International Scholars Journals

African Journal of Dairy Farming and Milk Production ISSN 2375-1258 Vol. 6 (10), pp. 001-011, October, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Comparative morphology, palynology and anatomy of five astraceous species from Pakistan

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Accepted 05 August, 2019

In this study, *Scorzonera* L. (Asteraceae) collected from Pakistan was investigated by its morphology, leaf epidermal anatomy and pollen grain characteristics. *Scorzonera* is a perennial herb growing in wet nutrient-poor grasslands and wet heathlands. The stem texture is glabrous in *Scorzonera ammophila, Scorzonera picridioides* and *Scorzonera virgata* while tomentose in *Scorzonera hondae* and terete with fine striate above in *Scorzonera laciniata*. The bifacial leaves had anomotetracytic, amphianisocytic, brachyparacytic and staurocytic stomata. The pollen morphology results indicate that pollen grains in *Scorzonera* were lophate. Based on sculpturing, all pollens were echinate in *Scorzonera*. The pollen class was trizonocolporate in all taxa.

Key words: Morphology, palynology, anatomy, *Scorzonera* L., scanning electron micrographs, Pakistan.

INTRODUCTION

The tribe Scorzonerinae comprises the genera *Epiasia, Geropogon, Koelpinia, Pterachaenia, Scorzonera, Tourneuxia* and *Tragopogon*, and encompasses a total of approximately 300 species (Bremer, 1994). For the European flora 28 species of *Scorzonera*-including *Podospermum* (Chater, 1976) and 20 species of *Tragopogon*-including *Geropogon* have been reported (Richardson, 1976). The Central European flora is comparatively poor in members of the Scorzonerinae: only nine species of *Scorzonera* (including two of *Podospermum*) and four species of *Tragopogon* are reported for Austria (Adler et al., 1994); five of *Scorzonera* for Germany (Jager and Werner, 2002); and two species of *Scorzonera* for Switzerland (Heitz, 1990). Subaerial parts of *Scorzonera hispanica* L. and *Tragopogon porrifolius* L. are used as asparagus-like vegetables (Franke, 1997) and species from the genus *Scorzonera* were additionally employed as folk-medicinal plants. *Scorzonera doriae* is endemic to the western Balkan Peninsula. In Greece, it is known from a few localities, all on serpentine of the north Pindos area (Siegmund, 1874).

The purpose of this study to identify the selected spe-cies of Asteraceae on the basis of plant morphology, palynology and leaf epidermal anatomy and contribute towards the publication of family Asteraceae in Pakistan.

MATERIALS AND METHODS

Scorzonera was most common in the Baluchistan, North West Frontier Province and Punjab (Pakistan) . Collections were made from nine sites, given in the map (Figure 1a). Most of the material used for this study was collected directly from wild populations, and the voucher specimens for each of the samples studied have been placed in herbarium of Pakistan Islamabad (ISL). The specimens were also studied from herbarium of Pakistan Museum of Natural History, Islamabad (PMNH) and National herbarium, Islamabad (RAW). For morphological studies 10 specimens per species were used for assessment of morphological characters. Mature achenes from the peripheral florets of the capitulum were measured at low magnification under a stereomicroscope. The terminology of fruit-coat surface sculpturing follows (Stearn, 1973; Quer, 1979).

Pollen was removed from herbarium (ISL) sheets. General preparation consisted of acetolyzing mature pollen grains Erdtman (1960), removal of undigested plant debris (Chissoe and Skvarla, 1974; Chissoe and Skvarla, 1996) and separating the samples for SEM. Whole pollen grains and fragments of pollen walls obtained by cryomicrotomy Skvarla et al. (1988) were stained and dried using the repeat method of osmium and thiocarbohydrazide (that is,

