

CYPSELA MORPHOLOGY AND ITS TAXONOMIC SIGNIFICANCE FOR THE TRIBE SENECEONEAE (ASTERACEAE) FROM PAKISTAN

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Abstract

Cypselas of 26 species distributed in 9 genera of the tribe *Senecioneae* were examined from Pakistan. Micromorphological characters of cypselas in this group are not only found useful for assessing relationship but they are also useful for the delimitation of taxa both at the generic and specific levels, except that of the genera *Senecio* and *Doronicum* which could not be clearly separated as they do not have exclusive cypselas features.

Introduction

Senecioneae is the largest tribe of the family Asteraceae with 3000 species and 150 genera (Nordenstam, 2007). It is distributed all over the world and most common in Central and South America, South eastern Africa and Central and east Asia but less common in Mediterranean type areas of America, Australia and southwestern Asia (Bremer, 1994; Nordenstam 2007). In Pakistan, Senecioneae is represented by 9 genera viz., *Cremanthodium* Benth., *Doronicum* L., *Hertia* Less., *Ligularia* Cass., *Parasenecio* W.W.Sm. & J. Small., *Petasites* Miller., *Senecio* L., *Synotis* (C.B. Clark) C. Jeffery & L. Chen and *Tussilago* L., with 37 species (Qaiser & Abid, unpublished manuscript).

Cypselas morphology has received much attention for the taxonomic significance of the various groups of the family Asteraceae (Dittrich, 1968; Kynclova, 1970; Haque & Godward, 1984; Lovell *et al.*, 1986; Mateu & Guemes, 1993; Swelenkomo *et al.*, 2007). Similarly, from Pakistan various reports are available on cypselas morphology for the tribes Inuleae (Abid & Qaiser, 2002; Abid & Zehra, 2007), Plucheeae (Abid & Qaiser, 2007), Gnaphalieae (Abid & Qaiser, 2008a,b) and Anthemideae (Abid & Qaiser, 2009) but still there are no exclusive informations on cypselas morphology for the tribe Senecioneae. Present paper is the continuity of cypselas morphological studies from Pakistan for the taxonomic assessment of the family Asteraceae.

Materials and Methods

Mature and healthy cypselas of 26 species belonging to the tribe Senecioneae were collected from herbarium specimens (Appendix-I) and examined for micromorphological characters under stereomicroscope (Nikon XN Model), compound microscope (Nikon Type 102) and scanning electron microscope (JSM-6380A). For scanning electron microscopy mature cypselas were directly mounted on metallic stub using double adhesive tape and coated with gold for a period of 6 minutes in sputtering chamber and observed under SEM.

Following characters were studied: Cypselas: Shape, surface, colour, size. Pappus: Structure, shape, number, colour, size. Carpodium: Shape, position, diameter of carpodium and its foramen were observed under scanning electron microscope.

Appendix I. List of voucher specimens

Taxa	Collector, Number, Herbarium
<i>Cremanthodium arnicoides</i>	<i>M. Qaiser & Jan Alam</i> 2129 (KUH); <i>R.R. Stewart</i> 5777 (KUH); <i>R.R. Stewart</i> 9381 (KUH); <i>coll. ignot.</i> 786375 (KUH).
<i>C. decaisnei</i>	<i>R.R. Stewart</i> 6570 (KUH); <i>M. Qaiser & Jan Alam</i> 2127 (KUH); <i>J.F. Duthie</i> s.n. (KUH); <i>Jan Alam & M. Qaiser</i> 2179 (KUH); <i>R.R. Stewart</i> s.n.(RAW).
<i>C. ellisii</i>	<i>Jan Alam & Noor Din</i> 2876 (KUH); <i>M. Qaiser & Jan Alam</i> 2179 (KUH); <i>M. Qaiser & Jan Alam</i> 2128 (KUH).
<i>Doronicum falconeri</i>	<i>Sher Wall Khan & Shabbir Hussain</i> 644-A (KUH). <i>coll. ignot.</i> 1525(KUH).
<i>D. kamaonense</i>	<i>TahirAli</i> 1505 (KUH); <i>MohindarNath</i> 6025 (KUH); <i>S.Kitamura</i> s.n. (KUH); <i>Jan Alam, R.B.Tareen & Jahangir Iqbal</i> 2536 (KUH); <i>Jan Alam & Saleem</i> 3787 (KUH); <i>Jan Alam & Saleem</i> 3632 (KUH); <i>Abdul Ghafoor & Rizwan Yousuf</i> 1534 (KUH); <i>Saood Omer & A. Ghafoor</i> 1197 (KUH).
<i>Hertia intermedia</i>	
<i>L. fischeri</i>	<i>R.R. & I.D. Stewart</i> 17670 (RAW); <i>R.R. & I.D. Stewart</i> 50088 (KUH); <i>U.H. Zargar</i> 786372 (KUH).
<i>L. Jacquemontiana</i>	<i>R.R. & I.D. Stewart</i> 4617 (RAW); <i>R.R. Stewart</i> 12701 (RAW); <i>Jan Muhammad</i> J12 (RAW); <i>L.D.Kapoor</i> s.n.(RAW); <i>R.R.Stewart</i> 6628(RAW).
<i>L. sibirica</i>	<i>R.R. Stewart</i> 19279 (RAW).
<i>L. thomsonii</i>	<i>Kamal Akhtar & M. Qaiser</i> 591 (KUH); <i>Jan Alam & Karim Madad</i> 1838-C (KUH); <i>Abdul Ghafoor & Z. C. Butt</i> 819 (KUH); <i>R.R. & I.D. Stewart</i> 7195 (KUH).
<i>Parasenecio levingei</i>	<i>R.R. Stewart</i> 6715 (RAW); <i>U. H. Zargar</i> 786474 (KUH).
<i>Petasites tricholobus</i>	<i>Saood Omer, S. Nazimuddin & A. Wahid</i> 621 (KUH); <i>Saood Omer, S. Nazimuddin & A. Wahid</i> 662 (KUH); <i>Saood Omer, S. Nazimuddin & A. Wahid</i> 666 (KUH).
<i>Senecio analogus</i>	<i>Sultan-ul-Abedin & M. Qaiser</i> 6912 (KUH); <i>M. Qaiser & A. Ghafoor</i> 498 (KUH); <i>M. Qaiser & Rizwan Yousuf</i> 7668 (KUH); <i>Tahir Ali</i> 2494 (KUH); <i>S. Abedin</i> 6964 (KUH); <i>A. Ghafoor & students</i> 5379(KUH); <i>MohindarNaths.n.</i> (KUH); <i>Abdul Rashid</i> s.n. (KUH); <i>M. Qaiser & A. Ghafoor</i> 4997 (KUH).
<i>S.dubitabilis</i>	<i>Saood Omer & A. Ghafoor</i> 1860-A(KUH); <i>Ved Parkash</i> 16422 (RAW). <i>S.MA. Kazmi</i> 1846 (North regional Lab. Peshawar); <i>J.Leonard</i> 5937 (KUH); <i>TahirAli</i> 939 (KUH); <i>M. Qaiser & Abrar Hussain</i> 1075 (KUH).
<i>S. flavus</i>	
<i>S. glaucus</i>	<i>Sultan-ul-Abedin</i> 2928 (KUH); <i>S. Omer & M. Qaiser</i> 2436 (KUH); <i>A. Ghafoor & S. Omer</i> 2489 (KUH); <i>Abdul Ghafoor & Rizwan Yousuf</i> 1369 (KUH); <i>M. Rabbi</i> 2828 (KUH); <i>Abdul Ghafoor & Rizwan Yousuf</i> 1544 (KUH); <i>Sher Wall Khan & Shabbir Hussain</i> 557 (KUH); <i>A. Ghafoor & S. Omer</i> 3010 (KUH).

