

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

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Abstract

The pollen morphology of 22 species of *Inula* L. (s.str.) and its allied genera has been examined from Pakistan and Kashmir by light and scanning electron microscopy. Pollen grains are usually radially symmetrical, isopolar, prolate-spheroidal rarely oblate-spheroidal, tricolporate occasionally tetracolporate, zonoaperturate. Sexine slightly thicker than nexine or as thick as nexine. Tectum echinate, spines with acute-acuminate or rounded apices. On the basis of pollen size and tectum pattern in between spines. 3 major pollen types viz., Pollen type I: *Duhaldea cappa*, Pollen type II: *Inula acuminata*, Pollen type III: *Pentanema divaricatum* are recognized.

Introduction

The genus *Inula* L. (s.l.) is a heterogenous taxon and number of unrelated species were accommodated under the wide canopy of *Inula*. However, latter workers recognized number of its segregates as an independent genera and transferred several species from *Inula* to these genera to make the *Inula* L., more homogenous. Beside the genus *Inula* L. (s.str.) with 11 species, 4 more genera viz., *Dittrichia* Greuter (1 species), *Duhaldea* DC., (4 species), *Iphiona* Cass., (2 species) and *Pentanema* Cass., (4 species) are recognized from Pakistan and Kashmir (Dawar, 1998). Compositae is a eurypalynous family (Erdtman, 1952). An excellent historical account of pollen morphology of the family Compositae was published by Wodehouse (1926-1935) in a series of light microscopic studies but his investigations did little to elucidate the internal features of the pollen wall. From time to time number of papers dealing with external pollen morphological studies of certain representatives of Compositae have also been published by various workers viz., Singh & Joshi (1969), Dakshini & Prithipalsingh (1970), Keeley & Jone (1977), Robbins *et al.*, (1979), Clark *et al.*, (1980), Vincent & Norris (1989), Cilliers (1991), Sidhu *et al.*, (1994), Hodalova & Martonfi (1995), Nakajima & Monteiro (1995), Kaya *et al.*, (1996). Stix (1960) was the pioneer, who employed the electron microscopy for pollen morphological studies of the family Compositae and described the internal morphology of the grains and this was followed by Skvarla & Larson (1965a), Payne & Skvarla (1970), Tomb *et al.*, (1974), Bolic (1978), Blackmore (1981), Robinson & Marticorena (1986), Robinson (1994). In spite of the fact that considerable attention has been given to the palynological studies of the family Compositae but there are no specific reports on the genus *Inula* L. (s.l.) or even of the tribe *Inuleae* except some of the investigations of Skvarla & Turner (1966), in which they examined the different tribes including *Inuleae* and a species of *Inula* L. (i.e. *I. britannica* L.). Leins (1971) also studied the pollen of some members of subtribe *Imulinae*. Sharma (1994) in his palynotaxonomical approach of alpine plants of Western Himalaya reported the pollen characters of a single species of *Inula* L.

Apart from the above investigations on pollen grains of *Inula* L. (s.l.) there are exclusively no reports on the palynological studies of the genus from the area under consideration. The purpose of the present paper is two fold. Firstly there are no reports on the pollen morphology of these taxa from our area, secondly is to provide micromorphological characters in order to strengthen the recognition of 22 taxa belonging to *Inula* L. (s.str.) and its allied genera from Pakistan and Kashmir.

Materials and Methods

Polleniferous materials were obtained from various herbaria (viz., B, BM, E, K, KUII, LIV, M, RAW). A list of specimens investigated is given in Appendix-I. For scanning microscopic studies pollen were directly dusted from anthers on the aluminum stub and coated with gold/pallidum in sputtering chamber. Scanning electron microscopic (SEM) examination was carried out on a Hitachi scanning microscope (HSM-S570).

For light microscopy (LM) pollen were prepared by the standard acetolysis method following Erdtman (1952). The acetolyzed material was centrifuged for 5-10 minutes in 50% glycerine, then glycerine was decanted. The pollen material was mounted on slide in glycerine jelly. The slides were examined by using Nikon Type-102 microscope, under (E:40, 0.65) objective. Following measurements were taken (1) Polar length (2) Equatorial breadth (3) Colpus length (4) Mesocolpium (5) Apocolpium (6) Spine length (7) Interspinal distance (8) Exine thickness. P/E ratio (polar length/equatorial diameter) and polar area index (ratio of mesocolpium/equatorial diameter) were calculated and each character was statistically analyzed (Table 1).

The terminology used here is that of Erdtman (1952,1969), Faegri & Iverson (1964) and Walker & Doyle (1975).

General pollen characters of the species examined

Pollen grains are usually radially symmetrical, isopolar, prolate-spheroidal rarely oblate-spheroidal, tricolporate rarely tetracolporate, zonoaperturate. Sexine slightly thicker than nexine or as thick as nexine. Tectum echinate, spines with acute-acuminate or rounded along with few acute apices, and punctate or subsilicate bases, tectum punctate-subsilicate or punctate-fine scabrate or subsilicate-scabrate or punctate-granulated or to some extent rugulate in between spines.

On the bases of tectum pattern between spines and polar length, 22 taxa (belonging to 5 different genera) are grouped under 3 major pollen types viz., (i) *Duhaldea cappa*-type (ii) *Inula acuminata*-type and (iii) *Pentanema divaricatum*-type.

