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SEM-characterisation of achene morphology towards the taxonomy of Indian species of *Saussurea* DC. (Asteraceae)

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Abstract

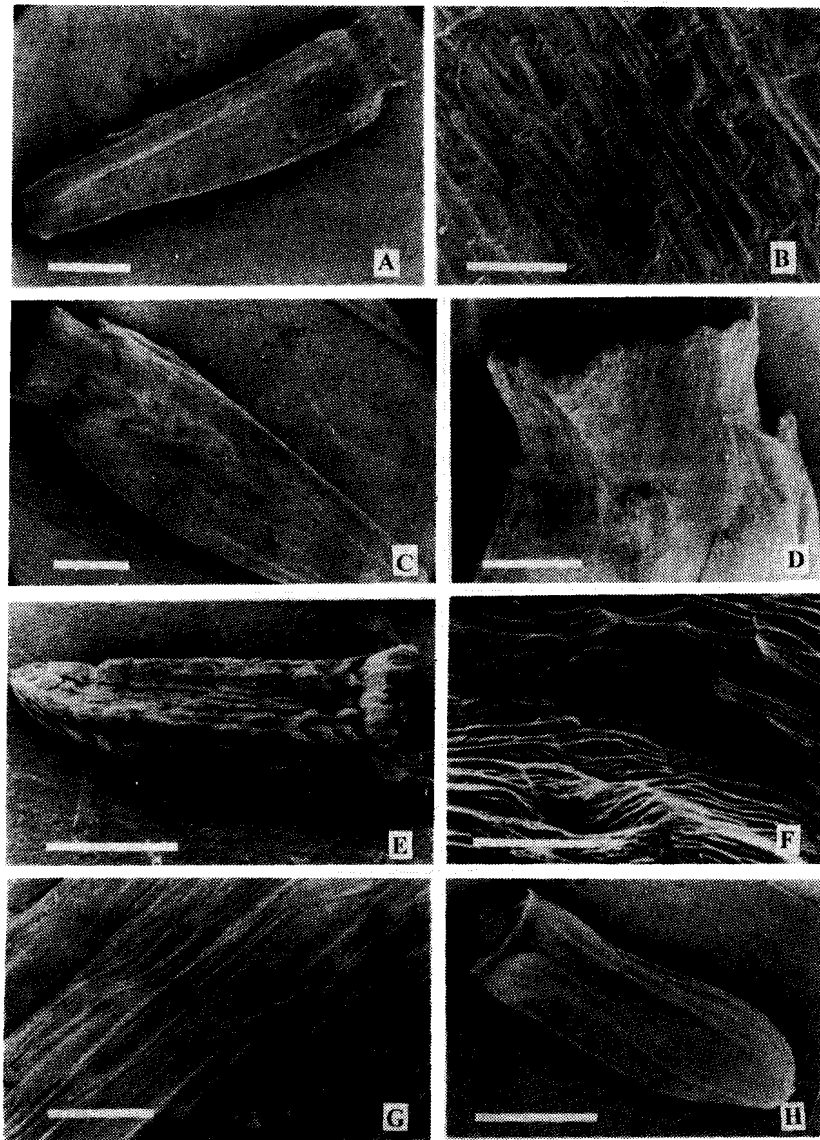
The paper deals with SEM-characterisation of achenes of 23 species of *Saussurea* DC. in India. The micromorphological characters of achenes are highly useful in the identification of different species of the genus. A key for identification of 23 species of *Saussurea* based on achene characters is provided.

INTRODUCTION

The genus *Saussurea* DC. comprises about 300 species in the world (Bremer, 1994) and about 61 species in India (Hajra, 1988, 1995). The genus is chiefly distributed in temperate Asia, with one species each in Europe, Australia and North and West America. *Saussurea* DC. is characterised by spineless leaf margins; usually purple or bluish flower heads with only disk florets; spineless multiseriate involucre bracts; receptacle with bristly scales; usually bi-seriate pappus, the outer usually of rigid bristles and the inner longer plumose with their bases fused in a ring.

The identification of some species of the genus is problematic due to their morphological plasticity. The distinction between the various *Saussurea* species is normally based on macromorphological parameters like habit and size of plants, size and shape of leaves and capitula, and the nature of phyllaries (Clarke, 1876; Hooker, 1881; Lipschitz, 1979; Hajra, 1988).

Many workers (Martin & Barkley, 1961; Dittrich, 1966, 1968, 1970; Kynclova-Petrocyova, 1970; Borgen, 1972; Singh *et al.*, 1972; Rajashekhara & Razi, 1976-77; Wagenitz, 1976; Chaudhary & Pandey, 1995) have considered the achene characters for segregation of species. According to Kynclova-Petrocyova (1970) the general shape of the achenes, the presence or absence of wings, carinae, ribs and border, and the colour are all reliable and stable distinguishing characters. Dittrich (1968) while examining the morphological characters of achenes of subtribe *Cardueae* - *Centaureinae* found the shape of the hilum, detachment of the

A. Saklani *et al.*Fig. 1. Scanning electron micrographs of achenes of *Saussurea*

Achene morphology of *Saussurea* DC.

fruits, presence of the epicarp and also the hairiness of the fruit as important characters for the identification of genera. Dittrich (1970) also investigated the fruits of 17 genera including *Saussurea* belonging to subtribe *Cardueae-Carduinae* and gave a key to the genera based on the fruit characters. Dittrich (1970) accepted that *Saussurea* stands apart in several important features and is taxonomically isolated from the other genera.