Appendix I. (Cont'd).

<i>Taxa</i>	<i>Collector, Number, Herbarium</i>
<i>S.graciliflorus</i>	MohindarNath 4350 (KUH); A. Rashid khan s.n. (RAW); MohindarNath s.n. (KUH); N.L Burt 15581 (RAW).
<i>S. korshinskyi</i>	Kamal Akhtar Malik & S. Nazimuddin 1790 (KUH); Kamal Akhtar Malik & S. Nazimuddin 1694 (KUH); S. Omer & M.Qaiser 2486 (KUH); R.R. & I.D. Stewart 212815 (RAW).
<i>S. krascheninnikovii</i>	M. Qaiser & A. Ghafoor 5293 (KUH); Sher Wall Khan & Mushtaq Hussain 761 (KUH); MohindarNath 2888 (KUH); Kamal Akhtar & S. Nazimuddin 723 (KUH); Kamal Akhtar & M. Qaiser 392 (KUH); S.Omer & M. Qaiser 2631 (KUH); S.Omer&M. Qaiser 2520 (KUH); Kamal Akhtar Malik & S. Nazimuddin 1791 (KUH); Sultan-ul-Abedin & M. Qaiser 8947 (KUH).
<i>S.naudicaulis</i>	Sultan-ul-Abedin 2089 (KUH); A. Ghafoor & TahirAli 4039 (KUH); A. Ghafoor & TahirAli 3951 (KUH); R.R. & I.D. Stewart 41201/2 (KUH); M. Qaiser & Sultan-ul-Abedin 5720 (KUH); Salahuddin Masud 7 (KUH); Sultan-ul-Abedin 8240 (KUH).
<i>S.paulsenii</i>	SM Toppin 272 (KEW) A.P. Young s.n. (BM) Jan Alam & Abdul
<i>S.royaleanus</i>	Hameed 1617 (KUH); Jan Alam & Sher Salman Baig 3398 (KUH);
<i>S. tibeticus</i>	MohindarNath 1707 (KUH); R.R. & I.D. Stewart s.n. (RAW); Saida Qureshi s.n. (KUH).
<i>S.vulgaris</i>	M. Qaiser s.n. (KUH). Ajit Singh 12 (KUH); MohindarNath 4267
<i>S. rufinervis</i>	(KUH); R.R. Stewart 15774 (KUH); coll. ignot.1742 (KUH); R.A.
<i>Tussilago farfara</i>	Sharma s.n. (KUH). Saood Omer, S. Nazimuddin & A. Wahid 621 (KUH).

Observations

General cypselas characters of the tribe Senecioneae: Cypselas monomorphic or dimorphic, oblong, oblong-oblongate, oblong-narrow elliptic, elliptic, oblongate, oblongate-narrow elliptic, angular or non-angular, laterally compressed or cylindrical 1-8x0.1-3 mm, greenish golden, yellowish golden, golden-brown, light brown, dark brown or maroonish brown, ribbed or non-ribbed, glabrous, striate, striate-lineate, striate-scalariform, striate-rugose, rugose-ruminate, colliculately ruminate, undulate, reticulate, foveate, sparsely pubescent or sparsely or densely pubescent between the ribs, sparsely or densely villous. Pappus uniseriate, biseriata or multiseriate, separately falling, caducous, flexuous, capillary, capillary-scabrid, scabrid, scabrid-barbellate or barbellate, apically barbed or apically not barbed, 10 to numerous, 1-10mm long, white, off-white, off-white-cream or cream. Carpopodium undeveloped or irregularly developed or narrow angular ring, broad angular ring, narrow circular ring or broad circular ring, basal, basal-subbasal or subbasal in position, 155-724 µm in diameter. Foramen of carpopodium 113-616µm in diameter (Table 1; Figs.1-5).

***Cremanthodium* Benth.:** Cypselas monomorphic, oblong or oblong-narrow elliptic, angular or non-angular, laterally compressed, 2-4x0.5-0.75mm, maroonish brown or brown, non-ribbed, glabrous, striate or striate-scalariform. Pappus uniseriate, bristles barbellate, separately falling, 35-50, 5-9mm long, white or off-white. Carpopodium broad angular ring like, basal in position, 258-381 µm in diameter. Foramen of Carpopodium 191-252 µm in diameter (Table 1; Fig. 1A-I).

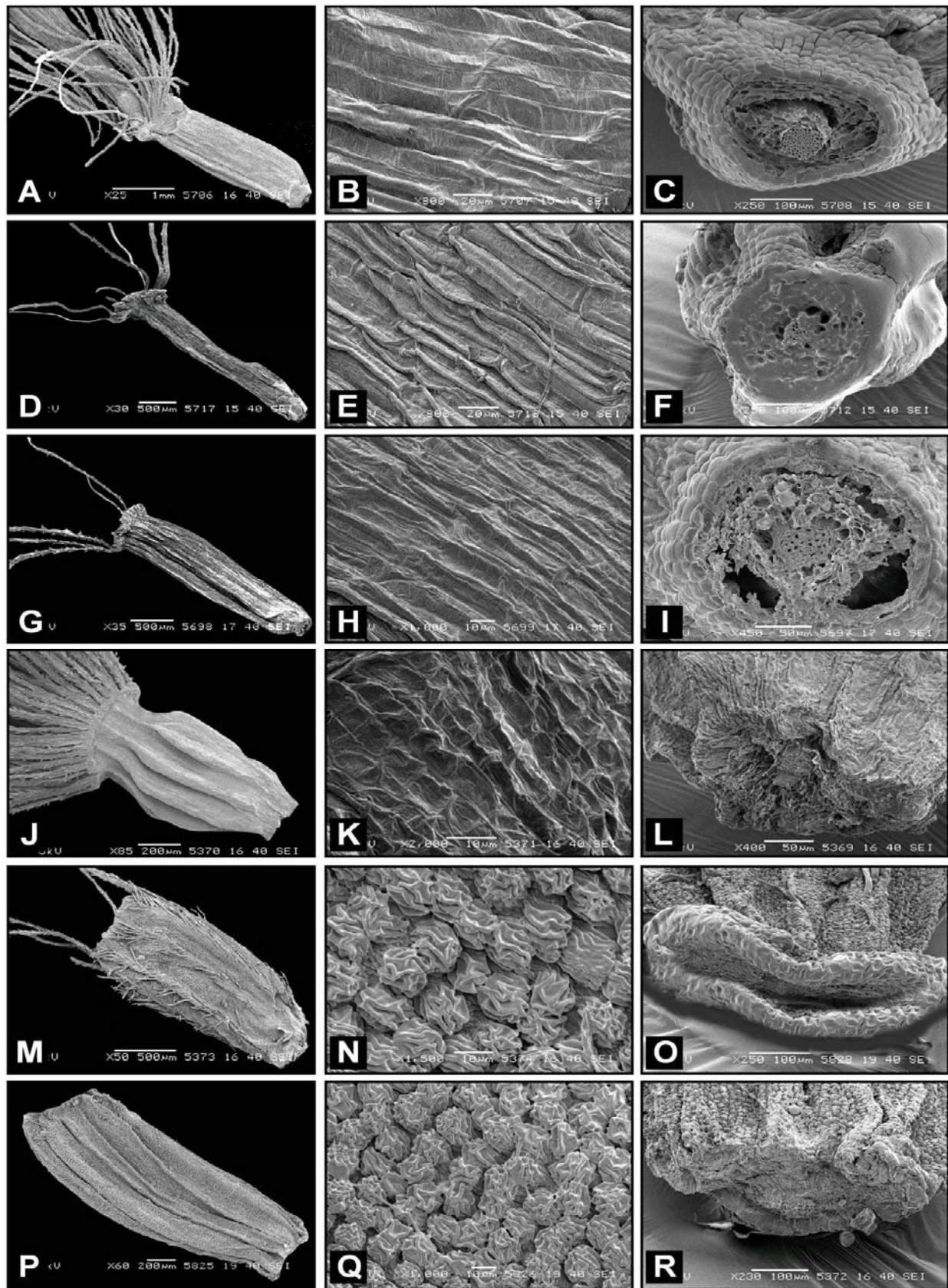


Fig. 1. Scanning electron micrographs: *Cremanthodium arnicoides*: A, cypselas; B, surface; C, carpodium. *C. decaisnei*: D, cypselas; E, surface; F, carpodium. *C. ellisii*: G, cypselas; H, surface; I, carpodium. *Doronicum falconeri*: J, cypselas; K, surface; L, carpodium. *D. kamaonense*: M, cypselas of the disc floret; N, surface; O, carpodium; P, cypselas of the ray floret; Q, surface; R, carpodium. (scale bar: A=1mm; D,G,M=500 μ m; J,P=200 μ m; C,F,O,R=100 μ m; I,L=50 μ m; B,E=20 μ m; H,K,N,Q=10 μ m).