Key to the pollen types

- 1 + Tectum densely punctate or punctate-fine scabrate in between spines
 Pollen type-I
 - Tectum sparsely punctate-subsilicate in between spines 2
- 2 + Polar length 17.5-28 μ m Pollen type-III
 - Polar length 30-50 μ m Pollen type-II

Appendix-I. List of voucher specimens

No.	Taxon	Collector, number and herbarium.
1.	<i>Dittrichia graveolens</i>	J.J. Stewart 245 (E, K).
2.	<i>Duhaiidea cappa</i>	A. Ghafoor & Tahir Ali 4005 (KUH); M. Qaiser & A. Ghafoor 4948 (KUH); A. Rashid Khan s.n. (RAW).
3.	<i>Duhaiidea cuspidata</i>	Tahir Ali, M. Qaiser & M. Ajmal 367 (KUH); E. Nasir & Nazir 10519 (RAW).
4.	<i>Duhaiidea eupatorioides</i>	R.R. Stewart & I.D. Stewart 4145 (RAW); J.K. Drummond 14619 (K).
5.	<i>Duhaiidea taifolia</i>	Koyic 113.2 (LIV).
6.	<i>inula acuminata</i>	Stainton 3077 (RAW); S.A. Bowes Lyon 22 (E).
7.	<i>inula britannica</i>	R.R. Stewart 19253 (RAW); R.R. Stewart 54 (RAW).
8.	<i>inula clarkei</i>	E. Nasir & G.L. Webster 5804 (RAW); Hans Hartmann s.n. (RAW).
9.	<i>inula falconeri</i>	R.R. Stewart 20484 (KUH); C.B. Clarke 30027 P (K).
10.	<i>inula grandiflora</i>	S. Omer & M. Qaiser 2734 (KUH); Tahir Ali, M. Qaiser & M. Ajmal 503 (KUH); R.R. Stewart 6687 (RAW); Jan Mohammed s.n. (RAW); J.F. Duthie 13969 (E).
11.	<i>inula koetzi</i>	W. Koelz 2818 (RAW); W. Koelz 2900a (KUH).
12.	<i>inula obtusifolia</i>	M. Qaiser, S. Omer & S.Z. Hussain 8414 (KUH); R.R. Stewart 18803 (RAW).
13.	<i>inula racemosa</i>	R.R. Stewart 14052 (KUH); J.F. Duthie 2565/a (RAW); Bowes Lyon 160 (BM).
14.	<i>inula rhizocephala</i>	M. Qaiser, S. Omer & S.Z. Hussain 8420 (KUH); A. Rashid 1088 (KUH); R.R. Stewart 18859 (RAW); Lloyd & Megaw II (BM).
15.	<i>inula royleana</i>	M. Qaiser & A. Ghafoor 5904 (KUH); J.F. Duthie 25657 (RAW); S.M.A. Kazmi 2212 (M); F. Ludlow & G. Sherrif 1432 (E).
16.	<i>inula stewartii</i>	R.R. Stewart s.n. (RAW); R.R. Stewart s.n. (K).
17.	<i>Iphiona ancheri</i>	Tahir Ali 737 (KUH); S.I. Ali, S.A. Farooqui & S. Abedin 1417 (B).
18.	<i>Iphiona grantioides</i>	S. Abedin & M. Qaiser 9816 (KUH); A. Ghafoor & S. Omer 1825 (KUH); S. Khatoun & M. Ahmed 19 (KUH); Jennifer Lamond & Tahir Ali 8220 (KUH).
19.	<i>Pentanema divaricatum</i>	A. Ghafoor & M. Qaiser 298 (KUH); W.A. Dick Peddie 43 (RAW); S. Abedin 1849 (KUH); S. Abedin & Abrar Hussain 6232 (KUH).
20.	<i>Pentanema glanduligerum</i>	Stainton 2944 (RAW); Stainton 2519 (E).
21.	<i>Pentanema indicum</i>	Farrukh Hussain s.n. (RAW); R.R. Stewart 28570 (RAW).
22.	<i>Pentanema vestitum</i>	S. Abedin 2659 (KUH); S. Abedin 2410 (KUH); M. Qaiser & S. Abedin 5633 (RAW).

