*Pak. J. Bot.*, 54(6): 2219-2231, 2022. DOI: http://dx.doi.org/10.30848/PJB2022-6(43)

# CYPSELA MORPHOLOGY AND ITS TAXONOMIC SIGNIFICANCE WITHIN THE GENUS *SCORZONERA* L. (CICHOREAE-ASTERACEAE) FROM PAKISTAN AND KASHMIR

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**Abstract**

Morphological characters of cypsela for 17 species of the genus *Scorzonera* L. were examined from Pakistan and Kashmir to assess their taxonomic significance. Macro and micro morphological characters of cypsela, pappus and carpopodium were studied by light and scanning electron microscopy. The genus showed considerable variations in the morphological characters of cypsela. However, linear shape was found to be dominant and ribbed surface was prevalent within the genus. Pappi were found in one or two series. Carpopodium was basal or sub basal with the variety of shapes. The data obtained was also analyzed numerically and found rewarding to strengthen the taxonomic decisions at specific levels.

**Key words:** *Scorzonera*, Asteraceae, Cypsela, Pakistan, Kashmir.

## Introduction

The genus *Scorzonera* L. is considered as polyphyletic (Shi & Kilian, 2011) and one of the largest genera of the tribe Cichoreae (Asteraceae). Cypselas are known for their remarkable features which can be used additionally as well as individually as a taxonomic marker to differentiate various groups of the family Asteraceae (Frangiote-Pallone & de Souza, 2014). Importance of cypsela morphology was highlighted in the family Asteraceae by various taxonomists (Pandey & Singh, 1980; Pandey *et al*., 1983; Puttock, 1994; Martins & Oliveira, 2007; Julio & Oliveira, 2009; Marzinek & Oliveira, 2010; Shamso *et al.*, 2021) and have been used for taxonomic evaluation at various levels (Dittrich, 1968; Kynclova, 1970; Haque and Godward, 1984; Lovell *et al*., 1986; Mateu and Guemes, 1993; Breitwiesser and Ward, 2005; Swelenkomo *et al*., 2007; Kothari *et al*., 2012; Frangiote-Pallone & de Souza, 2014). Similarly, a series on cypsela morphology for various tribes or groups of Asteraceae was published from Pakistan (Abid & Qaiser, 2002; Abid & Zehra, 2007; Abid & Ali, 2010; Abid & Qaiser, 2015). While, cypsela of the tribe Lactuceae were studied by various workers, such as Das and Mukherji (2008) examined cypsela diversity of 7 species distributed in 5 genera viz., *Hieracium* L., *Koelpinia* Pall., *Hedypnois* Mill., *Agoseris* Ret', and *Leontodon* L. Similarly, Dasgupta & Mukherji (2007) utilized cypsela morphology as a taxonomic marker in 8 species viz., *Crepis alpina* L., *C. aspera* L., *C. dioscoroides* L., *C. foetida* L., *Hieracium laevigatum* Willd., *Leontodon autumnalis* L., *Sonchus oleraceus* L., *Taraxacum laevigatum* (Willd.) DC. Bereich. where cypsela characters were proved to be an additional tool to strengthen the taxonomic decisions. Although from Pakistan various groups of Asteraceae have got attention for their cypsela morphology but the genus *Scorzonera* seems to be ignored regarding to its cypsela. Thus, in the present studies macro and micro morphological characters of cypsela for the genus *Scorzonera* were examined to strengthen the specific delimitation of the genus.

## Materials and Methods

Seventeen species of the genus *Scorzonera* L. were studied for their cypsela morphology from herbarium specimens (2-10 specimens/species and 5-10 cypsela/specimen) under stereomicroscope (Nikon XN Model), compound microscope (Nikon Type 102) and scanning electron microscope (JSM-6380A). For scanning electron microscopy (SEM) 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. The terminologies used are in accordance with Lawrence (1970), Radford *et al.*, (1974) and Stearn (1983) with slight modifications. Numerical analysis was carried out to recognize the relationship and variations of taxa within the genus *Scorzonera*. Hierarchical clustering was performed by using Euclidean distance index with the computer package (Anon., 2012). Each taxon was treated as an operational taxonomic unit (OTU). Macro and micro morphological characters of cypsela viz., shape, surface, colour, size, pappus series, number, colour, size, carpopodium shape, position, diameter of carpopodium and diameter of foramen of carpopodium were examined. Characters were recorded as presence or absence and coded as 1 or 0 respectively and the average values of the quantitative characters were directly used (Tables 1-3; Figs. 1-8).

## Observations and Results

**General cypsela characters of the genus *Scorzonera* L.:** Cypselas 4.5-16 mm long, linear, triangular, narrow elliptic, oblong or narrow oblong, sometimes stipitate, colour brown, light brown, yellow, white, off-white, pale white, grayish white or grayish, surface ribbed (4-12 ribs), reticulate, appressedly reticulate, reticulate-foveate, appressedly reticulate-foveate, scalariform, favulariate, sulcate, lineate, undulately lineate, sparsely areolate,

aculeate, muricate, verrucate, appressedly verrucate or appressedly papillate, indumentum puberulose, silky hairs or glabrous. Pappus uniseriate or biseriate, interwined plumose above often scabrid below, 7-35 mm long, 20-50 in number, brown, yellow, golden, white, dirty white, silky white or gray. Carpopodium developed, poorly developed or absent, sometimes with ring, elliptic, obliquely elliptic, transversally ovate, square, rounded or irregular in shape, basal or sub basal in position, diameter of carpopodium 129-884 (µm), diameter of foraman of carpopodium 101-435 (µm).Presently 17 species viz., *Scorzonera baluchistanica*, *S. codringtonii, S. ferganica, S. gageoides, S. hondae, S. intricata, S. koelpinoides, S. litwinowii, S. longipapposa, S. papposa, S. paradoxa, S. pusilla, S. raddeana, S. seidlitzii, S. tortuosissima, S. tunicata* and *S. virgata* are investigated.