The present study deals with the morphology of the achenes of 23 species of *Saussurea* under the light as well as Scanning Electron Microscope with a view to explore more characters of individual taxa and to assess and establish the taxonomic significance of them. The characters such as the base, the surface and the apex of achenes were found useful in differentiating the species and as such a key to all species studied established. The pappus bristles do not exhibit much variations among different species except *S. yakla* (Fig. 7, A), *S. simpsoniana* (Fig. 7, B), *S. albescens* (Fig. 7, C) and therefore, have not been discussed.

MATERIALS AND METHODS

Achenes of 23 species of *Saussurea* gathered afresh from the field as well as from the herbarium specimens have been examined under the light microscope and Scanning Electron Microscope (SEM). For SEM studies, the dry cleaned matured achenes were gold coated with SCD sputter coater and finally observations were carried out with a Phillips SEM XL20 at 15-20 KV and photographs were taken. For each species at least 4-5 achenes from different populations were scanned but photographs were taken only of the specimens cited under each species. Herbarium acronyms used are those given by Holmgren *et al.* (1990).

OBSERVATIONS

Saussurea abnormis Lipsch. (Fig. 1, A&B)

Achenes 5.0 x 1.2 mm, narrowly obovate, contracted at apex, apex truncate, hilum basal, surface reticulate.

Specimen examined: Uttar Pradesh, Chamoli Garhwal, opposite Niti village, 3800 m, *Naithani 56137* (BSD).

Saussurea albescens (DC.) Sch.-Bip. (Fig. 1, C&D)

Achenes 6.4 x 2.0 mm, narrowly obovate, straight, apex truncate and wavy, some irregular spiny structures below the apex (neck portion), hilum basal, surface rugose/muricate.

Explanation to Fig.1. A & B. *S. abnormis*: A. Achene, B. Surface of achene; C & D. *S. albescens*: C. Achene, D. Apical portion of the achene; E & F. *S. auriculata*: E. Achene, F. Surface of achene; G. *S. bracteata*: surface of achene; H. *S. candolleana*: Achene (Scale bars: A, C, E & H = 1 mm; B & G = 50 μ m; F = 20 μ m).

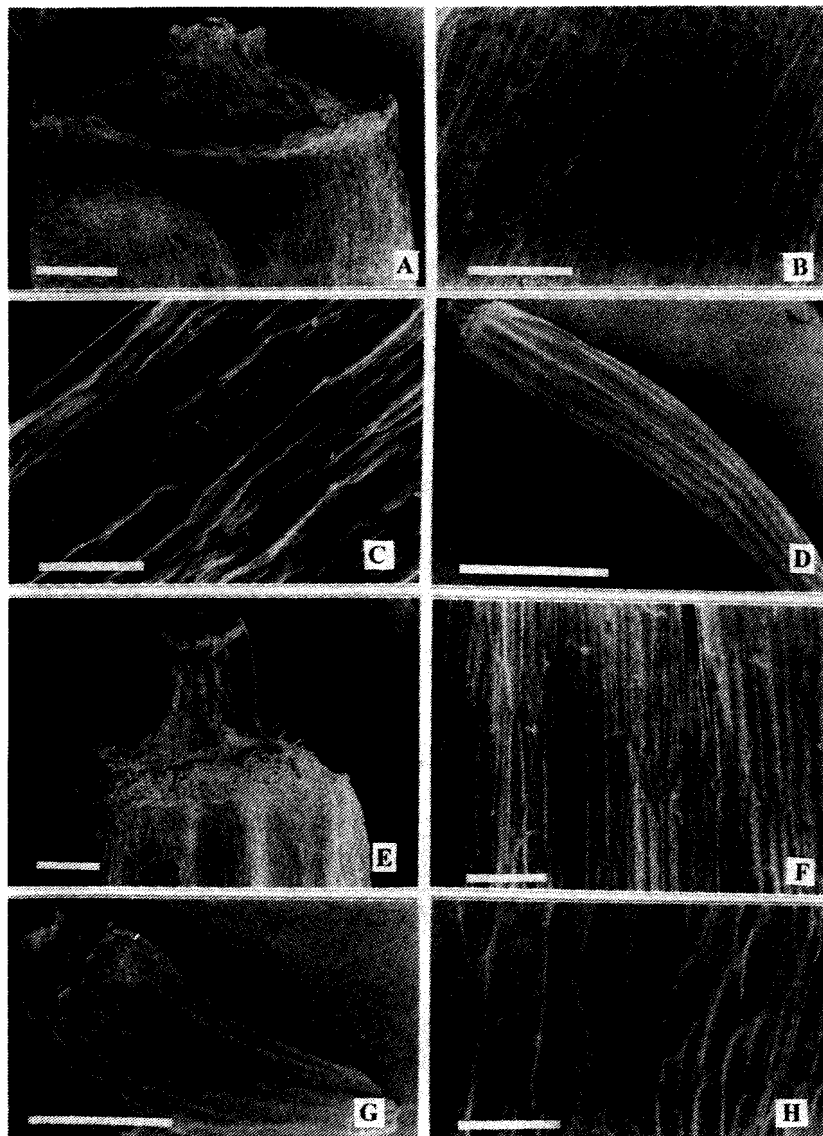
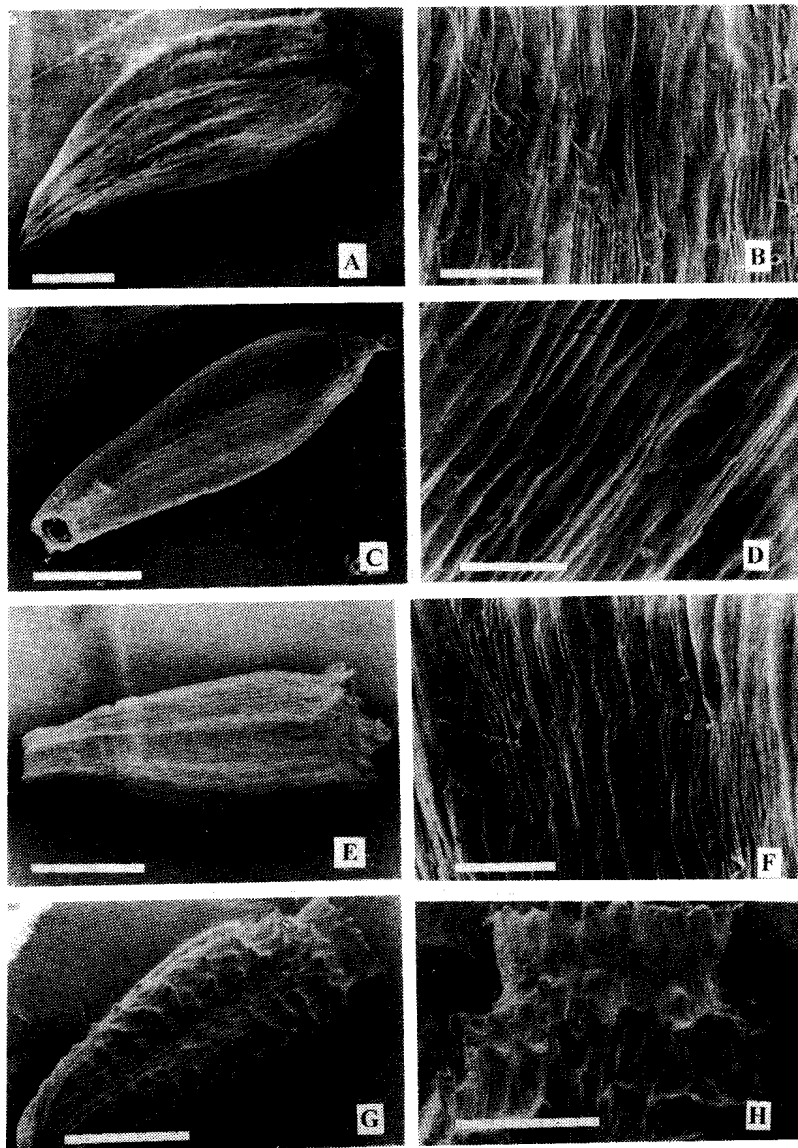
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Fig. 2. Scanning electron micrographs of achenes of *Saussurea*