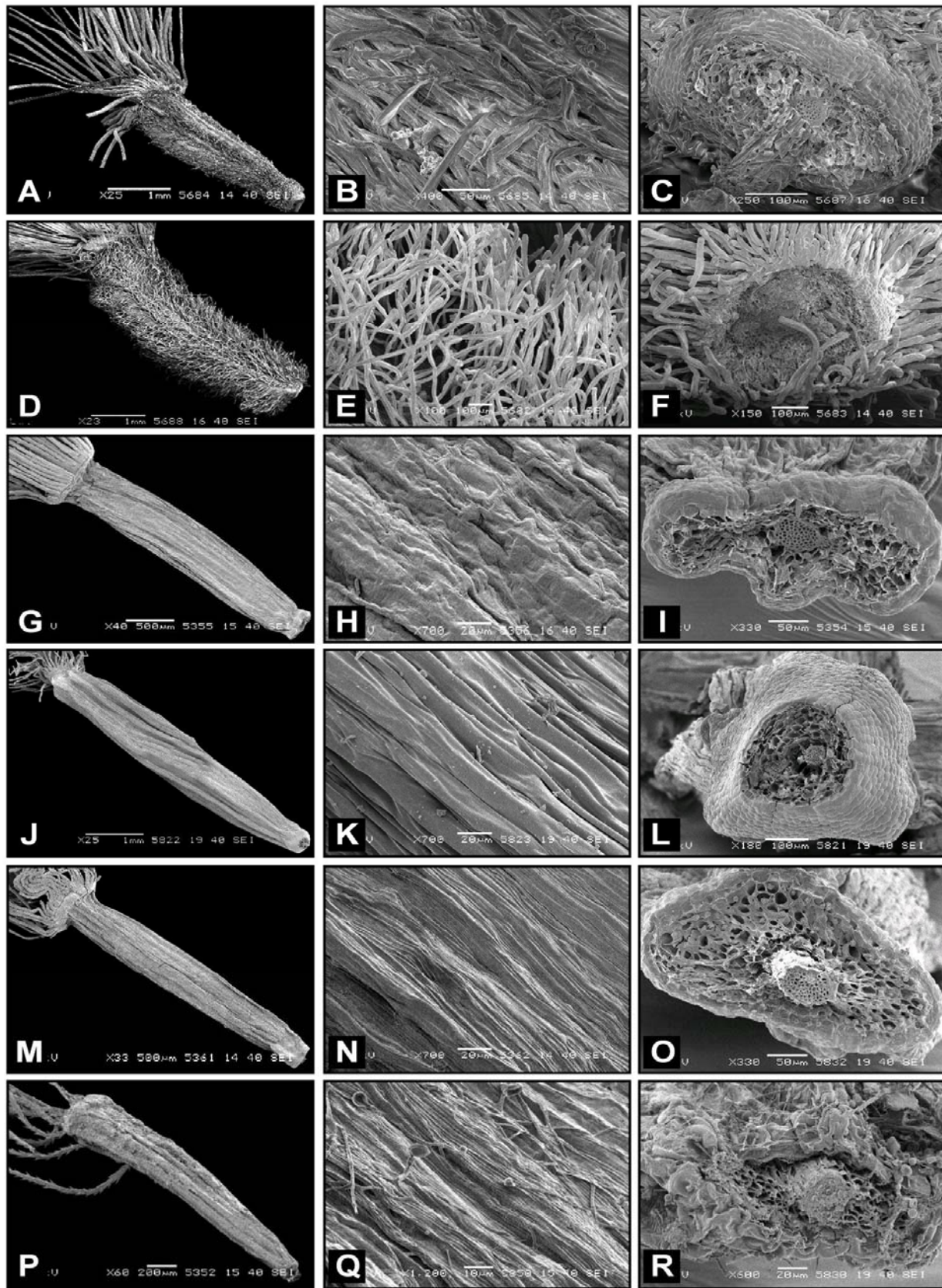


Fig. 2. Scanning electron micrographs: *Hertia intermedia*: A, cypselas of the disc floret; B, surface; C, carpopodium; D, cypselas of the ray floret; E, surface; F, carpopodium. *Ligularia fischeri*: G, cypselas; H, surface; I, carpopodium. *L. jaquemontiana*: J, cypselas; K, surface; L, carpopodium. *L. sibirica*: M, cypselas; N, surface; O, carpopodium. *L. thomsonii*: P, cypselas; Q, surface; R, carpopodium. (scale bar: A,D,J=1mm; G,M=500 μ m; P=200 μ m; C,E,F,L=100 μ m; B,I,O=50 μ m; H,K,N,R=20 μ m; Q=10 μ m).

Key to the genera

- 1+ Cypsela of ray and disc florets different (dimorphic).....*Doronicum*(p.p.) 2
 - Cypsela of ray and disc florets similar (monomorphic)..... 4
- 2+ Cypsela of ray floret 5.5-8 x 2.25-3mm, densely villous and cypsela of disc floret 3-4x1mm, sparsely villous.....*Hertia*
 - Cypsela of ray floret 1-2 x 0.1-0.75mm, glabrous and cypsela of disc floret 1-2 x 0.2-1 mm, glabrous or sparsely pubescent on the ribs.....3
- 3+ Cypsela of ray floret glabrous, ruminately colliculate, disc floret cypsela sparsely pubescent on the ribs. Pappus bristles barbellate.....*Doronicum*
 - Cypsela of both ray and disc florets glabrous, rugose-striate. Pappus bristles scabrid.....*Tussilago*
- 4+ Cypsela ribbed..... 5
 - Cypsela not ribbed.....6
- 5+ Cypsela glabrous.....*Doronicum*
 - Cypsela pubescent between the ribs.....*Senecio*
- 6+ Cypsela surface striate-lineate.....7
 - Cypsela surface not as above.....8
- 7+ Cypsela angular, 1x0.2mm*Synotis*
 - Cypsela not angular, laterally compressed, 3-8x0.25-3.75mm.....*Ligularia*
- 8+ Cypsela angular, surface striate or striate-scalariform.....9
 - Cypsela not angular, laterally compressed, surface rugose-ruminate.....*Petasites*
- 9+ Pappus bristles barbellate. Carpodium a broad angular ring*Cremanthodium*
 - Pappus bristles scabrid. Carpodium a narrow angular ring.....*Parasenecio*

It is represented by three species in the study area viz., *C. arnicoides* (DC.)R.Good, *C. decaisnei* C.B.Clarke and *C. ellisii* (Hook.f.)Kitam.