**Key to the species**

1 + Pappus uniseriate ..... 2
- Pappus biseriate ..... 15

2 + Cypsela hairy ..... 3
- Cypsela glabrous ..... 6

3 + Cypsela brown ..... 4
- Cypsela yellow or grayish ..... 5

4 + Cypsela surface reticulate ..... *S. gageoides*
- Cypsela surface aerolate, verrucate ..... *S. litwinowii*

5 + Cypsela surface deeply sulcate, aculeate ..... *S. codringtonii*
- Cypsela surface muricate ..... *S. seidlitzii*

6 + Cypsela linear ..... 7
- Cypsela linear-oblong, narrow elliptic, triangular or stipitate ..... 11

7 + Carpopodium not developed ..... *S. koelpinoides*
- Carpopodium developed ..... 8

8 + Carpopodium sub-basal ..... *S. hondae*
- Carpopodium basal ..... 9

9 + Carpopodium irregular without ring ..... *S. virgata*
- Carpopodium elliptic or rounded ring ..... 10

10 + Cypsela 9-10mm, carpopodium elliptic ring ..... *S. baluchistanica*
- Cypsela 15mm, carpopodium rounded ring ..... *S. raddeana*

11 + Cypsela not linear-oblong, carpopodium basal ..... 12
- Cypsela linear-oblong, carpopodium sub-basal ..... *S. seidlitzii*

12 + Cypsela yellow ..... *S. ferganica*
- Cypsela brown ..... 13

13 + Cypsela 4.5mm, surface appressedly reticulate ..... *S. paradoxa*
- Cypsela 14-16mm, reticulate-foveate verrucate ..... *S. tunicate*

14 + Cypsela white, pappus bristles 40-50 in number ..... 15
- Cypsela grayish white, pappus bristles 30 in number ..... *S. tortuosissima*

15 + Cypsela surface lineated verrucate ..... *S. hondae*
- Cypsela surface scalariform ..... *S. longipapposa*

16 + Cypsela 4.5 mm long, pappus uniseriate ..... *S. paradoxa*
- Cypsela 6.7 mm long, pappus biseriate ..... *S. papposa*

**Table 1. Cypsela morphological characters of the genus *Scorzonera*.**

| Name of taxa | Cypsela | | | | |
|---|---|---|---|---|---|
| | **Size (mm)** | **Shape** | **Colour** | **Surface** | **Indumentum** |
| *Scorzonera baluchistanica* | 9-10 | Linear | Grayish white | reticulate-foveate | Glabrous |
| *S. codringtonii* | 12-15 | Narrow elliptic | Yellow | deeply sulcate, aculeate | Puberulose |
| *S. ferganica* | 15 | Narrow elliptic | Yellow | reticulated verrucate | Glabrous |
| *S. gageoides* | 7 | Linear | Brown | Reticulate | Silky hairs |
| *S. hondae* | 5-8 | Linear | White | lineated verrucate | Glabrous |
| *S. intricata* | 10 | Linear | Pale white | Reticulate | Glabrous |
| *S. koelpinoides* | 9-11 | Linear | White | Reticulate | Glabrous |
| *S. litwinowii* | 5-7 | Linear | Light Brown | sparsely areolate, verrucate | Silky hairs |
| *S. longipapposa* | 10-12 | Linear-oblong | White | Scalariform | Glabrous |
| *S. papposa* | 6-7 | Triangular | Brown | lineated sulcate, appressedly verrucate | Glabrous |
| *S. paradoxa* | 4.5 | Triangular, stipitate | Brown | Appressedly reticulate | Glabrous |
| *S. pusilla* | 9-12 | Linear | White | Sulcate | Glabrous |
| *S. raddeana* | 15 | Linear | Grayish-Brown | reticulate-foveate, favulariated verrucate | Glabrous |
| *S. seidlitzii* | 13-14 | Linear | Grayish | Muricate | Sparsely puberulose |
| *S. tortuosissima* | 8-10 | Linear-oblong | Grayish white | undulately lineate | Glabrous |
| *S. tunicata* | 14-16 | Narrow elliptic, stipitate | Brown | reticulate-foveated verrucate | Glabrous |
| *S. virgata* | 10-15 | Linear | Brown-off-white | lineate, appressedly papillate | Glabrous |

**Table 1. (Cont'd.).**

| Name of taxa | Pappus | | | | Carpopodium | | | |
|---|---|---|---|---|---|---|---|---|
| | **Series** | **Length (mm)** | **Number** | **Colour** | **Shape** | **Position** | **Diameter of carpopodium (µm)** | **Diameter of foraman of carpopodium (µm)** |
| *Scorzonera baluchistanica* | Uniseriate | 15 | 25-30 | Dirty white | Elliptic with ring | Basal | 557 | 351 |
| *S. codringtonii* | Uniseriate | 16-18 | 38-40 | Yellow | Elliptic with ring | Basal | 733 | 108 |
| *S. ferganica* | Uniseriate | 12 | 30-40 | Brown | Obliquely elliptic with ring | Basal | 815 | 103 |
| *S. gageoides* | Uniseriate | 7-8 | 35 | Dirty white | Absent | - | - | - |
| *S. hondae* | Uniseriate | 10-16 | 40-45 | Dirty white | Distorted rounded without ring | Sub basal | 711 | 340 |
| *S. intricata* | Biseriate | 10-20 | 30 | Dirty white | Transversally ovate with ring | Basal | 695 | 424 |
| *S. koelpinoides* | Uniseriate | 14-17 | 30 | Dirty white | Absent | - | - | - |
| *S. litwinowii* | Uniseriate | 9-11 | 35 | Dirty white | Absent | - | - | - |
| *S. longipapposa* | Uniseriate | 22-24 | 40-45 | Dirty white | Irregular shape without ring (undeveloped) | Sub basal | - | - |
| *S. papposa* | Biseriate | 12-14 | 40-50 | Silky white | Elliptic without ring | Basal | - | - |
| *S. paradoxa* | Uniseriate | 10-12 | 30-40 | Silky white | Irregular shape without ring | Basal | - | - |
| *S. pusilla* | Biseriate | 20-35 | 35-40 | Silky white | Transversally ovate with ring | Basal | 817 | 435 |
| *S. raddeana* | Uniseriate | 15-18 | 35 | Gray | Rounded with ring | Basal | 781 | 106 |
| *S. seidlitzii* | Uniseriate | 17 | 20-22 | Yellow | Transversally ovate with ring | Basal | 129 | 101 |
| *S. tortuosissima* | Uniseriate | 14-20 | 30 | Dirty white | Elliptic without ring | Sub basal | - | - |
| *S. tunicata* | Uniseriate | 15-20 | 35-38 | Gloden-Brown | Square without ring (poorly developed) | Basal | 444 | 203 |
| *S. virgata* | Uniseriate | 10-20 | 40 | Gloden-Brown | Irregular shape without ring | Basal | 875 | 405 |