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

Name of taxa	Length (μm)	Diameter (μm)	P/E	Colpus length (μm)	Mesocolpium (μm)
<i>Dittrichia graveolens</i>	26(27.5)28 ± 0.317	25(26.5)28 + 0.401	1.03	15(16.5)17.5 + 0.245	12.5(17.0)20 ± 0.584
<i>Duhhaldea cappa</i>	30(33.05)37.5 ± 0.277	27.5(30.27)35 ± 0.309	1.09	15(19.42)22.5 ± 0.323	15(19.15)22.5 ± 0.288
<i>D. cuspidata</i>	30(35.87)42.5 ± 0.669	27.5(33.75)37.5 ± 0.564	1.06	17.5(21.25)25 ± 0.501	17.5(19.57)22.5 ± 0.402
<i>D. eupatorioides</i>	30(32.5)35 ± 0.366	30(30.4)32.5 ± 0.167	1.06	20(21.65)22.5 ± 0.211	17.5(19.57)20 ± 0.167
<i>D. latifolia</i>	26(27.08)28 ± 0.768	25(26.66)30 ± 0.8334	1.01	17.5(18.33)20 ± 0.832	12.5(16.25)17.5 ± 1.051
<i>Inula acuminata</i>	30(31.25)33 + 0.282	29.5(31.0)32.5 ± 0.213	1.06	12.5(15.25)17.5 ± 0.233	15(18.75)20 ± 0.298
<i>I. britannica</i>	30(34.42)37.5 ± 0.323	30(31.65)35 ± 0.333	1.08	17.5(20.0)22.5 ± 0.235	17.5(20.27)22.5 ± 0.200
<i>I. clarkei</i>	32.5(35.75)37.5 ± 0.263	30(32.5)35 ± 0.314	1.10	20(21.55)25 ± 0.263	20(22.8)25.0 ± 0.227
<i>I. falconeri</i>	30(32.5)35 + 0.236	27.5(30.25)32.5 ± 0.308	1.07	17.5(19.57)22.5 ± 0.308	15(19.25)20 ± 0.309
<i>I. grandiflora</i>	30(34.05)37.5 ± 0.597	30(32.8)37.5 ± 0.516	1.03	17.5(20.3)22.5 ± 0.227	17.5(20.3)22.5 ± 0.295
<i>I. koelzii</i>	40(46)50 + 0.814	40(43)50 ± 0.972	1.06	22.5(24)25 ± 0.321	25(27)30 ± 0.375
<i>I. obtusifolia</i>	30.5(33.0)37.5 ± 1.183	30(34.5)37.5 + 0.388	0.95	20(22.5)25 ± 0.210	22(24.25)25.0 ± 0.351
<i>I. racemosa</i>	35(38.42)42.5 ± 0.324	32.5(35)37.5 ± 0.268	1.0	22(21.85)25 ± 0.250	20(22.25)23.5 ± 0.314
<i>I. rhocephala</i>	35(37)40 ± 0.375	35(37)40 + 0.375	1.0	20(21.25)22.5 ± 0.317	20(21.87)25 + 0.478
<i>I. royleana</i>	37.5(41)45 ± 0.339	33(36.5)40 ± 0.213	1.12	22.5(25.5)27.5 ± 0.200	22(22.5)23.0 ± 0.249
<i>I. stewartii</i>	35(37)37.5 + 0.200	32.5(36)37.5 ± 0.401	1.02	20(22.5)25 ± 1.010	20(23.12)25.0 ± 0.478
<i>Iphiaona aucheri</i>	30(34.5)40 ± 0.399	30(32.0)35 ± 0.295	1.07	17.5(21.55)25 ± 0.421	17.5(18.75)20 ± 0.189
<i>I. grantioides</i>	37.5(38)40 ± 0.200	35(36.5)37.5 ± 0.231	1.04	20(22)22.5 ± 0.2005	15(19.5)25 ± 0.802
<i>Pentanema divaricatum</i>	17.5(23.17)24 + 0.304	17.5(21.8)25 ± 0.237	1.06	12.5(14.07)17.5 ± 0.243	12.5(4.07)15 ± 0.152
<i>P. glanduligerum</i>	20(23.05)24 ± 0.376	20(24.1)32.5 ± 0.429	0.95	12.5(16.05)20 ± 0.260	15(16.25)22.5 ± 0.379
<i>P. indicum</i>	17.5(19.25)20 ± 0.239	15(18.12)20 ± 0.478	1.06	7.5(9.35)10 ± 0.25	10(12.5)15 ± 0.408
<i>P. vestitum</i>	17.5(20)22.5 ± 2.50	17.5(18.75)20 ± 1.24	1.07	12.5(13.75)15 ± 0.50	12.5(13.75)15 ± 0.50

Table 1 (Cont'd)