A. Saklani *et al.*Fig. 3. Scanning electron micrographs of achenes of *Saussurea*

Achene morphology of *Saussurea* DC.

Specimen examined: Himachal Pradesh, Bashahr, Sarahan chaur road, Raizada 19800 (DD).

Saussurea auriculata (Spreng. ex DC.) Sch.-Bip. (Fig. 1, E&F)

Achenes 3.6 x 1.0 mm, 4-angled, narrowly obovate, straight, lacinate at apex, hilum lateral, surface sparsely spiny at lower magnification, ridged at higher magnification.

Specimen examined: Uttar Pradesh, Uttar Kashi, on way to Harkidun, 3000 m, Rana & Saklani 210142 (LWG).

Saussurea bracteata Decne. (Fig. 1, G)

Achenes 4.5 x 1.0 mm, narrowly obovate, slightly curved, apex truncate, hilum sub-lateral, surface striate.

Specimen examined: Uttar Pradesh, Kumaon, Dhauli valley, Duthie 3038 (DD).

Saussurea candolleana Wall. ex DC. (Figs. 1, H; 2, A & B)

Achenes 2.5 x 1.0 mm, 4-5-angled, oblong, straight, slightly contracted in middle, apex truncate, hilum basal, surface faintly rugose.

Specimen examined: Uttar Pradesh, Kumaon, Pindari, 3500-5000 m, Rao 4581 (BSD).

Saussurea costus (Falc.) Lipsch. (Fig. 2, C)

Achenes 8.5-11.0 x 2.5-4.0 mm, obovate, straight, apex truncate, hilum basal, surface striate.

Specimen examined: Uttar Pradesh, Uttarkashi, Barsu, 2500 m, Saklani 216699 (LWG).

Saussurea fastuosa (Decne.) Sch.-Bip. (Fig. 2, D&F)

Achenes 6.4 x 1.3 mm, oblong, slightly curved, apex truncate with a club-shaped beak, hilum basal, surface striate.

Specimen examined: Uttar Pradesh, Chamoli Garhwal, Valley of flowers, 3500 m, Rao 31743 (BSD).

Explanation to Fig. 2. A & B. *S. candolleana*: A. Apical portion of achene, B. Surface of achene; C. *S. costus*: Surface of achene; D, E & F. *S. fastuosa*: D. Achene, E. Apical portion of the achene, F. Surface of achene; G & H. *S. glacialis*: G. Achene, H. Surface of achene (Scale bars: A & E = 200 μ m; B, C, F & H = 50 μ m; D = 2 mm; G = 1 mm).

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Saussurea glacialis Herd. (Fig. 2, G&H)

Achenes 3.0 x 1.1 mm, oblong, slightly curved, apex like a pitcher head, hilum lateral, surface reticulate.

Specimen examined: Jammu & Kashmir, Ladakh, Thang Lang La, 5200 m, *Bhattacharyya* 41036 (BSD).