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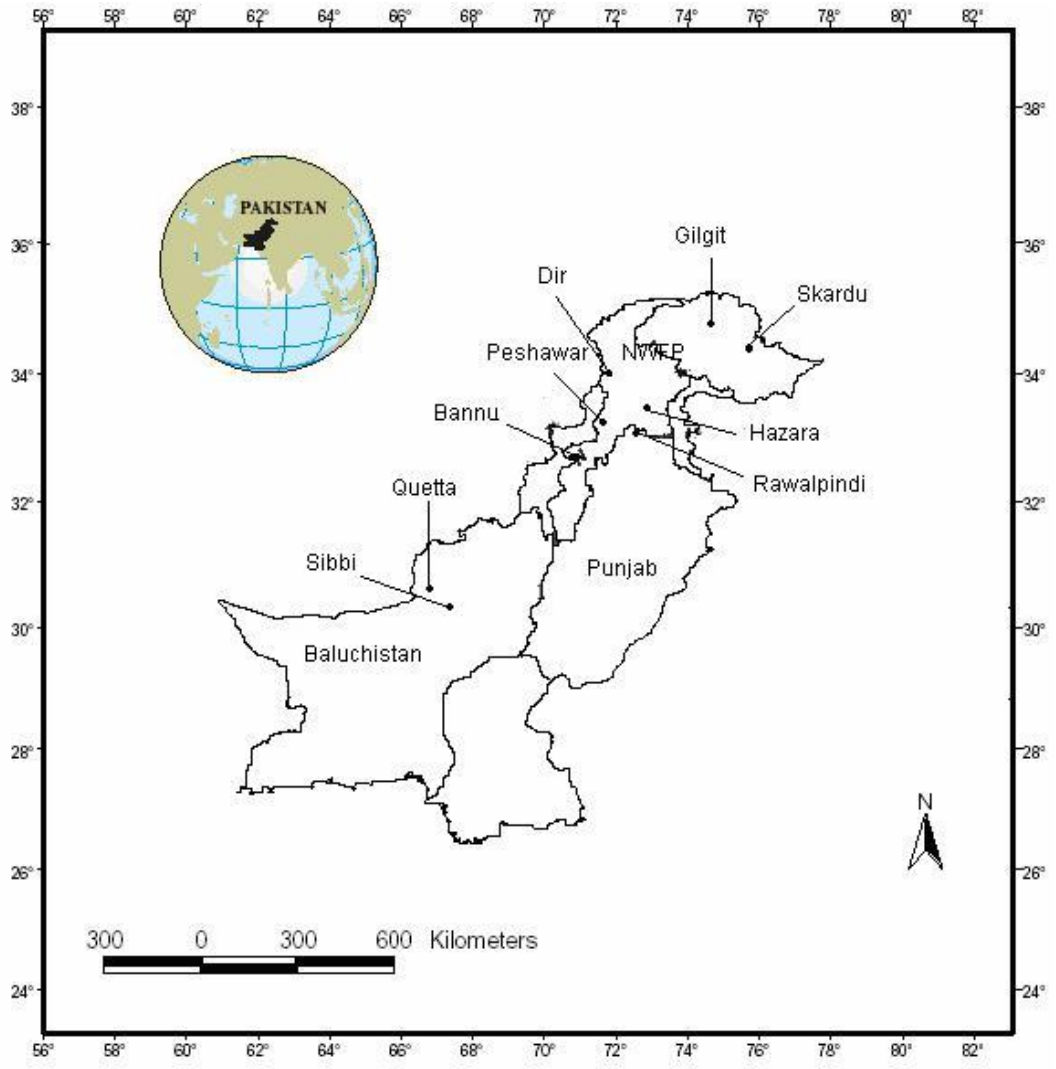

Figure 1a. Location of *Scorzonera* L. sampling sites from Pakistan.

OTOTO) as described by (Chissoe et al., 1995). Pollen was then mounted on double-stick tape and coating of gold was done using magnetron sputter coater model SC 7610 and Secondary electron images (SEI) were recorded using scanning electron microscope LE0440I (Chissoe and Skvarla, 1996). Secondary electron imaging and photography were done with a JEOL 880 scanning electron microscope equipped with a lanthanum hexaboride gun operating at 15 keV accelerating voltage.

Leaf samples were taken from the sixth/seventh nodes of the main stem at the full flowering stage between 9:00 and 10:00. Dried leaves were placed in boiling water for a few minutes to soften them until they became unfolded and were ready for epidermal scraping. Fresh leaves were used directly for anatomical studies. The fresh or dried leaves were placed in a test tube, filled with 88% lactic acid and kept hot in a boiling water bath for about 50 - 60 min. Lactic acid softens the tissue of leaf due to which it's peeling off is made possible. To prepare the abaxial surface, the leaf was placed keeping its adaxial surface upward and then it was flooded with 88% cold lactic acid. The adaxial epidermis was cut across the leaf using a sharp scalpel blade and scraped away together with the mesophyll cells until only the abaxial epidermis of the leaf remained on the tile. The epidermis was placed, outside uppermost and mounted in clean 88% lactic acid. A similar procedure was followed to prepare the adaxial epidermis. For anatomical studies, sections from fixed samples were taken by hand using a razor, and their photographs were taken with a camera marked Nikon FDX-35 by examining them under a microscope. The length and width of the stomata were measured with an ocular micrometer using surface sections from the upper and lower parts of the leaf epidermis. The number of stomata was evaluated by preparing slides from the clear nail polish impression on both lower and upper epidermis of the leaves. Stomata were counted and measured using 10X, 20X and 40X magnifications.

All original slides and photographic negatives were kept at the Centre for Microscopy and Microanalysis, Department of Plant Sciences, Quaid-i-Azam University Islamabad Pakistan. A statistical analysis was conducted in order to ascertain whether there is support for the taxa that have been discriminated base on their

Table 1. Comparative morphology of different species of genus *Scorzonera* L.