**Table 2. List of characters, scored for the cluster analysis for the species of the genus *Scorzonera* listed in table 3.**

| S. No. | Character description |
|---|---|
| | **Cypsela** |
| 1. | Length (mm) |
| | **Shape** |
| 2. | Narrow elliptic : Absent (0), Present (1) |
| 3. | Linear : Absent (0), Present (1) |
| 4. | Narrow oblong : Absent (0), Present (1) |
| 5. | Triangular : Absent (0), Present (1) |
| | **Surface** |
| 6. | Riged : Absent (0), Present (1) |
| 7. | Reticulate : Absent (0), Present (1) |
| 8. | Appressedly reticulate : Absent (0), Present (1) |
| 9. | Reticulate-foveate : Absent (0), Present (1) |
| 10. | Appressedly reticulate-foveate : Absent (0), Present (1) |
| 11. | Sulcate : Absent (0), Present (1) |
| 12. | Lineate : Absent (0), Present (1) |
| 13. | Favulariate : Absent (0), Present (1) |
| 14. | Scalariform : Absent (0), Present (1) |
| 15. | Undulate : Absent (0), Present (1) |
| 16. | Areolate : Absent (0), Present (1) |
| 17. | Aculeate : Absent (0), Present (1) |
| 18. | Verrucate/ Appressedly verrucate : Absent (0), Present (1) |
| 19. | Appressedly papillate : Absent (0), Present (1) |
| | **Indumentum** |
| 20. | Muricate : Absent (0), Present (1) |
| 21. | Lanate : Absent (0), Present (1) |
| 22. | Silky hairs : Absent (0), Present (1) |
| 23. | Puberulose : Absent (0), Present (1) |
| 24. | Glabrous : Absent (0), Present (1) |
| | **Colour** |
| 25. | Yellow : Absent (0), Present (1) |
| 26. | Brown : Absent (0), Present (1) |
| 27. | Light brown : Absent (0), Present (1) |
| 28. | Pale white : Absent (0), Present (1) |
| 29. | White : Absent (0), Present (1) |
| 30. | Grey : Absent (0), Present (1) |
| 31. | Greyish white : Absent (0), Present (1) |
| | **Pappus series** |
| 32. | Uniseriate : Absent (0), Present (1) |
| 33. | Biseriate : Absent (0), Present (1) |
| 34. | **Size :** Length (mm) |
| | **Colour** |
| 35. | Yellow : Absent (0), Present (1) |
| 36. | Brown : Absent (0), Present (1) |
| 37. | Dirty white : Absent (0), Present (1) |
| 38. | White : Absent (0), Present (1) |
| 39. | Silky white : Absent (0), Present (1) |
| 40. | Grey : Absent (0), Present (1) |
| 41. | Golden : Absent (0), Present (1) |
| | **Carpopodium** |
| 42. | Ring : Absent (0), Present (1) |
| 43. | Elliptic: Absent (0), Present (1) |
| 44. | Obliquely elliptic: Absent (0), Present (1) |
| 45. | Rounded : Absent (0), Present (1) |
| 46. | Distorted rounded : Absent (0), Present (1) |
| 47. | Transversally ovate : Absent (0), Present (1) |
| 48. | Square : Absent (0), Present (1) |
| 49. | Irregular shape : Absent (0), Present (1) |
| | **Position** |
| 50. | Basal : Absent (0), Present (1) |
| 51. | Sub basal : Absent (0), Present (1) |
| 52. | Diameter of carpopodium (µm) |
| 53. | Diameter of foraman of carpopodium (µm) |

## Discussion

Cypsela characteristics have been effectively used by various authors for specific delimitation within the family Asteraceae (Mukherjee, 2000; Abid & Qaiser, 2002; Abid & Ali, 2010; Karaismailoglu, 2015; Sirin *et al*., 2017; Shamso *et al*., 2021). In the present study, 17 species of the genus *Scorzonera* (Cichoreae) have been numerically analyzed for their cypsela characters. The cypsela of *Scorzonera* are characterized by the presence of ribs. Abid & Qaiser (2015) also reported ribs as persistent character in *Lactuca* and its allied genera from Cichoreae. The genus *Scorzonera* can be divided into two groups by the presence or absence of Carpopodium (Coskuncelebi, 2016). Similarly, on the other hand, dendrogram based on cypsela morphology clearly indicates the establishment of two main groups viz., group I comprised of *S. intricata, S. pusila, S. seidlitzii, S, baluchistanica, S. raddeana, S. codringtonii, S. ferganica, S. tunica, S. virgata, S. papposa* and *S. paradoxa* with basal carpopodium except *S. intricata* where carpopodium was absent and group II includes *S. longipapposa, S. tortuosissima, , S. litwinowii, S. hondae* with sub-basal carpopodium except *S. gageoides* and *S. Koelpinioides* where carpopodium was absent. Similarly, Ayaz *et al*., (2020) also reported the basal, sub-basal or lateral carpopodium in Cichoreae (Asteraceae).