Saussurea glanduligera Sch.-Bip. ex Hook. f. (Fig. 3, A&B)

Achenes 5.1 x 2.0 mm, 4-angled, obovate, slightly curved towards base, apex slightly concave, collar present, hilum sub-lateral, surface reticulate.

Specimen examined: Himachal Pradesh, Spiti, Gyundi Nala, 3900 m, *Bhattacharyya* 49377 (BSD).

Saussurea gnaphalodes (Royle ex DC.) Sch.-Bip. (Fig. 3, C&D)

Achenes 3.8 x 1.2 mm, 5-angled, narrowly obovate, straight, apex obtuse, hilum lateral, surface ribbed.

Specimen examined: Jammu & Kashmir, Ladakh, Thang Lang La, 5000 m, *Bhattacharyya* 41031 (BSD).

Saussurea graminifolia Wall. ex DC. (Fig. 3, E&F)

Achenes 3.3 x 1.3 mm, obovate, straight, apex obtuse, irregularly wavy ring at the base of apex, hilum basal, surface rugose.

Specimen examined: Uttar Pradesh, Pindari, Furkia, 3500-5000 m, *Rao* 4512 (BSD).

Saussurea heteromalla (D. Don) Hand.-Mazz. (Fig. 3, G&H; 4, A)

Achenes 3.3 x 1.1 mm, 4-5-angled, obovate, straight, apex truncate and spiny, hilum lateral, surface muricate.

Specimen examined: Uttar Pradesh, Uttarkashi, Sankari, 1800 m, *Rana & Party*, 219718 (LWG).

Explanation to Fig. 3. A. & B. *S. glanduligera*: A. Achene, B. Surface of achene; C & D. *S. gnaphalodes*: C. Achene, D. Surface of achene; E & F. *S. graminifolia*: E. Achene, F. Surface of achene; G & H. *S. heteromalla*: G. Achene, H. Surface of achene. (Scale bars: A, C, E & G = 1 mm; B, D & F = 50 μ m; H = 500 μ m).

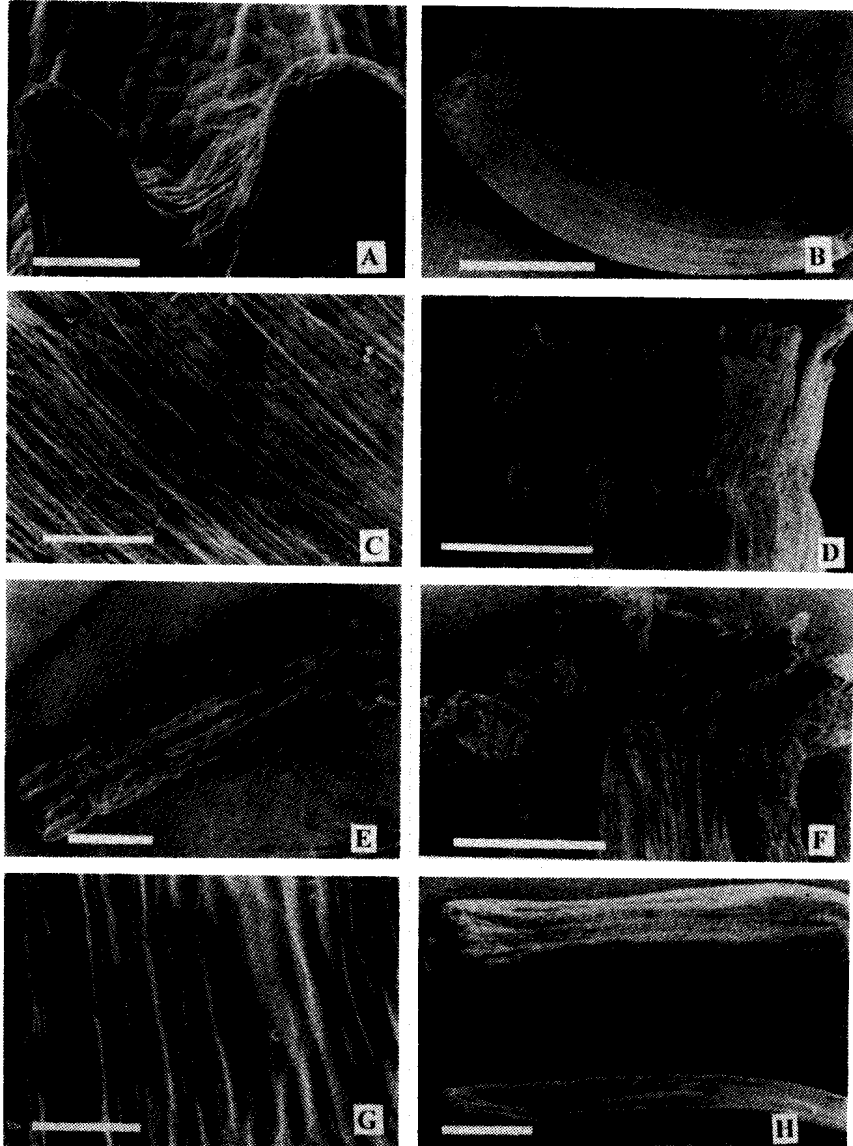
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Fig. 4. Scanning electron micrographs of achenes of *Saussurea*

Achene morphology of *Saussurea* DC.

***Saussurea hookeri* C. B. Clarke (Fig. 4, B&C)**

Achenes 3.5 x 1.0 mm, almost oblong, slightly curved and narrow towards the base, apex truncate, hilum basal, surface striate.

Specimen examined: Sikkim, Lachung, G. A. Gammie s. n. (DD).