Character	*Scorzonera ammophila*	*Scorzonera hondae*	*Scorzonera laciniata*	*Scorzonera picridioides*	*Scorzonera virgata*
Habit	Perennial	Perennial	Annual to Biennial	Perennial	Perennial
Height of plant	50-70 cm	70-90 cm	50-85 cm	30-50 cm	90-120 cm
Stem Texture	Glabrous	Tomentose	Terete & fine striate above	Glabrous	Glabrous
Basal leaves	Sessile	Sessile	Petiolate	Sessile	Sessile
Basal leaf blade	Linear to filiform	Linear lanceolate	Pinnatipartite	Elliptic to linear	Linear
Middle stem leaves	Linear to filiform	Linear lanceolate	Pinnatipartite	Elliptic to linear	Linear
Upper stem leaves	Linear to filiform	Linear lanceolate	Obovate lanceolate	Elliptic to linear	Linear
Phyllaries	4 rows	2 rows	2 rows	5 rows	4 rows
Outer phyllaries	Ovate lanceolate	Lanceolate	Ovate lanceolate	Ovate to triangular ovate	Ovate
Middle phyllaries	Elliptic lanceolate	Absent	Absent	Lanceolate to elliptic lanceolate	Ovate-lanceolate
Inner phyllaries	Linear lanceolate	Lanceolate	Linear lanceolate	Elliptic to linear lanceolate	Oblong lanceolate
Size of Achene (L X W)	10 X 3 mm	12 X 2 mm	15 X 3 mm	7 X 2 mm	10 X 14 mm
No. of ribs on each face	7 ribs	6 ribs	5 ribs	5 ribs	3 ribs
Achene beak	Beakless	Beakless	Beakless	Beakless	Beakless
Pappus	Persistent	Persistent	Persistent	Persistent	Persistent
Size of Pappus	4.5 cm long	20 mm long	12 mm long	1.5 cm long	1 cm long

vegetative and pollen characters (Tables 2 and 4).

RESULTS

Scorzonera L. Sp. Pl. 2: 790. 1753; Gen. Pl. ed. 5. 346. 1754.

Taxonomic treatment

Herbs, perennial or annual, tuberous roots. Stem erect, solitary or divaricately branched, glabrous or pubescent. Basal leaves simple and entire, linear to broadly ovate-lanceolate, or deeply divided, petiolate or sessile. Capitula solitary, homogamous, large, corymbose or racemose with numerous florets. Involucre ovate or cylindrical. Phyllaries in 2 rows, inner longer than outer. Florets yellow. Achenes cylindric to ellipsoid with many tuberculate ribs, puberulent or villous, apex truncate and beakless or almost so. Pappus in several rows, base connate into a ring, usually plumose for most of length, usually with 3-10 superlong hairs, persistent or caduceus.

Key to the species

1. Perennial, 50 - 70 cm tall, stem glabrous, basal leaf sessile, linear to filiform……4
1a Annual or Biennial, 50 - 85 cm tall, stem terete and fine striate above, basal leaf petiolate, pinnatipartite……3
2. Basal leaf blade linear lanceolate, phyllaries have 2 rows, 6 ribs on each face, pappus 20 mm long……*S. hondae*
2a. Basal leaf blade elliptic to linear, phyllaries have 5 rows, 5 ribs on each face, pappus 15 mm long……*S. picridioides*
3. Plant 90 - 120 cm tall, basal leaf sessile, linear, phyllaries have 4 rows, 3 ribs on each face……*S. virgata*

Table 2. Pollen characteristics of different species of genus *Scorzonera* L. of tribe *Lactuceae*.

Taxon	Equatorial Diameter (µm)	Polar Diameter (µm)	P/E	Exine Thickness (µm)	Spine Length (µm)	Number of Spine rows b/w colpi	Shape in polar view	Shape in Equatorial view	Aperture type	Pollen Class	Sculpturing
Scorzonera ammophila	42-46 44.3+0.7	44-54 49.8+1.6	1.1	7-13 10+1	2.7-5.8 4.4+0.5	10-12 11.1+0.3	Semiangular	Prolate-spheroidal	Nonlacunate	Trizonocolporate	Echinate
S. hondae	32.5-50.5 40.6+2.8	40.5-48.8 43.9+1.5	1.1	4.7-7.4 5.7+0.5	4-6 5.2+0.3	10-14 11.7+0.7	Semiangular	Prolate-spheroidal	Nonlacunate	Trizonocolporate	Echinate
S. laciniata	29-35 32.6+0.9	24-32 28+1.4	0.9	1.7-3 2.4+0.2	2-3.4 2.9+0.2	12-16 14+0.6	Semiangular	Prolate-spheroidal	Nonlacunate	Trizonocolporate	Echinate
S. picridioides	32-42.5 36.7+1.7	36-48 40.6+2	1.1	2.3-5.5 4.1+0.5	3.5-5 4.4+0.2	10-12 11+0.3	Semiangular	Prolate-spheroidal	Nonlacunate	Trizonocolporate	Echinate
S. virgata	34-41.5 37.3+1.2	36-43.5 39.5+1.1	1.1	1.5-2.4 2+0.1	4-5 4.6+0.2	12-15 13.7+0.5	Semiangular	Prolate-spheroidal	Nonlacunate	Trizonocolporate	Echinate

3a. Plant 50 - 70 cm, tall, basal leaf petiolate, pinnatipartite, phyllaries have 2 rows, 5 ribs on each face……4

4. Phyllaries have 4 rows, achene size 10 x 3 mm, 7 ribs on each face, pappus 45 mm long……*S. ammophila*

4a. Phyllaries have 2 rows, achene size 15 x3 mm, 5 ribs on each face, pappus 12 mm long…….*S. laciniata*