Key to the species of *Cremanthodium*

- 1 + Cypsela surface striate. Pappus bristles off white.....*C. arnicoides*
 - Cypsela surface striate- scalariform. Pappus bristles white.....2
- 2 + Cypsela oblong.....*C. decaisnei*
 - Cypsela oblong- narrow elliptic.....*C. ellisii*

***Doronicum* L.:** Cypsela monomorphic or dimorphic, broad elliptic or oblanceolate, angular, or non-angular laterally compressed, 1-2x0.5-1mm, dark brown or dark

maroonish brown, ribbed, glabrous reticulate-foveate or colliculately ruminant or sparsely pubescent on the ribs. Pappus uniseriate, bristles scabrid or barbellate, separately falling, 10-70, 1.5-8mm long, cream. Carpodium undeveloped or narrow angular ring, sub-basal in position, 501 μm in diameter. Foramen of carpodium 342 μm in diameter (Table 1; Fig. 1J-R)

It is represented by two species viz., *D.falconeri* C.B.Clarke and *D. kamaonense* (DC.) Alvarez Fernandez.

Key to the species of *Doronicum*

- 1 + Cypselas monomorphic, glabrous, reticulate-foveate *D.falconeri*
 - Cypselas dimorphic, disc floret cypselas sparsely pubescent on the ribs, ray floret
 Cypselas glabrous, colliculately ruminant *D.kamaonense*

Hertia Less.: Cypselas dimorphic, oblong or oblong-oblancheolate, angular or non-angular, cylindrical, 3-8x1-3mm, yellowish golden or golden brown, sparsely or densely villous. Pappus biseriata or multiseriata, bristles barbellate, separately falling, 90-numerous, 4-10mm long, off-white. Carpodium narrow circular ring, sub-basal in position, 476-512 μm in diameter. Foramen of carpodium 275-375 μm in diameter (Table 1; Fig. 2A-F).

It is represented by single species viz., *H. intermedia* (Boiss.) O. Kuntze.

Ligularia Cass.: Cypselas monomorphic, oblong or oblancheolate-narrow elliptic, non-angular, laterally compressed, 3-8x0.25-3.75mm, brown or dark brown, non-ribbed, glabrous, striate-lineate. Pappus uniseriate, bristles scabrid or barbellate, separately falling, 40-65, 1-10mm long, white or cream. Carpodium undeveloped, narrow angular ring or broad angular, basal or basal to sub-basal in position, 370-377 μm in diameter. Foramen of carpodium 247-349 μm in diameter (Table 1; Fig. 2G-R).

It is represented by four species viz., *L.fischeri* (Ledebour) Turczaniov, *L.jacquemontiana* (Decne.) M.A.Rau, *L.sibirica* (L.) Cass., *L. thomsonii* (C.B.Clarke) Pojark.

Key to the species of *Ligularia*

- 1 + Cypselas oblong. Pappus bristles barbellate. Carpodium narrow angular ring or undeveloped 2
 - Cypselas oblancheolate. Pappus bristles scabrid. Carpodium broad angular ring like *L. jacquemontiana*
- 2 + Pappus bristles 8-10 mm long. Carpodium developed *L. sibirica*, *L.fischeri*
 - Pappus bristles 4-5 mm long. Carpodium undeveloped *L. thomsonii*

Parasenecio W.W.Sm. & J. Small : Cypselas monomorphic, oblong, angular, 5-5.5x0.75mm, golden brown, non-ribbed, glabrous, striate-scalariform. Pappus uniseriate, bristles scabrid, separately falling, 45, 6-7mm long, off-white. Carpodium narrow slightly angular ring, basal position, 302 μm in diameter. Foramen of carpodium 232 μm in diameter (Table 1; Fig. 3A-C).

It is represented by single species viz., *P. levingei* (Clarke) Qaiser & Abid

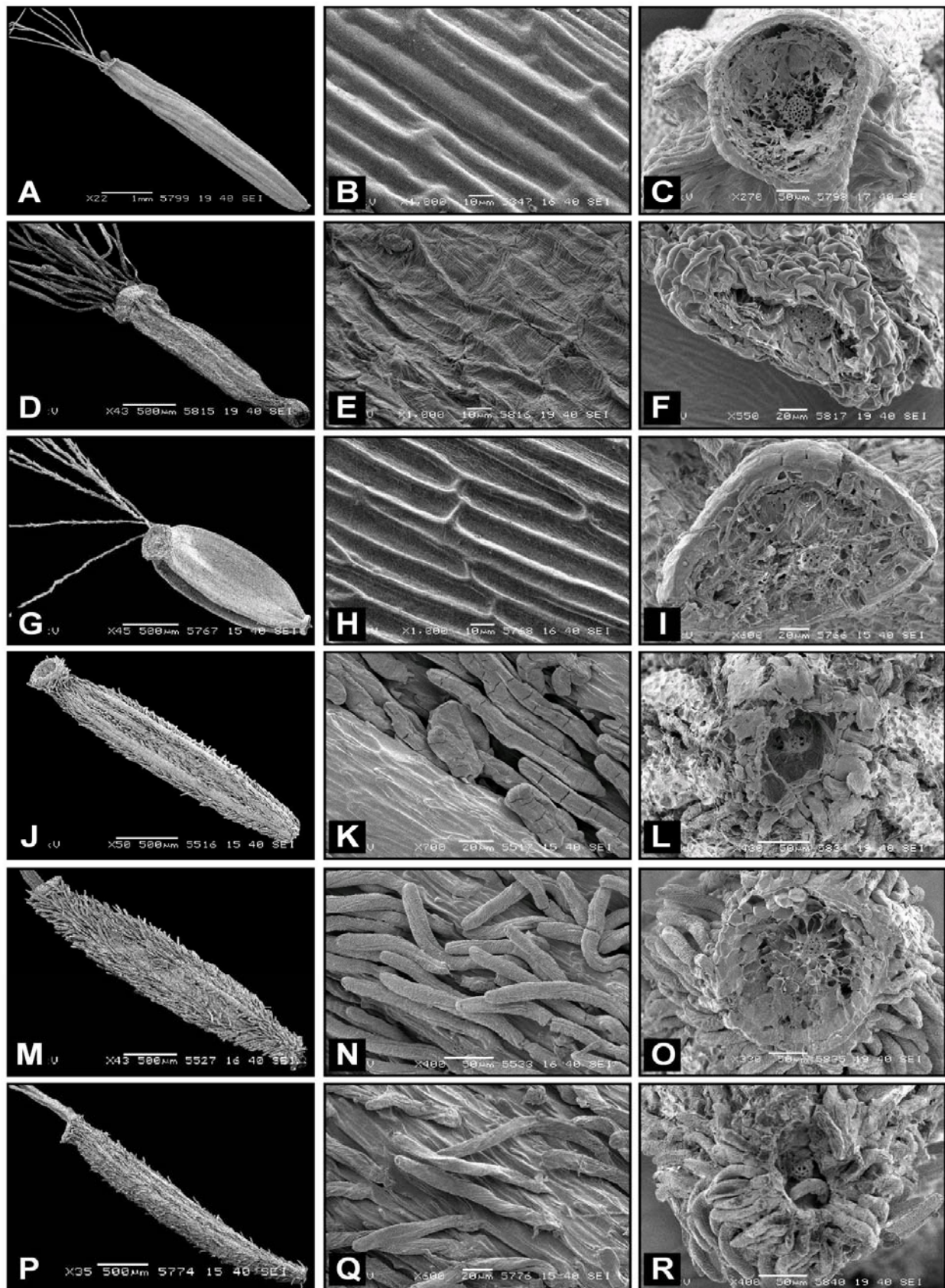


Fig. 3. Scanning electron micrographs: *Parasenecio levingei*: A, cypselas; B, surface; C, carpodium. *Petasites tricholobus*: D, cypselas; E, surface; F, carpodium. *Senecio analogus*: G, cypselas; H, surface; I, carpodium. *S. dubitabilis*: J, cypselas; K, surface; L, carpodium. *S. flavus*: M, cypselas; N, surface; O, carpodium. *S. glaucus*: P, cypselas; Q, surface; R, carpodium. (scale bar: A=1mm; D,G,J,M,P=500 μ m; C,L,N,O,R=50 μ m; F,I,K,Q=20 μ m; B,E,H=10 μ m).