***Saussurea jacea* (Klotzsch) C. B. Clarke (Fig. 4, D)**

Achenes 8.0 x 1.5 mm, oblong, straight, apex truncate, hilum basal, surface ridged under light microscope.

Specimen examined: Jammu & Kashmir, Ladakh, Dras, 2700 m, *Bhattacharyya 41198* (BSD).

***Saussurea leontodontoides* (DC.) Sch.-Bip. (Fig. 4, E,F&G)**

Achenes 5.0 x 1.3 mm, more or less oblong, straight, apex obtuse with some irregular structure, hilum basal, surface muricate in lower half at low magnification, striate at higher magnification.

Specimen examined: Uttar Pradesh, Chamoli Garhwal, Amritganga valley, 3000 m, *Naithani 37981* (BSD).

***Saussurea obvallata* (DC.) Edgew. (Fig. 4, H & 5, A)**

Achenes 5.2 x 1.0 mm, oblong, straight, sometimes contracted in middle, apex truncate, hilum basal, surface reticulate.

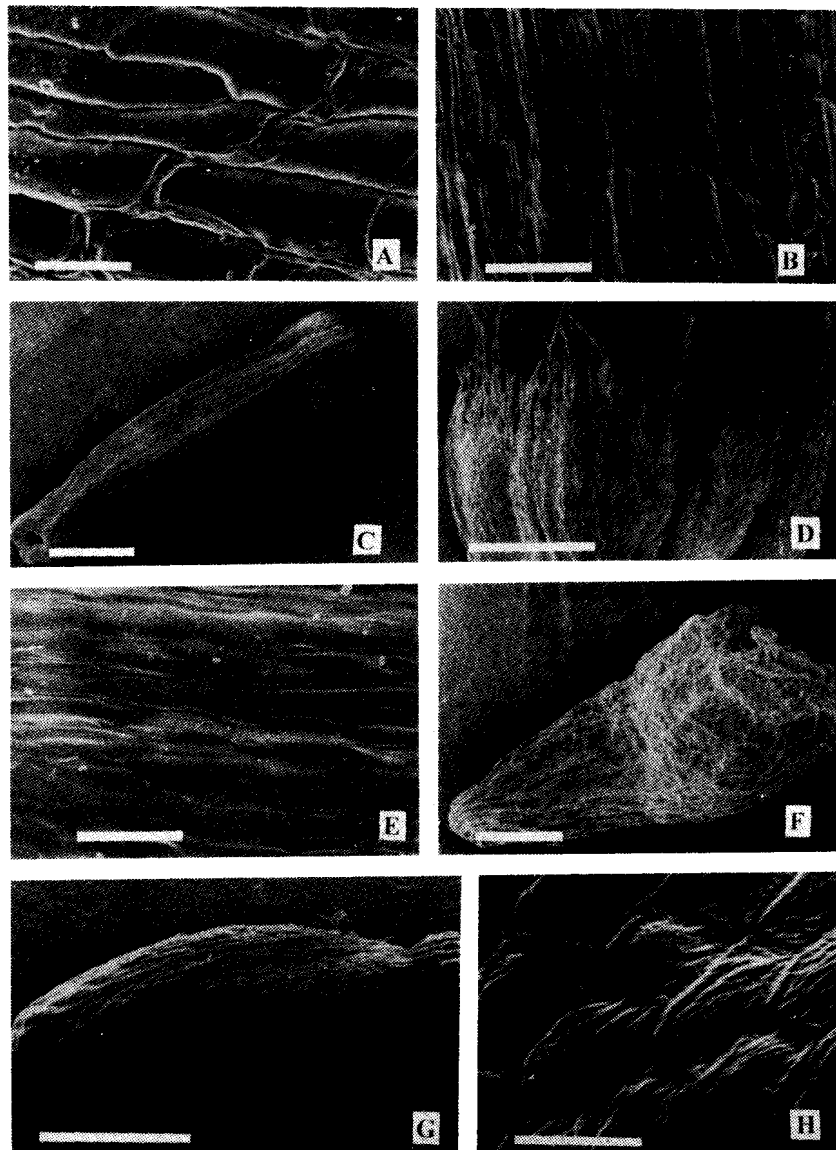
Specimen examined: Uttar Pradesh, Chamoli Garhwal, Hemkund, 4200 m, *Bhattacharyya 24489* (BSD).

***Saussurea piptathera* Edgew. (Fig. 5, B)**

Achenes 5.0 x 1.3 mm, oblong, straight, apex sub-truncate, hilum lateral, surface ridged.

Specimen examined: Himachal Pradesh, Lahul, Koksar, 3425 m, *Bhattacharyya 17029* (BSD).

Explanation to Fig. 4. A. *S. heteromalla*: Surface of achene; B & C. *S. hookeri*: B. Achene, C. Surface of achene; D. *S. jacea*: Apical portion of achene; E, F & G. *S. leontodontoides*: E. Achene, F. Apical portion of achene, G. Surface of achene; H. *S. obvallata*: Achene (Scale bars: A, C & G = 50 μ m; B, E & H = 1 mm; D & F = 500 μ m).

A. Saklani *et al.*Fig. 5. Scanning electron micrographs of achenes of *Saussurea*

Achene morphology of *Saussurea* DC.

***Saussurea roylei* (DC.) Sch.- Bip. (Fig. 5, C,D&E)**

Achenes 5.0 x 1.3 mm, narrowly obovate, straight, apex lacinate, hilum sub-lateral, surface faintly reticulate.

Specimen examined: Uttar Pradesh, Uttarkashi, Bhojwasa, 3700 m, *Bhattacharyya 74761* (BSD).