***Scorzonera ammophila* Bunge Beitr. Fl. Russl. 202 (1852). [7 Nov. 1852]**

Herbs, perennial, 50 - 70 cm tall. Stem erect, branched, glabrous. Basal leaves sessile, linear to filiform, 15 - 22 cm x 0.7 - 1 mm, apex acumi- nate. Middle stem leaves 14 - 17 cm x 0.4 - 0.8 mm, similar to basal leaves. Upper stem leaves similar to lower one but small, glabrous. Capitula terminal few, corymbose. Involucre cylindric 5 - 6 x 1 - 1.5. Phyllaries in 4 rows, puberulent; outer phyllaries ovate lanceolate, 2 - 3 x 0.2 - 0.6 mm; middle phyllaries 6 x 0.7 mm, elliptic lanceo-late, apex acute to acuminate; inner phyllaries, 4 x 0.2 mm, linear lanceolate. Florets yellow. Ache-nes yellowish brown, cylindric, 10 x 3 mm, 7 ribs, glabrous, apex truncate and beakless. Pappus numerous, 45 mm, basally plumose, apically scabrous, persistent.

Flowering and Fruiting: May-September

***Scorzonera hondae* Kitam. Acta Phytotax. Geobot. xix. 105 (1963)**

Herb, perennial, 70 - 90 cm tall. Stem erect, compact, dichotomously branched from the base, appressedly tomentose. Basal leaveas sessile, linear lanceolate, 4 – 5 x 0.2 - 0.3 cm, with entire margin, acute tip, glabrous. Middle stem leaves 1.4 - 2 cm x 2 - 3 mm, similar to basal leaves. Upper stem leaves similar to lower one but smaller in size. Capitula solitary, terminal, peduncled. Involucre cylindrical, 2 - 2.5 x 0.5 - 0.8 cm. Phyllaries in 2 rows, lanceolate, margin entire, apex acute, glabrous; outer phyllaries 0.4-0.8 X 0.1-0.2 mm; inner phyllaries 1.4 x 0.2 mm. Florets yellow. Achene light brown, cylindrical, truncate above 12 x 2 mm, 6 ribs, ribs are muricate-rugose, beakless. Pappus white, 20 mm long, persistent.

Flowering and Fruiting: April-September

***Scorzonera laciniata* L. Sp. Pl. 791. 1753.**

Herbs, annual or biennial, 50 - 85 cm tall. Stem terete and finely striate above. Basal leaves pinnatipartite, 13.5 - 14 x 2 - 4 cm, usually crisped-pubescent when young, becoming glabrous, petiolate, leaf segments linear lanceolate, apex acute. Middle stem leaves 9.5 - 10.8 x 1 - 2.3 cm, similar to basal leaves. Upper stem leaves obovate-lanceolate, sessile, margin entire, apex

apex acute. Capitula few, terminal. Involucre cylindrical, 24 - 30 x 0.8 - 2 mm. Phyllaries in 2 rows, margin entire, apex acute; outer phyllaries 4-8 x 0.8 - 1 mm, ovate lanceolate; inner phyllaries 6 x 0.6 mm, linear lanceolate. Florets yellow. Achene stipitate cylindrical, 15 x 3 mm, 5 ribs, prominently ridged, glabrous, beakless. Pappus hairs plumose, 12 mm long, persistent.

Flowering and Fruiting: April-June

***Scorzonera picridioides* Boiss Diagn. Ser. 1. vii. 6. 1846.**

Herbs, perennial, 30 - 50 cm tall. Stem erect, branched glabrous. Basal leaves glabrous, sessile, leaf blade elliptic to linear, 7 - 20 x 0.2 - 2.5 cm, apex acute to acuminate. Middle stem leaves sessile, 5 - 12 x 0.2 - 1.4 cm, similar to basal leaves. Upper stem leaves similar to lower leaves, sessile, smaller than others. Subulate-lanceolate. Capitula solitary, terminal. Involucre cylindric, 1-1.5 cm x 0.4 - 0.8 cm. Phyllaries in 5 rows, glabrous; outer phyllaries ovate to triangular-ovate, 4-8 x 3-4 mm; middle phyllaries lanceolate to elliptic-lanceolate, 15 x 4 mm; inner phyllaries linear elliptic to linear lanceolate, 1.8 x 0.3 mm. Florets yellow. Achene cylindric, brown, 7 x 2 mm, 5 ribs, beakless. Pappus numerous, dirty white, 15 mm, plumose at base and apically scabrous, persistent.

Flowering and Fruiting: June-September.

***Scorzonera virgata* DC. Prodr. (DC.) 7 (1): 125. 1838. [late Apr. 1838].**

Herb, perennial with thick woody root, 90 - 120 cm tall. Stem erect, branched, rough, rigid, glabrous. Basal leaves sessile, 5.5 - 7 x 1 - 1.5 cm, linear, margin entire, apex acute, glabrous above and below. Middle stem leaves 4.5 - 5 x 0.6 - 1 cm, similar to basal leaves. Upper stem leaves similar to lower leaves but smaller in size. Capitula terminal and axillary. Involucre cylindrical 24 - 32 x 2 - 8 mm. Phyllaries in 4 rows, glabrous, margin entire, apex acute; outer phyllaries 0.2 - 0.4 x 0.1 - 0.2 mm, ovate; middle phyllaries 1.3 x 0.5 mm, ovate-lanceolate; inner phyllaries 1.5 x 0.2 mm, oblong-lanceolate. Florets yellow. Achene 10 x 14 mm, 3 ribs, brownish, beakless. Pappus numerous, white, 10 mm, persistent (Table 1).