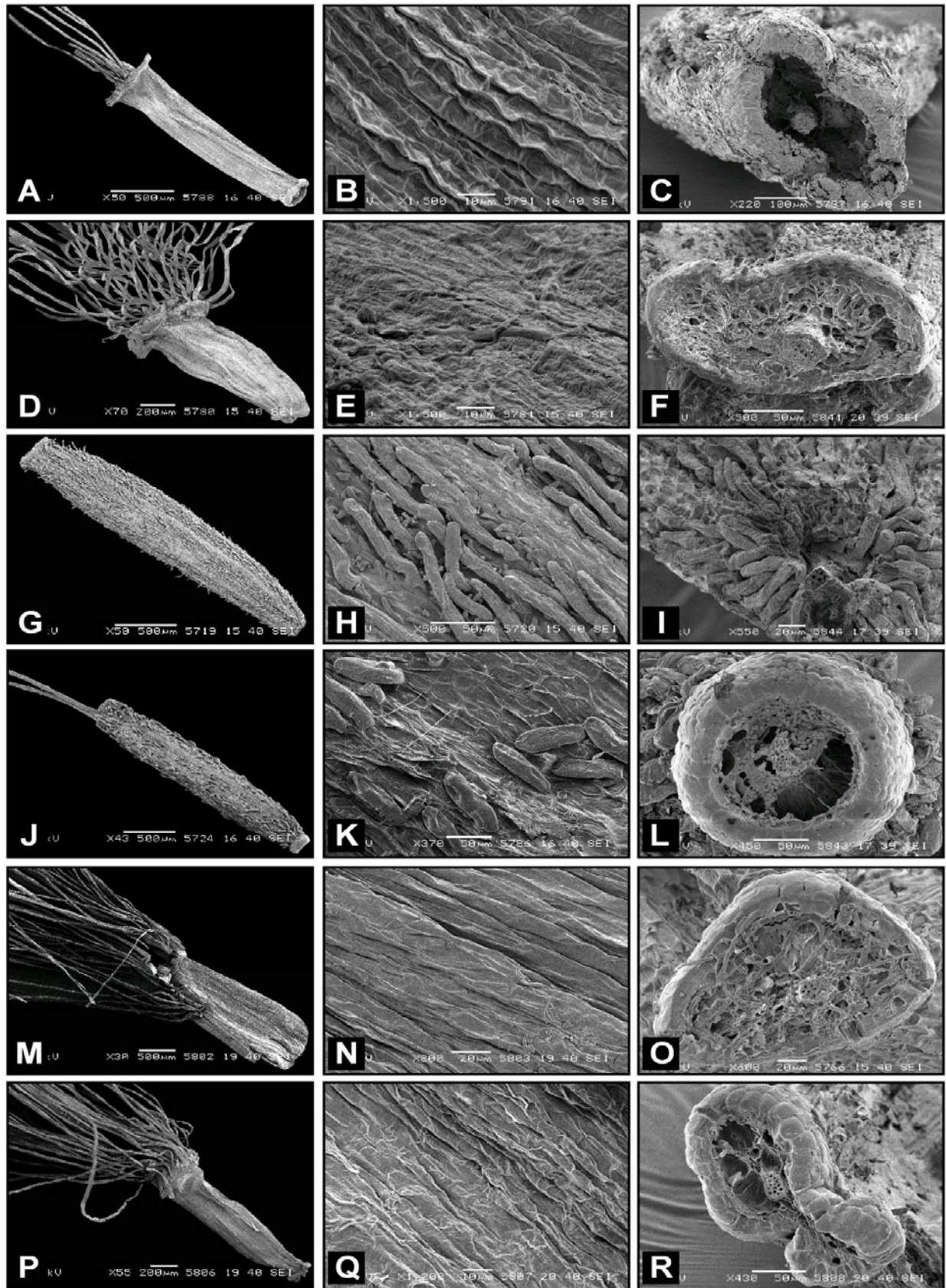


Fig. 4. Scanning electron micrographs: *Senecio graciliflorus*: A, cypselas; B, surface; C, carpodium. *S. korshinskyi*: D, cypselas; E, surface; F, carpodium. *S. krascheninnikovii*: G, cypselas; H, surface; I, carpodium. *S. nudicaulis*: J, cypselas; K, surface; L, carpodium. *S. paulsenii*: M, cypselas; N, surface; O, carpodium. *S. royaleanus*: P, cypselas; Q, surface; R, carpodium. (scale bar: A,G,J,M=500 μ m; D,P=200 μ m; O=100 μ m; F,H,K,L,R=50 μ m; C,I,N=20 μ m; B,E,Q=10 μ m).