***Saussurea simpsoniana* (Field. & Gard.) Lipsch. (Fig. 5,F)**

Achenes 2.5 x 1.1 mm, 4-5-angled, obovate, straight, apex rounded, hilum sub-lateral, surface rugose.

Specimen examined: Uttar Pradesh, Chamoli Garhwal, Hemkund, 4200 m, *Rao 31771* (BSD).

***Saussurea stracheyana* (Kuntze) Lipsch. (Fig. 5, G&H)**

Achenes 3.3 x 0.7 mm, 4-5-angled, oblong, slightly curved, apex truncate, contracted at neck, hilum lateral, surface faintly reticulate.

Specimen examined: Uttar Pradesh, Uttarkashi, on way to Harkidun, 2460 m, *Rana & Saklani 210137* (LWG).

***Saussurea taraxicifolia* Wall. ex Sch.-Bip. (Fig. 6, A&B)**

Achenes 4.5 x 0.8 mm, obovate, straight, apex truncate with papillose structure, hilum basal, surface rugose.

Specimen examined: Uttar Pradesh, Chamoli Garhwal, Keal Bhairawn, 3600 m, *Kapoor & Party 70579* (LWG).

***Saussurea uniflora* (DC.) Wall. ex Sch.-Bip. (Fig. 6, C&D)**

Achenes 4.2 x 1.0 mm, oblong, slightly curved, apex obtuse, hilum basal and surface ribbed.

Specimen examined: Sikkim, Lachung, *Gammie s. n.*, (DD).

Explanation to Fig. 5. A. *S. obvallata*: Surface of achene; B. *S. piptathera*: Surface of achene; C, D & E. *S. roylei*: C. Achene, D. Apical portion of the achene, E. Surface of achene; F. *S. simpsoniana*: Achene; G & H. *S. stracheyana*: G. Achene, H. Surface of achene (Scale bars: A & H = 20 μ m; B & E = 50 μ m; C, F & G = 1 mm; D = 500 μ m).

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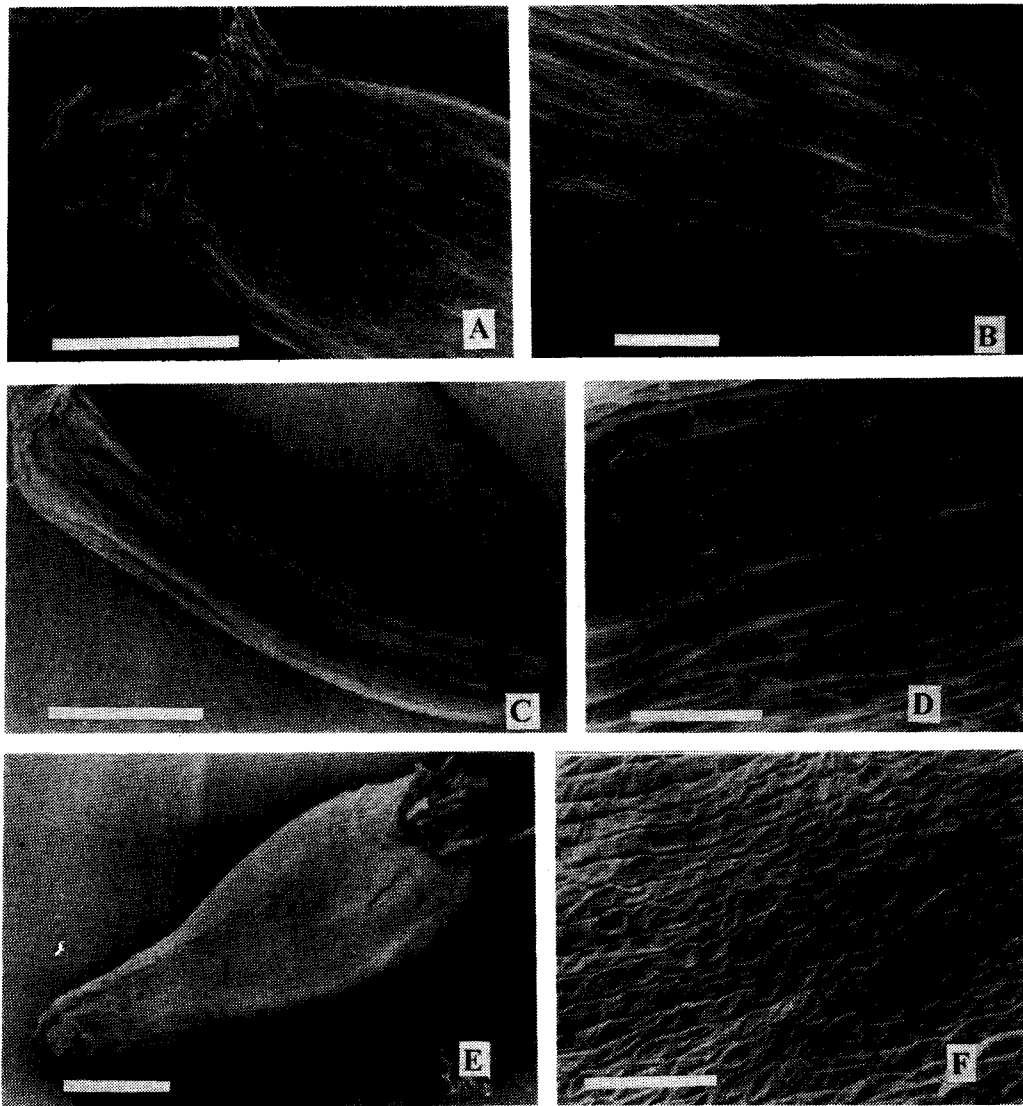


Fig. 6. Scanning electron micrographs of achenes of *Saussurea*. A & B. *S. taraxifolia*: A. Apical portion of the achene; B. Basal portion of the achene; C & D. *S. uniflora*: C. Achene, D. Surface of the achene; E & F. *S. yakla*: E. Achene, F. Surface of achene (Scale bars: A = 500 µm; B = 200 µm; C & E = 1 mm; D & F = 50 µm).