Flowering and fruiting: June-August

DISCUSSION

Taxonomic studies of the genus *Scorzonera* L. were carried out for the first time from Pakistan. Literature on the taxonomic studies of the genus *Scorzonera* L. and even on the tribe *Lactuceae* of family Asteraceae from Pakistan has not been published as yet. So the studies were started on the materials available in the herbaria of Pakistan. The materials so observed had been collected during field trips, especially conducted for the studies. Observations on the species were recorded in the field in their habitat in living form. During the present investigation, 5 species were included from Pakistan.

The main morphological characters which are useful in distinguishing and in describing the species are habit, height of plant, stem texture, basal leaves, middle and upper stem leaves, phyllaries, achene size, number of ribs and surface between ribs, achene beak and pappus. Plant morphology in all its aspects is hugely important and is the first step in plant identification. The stem texture was glabrous in *S. ammophila*, *Scorzonera picricdioides* and *Scorzonera virgata* while tomentose in *Scorzonera hondae* and terete with fine striate above in *Scorzonera laciniata*. In the research it was found that the basal leaves were sessile in all except in *S. laciniata* was petiolate. It was also determined that basal leaf blade was linear to filiform (*S. ammophila*), linear-lanceolate (*Scorzonera hondae*), pinnatipartite (*S. laciniata*), elliptic to linear (*S. picridioides*) and linear (*S. virgata*). The middle and upper stem leaves were more or less similar to basal leaves except in *S. laciniata*. Furthermore, it has been found out that phyllaries were in 4 rows in *S. ammophila* and *S. virgata*; while 2 rows in *S. hondae* and *S. laciniata* and 5 rows in *S*. *picridioides*. The middle phyllaries were absent in *S. hondae* and *S. laciniata*. Achenes were beakless in all species and number of ribs ranged from 3 to 7 in different species (Table 1; Figure 1-5).

Systematic and evolutionary themes based on Asteraceae pollen morphology were definitively set forth by Wodehouse in a publication from Wodehouse (1928, 1935) although from an historical perspective, it is noteworthy that Steetz (1864), is credited to be the first to employ pollen as a taxonomic character in the Asteraceae (Bentham and Hooker, 1873; Robinson, 1992a; Robinson, 1992b). Wodehouse recognized four pollen morphological forms in the family: simple echinate, subechinolophate, echinolophate, and psilolophate together with many intermediates. Wodehouse (1928), shows one morphological form to be present in genus *Scorzonera* L. of tribe *Lactuceae* (Asteraceae). Blackmore's (1986), defining study of lophate pollen recognized, minimally, 23 different pollen types in the Asteraceae, and lophate patterning was most variable. The ultraviolet microscopy of Stix (1960), provided the foundation for interpreting structural types throughout the family. The influence of pollen morphology in Asteraceae systematics is understood from his comments (Robinson, 1992a), "….pollen is one of a series of characters such as stylar bases and anther appendages, observable with the compound microscope, that prove useful in delimiting natural groups. The point has been reached where I believe

Figure 1. *Scorzonera ammophila*.

Figure 2. *S. hondae*

Figure 3. *S. laciniata*.

Figure 4. *S. picridioides*.

Figure 5. *S. virgata*

every taxonomic treatment in the *Lactuceae* should include mention of pollen type". Later Robinson (1999), reinforced these feelings by stating "The pollen is one of the most useful characters available, and it is that taxa would be described at this time without detailed description of the pollen". Similarly, Bolick and Keeley (1994), concluded, "Within the tribe, pollen is a good character for delimiting sections, subsections and series"

Finally the most contemporary review of pollen literature, which extended the impressive bibliography assembled is by Bolick and Keeley (1994), and collaborators Isawumi et al. (1996) in the introduction to their taxonomic study of *Baccharoides* pollen. Based on sculpturing, all pollens were echinate in *Scorzonera*. The pollen class was trizonocolporate in all taxa. Dimension of the polar and equatorial axis ranged from 29, 24 µm (*S. laciniata*) to 46, 54 µm (*S. ammophila*) respectively. The ratio of polar to equatorial axis (P/E) varied between different taxa as 0.9 in *S. laciniata* and 1 in rest of species. The exine thickness ranged from 1.5 µm (*S. virgata*) to 13 µm (*S. ammophila*). Spines were present in all taxa. The character of pollen spine shows an impressive variation which was significance at the specific and generic level and has also been helpful to understand the process of spine evolution within the tribe *Lactuceae*. Spine length differed considerably among all species. It ranged from 2 µm (*S. laciniata*) to 6 µm (*S. hondae*). Number of spine rows between colpi considerably differed in the *Scorzonera* and varied from 10 to 16.

The pollen morphology results indicate that pollen grains in *Scorzonera* were lophate. The spines were more or less similar in all cases, except for differences in their size and distribution. Wodehouse (1935), reported that pollen grains of Compositae were unique and true to form and he outlined the principles of morphological evolution of the spine form of the family in which he suggested the reduction series from long to minute spines.