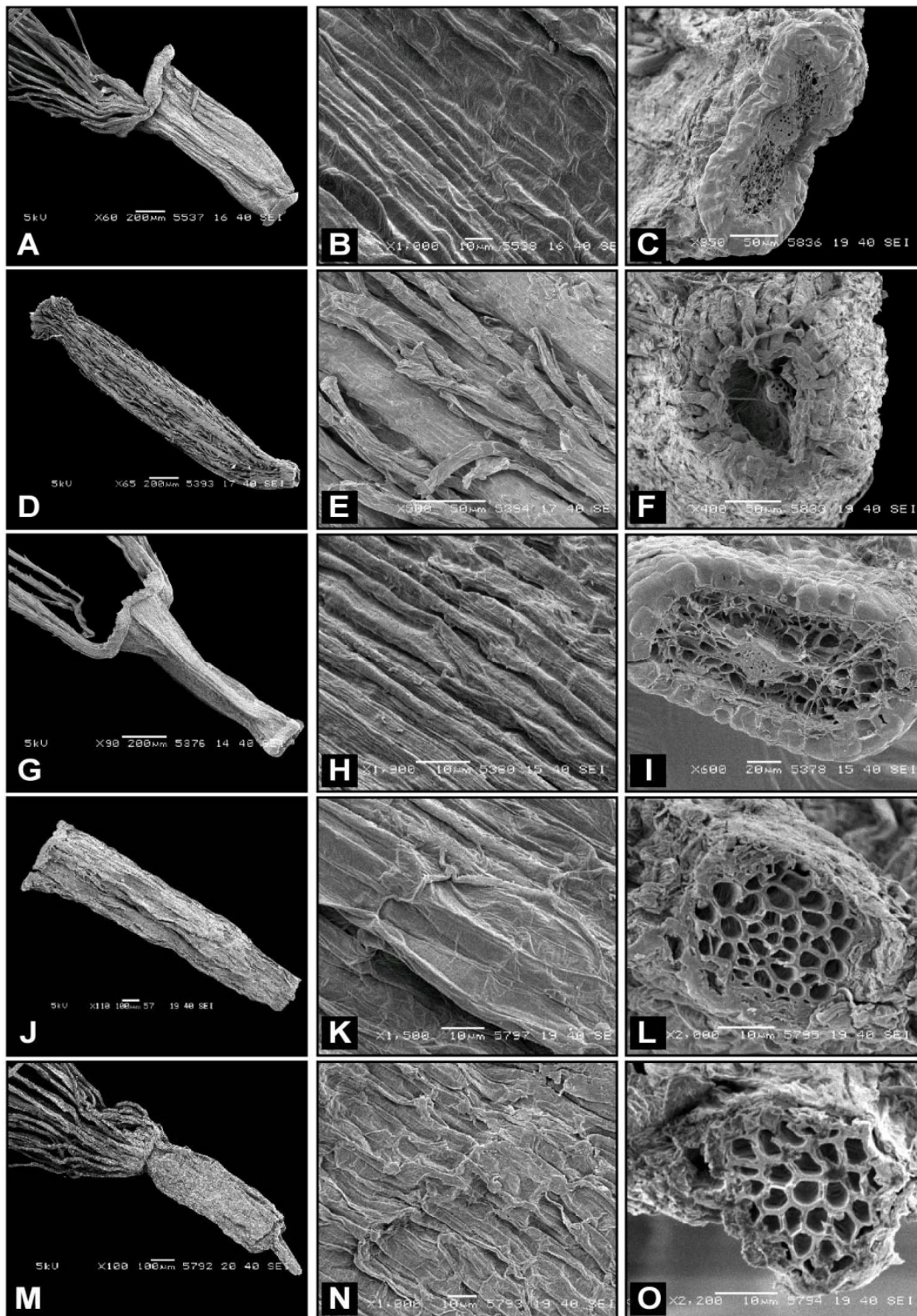


Fig. 5. Scanning electron micrographs: *Senecio tibeticus*: A, cypselas; B, surface; C, carpodium. *S. vulgaris*: D, cypselas; E, surface; F, carpodium. *Synotis rufinervis*: G, cypselas; H, surface; I, carpodium. *Tussilago farfara*: J, cypselas of the disc floret; K, surface; L, carpodium; M, cypselas of the ray floret; N, surface; O, carpodium. (scale bar: A,D,G=200µm; J,M=100µm; C,E,F=50µm; I=20; B,H,K,L,N,O=10µm).

Table 1. Cypselia morphological characters in the tribe Senecioneae (Asteraceae)

		Cypselia			
Name of Taxa	Monomorphic/ Dimorphic	Shape	Surface	Colour	Size(mm)
<i>Cremanthodium amicoides</i>	Monomorphic	Oblong, angular	Non-ribbed, glabrous, striate	Maroonish brown	2-3x0.75
<i>C. decaisnei</i>	Monomorphic	Oblong, angular	Non-ribbed, glabrous, striate-scalariform	Brown	4x0.5
<i>C. ellisii</i>	Monomorphic	Oblong-narrow elliptic, angular or laterally compressed	Non-ribbed, glabrous, striate-scalariform	Maroonish brown	2.5-3x0.5
<i>Doronicum falconeri</i>	Monomorphic	Broad elliptic, angular	Ribbed, glabrous, reticulate-foveate	Dark brown	1x0.5
<i>D. kamaonense</i>	Dimorphic	Disc floret; oblancoeolate, non-angular, laterally compressed	Disc floret: ribbed, sparsely pubescent on the ribs, colliculately ruminata	Disc floret; Dark maroonish brown	Disc floret; 2x1
		Ray floret; oblancoeolate, non-angular, laterally compressed	Ray floret: ribbed, glabrous, colliculately ruminata	Ray floret; Dark maroonish brown	Ray floret: 2x0.75
<i>Hertia intermedia</i>	Dimorphic	Disc floret; oblong-oblancoeolate, angular cylindrical, curved	Disc floret; Sparsely villous	Disc floret; Golden brown	Disc floret; 3-4x1
		Ray floret; oblong, non-angular, cylindrical, curved	Ray floret; Densely villous	Ray floret; Yellowish golden	Ray floret; 5.5-8x2.25-3
<i>Ligularia fischeri</i>	Monomorphic	Oblong, non-angular, laterally compressed	Non-ribbed, glabrous, striate-lineate	Dark brown	4x0.75
<i>L. jacquemontiana</i>	Monomorphic	Oblancoeolate-narrow elliptic, non-angular, laterally compressed	Non-ribbed, glabrous, striate-lineate	Brown	5-8xl.5-3.75
<i>L. sibirica</i>	Monomorphic	Oblong, non-angular, laterally compressed	Non-ribbed, glabrous, striate-lineate	Dark brown	4x0.5
<i>L. thomsonii</i>	Monomorphic	Oblong, non-angular, laterally compressed	Non-ribbed, glabrous, striate-lineate	Dark brown	3x0.25-0.5
<i>Parasenecio levingei</i>	Monomorphic	Oblong, non-angular, laterally compressed	Non-ribbed, glabrous, striate-scalariform	Golden brown	5-5.5x0.75
<i>Petasites tricholobus</i>	Monomorphic	Oblong, non-angular, laterally compressed	Non-ribbed, glabrous, rugose-ruminata	Maroonish brown	2.25x0.3
<i>Senecio analogus</i>	Monomorphic	Elliptic, angular	Non-ribbed, glabrous, striate-scalariform	Light brown	1.5-2x0.5
<i>S. dubitabilis</i>	Monomorphic	Narrow elliptic, non-angular, cylindrical	Ribbed, sparsely pubescent between the ribs	Light brown	2.5x0.5
<i>S. flavus</i>	Monomorphic	Oblong-narrow elliptic, non-angular, cylindrical	Ribbed, densely pubescent between the ribs	Greenish golden	3-3.25x0.5
<i>S. glaucus</i>	Monomorphic	Oblong-narrow elliptic, non-angular, cylindrical	Ribbed, sparsely pubescent between the ribs	Greenish golden	3x0.25
<i>S. graciliflorus</i>	Monomorphic	Oblong, angular	Non-ribbed, glabrous, striate-rugose	Dark brown	1.25-1.75x0.25
<i>S. korshinskiyi</i>	Monomorphic	Oblong, angular	Non-ribbed, glabrous, undulate	Dark brown	1.5x0.5
<i>S. krascheninikovii</i>	Monomorphic	Narrow elliptic, non-angular, cylindrical	Ribbed, sparsely pubescent between the ribs.	Dark brown	2-2.5x0.5
<i>S. nudicaulis</i>	Monomorphic	Oblong-narrow elliptic, angular	Non-ribbed, sparsely pubescent	Dark brown	2.5x0.5
<i>S. paulsenii</i>	Monomorphic	Oblong, non-angular, laterally compressed	Non-ribbed, glabrous, striate-rugose	Maroonish brown	2.25x0.75
<i>S. royaleanus</i>	Monomorphic	Oblong-oblancoeolate angular	Non-ribbed, glabrous, striate	Dark brown	1-1.5x0.25
<i>S. tibeticus</i>	Monomorphic	Oblong, angular	Non-ribbed, glabrous, striate	Dark brown	1.25x0.5
<i>S. vulgaris</i>	Monomorphic	Narrow elliptic, non-angular, cylindrical	Ribbed, sparsely pubescent between the ribs	brown	2.25x0.5
<i>Synotis rufinervis</i>	Monomorphic	Oblong-angular	Non-ribbed, glabrous, striate-lineate	Maroonish Brown	1x0.2
<i>Tussilaga farfara</i>	Dimorphic	Disc floret; Oblong-oblancoeolate, non-angular, laterally compressed	Disc floret; Non-ribbed, glabrous, rugose-striate	Disc floret; Dark brown	disc floret; 1x0.2
		Ray floret; oblancoeolate, non-angular, laterally compressed	Ray floret; Non-ribbed, glabrous, rugose-striate	Ray floret; Light brown	Ray floret; 1x0.1

Table 1.(Cont'd.).

