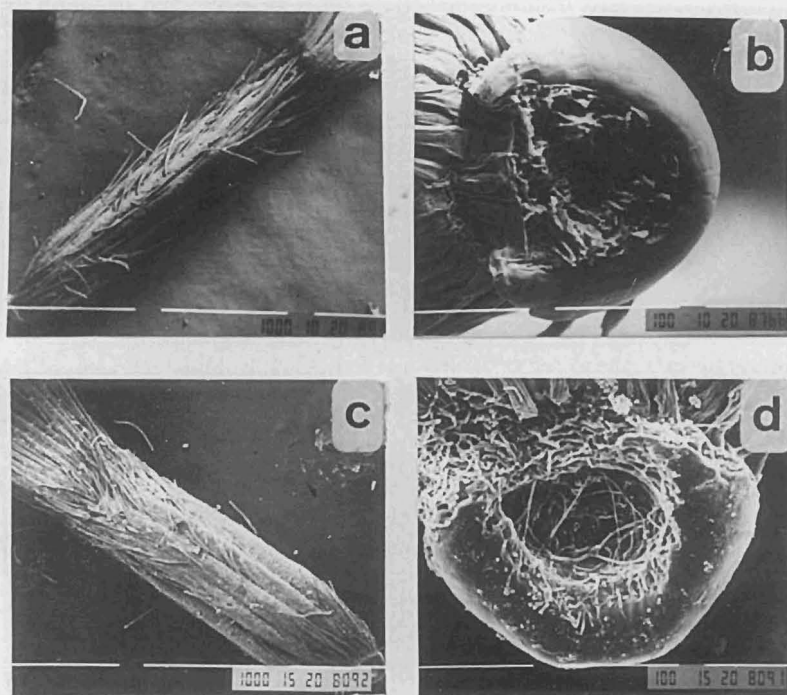


Fig. 6. Scanning Electron micrographs. *Iphiona aucheri*: a, cypselae; b, carpopodium. *I. grantioides*: c, cypselae; d, carpopodium (Scale bar: a,c,=1000 μ m; b,d=100 μ m).

Results and Discussion

On the basis of cypsela morphology three genera are clearly segregated viz., *Pentanema* Cass., *Dittrichia* Greuter and *Iphiona* Cass., whereas, the genera *Inula* L., (s.str.) and *Duhaldea* DC., could not be clearly separated from each other due to similar characters of cypselae. However, at the specific level in the genus *Inula* (s.str.) 5 species i.e., *I. rhizocephala* Schrenk, *I. koelzii* Dawar & Qaiser, *I. britannica* L., *I. grandiflora* Willd., and *I. stewartii* Abid & Qaiser, are easily distinguishable. The remaining 6 species are coupled into 3 different groups viz., *I. racemosa* Hook.f. and *I. royleana* DC. (Group I), *I. acuminata* Royle ex DC., and *I. falconeri* Hook.f. (Group II) and *I. obtusifolia* Kern. and *I. clarkei* (Hook.f.) Stewart (Group III). Among the three groups the cypselae are diagnostic but their differences are subtle i.e., in group I, the pappus is reddish-brown and cypselae are dark brown in *I. racemosa*, while in *I. royleana* pappus are golden yellow and cypselae are yellowish-brown in colour. Similarly in the group II and group III the differences are only in the diameter of carpodium and its foramen. However, the species within a group could be identified but the characters are not strong enough to construct a clear key. However, in the genera *Duhaldea* DC., and *Pentanema* Cass., their species can be delimited on the basis of nature of pubescence, cypselae colour, shape and diameter of carpodium and its foramen. Similarly both the species of *Iphiona* Cass., are clearly distinguished on the basis of pappus morphology.

Therefore, the micromorphological characters of cypselae have been proved very rewarding in this intricate group. Most of the characters of cypselae are quite stable and characteristic. As evident from the different generic and specific keys that almost all the taxa can be delimited on the basis of cypselae characters. However, the genus *Duhaldea* DC., and *Inula* L., (s.str.) have quite similar type of cypselae and both are placed in one cypselae type. The resemblance of cypselae of *Inula* (s.str.) and *Duhaldea* clearly indicate their close relationship as compared to the other genera viz., *Pentanema*, *Dittrichia* and *Iphiona* from Pakistan and Kashmir.

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