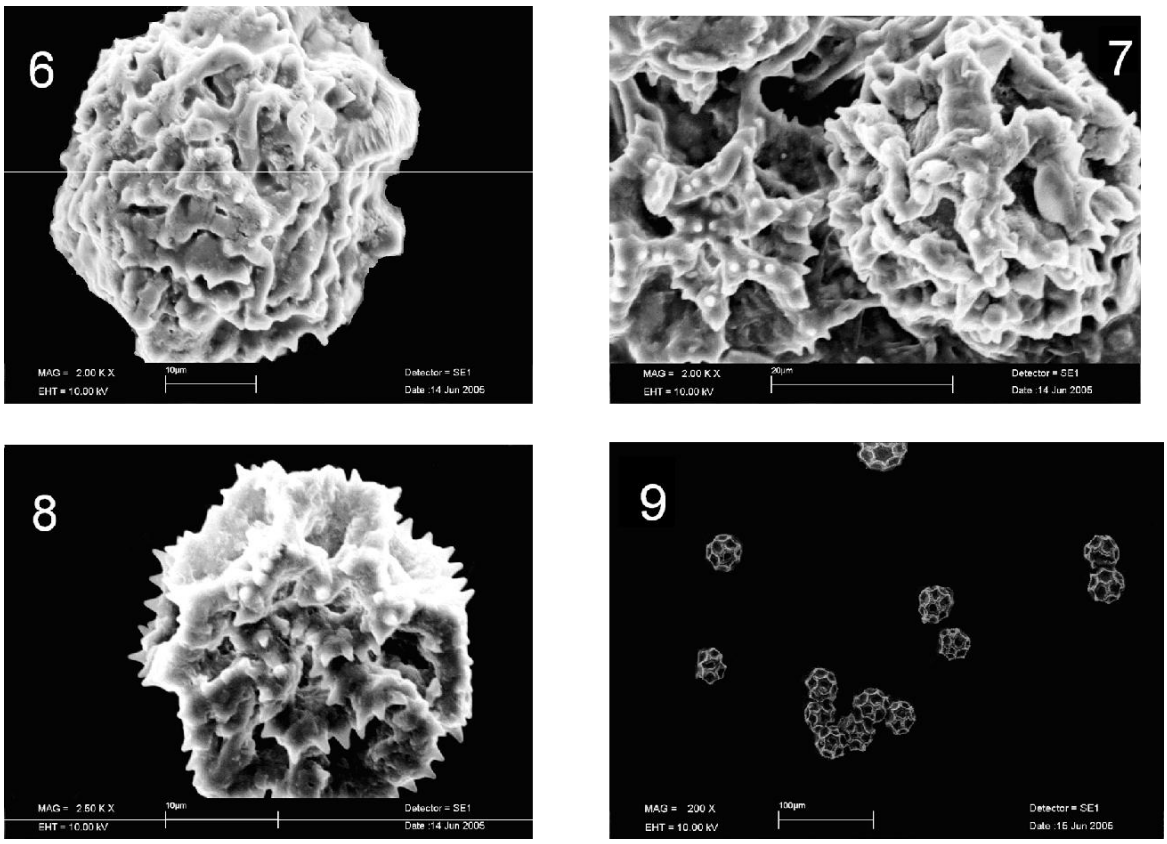

Figure 6 - 9. Scanning Electron Micrographs (SEM) of pollen grains. 6. *Scorzonera ammophila*, subpolar view; 7. *Scorzonera hondae*, exine detail; 8. *Scorzonera hondae*, polar view; 9. *Scorzonera picridioides*, polar and equatorial view.

spines. There seems to be a potential for indicating the evolutionary processes of pollen spines in the *Lactuceae*. The peculiar spine character perhaps represents a climax in the apertural evolution. The occurrence of spines and its absence indicate a trend of evolution of spine reduction in the tribe *Lactuceae*. The reduction and the absence of spines is an evolved character in *Lactuceae* and the genus with spinate pollen as in *Scorzonera*, indicate primitive feature as compared to the genera with spineless pollen which were considered as advanced features within the tribe. The data may be used in establishing relationship at the generic and specific level of the tribe *Lactuceae* within the family Asteraceae (Figure 6-12).

Scorzonera species had anomotetracytic, amphianisocytic, brachyparacytic and staurocytic stomata. Number of stomata and epidermal cells varied from 4 - 14/mm^2 and 30 - 44/ mm^2. The % of each type in abaxial and ada-xial surface was 100% (Table 3). All the species had stomata on both surfaces. Sajo and Menezes (1994), observed that the Asteraceae species *Vernonis psilophylla* and *Vernonis sessilifolia* had stomata on both surfaces whilst *Vernonis linearis* has stomata only on the abaxial epidermis. Metcalfe and Chalk (1950), reported that due to the diversity of habits, Asteraceae species show various anatomical structures and some present ecological specialization. Trichome and crystals were absent in all the species. The % of open stomata varied from 13.33% (*S. virgata*) to 83.3% (*S. ammophila*) and % of closed stomata ranged from 16.6% (*S. ammophila*) to 86.66% (*S. virgata*). The size of stomatal complex varied from 63 µm (*S. picridioides*) to 193 µm (*S. hondae*). The size of epidermal cell ranged from 34 µm (*S. picridioides*) to 164 µm (*S. ammophila*) (Table 4) . The length of guard cells varied from 21 µm (*S. hondae* and *S. virgata*) to 42 µm (*S. virgata*) while the width of guard cells varied from 2 µm to 22 µm in (*S. virgata*). The length of stomatal pore ranged from 12 µm to 21 µm while the width of stomatal pore varied from 1 µm to 9 µm. The micro hairs were found to be present in *S. hondae* and *S. virgata* while absent in rest of species (Table 5; Figure 13-22).