Name of Taxa	Pappus			Colour
	Bristles	Length(mm)	Number	
<i>Cremanthodium amnicoides</i>	Barbellate, uniseriate, seperately falling	7-9	40-50	Offwhite
<i>C. decaysnei</i>	Barbellate, uniseriate seperately falling	7-9	45-50	White
<i>C. ellisii</i>	Barbellate, uniseriate seperately falling	5-6	35-40	White
<i>Doronicum falconeri</i>	Scabrid, uniseriate, seperately falling	6-8	70	Cream
<i>D. kamaonense</i>	Disc floret; Barbellate, uniseriate; seperately falling	Disc floret; 1.5	Disc floret; 10	Disc floret; cream
<i>Hertia intermedia</i>	Ray floret; Barbellate, Disc floret;; Barbellate, biseriate, seperately falling	-	-	-
	Ray floret; Barbellate; multiseriate, seperately falling	Disc floret; 5-7	Disc floret; 90	Disc floret; offwhite
	seperately falling	Ray floret; 4-10	Ray floret; numerous	Ray floret; offwhite
<i>Ligularia fischeri</i>	Barbellate; uniseriate, seperately falling	8-10	50	Cream
<i>L. jacquemontiana</i>	Scabrid; uniseriate, seperately falling	1-2.5	40-45	Cream
<i>L. sibirica</i>	Barbellate, uniseriate, seperately falling	8-9	50	Cream
<i>L. thomsonii</i>	Barbellate; uniseriate, seperately falling	4-5	60-65	White
<i>Parasenecio levingei</i>	Scabrid; uniseriate, seperately falling	6-7	45	Offwhite
<i>Petasites tricholobus</i>	Barbellate, uniseriate, seperately falling	3.5-6	c.30	Cream-Offwhite
<i>Senecio analogus</i>	Barbellate, uniseriate, seperately falling	3-4	50	Offwhite
<i>S. dubitabilis</i>	Scabrid, uniseriate, seperately falling, caducous, flexuous	4-5	-	White
<i>S. flavus</i>	Scabrid-capillary, uniseriate, seperately falling, caducous, flexuous, apically barbed	4-5	c.100	White
<i>S. glaucus</i>	Scabrid-capillary, uniseriate, seperately falling, caducous, flexuous, apically barbed	3-5	c.120	White
<i>S. graciliflorus</i>	Barbellate, uniseriate, seperately falling	4-5	60	White
<i>S. korschinskyi</i>	Scabrid-barbellate, uniseriate, seperately falling	5-7	50	Offwhite
<i>S. krascheninnikovii</i>	Barbellate, uniseriate, seperately falling	3	-	Offwhite
<i>S. nudicaulis</i>	Barbellate, uniseriate, seperately falling	4-5	40-50	Offwhite
<i>S. paulsenii</i>	Barbellate, biseriate, seperately falling	9-10	c.100	White
<i>S. royaleanus</i>	Barbellate, uniseriate, seperately falling	4-4.5	c.100	White
<i>S. tibeticus</i>	Scabrid-barbellate, uniseriate, seperately falling	4-6	c.60	White
<i>S. vulgaris</i>	Scabrid, uniseriate, seperately falling, caducous, flexuous	-	-	-
<i>Synotis rufinervis</i>	Barbellate, uniseriate, seperately falling	4-6	50	White
<i>Tussilago farfara</i>	Disc floret; Scabrid, uniseriate, seperately falling	Disc floret; 3-3.5	Disc floret; 35	Disc floret; White
	Ray floret; Scabrid, uniseriate, seperately falling	Ray floret; 3-3.5	Ray floret; 35	Ray floret; White

Table 1. (Cont'd.).

Name of Taxa	Carpopodium			
	Shape	Position	Diameter of carpopodium (µm)	Diameter of foramen of carpopodium (µm)
<i>Cremanthodium arnicoides</i>	Broad angular ring	Basal	381	252
<i>C. decaisnei</i>	Broad angular ring	Basal	282	202
<i>C. ellisii</i>	Broad angular ring	Basal	258	191
<i>Doronicum falconeri</i>	Undeveloped	-	-	-
<i>D. kamaonense</i>	Disc floret; Narrow angular ring Ray floret; Undeveloped	Disc floret; Sub-basal	Disc floret; 501	Disc floret; 342
<i>Hertia intermedia</i>	Disc floret; Narrow circular ring Ray floret; Narrow circular ring	Disc floret; Sub-basal Ray floret; Sub-basal	Disc floret; 476 Ray floret; 512	Disc floret; 275 Ray floret; 375
<i>Ligularia fischeri</i>	Narrow angular ring	basal	370	314
<i>L. jacquemontiana</i>	Broad angular ring	Basal-sub-basal	465	247
<i>L. sibirica</i>	Narrow angular ring	Basal	377	349
<i>L. thomsonii</i>	Undeveloped	-	-	-
<i>Parasenecio levingei</i>	Narrow slightly angular ring	Basal	302	232
<i>Petasites tricholobus</i>	Irregularly developed narrow angular ring	Sub-basal	204	114
<i>Senecio analogus</i>	Narrow angular ring	Basal-sub-basal	190	145
<i>S. dubitabilis</i>	Undeveloped	-	-	-
<i>S. flavus</i>	Narrow circular ring	Basal	239	177
<i>S. glaucus</i>	Undeveloped	-	-	-
<i>S. gracilliflorus</i>	Narrow angular ring	Basal-sub-basal	155	113
<i>S. korshinskyi</i>	Narrow angular ring	Sub-basal	246	220
<i>S. krascheninnikovii</i>	Undeveloped	-	-	-
<i>S. nudicaulis</i>	Broad circular ring	Basal; sub-basal	217	116
<i>S. paulsenii</i>	Narrow angular ring	Basal-sub-basal	724	616
<i>S. royaleanus</i>	Narrow angular ring	Basal	238	181
<i>S. tibeticus</i>	Narrow angular ring	Basal-sub-basal	276	179
<i>S. vulgaris</i>	Undeveloped	-	-	-
<i>Synotis rufinervis</i>	broad circular disc	Basal	199	138
<i>Tussilaga farfara</i>	Disc floret; Undeveloped Ray floret; Undeveloped	-	-	-

***Patasis* Miller:** Cypselas monomorphic, oblong, non-angular, laterally compressed, 2.25x0.3mm, maroonish brown, non-ribbed, glabrous, rugose-ruminate. Pappus uniseriate, bristles barbellate, separately falling, c. 30, 3.5-6mm long, cream-off-white. Carpopodium irregularly developed, narrow angular ring, sub-basal in position, 204 µm in diameter. Foramen of carpopodium 114µm in diameter (Table 1; Fig. 3D-F).

It is represented by single species viz., *P. tricholobus* Franchet.

***Senecio* L.:** Cypselas monomorphic, oblong, oblong-narrow elliptic, oblong-ob lanceolate or narrow elliptic, elliptic, angular or non-angular, laterally compressed or cylindrical, 1-3.25x0.25-0.75mm, greenish golden, light brown, brown, dark brown or maroonish brown, non-ribbed, glabrous, sparsely pubescent or ribbed and sparsely or densely pubescent between the ribs, striate, striate-scalariform, striate-rugose or undulate. Pappus uniseriate or biseriate, bristles capillary to scabrid, scabrid, scabrid-barbellate, barbellate, separately falling, caducous, flexuous, apically barbed or apically not barbed, 40- c.120, 3-10mm long, white or off-white. Carpopodium undeveloped or narrow angular ring, narrow circular ring or broad circular ring, basal to sub-basal in position, 155-724µm in diameter. Foramen of carpopodium 113-616µm in diameter (Table 1; Fig. 3G-R, 4A-R, 5A-F).

It is represented by 12 species viz., *S. analogus* DC., *S. dubitabilis* CJeffrey and Y.L.Chen, *S. flavus* (Decne.) Sch.-Bip., *S. glaucus* L., *S. graciliflorus* DC., *S. korshinskyi* Krasch., *S. krascheninnikovii* Schischk., *S. nudicaulis* Buch.-Ham. ex D.Don, *S. paulsenii* O.Hoffm., *S. royaleanus* DC., *S. tibeticus* Hook.f., *S. vulgaris* L.