Apocolpium (μm)	Spine length (μm)	Interspinal distance (μm)	Polar area index	Exine thickness (μm)	Tectum
7.5(10.0)12.5 ± 0.317	2.5(4.25)5.0 ± 0.200	3.75(5.0)6.25 ± 0.339	0.64	2.5(4.0)5.0 ± 0.187	Ech. spr. punc- subps
10(11.15)12.5 ± 0.175	2.5(3.6)5.0 ± 0.154	3.75(4.7)9.5 ± 0.073	0.63	3.75(4.15)5.0 ± 0.083	Ech, dns punc+ fine scab
10(12.07)12.5 ± 0.167	2.5(4.15)5.0 ± 0.167	3.75(4.57)5.0 ± 0.105	0.58	2.5(4.77)6.25 ± 0.083	Ech, dns punc
10(10.4)12.5 ± 0.167	2.5(3.75)4.5 ± 0.195	2.5(2.9)3.75 ± 0.105	064	3.75(5.0)6.25 ± 0.129	Ech, spr. punc- subps
12.5(13.12)15 ± 0.625	2.5(2.75)3.75 ± 0.250	2.5(2.75)3.75 ± 0.250	0.60	2.5(2.82)3.75 ± 0.312	Ech, dns punc
7.5(8.5)10 ± 0.163	2.5(3.0)3.75 ± 0.038	5.0(6.125)7.5 ± 0.157	0.60	3.75(4.25)5.0 ± 0.081	Ech, spr. punc- subps
10(10.82)12.5 ± 0.166	2.5(4.5)5.0 ± 0.116	4.5(5.0)6.0 ± 0.065	0.64	3.75(4.42)5.0 ± 0.087	Ech, spr. punc - subps
10(11.87)12.5 ± 0.164	3.75(4.35)5.0 ± 0.087	7.5(7.77)10 ± 0.111	0.70	2.5(3.75)5.0 ± 0.1178	Ech, spr. punc- subps.
7.5(10.0)11.25 ± 0.201	3.75(4.77)5.0 ± 0.083	5.0(6.25)7.5 ± 0.183	0.63	3.75(4.15)5.0 ± 0.105	Ech, spr. punc- subps
10(12.17)12.5 ± 0.125	3.75(4.75)5.0 ± 0.088	3.75(4.82)5.0 ± 0.062	0.61	4.5(5.0)6.0 ± 0.099	Ech, dns punc
12.5(13.75)15 ± 0.129	3.75(4.75)5.0 ± 0.100	5(6.25)8.75 ± 0.158	0.62	4.25(5.0)6.0 ± 0.188	Ech, dns punc
7.5(10.3)12.5 ± 0.295	2.5(4.37)5.0 ± 0.11	5.0(6.5)7.5 ± 0.124	0.70	3.75(4.2)5.0 ± 0.079	Ech, spr. punc- subps.
10(11.55)12.5 ± 0.183	3.75(4.15)5.0 ± 0.166	5.0(6.25)7.5 ± 0.289	0.59	5.0(5.62)6.25 ± 0.094	Ech, dns punc
12.5(13.12)15 ± 0.25	3.75(4.15)5.0 ± 0.166	5.0(6.25)7.5 ± 0.289	0.59	2.5(3.32)3.75 ± 0.166	Ech, spr. punc- subps-rug
10(11.75)12.5 ± 0.152	3.75(4.62)5.0 ± 0.076	6.25(7.37)7.5 ± 0.050	0.61	5.0(6.0)6.25 ± 0.066	Ech, dns punc
10.5(12.5)13.5 ± 0.26	3.75(4.5)5.0 ± 0.122	5.0(6.55)7.5 ± 0.239	0.64	5.0(5.31)6.25 ± 0.125	Ech, spr. punc- subps.
10(11.55)12.5 ± 0.186	2.5(3.52)5.0 ± 0.175	2.5(2.82)3.75 ± 0.107	0.58	2.5(3.2)5.0 ± 0.226	Ech, spr. punc- subps
10(12.5)15 ± 0.3170	2.5(4.25)5.0 ± 0.200	2.5(4.10)5.0 ± 0.216	0.53	2.5(4.25)5.0 ± 0.201	Ech, spr. punc- subps
5.0(6.95)7.5 ± 0.103	2.5(2.75)3.75 ± 0.05	2.5(3.65)5.0 ± 0.142	0.64	2.5(3.4)5.0 ± 0.118	Ech, subps+ scab
6.25(6.65)8.75 ± 0.154	2.5(3.15)3.75 ± 0.055	2.5(4.25)5.0 ± 0.154	0.67	2.5(4.25)5.0 ± 0.114	Ech, spr. punc- subps - rug
5.0(6.85)7.5 ± 0.25	2.5(2.75)3.75 ± 0.048	2.5(3.0)3.75 ± 0.212	0.68	1.5(2.81)3.75 ± 0.125	Ech, punc+gran
6.25(7.15)7.5 ± 0.125	2.5(3.125)3.75 ± 0.510	2.5(3.0)3.75 ± 0.352	0.73	2.5(2.9)3.75 ± 0.105	Ech. spr. punc- subps

Key: Ech= echinate. dns= densely, spr.= sparsely, punc=punctate, subps= subsilate, rug= rugulate, gran= granulate

Description of pollen type.**Pollen type-I: *Duhaldea cappa*** (Figs. 1 C-E; 2 C,D,G,H,I; 4 A,B,I,J,G)**Pollen class:** Tricolporate, zonoaperturate**P/E ratio:** Semierect**Shape:** Prolate-Spheroidal.**Aperture:** Ectoaperture, colpi medium,narrow with acute ends. Endoaperture small \pm circular.**Exine:** Sexine slightly thicker than nexine or as thick as nexine.**Ornamentation:** Tectum echinate, spines apices acute-acuminate with punctate spine base. Tectum densely punctate in between spines.**Measurements:** Polar length (P) (26.0-) 38.05 (-50.0) μm , Equatorial diameter (E) (25.0-) 36.75 (-50.0) μm . Colpi (15.0-) 20.35 (-27.5) μm long, Mesocolpium (15.0-)21.75 (-30.0), Apocolpium (10.0-)11.85 (-15.0), P/E ratio: 1.01-1.12, Spine (2.5-) 3.75 (-5.0) μm long, Interspal distance (2.5-) 5.625 (-8.75) μm , Exine thickness (2.5-) 4.188 (-6.25) μm , Polar area index: 0.58-0.62**Species included:** *Duhalaea cappa* (Ham.ex D.Don) A. Anderb., *D. cuspidata* (Wall. ex DC.) A. Anderb., *D. latifolia* (DC.) Dawar & Qaiser, *I. grandiflora* Willd., *Inula koetzii* Dawar & Qaiser, DC., *I. racemosa* Hook.f. and *I. royleana* DC.**Key to the species and species group of *Duhaldea cappa*-type**

- 1 + Polar length 26-28 μm *D. latifolia*
 - Polar length 30-50 μm 2
- 2 + Polar area index 0.58 *D. cuspidata*
 - Polar area index 0.61-0.64 3
- 3 + Mesocolpium 25-30 μm *Inula koetzii*
 - Mesocolpium 15-23.5 μm 4
- 4 + Tectum densely punctate with fine scabrae in between spines *D. cappa*
 - Tectum densely punctate in between spines
 *I. royleana* group (*I. grandiflora*, *I. racemosa*, *I. royleana*)

Pollen type II: *Inula acuminata* (Figs. 2 A,B,E,F; 3 A-F; 4 C,D,K-P)**Pollen class:** Tri-tetra colporate, zonoaperturate.**P/E ratio:** Semierect rarely subtransverse**Shape:** Prolate-Spheroidal rarely oblate-spheroidal.**Aperture:** Ectoaperture, colpi medium,narrow with acute ends. Endoaperture small \pm circular.**Exine:** Sexine slightly thicker than nexine or as thick as nexine.**Ornamentation:**Tectum echinate, spines apices acute-acuminate occassionally rounded with punctate spine base, long, tectum sparsely punctate-subpsilate in between spines.**Measurements:** Polar length (P) (30.0-) 35.75 (-40.0) μm , Equatorial diameter (E) (27.5-) 33.75 (-40.0) μm , Colpi (12.5-)18.75 (-25.0) μm long, Mesocolpium (15.0-) 22.5