Our results so far indicate plant morphology; pollen morphology and anatomy studies conducted from Pakistan provide evidence for identification on one hand as well as a contribution towards the publication of family Asteraceae.

Table 3. Percentage of different types of stomata, and epidermal cells in the upper (U.E.) and lower (L.E.) epidermis of *Scorzonera* L.

Name	Type of Cell Wall		Type of Stomata		% of Each Type		No. of Stomata /mm^2		No. of Epidermal cell/mm^2	
	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.
Scorzonera ammophila	Straight, Tubular, Angular	Undulate	Anomotetracytic	Staurocytic	100	100	8	10	32	36
S. hondae	Straight, Tubular, Angular	Straight, Tubular, Angular	Brachyparacytic	Brachyparacytic	100	100	6	8	30	24
S. laciniata	Straight, Tubular, Angular	Straight, Tubular, Angular	Amphianisocytic	Amphianisocytic	100	100	8	6	44	36
S. picridioides	Straight, Tubular, Angular	Undulate	Brachyparacytic	Brachyparacytic	100	100	12	14	43	36
S. virgata	Undulate	Undulate	Staurocytic	Staurocytic	100	100	4	11	32	37

U.E. = Upper Epidermis L.E. = Lower Epidermis

Table 4. Dimension and state of epidermal cell, stomatal complex and % of open and close stomata.

Name	Size of Epidermal Cell (µm)		Size of Stomatal Complex (µm)		% of Open Stomata		% of Close Stomata		Crystals		Length of Trichome (µm)		Base of Trichome (µm)	
	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.
Scorzonera ammophila	52-94 74.2+6.8	98-164 133.4+10.4	93-132 113+6.5	123-156 141.8+5.5	83.3	83.3	16.6	16.6	Absent	Absent	Absent	Absent	Absent	Absent
S. hondae	68-141 104+11.6	43-102 75.6+9	145-193 172.2+8	142-181 163.2+6.6	69.56	80	30.43	20	Absent	Absent	Absent	Absent	Absent	Absent
S. laciniata	56-81 70.6+4.3	57-123 88.8+9.7	102-164 132.2+11.3	91-132 112.2+6.6	68.42	76.92	31.57	23.06	+	+	Absent	Absent	Absent	Absent
S. picridioides	34-76 56.8+6.7	43-102 75.8+9.9	86-112 101+4.6	63-86 76.4+3.4	17.4	21.1	82.6	78.9	Absent	Absent	Absent	Absent	Absent	Absent
S. virgata	48-132 89.2+13.3	112-142 129.2+5.1	86-103 96.2+2.6	92-113 102.6+3.29	36.66	13.33	63.33	86.66	Absent	Absent	Absent	Absent	Absent	Absent

U.E. = Upper Epidermis; L.E. = Lower Epidermis; ± Standard Error.

Table 5. Dimension and state of stomatal complex.

Name	Length of Guard Cell (µm)		Width of guard Cell (µm)		Length of Stomatal Pore (µm)		Width of Stomatal Pore (µm)		Size of Microhairs (µm)	
	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.
Scorzonera ammophila	39	35	13	13	21	12	9	3	Absent	Absent
S. hondae	21	32	9	9	16	21	2	2	102-132 119.2+5.1	118-134 127.2+2.5
S. laciniata	31	39	13	12	12	21	4	8	Absent	Absent
S. picridioides	38	31	14	14	12	13	3	2	Absent	Absent
S. virgata	21	42	2	22	12	21	1	2	92-98 95.4+0.9	Absent

U.E. = Upper Epidermis; L.E. = Lower Epidermis.