Group I is further divided into two sub-groups i.e., group $I_A$ and group $I_B$. Group $I_A$ has cypsela with the variety of white shades, yellow or grey and group $I_B$ has brown cypselas. However, Bhar & Mukherjee (2004) stated that colour of cypsela varies with maturity but we found colour as consistent character in *Scorzonera* species. Within group $I_A$, *S. codringtonii* and *S. ferganica* are closely placed due to their yellow and narrow elliptic cypsela but remains separate due to their distinct cypsela surface i.e. deeply sulcate, aculeate in former and reticulated verrucate in later one. While, *S. baluchistanica* and *S. raddeana* were placed together for having reticulate-foveate and favulariated verrucate cypsela and can be distinguished by dirty white pappus and elliptic carpopodium in *S. baluchistanica* and grey pappus and rounded carpopodium in *S. raddeana*. Similarly, *S. intricata, S. pusila* and *S. seidlitzii* remains together due to their similar carpopodium i.e., transversally ovate with ring. Among them *S. seidlitzii* remains separate by its uniseriate pappus pappus. While, *S. intricata* and *S. pusilla* are differentiated by their reticulate and sulcate cypsela surface respectively. In group $I_B$ *S. tunicata* and *S. virgata* are placed together due to their golden-brown pappus while other two species of this sub-group i.e., *S. papposa* and *S. paradoxa* are placed together due to silky white pappus. While, all the four species in in this group have distinct cypsela surfaces.

Similarly, group II was bifurcated into groups $II_A$ and $II_B$. In group $II_A$ *S. longipapposa* and *S. tortuosissima* occupied the same clad due to linear-oblong cypselas and remained separate by their distinct cypsela surfaces i.e.,

scalariform and undulately lineate respectively. While species in group $II_B$ have linear cypsela. Hussein & Eldemerdash (2016) also reported cypsela shape as diagnostic character of species within family Asteraceae. Similar findings were reported by Abid & Zehra (2007). Within group $II_B$ *S. gageoides* and *S. litwinowii* were found to be closely related due to their brown coloured cypsela with silky hairs (Ghafoor *et al*., 2017) but have distinct cypsela surfaces. While, other two species i.e., *S. hondae* and *S. koelpinioides* have white and glabrous cypselas and remain distinct by well-developed carpopodium in *S. hondae* and undeveloped carpopodium in *S. koelpinioides*. Thus, from the ongoing discussion it is evident that cypsela morphological characters provides additional micromorphological characters for the specific delimitation of the genus *Scorzonera* from Pakistan.

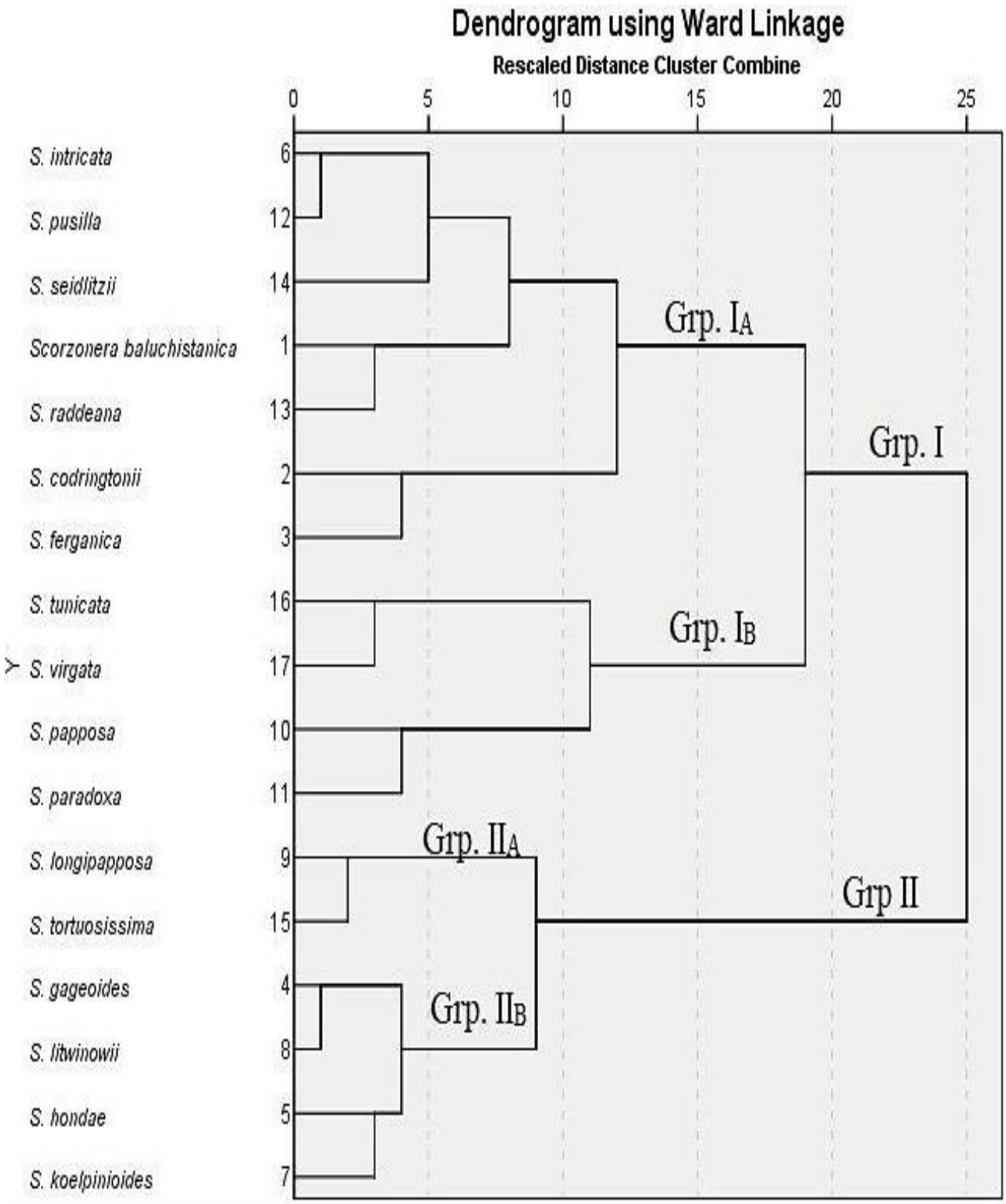


Fig. 1. Dendrogram showing the relationship of the species within the genus *Scorzonera*.