Achene morphology of *Saussurea* DC.

Saussurea yakla C. B. Clarke (Fig. 6, E&F)

Achenes 7.7 x 2.0 mm, obovate (spatulate), almost straight, apex concave, hilum basal, surface beaded, cells faint, rectangular and arranged in linear rows.

Specimen examined: South East Lhasa, *Chapman 113* (DD).

DISCUSSION AND CONCLUSIONS

The morphological characters such as the shape of the achene, the areole, the apex and surface of achenes are usually stable and reliable and hence they are taken into consideration for taxonomic treatment. Based on achene characters a key for the identification of 23 species of *Saussurea* is provided.

The size of achenes is not a reliable distinguishing character in most of the cases, however, in some species like *A. graminifolia*, *S. yakla*, *S. abnormis*, *S. costus* and *S. jacea*, it can be used as a key character. The length and width ratio of achenes is usually 3:1 to 4:1, but in *S. simpsoniana* and *S. jacea* it ranges from 2:1 to 5:1 respectively.

In most species, the achenes are obovate, narrowly obovate or oblong. Commonly the achenes are straight or sometimes slightly curved (*S. glacialis* and *S. hookeri*).

Among the species investigated, the hilum is basal in as many as 13 species, while in *S. glanduligera*, *S. bracteata*, *S. roylei* and *S. simpsoniana* it is sub-lateral, and in the species like *S. auriculata*, *S. glacialis*, *S. gnaphalodes*, *S. heteromalla*, *S. piptathera* and *S. stracheyana* the hilum is lateral.

The apex of achenes is usually truncate or obtuse, or sometimes concave as in *S. glanduligera* and *S. yakla*. In a few species such as *S. albescens*, *S. auriculata*, *S. heteromalla*, *S. neglecta* and *S. roylei* the apex is like a cup and the pappus arises inside the cavity. In certain species the margins of cup become lacinate (*S. roylei*), wavy (*S. albescens*), spiny (*S. heteromalla*) or divaricate (*S. leontodontoides*). In *S. taraxicifolia* the apex has some papillose structure. In *S. glacialis* pitcher's head like structure is formed at the apex while in *S. fastuosa* the apex is protruded into a beak-like structure.

At lower magnification the surface of achenes in most of the species is rugose, striate or smooth. In *S. heteromalla* the surface is muricated while it is tubercled in *S. auriculata*. The lower half of the achenes in case of *S. leontodontoides* has ornamentations while the upper portion is almost striate. At higher magnification (above 500 x) under SEM many patterns on the surface such as reticulate, rugose, striate and ribbed are commonly observed. Sometimes the surface is ridged (*S. auriculata* and *S. piptathera*), muricate (*S. heteromalla*) or beaded (*S. yakla*).

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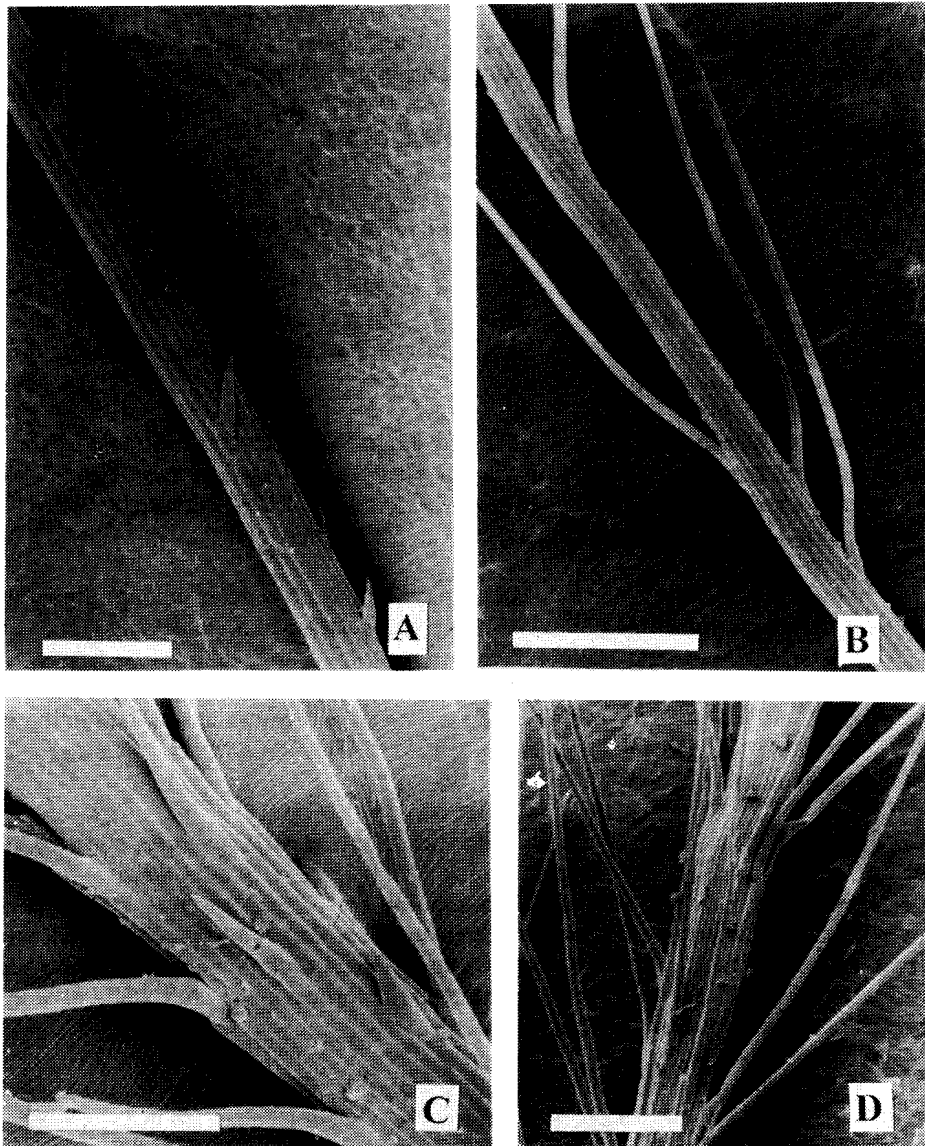