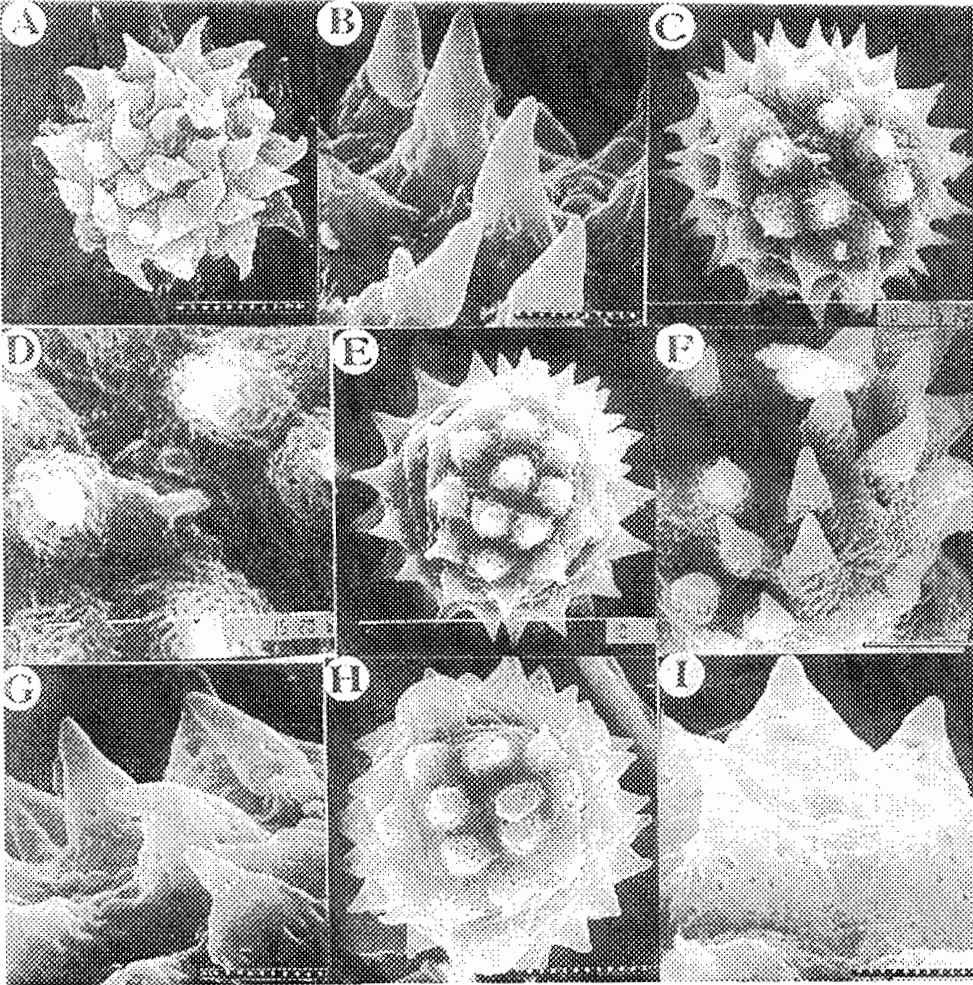


Fig. 1. Scanning electron micrographs (SEM) of the pollen grains. *Dittrichia graveolens*: A, equatorial view; B, exine pattern. *Duhaldea cappa*: C, equatorial view; D, exine pattern. *D. cuspidata*: E, equatorial view; F, exine pattern. *D. latifolia*: G, exine pattern. *Inula koelzii*: H, equatorial view; I, exine pattern (Scale bar: A, C, E, H = 10 μ m; D = 1.0 μ m; B, G, I = 3.0 μ m; F = 5.0 μ m).

(-25.0), Apocolpium (7.5-) 11.25 (-15.0), P/E ratio: 0.95-1.08, Spine (2.5-) 3.75 (-5.0) μ m long. Interspinal distance (2.5-) 5.0 (- 7.5) μ m, Exine thickness (2.5-) 4.38 (-6.25) μ m, Polar area index : 0.53-0.70.

Species included: *Duhaldea eupatorioides* (Wall.ex DC.) A. Anderb., *Inula acuminata* Royle ex DC., *I. britannica* L., *I. clarkei* (Hook.f.) Stewart, *I. falconeri* Hook.f., *I. obtusifolia* Kern., *I. rhizocephala* Schrenk, *I. stewartii* Dawar & Qaiser, *Iphiona aucheri* (Boiss.) A. Anderb. and *Iphiona grantioides* (Boiss.) A. Anderb.