Table 3. **Data matrix of *Scorzonera* species scored for 53 characters present in table 2.**

| Name of species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scorzonera baluchistanica* | 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *S. codringtonii* | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| *S. ferganica* | 15 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *S. gageoides* | 7 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| *S. hondae* | 8 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *S. intricata* | 10 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *S. koelpinioides* | 10 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *S. litwinowii* | 6 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *S. longipapposa* | 10 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *S. papposa* | 6 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *S. paradoxa* | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *S. pusilla* | 12 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *S. raddeana* | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *S. seidlitzii* | 14 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *S. tortuosissima* | 10 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *S. tunicata* | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |

Table 3. **(Cont'd.).**

| Name of species | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scorzonera baluchistanica* | 0 | 0 | 0 | 1 | 1 | 0 | 15 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 557 | 351 |
| *S. codringtonii* | 0 | 0 | 0 | 0 | 1 | 0 | 18 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 733 | 108 |
| *S. ferganica* | 0 | 0 | 0 | 0 | 1 | 0 | 12 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 815 | 103 |
| *S. gageoides* | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *S. hondae* | 0 | 1 | 0 | 0 | 1 | 0 | 16 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 711 | 340 |
| *S. intricata* | 1 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 695 | 424 |
| *S. koelpinioides* | 0 | 1 | 0 | 0 | 1 | 0 | 15 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *S. litwinowii* | 0 | 0 | 0 | 0 | 1 | 0 | 11 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *S. longipapposa* | 0 | 0 | 0 | 0 | 1 | 0 | 24 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| *S. papposa* | 0 | 0 | 0 | 0 | 0 | 1 | 14 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *S. paradoxa* | 0 | 0 | 0 | 0 | 1 | 0 | 12 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| *S. pusilla* | 0 | 1 | 0 | 0 | 0 | 1 | 30 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 817 | 435 |
| *S. raddeana* | 0 | 0 | 1 | 0 | 1 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 781 | 106 |
| *S. seidlitzii* | 0 | 0 | 1 | 0 | 1 | 0 | 17 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 129 | 101 |
| *S. tortuosissima* | 0 | 0 | 0 | 1 | 1 | 0 | 18 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *S. tunicata* | 0 | 0 | 0 | 0 | 1 | 0 | 18 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 444 | 203 |
| *S. virgata* | 0 | 0 | 0 | 0 | 1 | 0 | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 875 | 405 |

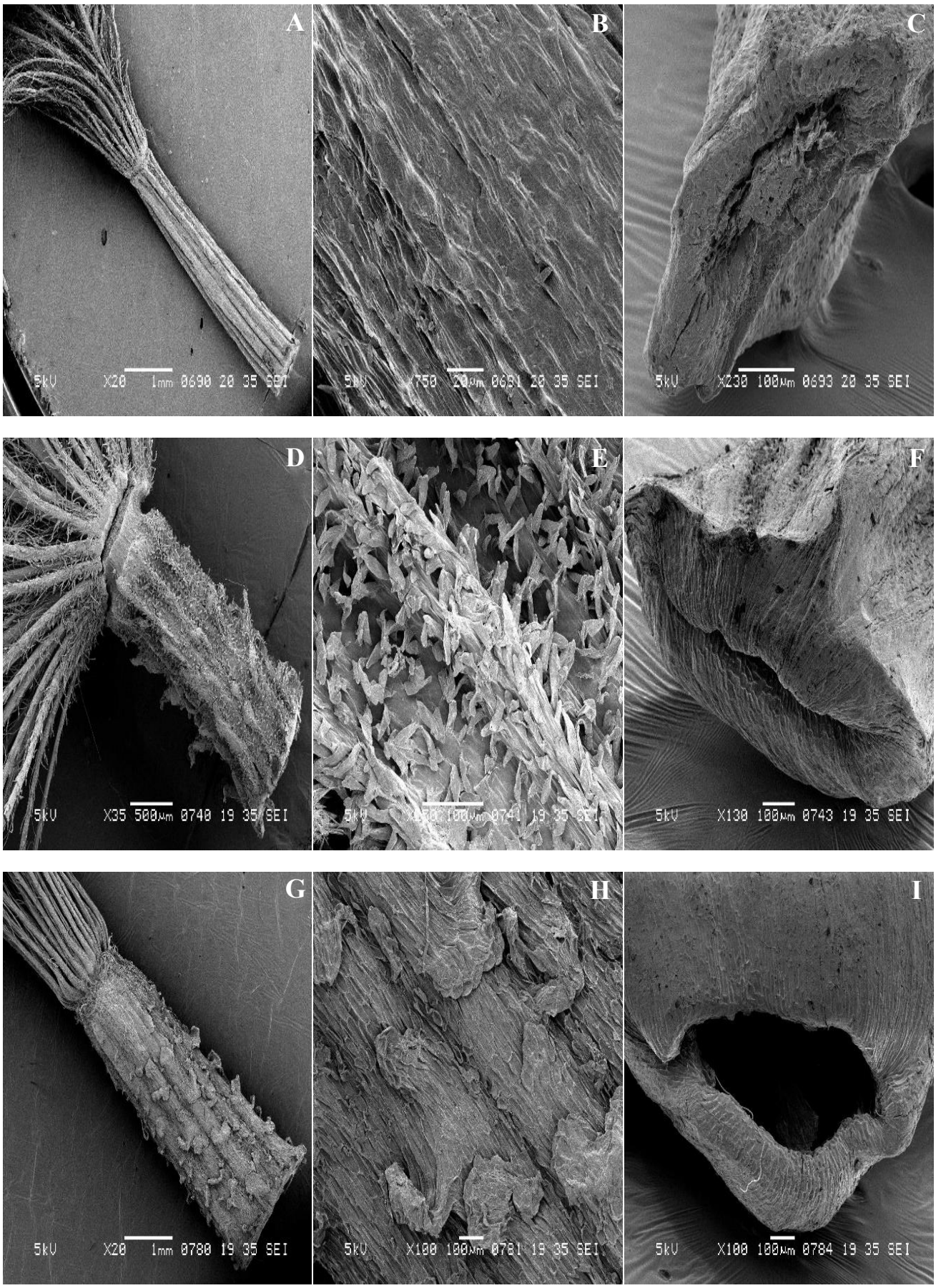


Fig. 2. **Scanning electron micrographs.** *Scorzonera baluchistanica*: A, upper part of cypsela; B, surface; C, carpopodium. *S. codringtonii*: D, upper part of cypsela; E, surface; F, carpopodium. *S. ferganica*: G, upper part of cypsela; H, surface; I, carpopodium (Scale bars: A, G= 1 mm; D= 500 µm; C, E, F, H, I= 100 µm; B= 20 µm).