Fig. 7. Scanning electron micrographs of of pappus bristles in *Saussurea*. A. *S. yakla*; B. *S. simpsoniana*; C. *S. albescens*; D. *S. obvallata* (Scale bars: A, B & D = 200 μm ; C = 100 μm).

Achene morphology of *Saussurea* DC.

In most of the species of *Saussurea* studied, the pappus are plumose (feathery). The secondary pappus hairs on the inner pappus bristles are long and distributed throughout the surface. The surface of bristles is striate in all species investigated. However, at least 4 types of inner pappus bristles are found in the species investigated - (a) bristles with minute and sparsely distributed secondary pappus hairs throughout the surface (*S. yakla*, Fig. 7, A) (b) bristles with only a few long, secondary pappus hairs, that too sparsely distributed on their margins only (*S. simpsoniana*, Fig. 7, B), (c) bristles with longer and a few minute secondary pappus hairs sparsely distributed on the bristle surface (*S. albescens*, Fig. 7, C), and (d) the bristles with long feathery secondary pappus hairs, common in rest of the species (Fig. 7, D).

Key to the species based on achene morphology

- | | | |
|-----|--|-------------------------|
| 1a. | Surface of achenes spiny | 2 |
| 1b. | Surface of achenes not spiny | 3 |
| 2a. | Achenes lacinate at apex | S. auriculata |
| 2b. | Achenes wavy (spiny) at apex | S. heteromalla |
| 3a. | Hilum of achenes basal | 4 |
| 3b. | Hilum of achenes lateral or sub-lateral | 16 |
| 4a. | Achenes narrowly obovate to obovate | 5 |
| 4b. | Achenes oblong | 10 |
| 5a. | Apex of achenes obtuse to concave | 6 |
| 5b. | Apex of achenes truncate | 7 |
| 6a. | Achenes 3.3 x 1.3 mm, obtuse with irregular wavy ring at apex, surface rugose | S. graminifolia |
| 6b. | Achenes 7.7 x 2.0 mm, concave at apex, surface beaded | S. yakla |
| 7a. | Surface of achenes rugose | 8 |
| 7b. | Surface of achenes reticulate or smooth | 9 |
| 8a. | Apex of achenes wavy with some irregular spiny structure around the neck | S. albescens |
| 8b. | Apex of achenes papillose | S. taraxicifolia |
| 9a. | Achenes 5.0 x 1.2 mm, narrowly obovate, contracted at apex, surface reticulate | S. abnormis |
| 9b. | Achenes 8.5-11.0 x 2.5-4.0 mm, obovate, surface smooth and black spotted | S. costus |

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10a.	Achenes with club-shaped beak	S. fastuosa
10b.	Achenes with obtuse or truncate apex	11
11a.	Apex of achenes obtuse	12
11b.	Apex of achenes truncate	13
12a.	Achenes oblong, straight, surface muricate to striate in lower half ...	S. leontodontoides
12b.	Achenes oblong, slightly curved, surface ribbed	S. uniflora
13a.	Surface of achenes ridged	S. jacea
13b.	Surface of achenes almost smooth	14
14a.	Achenes reticulate	S. obvallata
14b.	Achenes striate or faintly rugose	15
15a.	Achenes 4-5-angled, surface faintly rugose	S. candolleana
15b.	Achenes almost terete, slightly curved, surface striate	S. hookeri
16a.	Apex of achenes pitcher head like	S. glacialis
16b.	Apex of achenes otherwise	17
17a.	Achenes lacinate at apex	S. roylei
17b.	Achenes obtuse, rounded, subtruncate or concave at apex	18
18a.	Apex of achenes obtuse or rounded	19
18b.	Apex of achenes sub-truncate, truncate, or slightly concave	20
19a.	Achenes with obtuse, lateral hilum, surface ribbed	S. gnaphalodes
19b.	Achenes with round apex, sub-lateral hilum, rugose surface	S. simpsoniana
20a.	Apex of achenes slightly concave, with a distinct collar	S. glanduligera
20b.	Apex of achenes truncate or sub- truncate, collar absent	21
21a.	Achenes 4-angled, contracted at neck, surface faintly reticulate	S. stracheyana
21b.	Achenes almost terete, surface striate or ridged	22
22a.	Surface of achenes striate, hilum sub-lateral	S. bracteata
22b.	Surface of achenes ridged, hilum lateral	S. piptathera

Achene morphology of *Saussurea* DC.

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