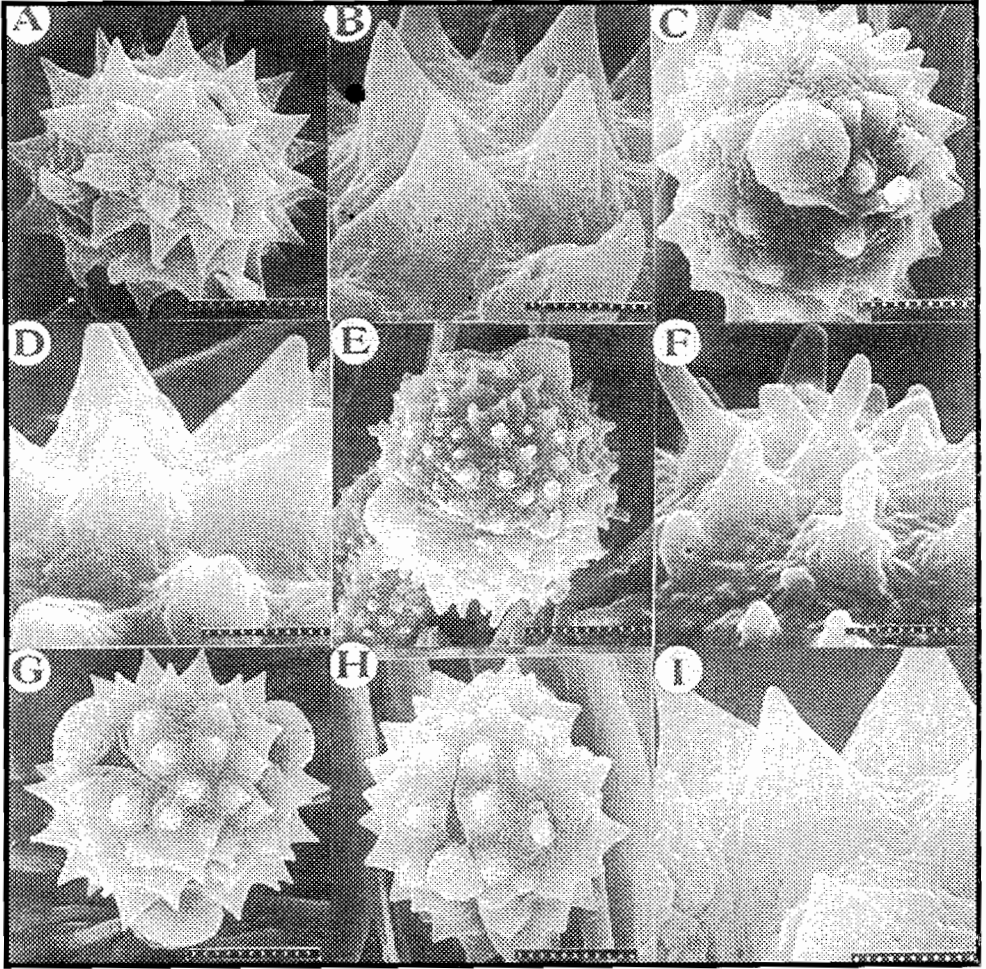


Fig. 2. Scanning electron micrographs (SEM) of the pollen grains. *Inula britannica*: A, equatorial view; B, exine pattern. *I. racemosa*: C, equatorial view; D, exine pattern. *I. rhizocephala*: E, polar view; F, exine pattern. *I. royleana*: G, polar view; H, equatorial view; I, exine pattern (Scale bar: A, C, E = 10 μm ; B, D, F, I = 3.0 μm ; G, H = 13.0 μm)

Pollen type-III: *Pentanema divaricatum* (Figs.1A, B; 3 G-I ; 4H-J).

Pollen class: Tricolporate, zonoaperturate.

P/E ratio: Semicrect-erect rarely subtransverse.

Shape: Prolate-Spheroidal rarely oblate-spheroidal.

Aperture: Ectoaperture, colpi medium, narrow with acute ends. Endoaperture small \pm circular.

Exine: Sexine slightly thicker than nexine.