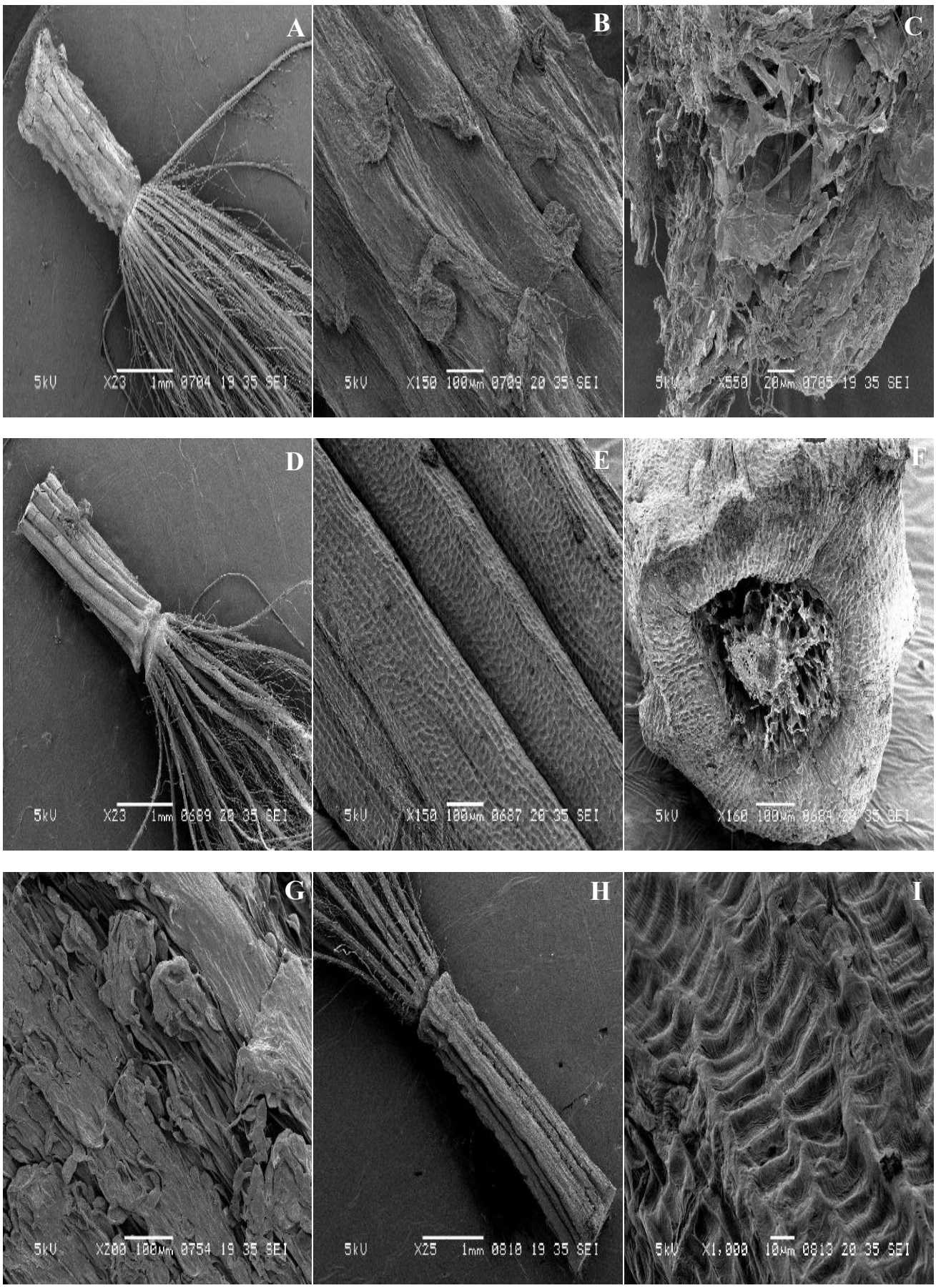


Fig. 3. **Scanning electron micrographs.** *Scorzonera hondae*: A, upper part of cypsela; B, surface; C, carpopodium. *S. intricata*: D, upper part of cypsela; E, surface; F, carpopodium. *S. litwinowii*: G, surface. *S. longipapposa*: H, upper part of cypsela; I, surface (Scale bars: A, D, H= 1 mm; B, E, F, G= 100 µm; C= 20 µm; I= 10 µm).