Key to the species of *Senecio*

- 1 + Cypselas ribbed7
- Cypselas not ribbed.....2
- 2 + Cypselas angular. Pappus bristles uniseriate, less than 8mm long3
- Cypselas not angular, laterally compressed. Pappus bristles biseriate, 9-10 mm longs..... *Paulsenii*
- 3 + Cypselas glabrous. Carpopodium a narrow angular ring4
- Cypselas sparsely pubescent. Carpopodium a broad angular ring*S. nudicaulis*
- 4 + Cypselas glabrous, striate or striate-scalariform or striate-rugose.....5
- Cypselas glabrous, undulate.....*S. korshinskyi*
- 5 + Cypselas oblong or oblong-ob lanceolate, dark brown.....6
- Cypselas elliptic, light brown.....*S. analogus*
- 6 + Pappus bristles c.100.....*S. royaleanus*
- Pappus bristles c. 607
- 7 + Cypselas surface striate- rugose. Pappus bristles barbellate.....*S. graciliflorus*
- Cypselas surface striate. Pappus bristles scabrid- barbellate.....*S. tibeticus*
- 8 + Cypselas sparsely pubescent between the ribs. Carpopodium undeveloped.....9
- Cypselas densely pubescent between the ribs. Carpopodium developed...*S. flavus*

- 9 + Pappus bristles capillary-scabrid or scabrid10
 - Pappus bristles barbellate*S. krascheninnikovii*
- 10 + Pappus bristles capillary-scabrid,.....*S. glaucus*
 - Pappus bristles scabrid.....*S. vulgaris, S. dubitabilis*

Synotis (C.B. Clarke) C. Jeffrey & Y.L. Chen: Cypselas monomorphic, oblong, angular, 1x0.2mm, maroonish brown, not ribbed, glabrous, striate-lineate. Pappus uniseriate, bristles barbellate, separately falling, 50, 4-6mm long, white. Carpodium broad circular disc, basal in position, 199 µm in diameter. Foramen of Carpodium 138 µm in diameter (Table 1; Fig. 5G-I).

It is represented by single species viz., *S. rufinervis* (DC.) C. Jeffrey & Y.L. Chen.

Tussilago L: Cypselas dimorphic oblong-ob lanceolate or ob lanceolate, not angular, laterally compressed, 1x0.1-0.2mm, light or dark brown, non-ribbed, glabrous, rugose-striate. Pappus uniseriate, bristles scabrid, separately falling, 35, 3-3.5mm long, white. Carpodium undeveloped (Table 1; Fig. 5J-O).

It is represented by single species viz., *T. farfara* L.

Results and Discussion

Most of the tribes of the family Asteraceae have quite similar cypselas features (Abid & Qaiser, 2007, 2008, 2009) with the exception of Helianthae, Eupatorieae and Inuleae where cypselas epidermis are found very useful for tribal delimitation (Bremer, 1994; Breitwieser & Ward, 2005). Similarly the tribe Senecioneae has no exclusive cypselas features but they are found quite rewarding for taxonomic delimitation as all the genera could be grouped by having monomorphic and dimorphic cypselas except to the genus *Doronicum* which falls in both the groups. The group of taxa having dimorphic cypselas includes *Doronicum*, *Hertia* and *Tussilago*. Among these three genera *Hertia* can easily be distinguished from rest of the two genera by having comparatively larger cypselas with villous hairs and bi-multiseriate pappus bristles. While in the remaining two genera cypselas are smaller in size with glabrous surface and uniseriate pappus bristles. These two genera can be further distinguished from each other, as in *Doronicum* cypselas have ruminately colliculate surface while in *Tussilago* cypselas have rugose-striate surface.

The second group of taxa with monomorphic cypselas includes *Cremanthodium*, *Doronicum* (p.p.), *Ligularia*, *Parasenecio*, *Petasites*, *Senecio* and *Synotis*. All the above genera can be further separated into two groups i.e. cypselas ribbed or not ribbed, except that of the genus *Senecio* which falls in both groups. Ribbed cypselas are found in *Doronicum* and *Senecio* (p.p.), but both these genera can be distinguished by having entirely glabrous cypselas in *Doronicum*, while the cypselas of *Senecio* are pubescent between the ribs. Within the group of non-ribbed cypselas *Ligularia* and *Synotis* are further grouped by having striate-lineate surface pattern, while the remaining genera do not have such surface patterns. However, the above two genera *Ligularia* and *Synotis* still remain distinct by having non-angular and laterally compressed cypselas in *Ligularia*, whereas *Synotis* is characterized by having angular cypselas. Furthermore, the genus *Senecio* is distinguished from rest of the non-ribbed genera by having elliptic

cypsela, while in rest of the genera cypselas are oblong or oblong-narrow elliptic. All these genera could also be separated as the genus *Petasites* is characterized by having non-angular laterally compressed cypsela with rugose-ruminate surface pattern, while in rest of the genera cypselas are angular. Among them, *Cremanthodium* remains distinct by having broad angular carpodium and barbellate bristles in contrast to that of *Parasenecio* where narrow angular carpodium and scabrid bristles were observed.

Similar to the generic delimitation, cypsela features could also be used for specific delimitation within the genus *Cremanthodium*, *C. arnicoides* is characterized by having offwhite bristles and striate surface pattern. While in rest of the two species bristles are white and surface is striate-scalariform but both the species remain distinct by having oblong and oblong-narrow elliptic cypselas in *C. decaisnei* and *C. ellisii* respectively. Similarly the species of *Ligularia*, *L. Jacquemontiana* remain distinct by having comparatively larger and oblanceolate cypselas with scabrid pappus bristles. While in rest of the three species oblong cypselas and barbellate pappus bristles are found from which *L. thomsonii* is characterized by having 4-5mm long pappus bristles and undeveloped carpodium. However, the two species *L. sibirica* and *L. fischeri* are grouped by having 8-10 mm long pappus bristles with narrow angular ring like carpodium. Both the species could not be further distinguished as they share common cypsela characters.

The species of the genus *Senecio* can be grouped on the basis of ribbed or non-ribbed cypselas. Amongst the species with non-ribbed cypselas, *S. paulsenii* is characterized by having non-angular laterally compressed cypsela with biseriate pappus bristles. While in remaining species cypselas are angular with uniseriate pappus bristles, from the group of these species *S. nudicaulis* is the only one where the cypselas are pubescent with a broad circular ring like carpodium and remaining ones have glabrous cypselas with narrow angular carpodium. Amongst the members of such group, *S. korshinskyi* remains distinct by having undulate surface pattern and the rest of the species have striate or striate-scalariform or striate-rugose surface patterns. Within this group of species *S. analogus* is characterized due to the presence of elliptic cypsela and in the remaining species viz., *S. royaleanus* and *S. graciliflorus* and *S. tibeticus* cypselas are oblong or oblong-oblanceolate, among them *S. royaleanus* may be further distinguished by having c.100 pappus bristles while, the remaining two species are grouped together due to the presence of c. 60 pappus bristles but they still remain distinct by having striate-rugose surface in *S. graciliflorus* while, *S. tibeticus* is characterized by having striate surface pattern. Among the species of another group, having ribbed cypselas, *S. flavus* remains distinct due to the presence of well developed carpodium. While in rest of the species cypselas are without carpodium. But still they can be separated by having barbellate bristles in *S. krascheninnikovii* while capillary to scabrid bristles with barbed apex are found in *S. glaucus*. However, the two remaining species *S. vulgaris* and *S. dubitabilis* are grouped together due to the presence of entirely scabrid pappus bristles, and these two species could not be further separated as they do not have any specific cypsela characters. Therefore the cypsela morphology provides additional micromorphological characters for the delimitation of various taxa both at the generic and specific levels in the tribe Senecioneae.

Acknowledgement

We are grateful to the Directors and Curators of the herbaria, BM, K, KUH, RAW for providing the material on loan. Special thanks are also for Director, Karachi University Herbarium for providing the facilities of Scanning Electron Microscopy.

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