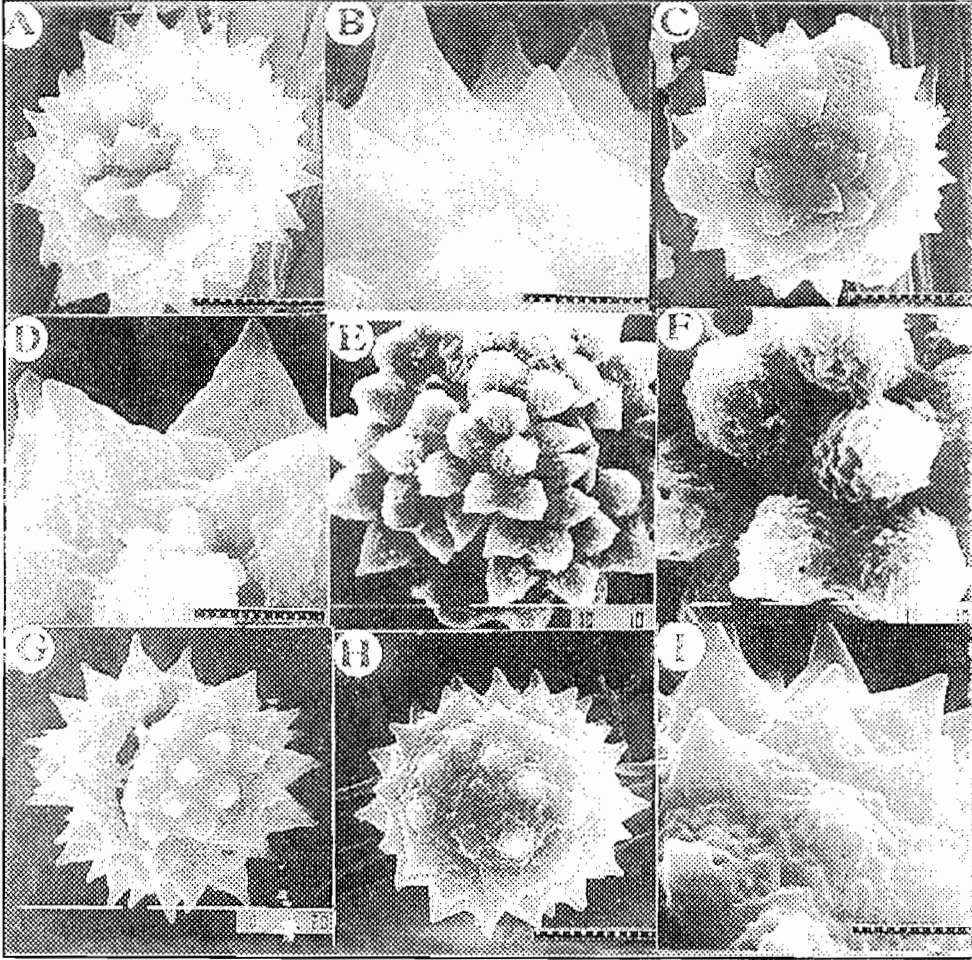


Fig. 3. Scanning electron micrographs (SEM) of the pollen grains. *Inula stewartii*: A. equatorial view; B. exine pattern. *Iphiaea aucheri*: C. equatorial view; D. exine pattern. *I. grantioides*: E. polar view; F. exine pattern. *Pentanema divaricatum*: G. equatorial view; H. equatorial view; I. exine pattern (Scale bar: A, E, G = 10 μ m; B, D, I = 3.0 μ m; C = 12 μ m; F = 1.0 μ m; H = 8.0 μ m).

Ornamentation: Tectum echinate, spines apices acute-acuminate with distinct punctate or perforated spine base. Tectum sparsely punctate-subpsilate rarely subpsilate-rugulate or scabrate-granulate.

Measurements: Polar length (P) (17.5-) 22.15 (-28.0) μ m, Equatorial diameter (E) (15.0-) 23.75 (-32.5) μ m, Colpi (7.5-) 13.75 (-20.0) μ m long, Mesocolpium (10.0-)15.85 (-22.5), Apocolpium (5.0-) 8.25 (-12.5), P/E ratio: 0.95-1.07, Spines (2.5-) 3.1 (-5.0) μ m long. Interspinal distance (2.5-) 3.75 (-6.25) μ m, Exine thickness (1.5-) 3.25 (-5.0) μ m, Polar area index: 0.64-0.73.

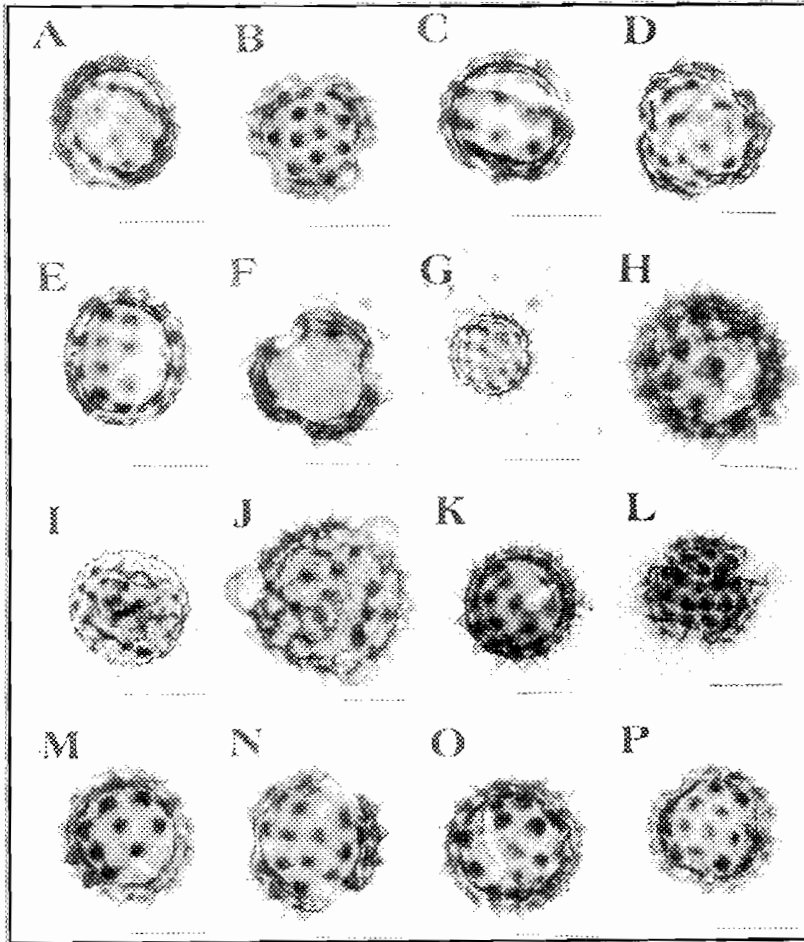


Fig. 4. Light micrographs (LM) of the pollen grains. *Duhaldea cappa*: A. equatorial view; B. polar view. *D. eupatorioides*: C. equatorial view; D. polar view. *D. cuspidata*: E. equatorial view; F. polar view. *D. latifolia*: G. equatorial view. *Pentanema divaricatum*: H. equatorial view. *Dittrichia graveolens*: I. equatorial view; J. polar view. *Iphiona aucheri*: K. equatorial view; L. polar view. *Iphiona grantioides*: M. equatorial view; N. polar view. *Inula rhizocephala*: O. equatorial view; P. polar view (Scale bar: A-C, E-I, K-P = 20 μ m; D, J = 10 μ m)

Species included: *Pentanema divaricatum* Cass., *P. glanduligerum* (Krasch.) Gorsckh., *P. indicum* (L.) Ling, *P. vestitum* (Wall. ex DC.) Ling, *Dittrichia graveolens* (L.) Greuter.