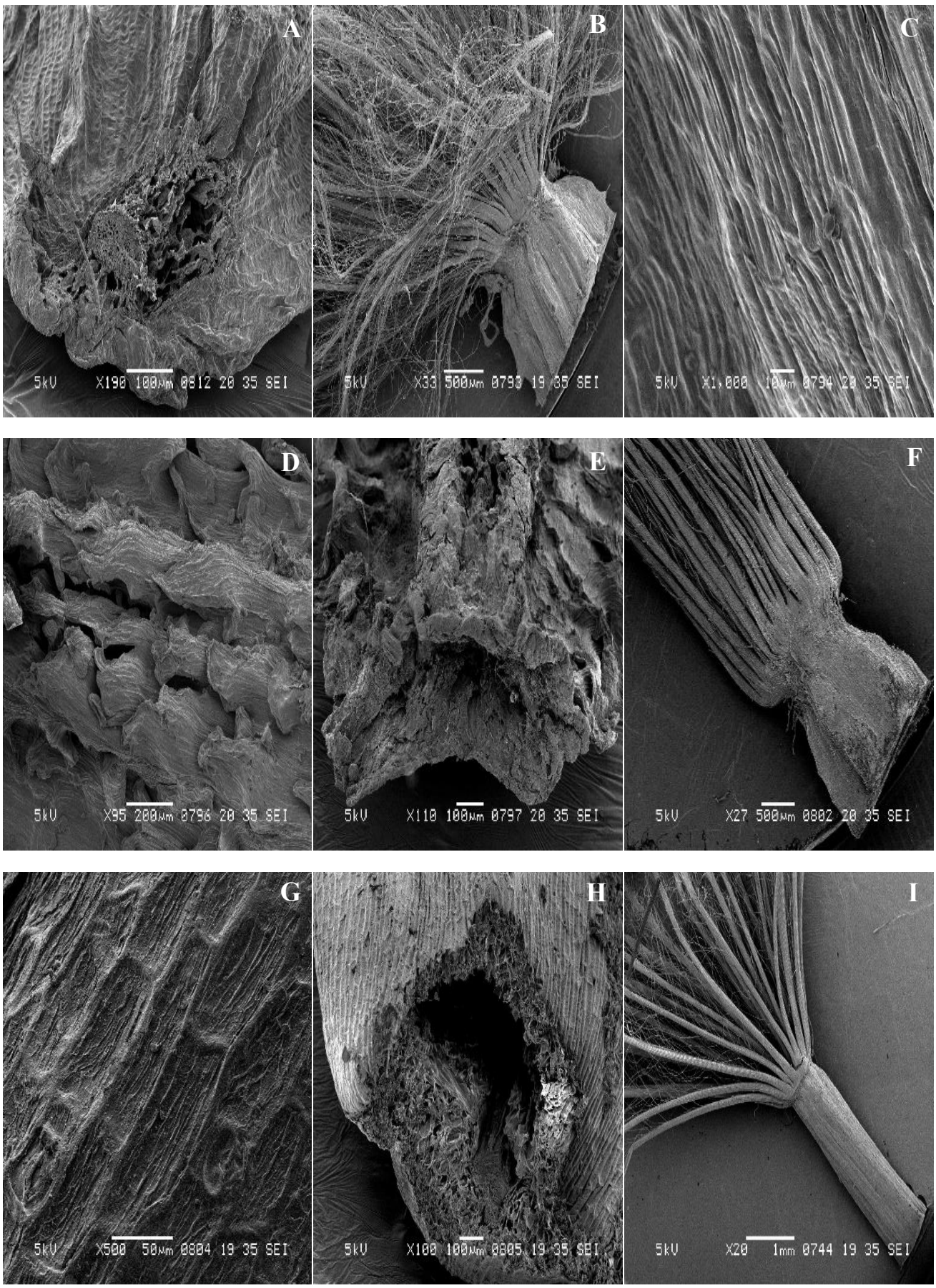


Fig. 4. **Scanning electron micrographs.** *Scorzonera longipapposa*: A, carpopodium. *S. papposa*: B, upper part of cypsela; C, D, surface; E, carpopodium. *S. paradoxa*: F, upper part of cypsela; G, surface; H, carpopodium. *S. pusilla*: I, upper part of cypsela (Scale bars: I= 1 mm; B, F= 500 µm; D= 200 µm; A, E, H= 100 µm; G= 50 µm; C= 10 µm).