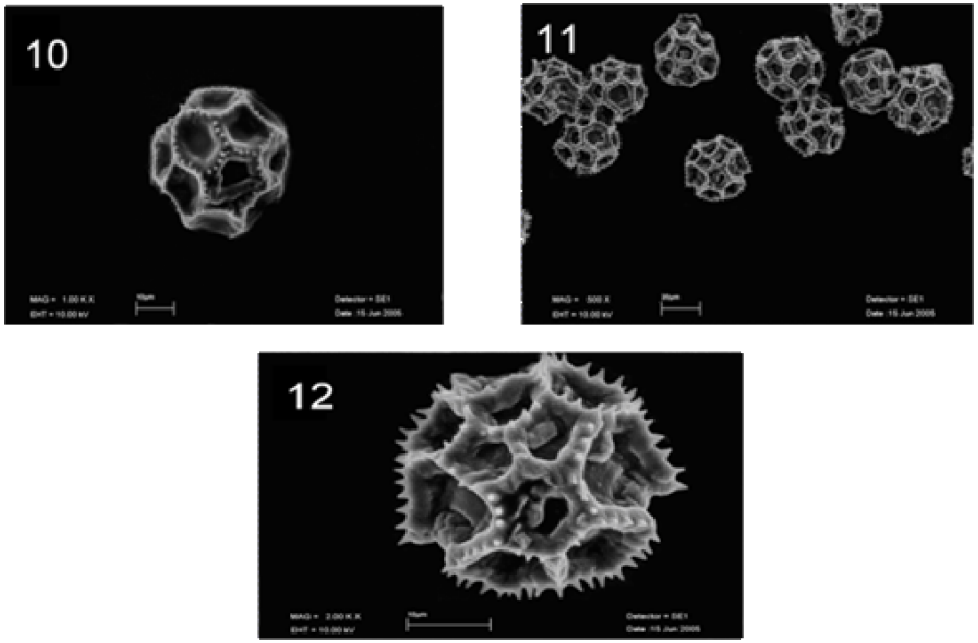

Figure 10 - 12. Scanning Electron Micrographs (SEM) of pollen grains. 10. *Scorzonera picridioides*, subpolar view; 11. *Scorzonera virgata*, polar and equatorial view; 12. *Scorzonera virgata*, polar view.

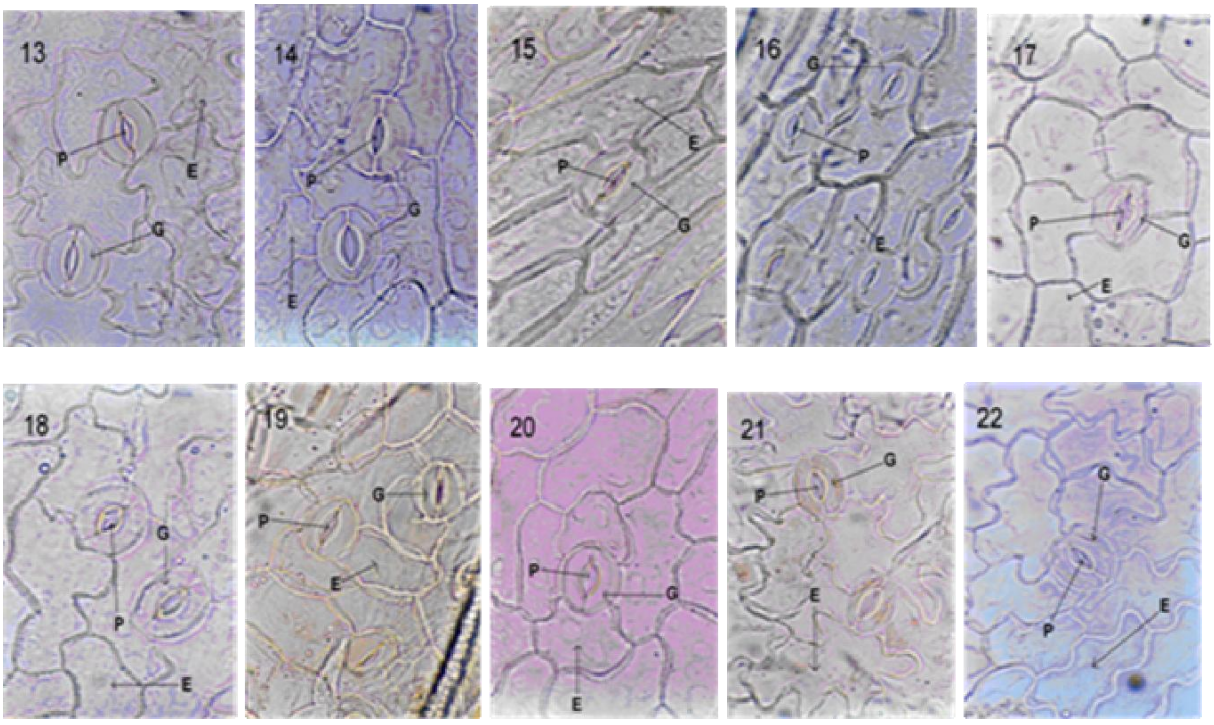

Figure 13 - 22. *Scorzonera ammophila*, **13.** Upper epidermis at 40X, **14.** Lower epidermis at 40X; *S. hondae*, **15.** Upper epidermis at 40X, **16.** Lower epidermis at 40X; *S. laciniata*, **17.** Upper epidermis at 40X; **18.** Lower epidermis at 40X; *S. picridioides*, **19.** Upper epidermis at 40X, **20.** Lower epidermis at 40X; *S. virgata*, **21.** Upper epidermis at 40X, **22.** Lower epidermis at 40X. These taxa show stomatal pore (**P**), guard cell (**G**), epidermal cell (**E**).

ACKNOWLEDGEMENT

We are deeply grateful to Prof. Dr. Audil Rashid for his expert advice and helpful suggestions on the taxonomy of Genus *Scorzonera* L. of Asteraceae. Thanks are due also to Prof. Dr. Muhammad Arshad for his assistance in field work and many other aspects of research. We also thank to Mr. Khalil Subhan, Physics Division, PINSTECH Islamabad for technical assistance.

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