Key to the species and species group of *Inula acuminata*-type

- 1 + Pollen grain oblate-spheroidal *Inula obtusifolia*
 - Pollen grain prolate-spheroidal 2

- 2+ Colpi length 12-17 μ m *Inula acuminata*
 - Colpi length > 17 μ m 3
- 3+ Spines with acute or acuminate apices 4
 - At least some of the spines with rounded apices *I. rhizocephala*
- 4+ Polar area index 0.53 - 0.58 5
 - Polar area index 0.60-0.70 6
- 5+ Spines base psilate-punctate *Iphiona aucheri*
 - Spines base punctate *Iphiona grantioides*
- 6+ Polar area index 0.70 *Inula clarkei*
 - Polar area index < 0.70
 *Inula*
britannica group (*Duhaldea eupatorioides*, *I. britannica*, *I. falconeri*, *I. stewartii*)

Key to the species of *Pentanema divaricatum*-type

- 1+ Polar length 17.5-24 μ m 2
 - Polar length 26-28 μ m *Dittrichia graveolens*
- 2+ Pollen oblate-spheroidal, 3-4-colporate *P. glanduligerum*
 - Pollen prolate-spheroidal, 3-colporate 3
- 3+ Tectum punctate with granules in between spines. Colpus 7.5-10 μ m long
 *P. indicum*
 - Tectum sparsely punctate-subpsilate or subpsilate with scabrae in between spines.
 Colpus 12.5-17.5 μ m long 4
- 4+ Tectum sparsely punctate-subpsilate in between spines. Polar area index 0.73
 *P. vestitum*
 - Tectum subpsilate with scabrae in between spines. Polar area index 0.64
 *P. divaricatum*

Discussion

The genera *Inula* L., *Dittrichia* Greuter, *Duhaldea* DC., *Iphiona* Cass., and *Pentanema* Cass., are stenopalynous taxa. Pollen grains are usually radially symmetrical, isopolar, prolate-spheroidal rarely oblate-spheroidal, tricolporate, zonoaperturate occasionally tetracolporate. Sexine slightly thicker than nexine or as thick as nexine. Tectum echinate, spines with acute-acuminate or rounded along with few acute apices and punctate or subpsilate bases. They also show little variation in pollen size and tectum type in between spines. On the bases of these characters, 22 taxa (belonging to 5 different genera) are grouped under 3 major pollen types viz., (i) *Duhaldea cappa*-type (ii) *Inula acuminata*-type (iii) *Pentanema divaricatum*-type.

Type-I: *Duhaldea cappa*, is easily recognized by having densely punctate or punctate-fine scabrate tectum in between spines. This type is represented by *Duhaldea cappa*, *D. cuspidata*, *D. latifolia*, *I. grandiflora*, *Inula koelzii*, *I. racemosa* and *I. royleana*.

Within this pollen type *Duhaldea cappa* is the only taxon which is distinguished from the rest of species due to its punctate-fine scabrate tectum in between spines, while in others tectum is densely punctate in between the spines. However, these species are further delimited on the basis of polar length, mesocolpium and polar area index (see key to the species and species groups).

Type-II: *Inula acuminata*, is delimited by having 30-50 μ m polar length. It has maximum number (10) of taxa viz., *Duhaldea eupatorioides*, *Inula acuminata*, *I. britannica*, *I. clarkei*, *I. falconeri*, *I. obtusifolia*, *I. rhizocephala*, *I. stewartii*, *Iphiona aucheri* and *Iphiona grantioides*.

Within *Inula acuminata*-type, *Inula obtusifolia* has oblate-spheroidal pollen grains while in remaining species pollen grains are prolate-spheroidal. Furthermore, *Inula rhizocephala* is distinguished from rest of the taxa by having some spines with rounded apices, whereas in the others species spine apices are acute or acuminate. (see key to the species and species groups).

Type-III: *Pentanema divaricatum*, is delimited by having 17.5-28 μ m polar length and is represented by *Pentanema divaricatum*, *P. glanduligerum*, *P. indicum*, *P. vestitum* and *Dittrichia graveolens*.

Within this pollen type *Dittrichia graveolens* is distinct from rest of the species due to 26-28 μ m polar length while in remaining species polar length varies from 17.5-24 μ m. Similarly this pollen type shows little variation in pollen shape class, such as *P. glanduligerum* is distinguished due to its oblate-spheroidal shape of pollen and 3-4-colporate, while in remaining species pollen grains are prolate-spheroidal and 3-colporate. However, our observations do not agree with those of Dakshini & Prithipalsingh (1970), who have studied the pollen grains of Compositae including one species from this type i.e., *P. indicum*, in which spheroidal pollen grains have been observed. While, Nair (1965) also reported the prolate-spheroidal pollen grain in *P. indicum*. Beside the above qualitative characters, tectum pattern between spines is also very distinct among all the four species as in *P. glanduligerum*, tectum is sparsely punctate-subspilate or somewhat rugulate in between spines. In *P. indicum* tectum is punctate with granules, while in *P. vestitum* tectum is sparsely punctate-subspilate in between spines, whereas, subspilate tectum with scabrae is found in *P. divaricatum*.

From the ongoing discussion, one may conclude that pollen morphological characters are though quite important but sometimes may not be helpful in delimiting all the taxa of *Inula* L. (s.str.) and its related genera. Although all the taxa may be grouped into three major pollen types, however, from these proposed pollen types, two pollen types viz., *Inula acuminata*-type and *Duhaldea cappa*-type have more or less morphologically diversified taxa. The present findings are also in complete agreement with earlier conclusion drawn by Stix (1960) on certain members of Compositae, from which 41 major pollen types were recognized, having various taxa belonging to diverse tribes.

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