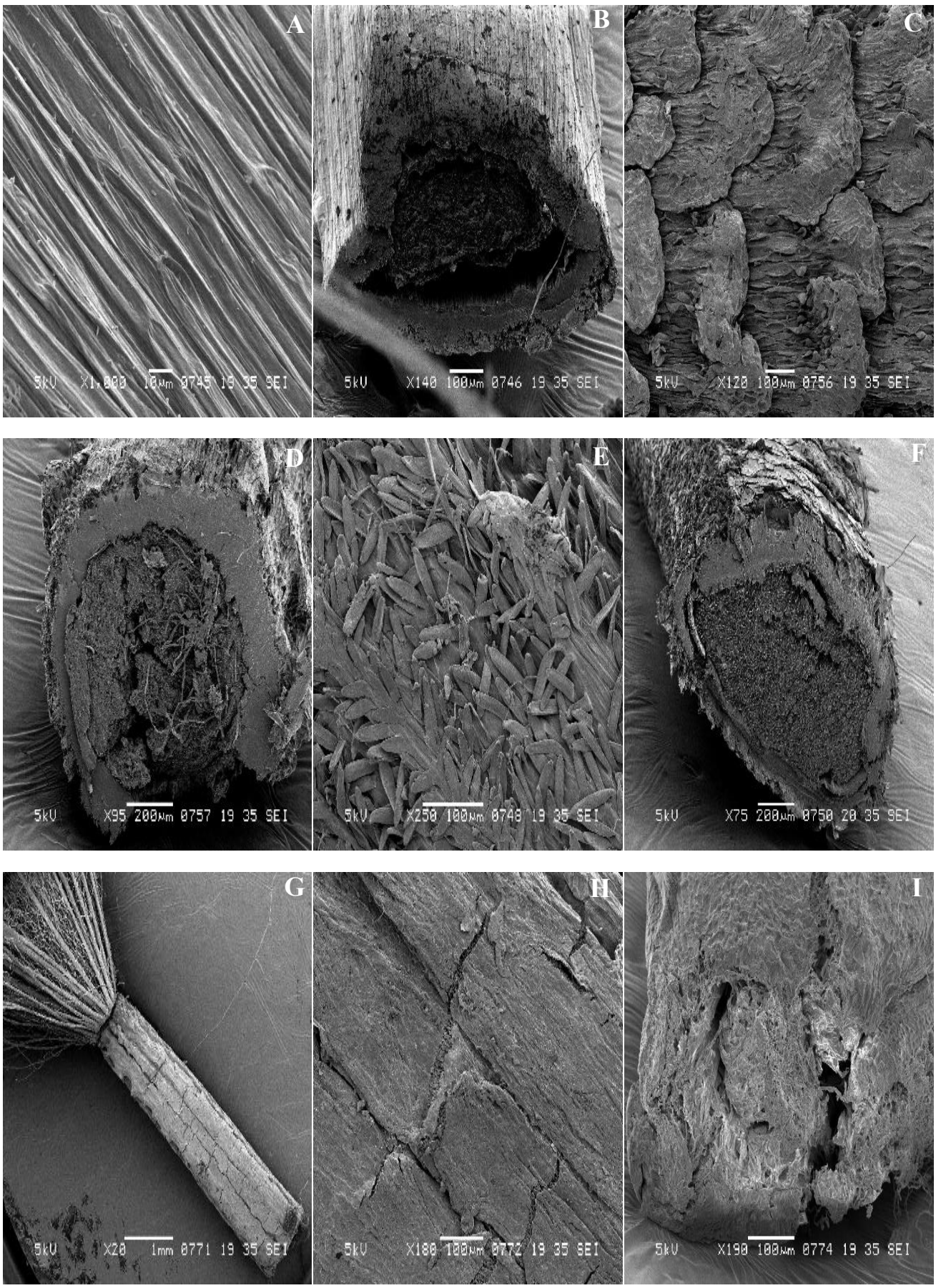


Fig. 5. **Scanning electron micrographs.** *Scorzonera pusilla*: A, surface; B, carpopodium. *S. raddeana*: C, surface; D, carpopodium. *S. seidlitzii*: E, surface; F, carpopodium. *S.* sp. nov. B: G, upper part of cypsela; H, surface; I, carpopodium. (Scale bars: G= 1 mm; D, F= 200 µm; B, C, E, H, I= 100 µm; A= 10 µm).

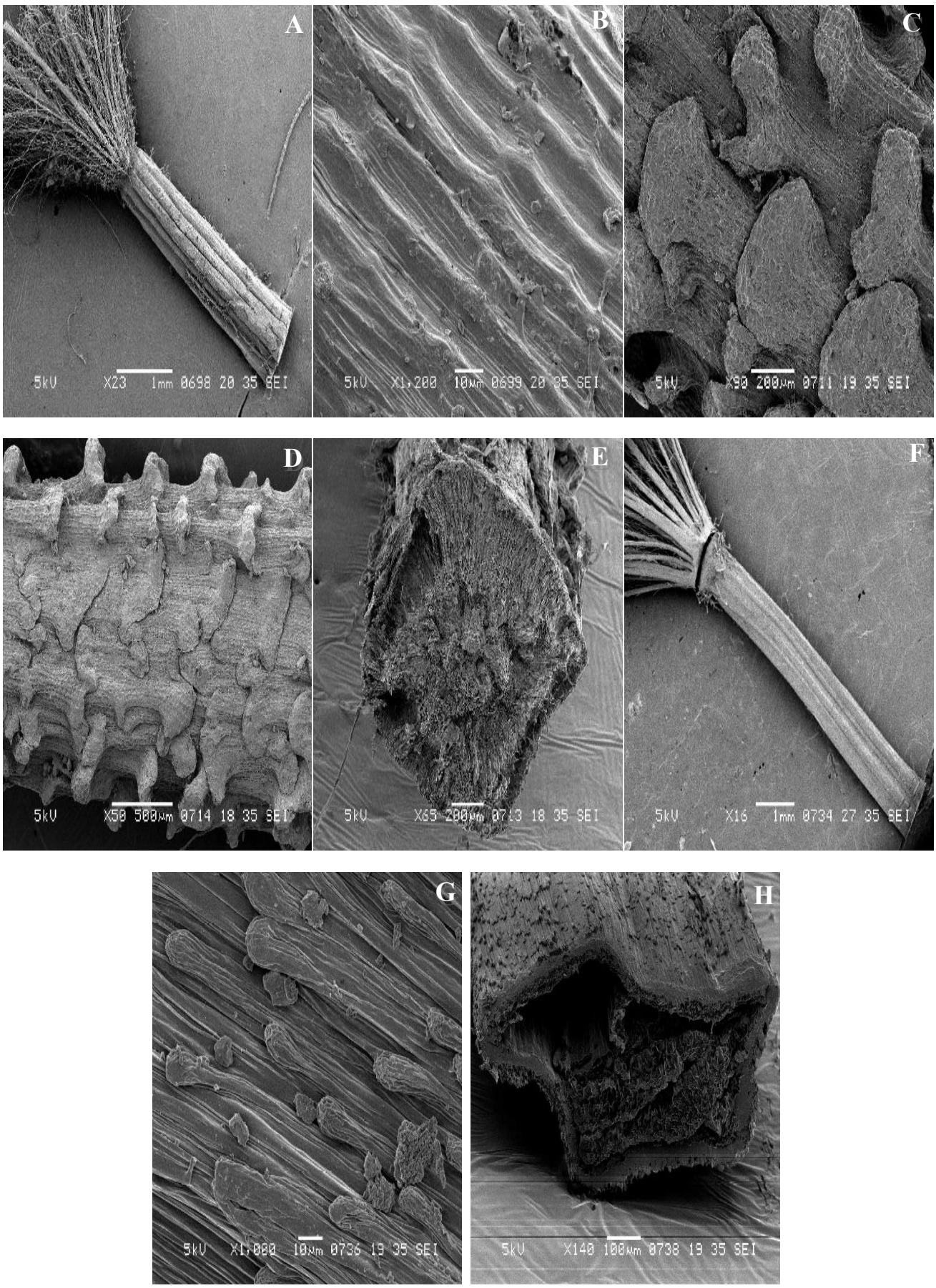


Fig. 6. **Scanning electron micrographs.** *S. tunicata*: A, upper part of cypsela; B, C, D, surface. E, carpopodium. *S. virgata*: F, upper part of cypsela; G, surface; H, carpopodium (Scale bars: A, F= 1 mm; D= 500 µm; C, E= 200 µm; H= 100 µm; B, G = 10 µm).


Fig. 7. **Light micrographs.** *Scorzonera codringtonii*: A, cypsela. *S. ferganica*: B, cypsela. *S. gageoides*: C, cypsela. *S. hondae*: D, cypsela. *S. intricata*: E, cypsela. *S. litwinowii*: F, cypsela (Scale bars: A, B, C, E = 2 mm; D, F = 1 mm).


Fig. 8. **Light micrographs.** *S. pusilla*: A, cypsela. *S. raddeana*: B, cypsela. *S. seidlitzii*: C, cypsela. *S. tortuosissima*: D, cypsela. *S. tunicata*: E, cypsela. *S. virgata*: F, cypsela (Scale bars: A, B, C, D, E, F = 2 mm).

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(Received for publication 5 September 2021)